Epistemic geographies of climate change: the IPCC and the spaces, boundaries and politics of knowing

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Thesis submitted for the Degree of Doctor of Philosophy to the

School of Environmental Sciences,

University of East Anglia

September 2013

Abstract

Science, like other realms of human activity, has its geographies. It proceeds in and through space, and participates in the construction of the political and cultural geographies by which human interactions with the nonhuman come to be known, understood and governed. The phenomenon of climate change stands at this juncture of science, politics, and the elemental materiality of the nonhuman. High-profile controversies about the physical reality, effects and management of the changing climate point to more deep-seated contestations about the place of science in modern democratic societies. This thesis engages with literatures on the historical and cultural geographies of science in order to open-up questions about the situatedness of climate change knowledges, the contested boundaries between the scientific and the political, and the spatial politics of relating epistemic claims to normative interventions in the world. The thesis proceeds through a series of linked case studies which traverse a range of emergent transnational spaces of knowledge production. It begins inside the Intergovernmental Panel on Climate Change (IPCC) and moves through the contested spaces of international climate diplomacy at the 2009 Copenhagen climate talks and through diverse cultures of knowledge authorisation in Indian climate politics. The thesis develops the notions of 'boundary spaces' and 'epistemic geographies' to capture the emergence, conjuncture and contestation of different modes of knowing and governing climate change. By following the objects of climate change knowledges – like visualisations, numerical targets, simulation models and predictions – conceptual distinctions between the spaces of knowledge production and consumption break down. Instead, a picture emerges of travelling knowledges which emphasises mutability, interpretive flexibility, and the spatial and discursive co-production of the epistemic and the normative. It is argued that by moving from 'geographies of science' to 'epistemic geographies', the hybridity of science and politics can be more effectively written-in to our accounts of contemporary knowledge politics.

What of a truth that is bounded by these mountains
and is falsehood to the world that lives beyond?

- Michel de Montaigne

Border areas…are not marginal to the constitution of a
public sphere but rather are at the centre.

- Étienne Balibar

Contents

Abbreviations

ANT	Actor-network theory
AR4	Fourth Assessment Report of the IPCC
CPR	Centre for Policy Research
CSE	Centre for Science and Environment
DAI	Dangerous anthropogenic interference
DSF	Delhi Science Forum
ESRC	Economic and Social Research Council
EEA	European Economic Area
EU	European Union
FAR	First Assessment Report of the IPCC
INCCA	Indian Network for Climate Change Assessment
INC	Intergovernmental Negotiating Committee
IPCC	Intergovernmental Panel on Climate Change
IARU	International Alliance of Research Universities
MoEF	Ministry of Environment and Forests (Government of India)
MoST	Ministry of Science and Technology (China)
NRC	National Research Council
NGO	Non-Governmental Organisation
PSM	People's Science Movement
RFCs	Reasons For Concern
STS	Science and technology studies
SAR	Second Assessment Report of the IPCC
SCEP	Study of Critical Environmental Problems
SMIC	Study of Man's Impact on Climate
SPM	Summary for Policymakers
TAR	Third Assessment Report of the IPCC
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	United Nations General Assembly
USCCSP	United States Climate Change Science Program
USA	United States of America
WBGU	Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen (German Advisory Council on Global Environmental Change)
WG	Working Group (I, II or III)
WMO	World Meteorological Organisation
WRI	World Resources Institute

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Acknowledgements

The work underpinning this thesis was made possible by an Economic and Social Research Council (ESRC) PhD studentship (ES/H01110/1) for which I will be eternally grateful. My receipt of this support was made possible in the first instance by my supervisor, Professor Mike Hulme; you placed a great deal of trust in the potential of someone who had spent the previous twelve months dressed as a hedgehog teaching schoolchildren about recycling. From that early vote of confidence, through the formulation of new ideas and plans, the torrent of drafts, right through to the final splitting of my overlong paragraphs and sentences (how’s this one?), you have been a constant source of inspiration, encouragement and support. For opening so many doors, thank you. Thanks also to Jason Chilvers and Peter Simmons for your supervisory input, for testing my ideas, and for your always-valuable advice.

My thanks also go to Sheila Jasanoff, whose invitation to join her STS Fellows Program at Harvard opened up an exciting new chapter of my PhD experience. My three months on the program in Autumn 2012 were an invigorating re-introduction to the intellectual lineage in which I have sought to situate myself, and my thinking on Indian and US climate politics was greatly enhanced by our conversations. Thanks also to Shana Rabinowich for all your assistance, and to all the other Fellows for your collegiality and stimulation. Likewise, Silke Beck has been a frequent source of new ideas, criticism and encouragement, while Mathis Hampel has frequently reminded me that social construction is always a question of political philosophy. To all my colleagues at UEA and particularly in the 3S Group, thank you for the fertile intellectual ground in which this thesis has grown.

I am massively grateful to all those who gave their time to be interviewed by me, and whose insights and recollections form the bedrock of my argumentation. Thanks to Dave Dokken for the documents, George Clarke for the archival assistance at Harvard, and Dorthe Hedenstad Lund for the help with website statistics. I am greatly indebted to the Centre for Science and Environment, particularly Priyanka Dutta, Jagdeep Gupta, Mr. Bains, Anju Sharma and everyone in the CSE library and climate change team for their hospitality and assistance during my fieldwork in New Delhi. Thank you

Arpit for being such an accommodating flatmate, and thanks also to Srini for orienting me in the landscape of Indian climate science. My thanks also go to the editors and reviewers at *Geoforum*, *Social Studies of Science* and *Spontaneous Generations* for helping me to sharpen the arguments which have ultimately formed the backbone of this thesis.

Thank you to all of my friends, who have always been there for intellectual stimulation or social distraction; whatever seemed appropriate at the time. I'm sorry I couldn't answer all calls to the pub in the affirmative, and I thank you for indulging my preoccupation with geography when sometimes the books just need to be put down. Al, see you in the gym.

To my parents, my greatest teachers, I offer thanks for the love and support through it all. I wouldn't be here putting the finishing touches to this thesis without the leg-up you gave me into university education, and without the safety net you've provided when things haven't gone so smoothly. Thanks to all my wonderful siblings – I promise I'll get a proper job someday! – to my band of precocious and vivacious nephews, to the Bristol gang and to Brian, who's always in our thoughts. I am truly blessed to be surrounded by such a loving and supportive family.

Lastly, thank you Helen for being such a loving partner, cogent critic, and dependable friend. You've kept me going through all the stresses and strains with patient affection, and I'm convinced that the road to completion would have been significantly bumpier without you as my fellow traveller. I hope I can come close to returning the favour.

Chapter 1

Introduction

> *Our engagement with climate change and the disagreements that it spawns should always be a form of enlightenment.*
>
> Mike Hulme, *Why We Disagree About Climate Change*

Climate change, as both a physical reality and a cultural idea, is a deeply pervasive element of contemporary cultural politics. The scientific observation that humanity's emission of certain gases into the atmosphere has led to the warming of the entire planet has had far-reaching impacts on public policy, senses of community, human relationships with the nonhuman, and on understandings of the human potential to effect change in the environments which surround us. International political action to avoid or deal with the anticipated negative consequences of climate change is, however, fragmented at best, and quite dysfunctional at worst. Many would explain this as a function of a failure to heed the warnings of science, and to adapt collective political trajectories to the predictive knowledges of the environmental disciplines. However, it is also clear that climate change is an idea which brings to the fore disagreements on profound questions of equity, justice, hierarchy, development, evidence and risk, to name but a few. Climate change is thus an issue which offers new challenges to the relationship between scientific knowledge and political action. The domains of knowledge-making and decision-making – long considered separate – are revealed by the case of climate change to be socially and culturally entwined.

This is a thesis about the geographies of climate change knowledges. It starts from the observation that science is a geographical phenomenon – like all areas of social and cultural life, it has its geographies. It takes place in spaces specially delineated for the purpose. It is a collective activity formed of social relations. It is not just a disinterested window onto the material world, but a suite of social practices which configure representations and performances of the natural world in highly localised settings. The spatial mobility of scientific knowledge cannot be straightforwardly attributed to the force of its cognitive authority. Rather, diverse social and cultural practices, norms and assumptions shape how knowledge travels and how it is received in different settings. Like climate change, travelling knowledges can bring to light our differences, revealing often divergent cultures of interpretation and meaning-making.

In Chapter 2, I discuss existing scholarly engagements with the geographies of science. The chapter starts by justifying and building on the observation that science is a geographical phenomenon through an engagement with work arising from historical and cultural geography on the spatiality of knowledge. I suggest that such work, in tandem with insights from the sociology of scientific knowledge, has made important interventions about the significance of space and place in scientific practice. However, I also contend that geographies of science need to engage with conceptualisations of the broader 'co-production' of scientific knowledge and social order. The idiom of co-production draws attention both to the social and normative elements of knowledge production, and to the epistemic underpinnings of our social forms and normative commitments. Drawing on the work of actor-network and social worlds theorists, along with the productive insights of Michel Foucault, I aim to develop an approach to the geography of science suited to the contemporary politics of scientific knowledge and environmental change. This approach, which I begin to characterise as 'epistemic geographies', represents a new way of thinking about the entanglements of space, knowledge and power in the context of a complex phenomenon like climate change.

In Chapter 3 I turn to the case of the Intergovernmental Panel on Climate Change (IPCC) as an example of concerted, collective knowledge-making which has profoundly altered the contemporary geographies of climate science. I narrate the institutional history of the organisation, but also draw on critical social science accounts of the ways the IPCC has produced and mobilised climate change knowledges. I begin by conceiving of scientific assessment as a mode of environmental governance. Assessment is not just about collating or even producing knowledge – it is about reaching agreement on the forms of knowledge, the evidential standards, and the modes of reasoning which constitute governmental engagements with something like climate change. The history and practices of the IPCC allow me to draw together literatures on the politics of expertise, the construction of consensus, and 'boundary work' at the intersection of science and politics. I also touch upon recent controversies which have dogged the IPCC, which in turn open-up questions of how 'IPCC knowledge' travels about the political and cultural spaces of climate change deliberation. Throughout my account of the IPCC I begin to develop the research questions and introduce the case studies which constitute the remainder of this thesis.

In Chapter 4 I introduce a research design suited to addressing the questions and issues raised in the preceding two chapters. I justify my choice of a multi-case study design on the grounds that it offers the opportunity to capture some of the diversity of climate change knowledge politics, and to provide representations of diverse spaces without sacrificing empirical detail. I discuss how this research design might constitute a form of multi-sited ethnography, built around ideas of 'following' discrete objects of inquiry around diverse spaces of cultural life and meaning-making. Although I reserve the case-specific details of my research methods to each empirical chapter, in Chapter 4 I offer some reflections on the practice of interviewing as a data collection technique. I suggest that although the interpretive paradigm of social research has long acknowledged the relationality of data collection – i.e. that data is not simply 'extracted' from research subjects but is collaboratively constructed – an extractive model of data collection still dominates methodological discussion of interviewing. In pointing to my own experiences in the interdisciplinary field of climate change research, I highlight how interview data is relationally constructed through embodied, linguistic and discursive interactions between interviewer and interviewee.

The empirical chapters are all based on journal articles which are in various stages of publication, as detailed at the start of each chapter. The chapters represent expanded versions of the articles, with the arguments more explicitly linked to the overarching themes of the thesis and given greater evidential depth. In Chapter 5 I offer an empirical introduction to my case study of a particular diagrammatic visualisation of climate change risks. I discuss the origins of the diagram – known as the 'burning embers' for reasons which will become clear – and its circulation as a mutable 'epistemic thing' around the social worlds of climate science and policy. I begin the interpretive work of situating the diagram within late modern cultures of risk management and anticipation, and explore how 'consensus' has functioned as a powerful legitimating tool in the construction of authoritative, policy-relevant accounts of environmental risk.

In Chapter 6 I deepen my analysis of the social life of the burning embers. Drawing more directly on interviews with the scientists involved in the production of the diagram, I explore how the scientists dealt with (and subsequently talked about) their negotiation of epistemic uncertainty and the ambiguities of exercising 'expert judgment' in a field acknowledged to be populated by normative assumptions and deeply intertwined facts and values. I then explore how the diagram and its attendant analytic frameworks were received and interpreted among governmental actors. To do this, I use governmental reviews of the relevant IPCC chapters to reconstruct the interpretive geographies of the diagram's circulation. Patterns emerge which point to distinctive differences in assumptions about where science ends and where politics begins in the case of defining 'dangerous' climate change. In linking these patterns to the concept of 'civic epistemology' – the culturally constituted norms by which scientific knowledge is handled in the public sphere – I aim to form a picture of how the IPCC is challenged with negotiating diverse ways of reasoning about risk. The exclusion of the diagram from the 2007 IPCC report points to how such rifts can have significant effects on the outcomes of knowledge production processes in hybrid scientific and political spaces like the IPCC.

In Chapter 7 I follow the diagram to the ultimately ill-fated international climate negotiations in Copenhagen, Denmark in 2009. Prior to the talks, two initiatives sought to bring-together the latest scientific knowledge on climate change in order to inform and persuade decision makers of the need to take decisive action. The *Copenhagen Diagnosis* synthesised the latest scientific findings on observed and predicted climate change, while the so-called 'Climate Congress' of March 2009 convened interdisciplinary discussion and communication of emerging research across the natural and human sciences. In exploring the geographies of these two initiatives – the objects and actors which were assembled and the textual and physical spaces which were enacted – I investigate how complex and diverse debates were boiled-down into a strained negotiation over the veracity of the 2°C temperature rise target between a group of prominent scientists and the Danish Prime Minister. I argue that these interactions enacted and performed 'linear model' understandings of the relationship between scientific knowledge and political action, which ultimately failed to produce the desired political outcomes. I portray this episode as being resolutely situated in the spatial setting of Copenhagen, in relation to European commitments to a targets-based approach to climate policy. This represents a new way of understanding how the kinds of knowledge which are constructed and performed in civic spaces exist in a complex relation with situated forms of politics and locally accepted modes of reasoning.

In Chapter 8 I extend these observations, albeit in a very different context. Building on fieldwork in India, I explore how an error in the 2007 IPCC report about the possible rapid melting of Himalayan glaciers reanimated a history of epistemic contestation between Indian and Western scientists, and of occasional antagonism between the IPCC and Indian political communities. The concurrent establishment by the environment minister of the Indian Network for Climate Change Assessment (INCCA) – dubbed by some an 'Indian IPCC' – drew upon this lineage of contestation and represented a re-assertion of epistemic sovereignty in the international politics of climate change. Although long an opponent of binding emissions cuts, the Indian government between 2007 and 2010 began to shift its stance. By embracing a voluntary approach to emissions reductions, the Indian government re-cast the way national territory – with its attendant emissions, carbon sinks and climate change impacts – should be integrated into the global space of international climate politics. I argue that the emergence of INCCA represents a scientific re-construction of national space in the face of anxieties in some quarters about the ceding of political sovereignty: epistemic sovereignty is used as an anchor amid the turbulent waters of shifting forms of political autonomy and sovereignty. The case of INCCA again raises important questions about the capacity of international bodies like the IPCC to speak authoritatively to diverse constituencies. Yet it also represents a significant shift in the geographies of climate knowledge, as regional climate prediction tools become prominent 'boundary objects' in governmental engagements with territorial futures.

In the concluding chapter, I draw together these empirical findings into a more comprehensive account of the epistemic geographies of climate change. I argue that geographies of science have so far made important contributions to understanding the constitutive spaces of science – where and how knowledge is made. However, building on the work of Mark Whitehead and others, I suggest that geographies of science also need to consider how space functions as an epistemological category – as a mode of investigation and interpretation – and as a form of rationality through which powerful actors construct particular ways of governing human-nonhuman relationships. I suggest that the epistemic geographies of climate change consist of these three spatial modes – the constitutive, the epistemological and the rational – and that the notion of co-production can offer a way of reading their conjoined evolution. Building on the findings of Chapters 5 to 8, I suggest how geographers of science can make important interventions in debates about the shifting constitution of epistemic and normative powers in our collective efforts to come to terms with environmental change. In light of the chequered pervasiveness of ideas of 'limits' in environmental thought and debates about the constitution of the 'Anthropocene', questions of the spaces, boundaries and politics of knowledge-making are prominent and tightly intertwined. This thesis offers an illustration of that intertwining, while seeking to open new lines of enquiry into the constitution and contestation of knowledges which are radically redefining collective understandings of the natural, the human, the global, the national and the dangerous.

Chapter 2

Geographies of science

The spaces, boundaries and politics of knowing

In this chapter I seek to cultivate an approach to the geography of science which can respond to the contemporary cultures and power of scientific knowledge. To do this, I begin by exploring how geographers have capitalised on the spatial turn in broader currents of historical and cultural thought by developing new perspectives on the spatiality of geographic and, subsequently and more ambitiously, scientific knowledge. I then review recent debates in science and technology studies (STS) about the tensions between theoretical resources which emphasise the attainment of ontological stability at particular sites, and those which draw our gaze towards the ephemeral attainment of social and cultural order in moments of emergence and flux in science's relations to broader realms of social action. I argue that current approaches to the geography of science, while offering attractive resources for thinking about the power of particular sites and the achievement of mobility in scientific knowledge-making, fall short of adequately capturing the fluidity of scientific meaning as ideas, objects and politics travel from place to place. I argue that geographers of science can benefit from engaging more fully with conceptions of the co-production of scientific knowledge and social order. Furnished with insights on the indeterminate boundaries of science and the mutual constitution of epistemic and normative engagements with the nonhuman, I argue for a geography of science which can better engage with how science participates in the spatial, epistemic and normative re-ordering of the world.

In later chapters, these conceptual ideas are put to work across a range of empirical cases, before being re-evaluated in the concluding chapter of the thesis. Throughout, I aim to explore what might be gained from thinking in terms of the 'epistemic geographies' of an object like climate change. I start out by considering 'epistemic geographies' as a synonym for 'geographies of science' or perhaps 'geographies of knowledge'. However, in the concluding chapter I will build on some of the ideas which are introduced here and then drawn through the empirical material to consider how 'epistemic geographies' might re-animate the indeterminacy of the category 'science'[1], while offering an invitation to consider the co-production of scientific knowledge with epistemic constructions such as scale and territory. For now, let us turn to a particular, situated origin story of one idea which has begun to circulate and act productively in the world: the idea that science is a geographical phenomenon.

Science is made of places

"Scientific knowledge is a geographical phenomenon" (Livingstone 2010, 18). Such is the organising principle of a growing body of scholarship on the geographies of science which stresses that attention must be given to the spatial characteristics of science in order to make sense of its production and circulation. Geographers of science (e.g. Massey 1999; Naylor 2005a; Jöns 2006; Finnegan 2007; Powell 2007a; Hulme 2008; Livingstone 2010) emphasise the role of space and place in shaping the practices of knowledge production and the subsequent influence of science across political and cultural contexts. Science, rather than being a source of unproblematically 'global' or 'universal' knowledge as is conventionally assumed (Hulme 2010a), is seen as an activity which must employ locally-rehearsed material practices and social processes of legitimation to produce knowledge capable of acting productively in the world. For knowledge to successfully leave its place of production, a range of social and literary technologies (Shapin & Schaffer 1985) must be mobilised to overcome the challenges of space. Even if mobilisation and global travel is achieved, the indelible marks of these social and cultural practices will mean that an item of scientific knowledge will forever bear the marks of space and place – of local

[1] According to the *Oxford English Dictionary*, "In modern use", *science* is "often treated as synonymous with 'Natural and Physical Science', and thus restricted to those branches of study that relate to the phenomena of the material universe and their laws, sometimes with implied exclusion of pure mathematics. This is now the dominant sense in ordinary use" (OED 2013). This definition captures both the commonly received understanding of the meaning of science (a meaning largely adopted by geographers of science), and the epistemological ambiguity of the category which has led to decades of philosophical effort to define the boundaries of science (see Chalmers 1980). We might therefore add science to Gallie's (1955) list of "essentially contested concepts", on which agreement is ultimately impossible, and which serve a variety of functions for different groups employing them. See also Livingstone (2002).

practices, cultural contexts and social technologies. Science is a cultural accomplishment – an incredibly powerful one – and can thus only be fully understood as a series of locally rooted practices and cultures.

During the 1980s and 1990s, while historians of science shifted their focus towards local contexts of knowledge production and away from hagiographic accounts of pioneering individuals and of "free-floating ideas and philosophical abstractions" (Smith & Agar 1998, 2), geographers were becoming increasingly concerned with their discipline's own history. Historiographical analyses of geography's origins as the science of Enlightenment-era exploration and discovery (Driver 1991; Riffenburgh 1993) and of the epistemological challenges raised by the new possibilities of encountering objects, peoples and environments through the structures of virtual witnessing and scientific accounting elucidated how geographical knowledge was delivered to the great scientific centres of Western Europe (Livingstone 1993; Withers 2007). These analyses also attended to geography's relationship to imperialist political structures (Edney 1997; Ó Tuathail 2000). Work on the role of geographical knowledge in shaping the Enlightenment *mentalité* has highlighted the complex spatial arrangements which enabled knowledge of the expanding sphere of Western experience to be transformed from place-based accounts of local circumstances into a coherent cartography of the world's peoples and environments. The crystallisation of this purportedly universal knowledge was itself inherently local, originating as it did in the regional cultures of knowledge production which criss-crossed Western Europe (Livingstone & Withers 1999; Burke 2000). Historical studies of 'the Enlightenment' have stressed that the period cannot be seen as one of homogenous cultural shift, but rather as a complex set of evolving discursive practices and strategies, located in and shaped by local cultural and intellectual climates (Foucault 1984; Philo 2007).

This turn towards historical studies of the situated character of geographical knowledge-making drew on burgeoning ideas within the history and sociology of science about the significance of place and locality in scientific practice (e.g. Ophir & Shapin 1991; Shapin 1998). This "embracing of the spatial" (Turnbull 2002, 273) pursued a constructivist epistemology, which "regards scientific knowledge primarily as a human product, made with locally situated cultural and material resources, rather than as simply the revelation of a pre-given order of nature" (Golinski 2005, xvii). Ophir & Shapin (1991, 4) address the significance of space which a constructivist approach emphasises, in asking "[w]hat if knowledge in general has an irremediably local dimension? What if it possesses its shape, meaning, reference, and domain of application by virtue of the physical, social, and cultural circumstances in which it is made, and in which it is used?" The answer to these queries is arguably that a full account of scientific knowledge production demands sensitivity to local practices and cultural resources – to the geographies of scientific knowledge production and circulation.

Across the social sciences, increasing attention has been given to the need to characterise the local as a site of knowledge and action (e.g. Geertz 1993). Metaphysical concepts such as 'truth' and 'justice' have been recognised to be the accomplishments of locally situated knowledge practices and diverse rationalities (MacIntyre 1988; Haraway 1989; 1991; Harding 1991). Work on the situated geographies of knowledge which adopts what Withers (2010, 67) terms a "spatially sensitive social constructivism" also employs, often implicitly, a phenomenological spatiality which "conceives places as milieux that exercise a mediating role on physical, social and economic processes", with place thus a "distinctive coming together in space" of these processes which creates a unique assembly of phenomena and actors (Agnew 2011, 317). Place therefore is much more than just location, a point in geometric space; place is a site "in the *flow* of social relations...constituted out of space-spanning relationships" (ibid, 325).

The revival of interest in place in geographical thought has stemmed partly from a desire to reclaim the concept from an academic discourse which presents 'place' as akin to the local, the nostalgic, the romantic, even the regressive, while 'space' (often conflated with scale) is a hallmark of the global, the modern, and the progressive. Agnew (2011) attributes the loading of space and place with these oppositional political and cultural connotations to a tendency in Western thought to favour a linear, teleological historiography which favours the defeating of place by space in highly abstracted accounts of 'how the world works', without attention to the concrete geographical realities of everyday experience (cf. Friedman 2007;

Goldenberg & Levy 2009). For example, while globalisation and mass communication have enabled information, commodities and ideas to travel more freely in global space, these changes have also reconfigured and reorganised the spatial relations which constitute specific places (e.g. Green et al. 2005) while altering individual and collective senses of place-based meaning and identity (e.g. Agnew 2009). Place matters, even as many of us feel more able to overcome the frictions of geographic distance (Massey 2005).

A variety of intellectual traditions have converged to establish geography as a site of lively theoretical conversation on the re-imagining of space and place. Neo-Marxist writers have focused on the social production of space, including the abstract spaces of capital circulation and local sites of resistance (Lefèbvre 1991; Harvey 2001). Writers of a humanist persuasion have focused on the individual subjective experiences of place as part of space (Tuan 1974; 2001), such as the agency involved in constituting and knowing 'home' (Sack 1997). Under this perspective, "places are woven together through space by movement and the network ties that produce places as changing constellations of human commitments, capacities and strategies" (Agnew 2011, 325). Feminist perspectives have broadened this focus on identity and meaning-making while decentring the significance of individual agency, to conceive space in terms of multiplicity, interrelation and the co-existence of distinct social trajectories with place constituted at the confluence of these trajectories and space-spanning relationships (Massey 2005). Nigel Thrift (1999a; 2007) has advanced a performative theory of space which, through its links to post-humanist thought and actor-network theory, has added a materialist element to the conception of place as a particular space-time configuration constituted through the coming-together of various human and non-human actors.

Recognising the difficulty of mobilising these abstract conceptions of space in the service of empirical inquiry, Agnew (2011, 326) distils their essential commonalities into a set of definitional observations:

1) place as location in space, or a site where a particular object or activity is located, with relations to other sites through interaction and movement between them;

2) place as a "series of *locales* or settings where everyday-life activities take place...the where of social life" (emphasis in original). This might include workplaces, homes, churches and other social settings, "whose structuring of social interaction helps forge values, attitudes, and behaviours";

3) place as *sense of place*, or the association of place with a particular community, landscape or moral order. It is here that we encounter questions of identity and belonging, and of course the tension between totalising and exclusionary affective politics, and the seeming necessity of some sense of place and communal identity for any kind of social solidarity or collective action.

Employing the first and second of Agnew's conceptions of place, work by geographers, anthropologists and historians of science has focused on the conventional sites of knowledge production and the "performance spaces of science" (Livingstone 2005a, 97). The laboratory (Latour & Woolgar 1979; Latour 1987; Kohler 2002), the museum (Star & Griesemer 1989; Withers 1995; Naylor 2002), the botanic garden (Harris 1998), the library (Chartier 1994), the field site (Powell 2007b; Withers & Finnegan 2003; Forsyth 2013), learned societies (Shapin & Schaffer 1985; Finnegan 2005), and public spaces of experimentation and scientific debate (Golinski 1999; Withers 2010a) have all been scrutinised as sites of knowledge production and circulation. Others have focused on more unexpected sites of scientific investigation and deliberation, such as the cathedral (Heilbron 2001), the public house (Secord 1994) and private residences (Shapin 1988). Close ethnographic and historical work of this kind has revealed how solutions to epistemological problems of warrant, credibility and attribution are often found in spatial arrangements, which in turn may reflect contemporary approaches to the problem of social order.

For example, Shapin & Schaffer's (1985) magisterial study of the controversy between experimental natural philosopher Robert Boyle and political philosopher Thomas

Hobbes in 17th century Restoration England demonstrates how the definition and contestation of what they term 'intellectual space' enfolds epistemology and social space into each other. For Hobbes, our choices of how to produce knowledge reflect our political commitments. Therefore philosophy should be conducted in public spaces, and not be captured by special interests. For Boyle and the emerging community of experimentalists, the solution to the problem of how to generate reliable, useful knowledge involved the creation of hermetically-sealed spaces; close regulation of who could enter these nascent laboratories generated a socio-spatial analogue of Boyle's vacuum-filled air pump. Only reliable gentlemen could cross the threshold of these intellectual spaces or participate in the 'virtual witnessing' of experimental results through the 'invisible college' (see also Dear 1985)[2]. For Boyle, these intellectual spaces offered a model polity of consensual deliberation amid the otherwise fractious politics of Restoration England; a sentiment which would find new traction in the bipolar politics of the Cold War (Polanyi 1962). But for Hobbes, the exclusiveness of these experimental spaces undermined any claims to reliable objectivity, and the act of virtual witnessing was a deeply unreliable way of evaluating testimony. Hobbes maintained that "neither witnessing nor manipulating instruments and machines in the interrogation of nature can constitute a firm basis for distinguishing public from private experience and for enlisting the former for the purposes of separating valid from invalid claims" (Ezrahi 1990, 79). Boyle's model spaces of perception could not, according to Hobbes, reliably settle conflict and replace it with consensus, and the illusion thereof was a profound threat to social order and the stability of the state. Shapin and Schaffer (1985, 344) conclude in partial agreement with Hobbes on a point of social theory: "The form of life in which we make our scientific knowledge will stand or fall with the way we order our affairs in the state". Therefore, in his recognition that questions of knowledge and of social order are inextricably bound-up with one-another, "Hobbes was right".

[2] Robert Boyle used this term to describe the network of letter-writers through which much natural philosophy was practiced and from which the Royal Society was largely formed in 1660 - see Kronick (2001). For a more recent application of the notion of 'invisible colleges' to the question of knowledge diffusion within scientific communities, see Crane (1972).

The recognition that questions of space are central to the social constitution and legitimation of knowledge (Shapin 1988; Powell 2007a) means that for some, "debates about what formally constitutes 'science' are now focused as much on geography as on problems of epistemology" (Anderson & Adams 2008, 184; Serres 1982). If it is possible to narrate a 'social history of truth' (Shapin 1994), then it must also be possible to construct "social geographies of both warranted assertibility in general, and of science in particular, in ways sensitive to the context-dependent nature of meaning *and* to the negotiated transfer and movement of ideas between sites" (Withers & Livingstone 1999, 16, emphasis in original)[3]. Likewise for Fuller (1988), issues of epistemology cannot be divorced from their social substrate, with the spatial ordering of epistemic actors and practices playing a constitutive and formative role in the development of such categories as 'credible' and 'consensual' knowledge (Ophir & Shapin 1991). The mutual constitution of the social and the spatial in science has also inspired a great deal of work on the architectures of scientific spaces and their epistemic corollaries (Powell 2007a, 315-316; Schaffer 1998). For example, Gieryn (2008) positions the spatiality of the modern laboratory as a key element in the acceptance of knowledge claims which arise from within it. 'Idiosyncratic' laboratory spaces are untrustworthy, and thus a new type of laboratory which couples practical flexibility with a direct correspondence to comparable laboratories across the world has emerged (see also Gieryn 2002; Henke & Gieryn 2008). This echoes (and connects with) the networked spatialities of post-Fordist political economy; the replication of practice through the replication of place (Latour 1983)[4].

[3] The concept of 'warranted assertibility' can be traced to Dewey, and denotes the status afforded to an assertion which is deemed by a community of inquirers to be suitably justified within the practical process of inquiring into the world. See Dewey (1938), Rorty (1999), Misak (2013).

[4] Ophir & Shapin (1991) ask if the laboratory constitutes a form of heterotopia (Foucault 1986): a segregated space with regulated borders; linked to particular temporalities; constituted by overlapping social forms; and standing in a significant relation to a totality of other spaces. A major function of heterotopic spaces of science is "forcing the invisible to manifest itself, to leave traces, to betray a hidden presence. Yet the invisible only appears to the eyes of those authorized to observe it. The heterotopic site is at one and the same time a mechanism of social exclusion and a means of epistemically constituting conditions of visibility" (Ophir & Shapin 1991, 13-14).

Geography and co-production

Shapin and Schaffer's (1985) insistence on the interdependency of solutions to the problem of knowledge and of social order both channelled and spurred-on a line of thought within STS which understands science and social order as being co-produced (Jasanoff 2004a). The notion of co-production can be considered "shorthand for the proposition that the ways in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live in it" (Jasanoff 2004b, 2). Co-production seeks to transcend interpretations of social constructivism which hold social reality to be ontologically prior to material reality (Hacking 1999; Jasanoff 2004c). Although science has long been seen as constituted by social practices (Kuhn 1962; Bloor 1976; Latour & Woolgar 1979), work in STS has, broadly speaking, denied a "causal primacy" of the social (Jasanoff 2004c, 19; see also Pickering 1995; Knorr Cetina 1999). Co-production thus tracks a middle-way between claims that our knowledge of the world is wholly socially-determined (a caricature of constructivism which became fodder during the so-called 'Science Wars', see e.g. Sokal & Bricmont 1999), and a converse technological or material determinism which privileges the nonhuman as the determinant and driver of social change and human knowledge. Co-production is not anti-realist; it doesn't deny that reliable knowledge of physical reality is possible. Rather it draws on a constructivist lineage which stresses that the ways in which we go about constructing knowledge of the world are contingent on social circumstances, cultural preferences and institutional politics. Our engagements with the world and with representations of it are marked by an interpretive flexibility which contradicts the notion that the cognitive content of our knowledge is straightforwardly determined by the form of the physical world.

Co-productionist work stresses that solutions to problems of knowledge are always inseparable from efforts to tackle problems of social order. For example, as discussed above, the verification of new knowledge claims depends on the identification of a community of attestive witnesses, achieved for example through acts of exclusion which may variously reinforce or alter contemporary modes of social hierarchy (Shapin & Schaffer 1985). Knowledges of human societies – or of their interactions with physical environments – call forth new identities, subjectivities or senses of citizenship (Carson 2004; Rabeharisoa & Callon 2004; Sunder Rajan 2006; Doubleday & Wynne 2011). Contestations of the very definition of 'science' itself can be read as concerning not just epistemology, but the distribution of epistemic and moral authority in the ongoing ordering of democratic societies (Gieryn 1999). In accordance with poststructuralist understandings of order, co-productionist work emphasises the ongoing processes by which semblances of order – such as political sovereignty or legitimate expertise – are achieved in the constantly shifting sands of modern, technological societies. Scientific knowledge, while of course being an agent of social change, also functions as a touchstone of stability. The use of claims to scientific objectivity to foreclose normative debates - such as those concerning climate change (Hulme, 2009a) – or the co-option of science into diplomatic and economic missions – such as the US-led post-World War II reconstruction of Europe (Krige 2006) – highlight the fact that science does not operate in a socio-political vacuum, nor does it just operate against a cultural backdrop. Co-production teaches us that scientific knowledge participates in the never-ending efforts to order society, to reconfigure relations between state and citizens (Carson 2004), and to modify relations to certain 'others' – be they members of different, perhaps distant societies (Said 1979), or the nonhuman (Thompson 2004).

Jasanoff (2004c) identifies two broad strands of co-productionist work in STS – the *constitutive* and the *interactional*. While the *interactional* strand is concerned with the negotiation of political order in moments of epistemic emergence, the *constitutive* strand is concerned with questions of ontological and even metaphysical stability, and the creation and maintenance of ontological order at particular sites. Such questions address "how people perceive elements of nature and society, and how they go about relegating part of their experience and observation to a reality that is seen as immutable, set apart from politics and culture" (ibid, 19). The classic study of this oeuvre is perhaps Latour's *We Have Never Been Modern* (Latour 1993). Here, Latour seeks to explain how the 'modern constitution' of a foundational metaphysical distinction between nature and culture is the *outcome* of social controversies, rather than an ontological *a priori*. Through acts of purification, the hybridity and entanglement of nature and culture is obscured through the combined works of the sciences and of politics which are invested in maintaining the constitutional distinction and the forms of delegation which it supports – i.e. science speaks for nature, politics speaks for culture and society.

Elsewhere (e.g. Latour 2004a) Latour has argued that the ongoing construction of this constitutional bifurcation has precluded the possibility of an effective democratic engagement of the 'collective' with debates over the "gradual composition of the common world" (Latour 2012, 72). Like Hulme (2009a), Latour has argued that an issue like climate change, which radically undermines metaphysical distinctions between nature and culture, demands that spokespersons for nature (scientists, in the main) are able to step outside the demands of modernist rationalism and its amputation of facts from values. Everybody, Latour suggests, should speak to the question of what kind of world we would like to live in, with all the ideological baggage that such questions demand firmly in hand. Latour's theorising of a renewed politics of nature has proceeded alongside and in conversation with a broader field of inquiry broadly (or perhaps reductively) referred to as actor-network theory (ANT).

Actor-networks and constitutive co-production

> [R]eason has today much more in common with a cable television network than with Platonic ideas. It thus becomes much less difficult than it was in the past to see our laws and our contracts, our demonstrations, and our theories, as stabilised objects that circulate widely, to be sure, but remain within well laid out metrological networks from which they are incapable of exiting – except through branching, subscription and decodings.
>
> (Latour 1993, 199)

As one of the most significant theoretical innovations to have emerged from the sociological study of technoscientific systems, actor-network theory (see Callon 1986a; Latour 1987; 2005) has provided a theoretical and analytical framework for the study of the relational associations between human and nonhuman 'actors' across scientific and technological networks. In essence, ANT is "an infra-physical language for mapping out the traces of networks through an anthropology of the figures that set them going and keep them at work" (Bingham & Thrift 2000, 285).

ANT is a form of relational material semiotics, positing that the ontological status and meanings afforded to objects and subjects is a product of the "discourses, devices and practices that comprise heterogeneous networks" (Collinge 2006, 248). Therefore "entities take their form and acquire their attributes as a result of their relations with other entities" (Law 2003, 2). People, machines, ideas, the state, objects of scientific inquiry, epistemic and ontological boundaries (such as nature/culture); all these are viewed by ANT as the interactional *effects* of network-building, which in turn is wholly constitutive of 'the social' (Law 1992; Latour 2005; see also Serres & Latour 1995, 103-110). The 'network' of 'actor-network theory' should therefore be read as a verb rather than a noun. Processes of network-building not only connect heterogeneous objects and people, but actively bring them into existence and demarcate their ontological status, through "processes of reciprocal definition in which objects are defined by subjects and subjects by objects" (Akrich 1992, 222). ANT thus embodies a radical anti-essentialist ontological stance, which considers distinctions such as human/nonhuman, agency/structure and society/nature to be themselves products of network-building, rather than constitutive elements of reality (Latour 1992; 1993). Whereas much social theory sees "a purified world of categories", the approach developed by Michel Callon, Bruno Latour, John Law and others "sees a heterogeneous world of hybrids" (Bingham & Thrift 2000, 287). Thus "entities have no inherent qualities", and "essentialist divisions are thrown on the bonfire of the dualisms" (Law 2003, 2) in pursuit of a 'generalised symmetry'[5].

The 'actors' which constitute networks (or which go about networking) need not necessarily be human characters – "they can be anything" (Latour 1988, 5). An 'actant' is therefore any entity which has the capacity to act, i.e. is "able to make shifts in space and time" (Bingham & Thrift 2000, 287). Actants may be human or nonhuman,

[5] As Pels (1996) has suggested, the 'symmetry' practiced by proponents of the Strong Programme of the sociology of scientific knowledge (e.g. Bloor 1976; Barnes & Bloor 1982) differs from the generalised symmetry of ANT in its concern with epistemology and for using the same constructivist tools to explain both 'true' and 'false' beliefs. Actor-network writers are more concerned with what David Livingstone (2010) has referred to as an ambitious ontological project.

and embody both material and 'social' components (Callon 1986a)[6]. Network-building is a relational activity by which significance is afforded to particulars through their (re)positioning in space and time, and the bringing of objects "into relation with one another, often in new styles and unconsidered combinations" (Bingham & Thrift 2000, 281; Law & Williams 1982). This relationality means that the actors considered by ANT can be diverse. In Callon's famous case study, fishermen, scallops, breeding grounds and zoologists are all treated as entities capable of action within the actor-network[7] (Callon 1986a). It is in this diversity of actants that the heterogeneous world of hybrids is to be found (Law & Mol 2001; Jöns 2006).

The space of ANT

ANT proffers a radical spatiality in which "the 'real' space of traditional geography is replaced by a space that is articulated within networks and proximity is defined by connectability" (Collinge 2006, 248; Latour 1998; Murdoch 1998). ANT poses serious challenges to certain 'spatial structuralisms', such as notions of scale, nested hierarchy and regional space. In the case of the latter, the production of regional spaces should be seen as "a function of network connections, connections in which physical boundaries and differences of scale are achieved through the differential enrolment of objects within these networks" (Collinge 2006, 249). Space and time are "consequences of the ways in which bodies relate to one another" (Latour 1997, 174). 'Scale', therefore, is the outcome of network relationships, but ANT flattens the topology of 'vertical' scales (e.g. local, national, global) and reconceptualises it as a function of network strength and size. So what may intuitively be identified as a 'global' system of governance, for example, should instead be seen as a network capable of linking together a large number of spatially dispersed elements, which may in turn constitute key elements of other, shorter ('local') networks. Therefore, "even a longer network remains local at all points" (Latour 1993, 117), and the 'global' should be considered to be the product of a series of local accomplishments (Law

[6] A similar post-humanist model of agency is offered by Pickering (1995, 26): "The world makes us in one and the same process as we make the world". Pickering's 'mangle of practice' is something of an ontological oddity however, which elides human intentionality with a "godlike imperviousness to the contingencies of world-making" (Jasanoff 2004c, 24).
[7] Critics often disapprove of this granting of agency to nonhuman and often inanimate objects. However, to grant agency is not to grant *intentionality* of action.

2004a). There is thus no "general logic of emergence" (Collinge 2006, 249) of particular spatial forms, and ANT's network topology can draw attention to the discursive, material and institutional construction of particular spatial configurations (Bulkeley 2005), and to the scalar politics of emerging and evolving modalities of governance (e.g. MacKinnon 2010).

ANT posits that knowledge itself proceeds through travel (Serres & Latour 1995, 114; see also Serres 1982), i.e. through the linking of otherwise incommensurable space-times. Likewise, the 'facts' produced by scientific work can only function through the tracing and transformation of space. "To be universal, facts have to be spatially and temporally unlimited and therefore depend on the construction of a particularly stable network" (Sundberg 2005, 19). ANT thus emphasises the work that is necessary to stabilise a scientific fact or tool before it is able to travel. This work includes the processes of producing 'black boxes', in which resides "that which no longer needs to be reconsidered, those things whose contents have become a matter of indifference" (Callon & Latour 1981, 285). Mobility demands that a complex assemblage of actors, ideas and tools behaves as a functioning network in order for scientific knowledge to travel in the form of 'immutable mobiles' (Law 1986) and lay claim to the status of truth outside the laboratory (Latour 1999).

The circulation of immutable mobiles occurs through the production and linking of 'centres of calculation'. The analyst's task is thus to trace the:

> history of centres which are growing through the management of traces that have three main characteristics: they are as mobile, as immutable and faithful, and as combinable as possible. The circulation back and forth of these 'immutable mobiles' have networks – that is two-way paths leading from the centre to the now documented lens. These networks are constantly repaired against interruption by maintaining metrological claims that keep the frames equivalent.
>
> (Latour 1988, 21)

Criticisms and going beyond ANT

The main contribution of ANT to social theory was the re-casting of the nonhuman as an agentive actor in the constitution of the social and natural. This post-humanism has attracted great interest from geographers enthused by the new ways ANT offers for thinking about ontological hybridity and complexity, and about human entanglements with the nonhuman (e.g. Murdoch 1998; Whatmore 2002; 2006; Thrift 2007). However, Powell (2007a, 319) laments the lack of “substantive elaborations” of ANT in geographical applications of it. With a few exceptions (e.g. Castree 2002; Kirsch & Mitchell 2004), geographers have arguably yet to engage with how this important attempt “to reinvigorate the place of the nonhuman and the material in accounts of power entails substantial costs with respect to the treatment of human agency and human values” (Jasanoff 2004c, 23). Critics of ANT have lamented its tendency towards ontological totalisation in its oddly teleological characterisation of the modern and the non-modern (Rabinow 2002). Others have bemoaned the semiotic formalism which emphasises the structure of networks over the political relations they engender (Law 1999; Anderson & Adams 2008; Chilvers & Evans 2009; Papadopoulos 2010), and the studious neutrality of the approach which ignores the “quite real effectivity of victimisation” (Wise 1997, 39). One outcome of this neutrality is an inability to account for cultural differences in the reception of knowledge claims in different contexts; an outcome of the disavowal of questions of meaning, memory and institutional power (Jasanoff 2004c). Although attempts have been made to introduce greater ontological relationality and fluidity to the approach in order to account for the slipperiness of meaning across space (see Law & Hassard 1999; Law & Mol 2001), ANT has been seen to miss “the sizzle of the event” and the “dizzy (and often embodied) force of conjuncture” (Bingham & Thrift 2000, 299), an element which is vividly evident in the work of Gilles Deleuze – an important influence on both Michel Serres and Bruno Latour (Thrift 2000).

These criticisms are reflected in complaints about the “imperialistic language” (Shapin 1998, 7) of ANT, which has drawn particular ire from the postcolonial school of science studies. Here, a greater emphasis is placed on the hybridity of ‘contact zones’ between modernity and nonmodernity (Watson-Verran & Turnbull 1995; MacLeod

2000). Rather than an uncritical, managerialist focus on the domineering expansion of networks, postcolonial perspectives seek to shed greater light on the performance of power and reciprocity in scientific exchanges, thus challenging hierarchical models of centre-periphery which ANT seems to implicitly recapitulate, for example in Latour's (1990) ultimately economistic rendering of power as being equivalent to the number of inscriptions (mobile representations such as maps or money) which can be accumulated in one place. In accounts of the mobility of scientific knowledge, ecologies of mutual interdependence have begun to emerge (e.g. Jankovic 2004; Secord 2004; Raj 2007) which re-position science as a conduit and source of power, but a power which is distributed, relational, and a function and effect of cultures and institutions.

Space/knowledge/power: Foucault between constitutive and interactional co-production

The turn towards seeking understanding of the variegated geographies of scientific knowledge has been motivated in no small part by this kind of constitutive co-productionist inquiry. The work of the actor-network theorists and of Latour in particular has motivated a great deal of geographic inquiry into the mobility of scientific objects, tools and ideas (see e.g. Pestre 2012; Mahony & Hulme 2012). It has also stimulated a renewed interrogation of the materiality of scientific knowledges and the agentive entanglements of environmental change (e.g. Whatmore 2002; Lorimer 2012). However, as suggested above, ANT has been read by some as an insufficient theory of power at best, and an utterly unhelpful theory of politics at worst.

Michel Foucault's career-long exposition of the mutual constitution of knowledge and power situates his work in large part alongside the constitutive vein of co-productionist inquiry in STS. His inquiries into systems of thought, their ruptures and breaks, and the bringing-into-being of new objects and subjects chimes with the constitutive co-productionist interest in the creation and maintenance of ontological stability in diverse sites under conditions of ontological emergence (Foucault 2002; 2007a). Foucault consistently emphasises the spatial contingency of knowledge and its relationship to power (Foucault 1980a; 2010; see also Crampton & Elden 2007), as well as the importance of spatiality as a tool for the analysis of knowledge and power:

> Once knowledge can be analysed in terms of region, domain, implantation, displacement, transposition, one is able to capture the process by which knowledge functions as form of power and disseminates the effects of power. There is an administration of knowledge, a politics of knowledge, relations of power which pass via knowledge and which, if one tries to transcribe them, lead one to consider forms of domination designated by such notions as field, region and territory.
>
> (Foucault 2007b: 177)

For poststructuralist thinkers more broadly, Foucault's notion of discourse has been influential in elucidating the interdependency of knowledge, power and space. Discourse is "a relational totality of signifying sequences that together constitute a more or less coherent framework for what can be said and done". By encompassing both semantic and pragmatic aspects, discourse "does not merely designate a linguistic region within the social, but is rather co-extensive with the social" (Torfing 1999, 300) and is central to contested and situated meaning-making (Laclau 1993). Discourse is inherently spatial, and characteristic ways of thinking and doing "will appear across a range of texts, and as forms of conduct, at a number of different institutional sites" (Hall 2001, 73). Discourse has important productive effects, especially the production of knowledge, as knowledge of particular objects is always contingent on structures of meaning rather than simply on the objects themselves (Foucault 2007a).

Foucault applied the notion of discourse and the broader 'discursive formation' to explore how fields of knowledge have developed norms of objectivity and validity (Foucault 2002). In his later genealogical work (Foucault 1979; 2008), attention turned towards what he categorised as 'non-discursive' forces acting on the epistemic ruptures and transformations identified in his archaeological studies (Foucault 2002; 2007a). This brought his approach into closer alignment with early efforts in the sociology of knowledge to elucidate the socio-cultural ‘context’ of scientific knowledge (although differences exist, see Gutting 1989, 257). Throughout this evolution, Foucault sought to excavate the mutual constitution of knowledge and power (Rouse 1987). He held that there is “no power relation without the correlative constitution of a field of knowledge, nor any knowledge that does not presuppose and constitute at the same time, power relations” (Foucault 1979, 27).

Foucault’s power is non-subjective, cannot be possessed, and is “employed and exercised through a net-like organisation” (Foucault 1980, 98). Latour and Foucault arguably share a Nietzschean conceptualisation of power, which is particularly apparent in the mechanisms of ‘translation’ (Serres 1974; Harman 2009). With translation understood as “all the negotiations, intrigues, calculations, acts of persuasion and violence, thanks to which an actor takes, or causes to be conferred on itself, authority to speak or act on behalf of another” (Callon & Latour 1981, 279), we may see an indication of how actors are not the “inert and consenting target” of power, but “the elements of its articulation” (Foucault 1980a, 98) – providing empirical echoes of the Nietzschean *will to power* (Nietzsche 1968). John Law (2008) likewise suggests that ANT may be viewed as an empirical version of Foucault’s poststructuralism: while Foucault stresses the productive and strategic operation of power and discourse, ANT draws attention to the “strategic, relational, and productive character of particular, *smaller-scale*, heterogeneous actor-networks” (ibid, 145, emphasis added). For example, in Callon’s (1986b) account of the electric car, we can see the formation and evolution of new forms of meaning and representation through the linking-up of diverse elements (often from diverse ‘social worlds’ – see below) in a new network (Torfing 1999).

Foucault’s emphasis on knowledge as a form of spatialised power has been highly influential, for example in Edwards Said’s work on the discursive constructions of imperial subjects in European scientific and artistic depictions of the ‘Orient’ (Said 1979; 1994; see also Gregory, 2000). Yet Foucault encourages us not just to consider the mutual constitution of ontologies and power, but also to understand the *work* performed by concepts, categories and ideas in society[8]. The task of exploring how intellectual products become “an element in political activity” (Shapin & Schaffer 1985, 332) accords with Foucault’s efforts to elucidate the historical emergence of different forms of governmental rationality (Foucault 1991; 2009; 2010). In unstitching “the historical universals of State, society and economy” (and of course 'science' - Whitehead 2011, 232), Foucault offers a vision of emergent forms of reason (concerning such objects as ‘population’ and ‘economy’) which intersect with governmental imperatives to exercise new forms of sovereign and disciplinary power over a territorial area (see also Mitchell 2002). It could be argued that his emphasis on discursive structures of reason and rationality struggle, like ANT, to account for the persistence of diversity in ways of ordering the world (e.g. Scott 1998). But Foucault’s sensitivity to the constitutive and interactional co-production of space, knowledge and power may be furthered by considering how particular forms of knowledge and power undergo differential treatment across diverse cultural and institutional settings. Despite his tendency to generalise, Foucault’s work serves “to remind us not only of the cultural contingency of spatiality but also of a shift from universalist, unified and coherent conceptions of cosmic order to local, diverse and often contested orders embodied in complex sites” (Smith & Agar 1998, 1). By studying the spatiality of knowledges, we are able “to grasp precisely the points at which discourses are transformed in, through and on the basis of relations of power” (Foucault 2007b, 177). It is just such moments of transformation which have animated accounts of the interactional co-production of scientific knowledge and social order.

Interactional co-production and circulating knowledges

Less concerned with the ontological constitution of the natural and the social and more with the “myriad mutual accommodations between social and scientific practices that occur within existing socio-technical dispensations during times of conflict and change” (Jasanoff 2004c, 19), the *interactional* tradition of co-productionist inquiry has shed light on “knowledge conflicts within worlds that have already been demarcated, for practical purposes, into the natural and the social”

[8] See Foucault & Chomsky (2011).

(ibid). Knowledge conflicts nonetheless often erupt around the contested boundaries of the natural and the social – or the scientific and the political (Gieryn 1999) – a point which will be returned to below and throughout this thesis. At stake in these conflicts are resolutions to the problem of credibility and trust – whose knowledge should be taken as a reliable, metonymic rendering of the world (Shapin 1995a)? Should consequential political decisions be based on knowledge whose credibility is contested? What are the motivations – scientific or political – behind those who would contest the claims of an objective science? Such questions animated the debates between Hobbes and Boyle, and are characteristic of the knowledge politics which constitute almost any debate on the consequences and implications of climate change (Hulme 2010a; Grundmann & Stehr 2012).

The interest in interactional co-production accords with geographical interests in circulating knowledges. Knowledge has the capacity to circulate in a remarkable variety of vehicles (see e.g. Howlett & Morgan 2010). Imperious theories and travelling academics (Said 1983; Mahroum 2000; Jöns 2010), canonical texts (Secord 2000), material objects such as scientific instruments (Shapin & Schaffer 1985; Jankovic 2004), laboratory animals (Davies 2011), inexorable but not uncontested 'globalisation' discourses (Anderson & Adams 2008; Stehr 2010): all these provide the momentum and media for the local, regional and global circulation of scientific knowledge; its practices, assumptions, discourses and forms of social organisation.

Edward Said explicitly addresses the problems of travelling knowledge in his essay on 'travelling theory' (Said 1983, 227), where he argues that a sensitivity towards the environments in which ideas and theories originate, the distance and contexts they traverse, the conditions of acceptance or resistance and the ultimate accommodation (or not) of ideas and theories is a key element of the 'critical consciousness' (see also Thrift 1999b). Although speaking from within the realm of postcolonial literary theory, Said raises a number of questions pertinent to geographers of science, concerning for instance "the processes of representation and institutionalization" (Said 1983, 226) which differ across space and foster the transformation of ideas from one context to the next, and shape how successfully theories "acquire the status of authority within the cultural group, guild or affiliative family". Thus he calls on scholarly inquiry to “map the territory covered by all the techniques of dissemination, communication, and interpretation, to preserve some modest (perhaps shrinking) belief in noncoercive human community” (ibid, 247). While Said’s explicit normativity has yet to materialise in work on the geographies of science (Powell 2007a), his engagement with the spaces of knowledge production and circulation align closely to Livingstone’s (2003a) framing of science’s geographies, which has been influential in shaping further work in the field (e.g. Hulme 2008).

One way in which this concern with circulation has been enacted has been in studies of the *geographies of reading*. Work on the history of reading in scientific contexts has revealed it to be constitutive of cognitive practices; of observation, attention, meaning-making, and the solidification or erosion of belief (Secord 2000; Daston 2004; Livingstone 2005a; 2005b). Reading is thus an inherently subjective experience: a “book, like a landscape, is a state of consciousness varying with readers” (Dimnet 1928, 151). Historiographical studies of scientific texts have combined “analysis of what texts contain with consideration of how, when, where, why, and by whom they were read” (Daston 2004, 443). This attention to the local and the particular has thus enabled consideration of how the materiality of the text links together authors, readers, competing and complementary ideas in complex networks of scientific production and communication (e.g. Rupke 1999; Keighren 2010). This treating of texts as “material objects embedded in local milieux that imbue them with sense and significance” (Daston 2004, 448) gives rise to questions of hermeneutic struggle (Topham 2004): the ongoing and multi-faceted contestation of meaning in which science is always embroiled (Golinski 2005). The focus on the mutability of knowledge claims, the fluidity of meaning and the mutual accommodations or antagonisms of hermeneutic struggle places the geographies of reading in conversation with interactional accounts of co-production. Although there is a risk of valorising individual interpretations of texts over broader questions of the cultural trajectories of particular knowledge claims (Fish 1980), careful analytic work can offer important insights into communal acts of meaning-making (e.g. Rupke 1999).

Literary theorist Stanley Fish has dealt with this problem of accounting for what we might call the ‘representativeness’ of individual interpretation. Fish (1976; 1980; 1989) rails against the formalists who hold that the structure and spatiality of a text determine readers' interpretations, but also cautions against positing a wholly autonomous reading subject able to project any desired meaning onto a text. Fish develops the notion of the 'interpretive community' to describe the communal nature of the interpretive act:

> Interpretive communities are made up of those who share interpretive strategies not for reading (in the conventional sense) but for writing texts, for constituting their properties and assigning their intentions. In other words these strategies exist prior to the act of reading and therefore determine the shape of what is read rather than, as is usually assumed, the other way round.
>
> (Fish 1976: 483)[9]

So the interpretive community is a loosely connected set of actors, temporally stable but with sufficient space for the continuation of 'interpretive battles' which shape modes of interpreting literary forms through a lens formed by certain commitments, interests and situated norms. The use of these lenses constitutes an act of 'writing texts' as the meaning of a text isn't pre-given. Rather, it is constituted through the act of inter-subjective, communal interpretation (see also Barthes 1977). Livingstone (2005b) summons these ideas in his argument that a clear distinction between spaces of knowledge production and consumption is untenable. There are no "sites of knowledge that simply summon ideas and theories and practices out of thin air...the generation of knowledge involves interpretation as well as invention...because the coming together of texts and readers is a creative hermeneutic event, one in which meaning is made and remade" (ibid, 395). The hermeneutic encounter of reader and text is thus an act of knowledge production, complicating the notion that "the making and communicating of knowledge" (Secord 2004, 661) can be spatially or temporally delineated. The communal nature of the interpretive act thus draws us towards the "geographies of interpretation" of circulating texts and knowledge claims (Livingstone 2005b, 395).

[9] The notion of interpretive community offers an interesting rejoinder to the notion of 'epistemic community' (Haas 1992a; see also page 83, this volume)

Beginning in Chapter 5 and extending through Chapter 6, I aim to explore the interpretive geographies associated with a particular way of framing and representing the global risks associated with climate change. Building on the geographies of reading and interpretation described by Livingstone and others, I look to characterise the production and circulation of scientific visualisations as spaces of both constitutive and interactional co-production. As a suite of practices, norms and material relations, scientific visualisation has long been of interest to students of the social construction of scientific knowledge (Pauwels 2006; Burri & Dumit 2008). In accordance with those who have studied practices of visualisation as central tenets of laboratory practice (Knorr Cetina 1981; Lynch 1985), Latour (1990) positions the circulation of mobile, visual inscriptions as key to the constitutive power of scientific knowledge. The ability to translate the complex multi-dimensionality of the nonhuman world into transportable, two-dimensional depictions renders science unique among other forms of knowledge production. Yet, as discussed above, Latour's economistic emphasis on standardisation and accumulation overlooks the interpretive flexibility and cultural malleability of knowledge claims. Seeing scientific visualisations not as mobile, inert agents of power but as participants in broader cultural practices of meaning-making and collective reasoning (Jasanoff 2001; 2004d) offers an important entry point for Livingstone's hermeneutic geographies of interpretation to enter into dialogue with work on the production and interpretation of scientific images. In Chapters 5 and 6 I develop this line of inquiry in relation to debates about the boundaries between science and politics, with an interest in how scientific visualisations can function as sites of co-production – of scientific knowledge and of science's cultural boundaries. It is therefore necessary to begin considering how such boundaries are socially constituted. However, one question is prior to such considerations: how are the domains like 'science' and 'politics' constituted as distinct 'social worlds' in the first place?

'Social worlds' and the sociology of interaction

Within STS the circulation of scientific knowledge is often conceived sociologically, in terms of communication between scientific experts and lay persons (e.g. Wynne 1995) and in the application of particular forms of expertise and knowledge to political decision making (e.g. Jasanoff 1990). Circulation is thus conceived as a movement of knowledge between actors within forms of social, cultural and political space. This space must itself be *produced* (cf. Lefèbvre 1991) by the relevant actors in a situation, for example through the production of a 'global' knowledge space (Crawford et al. 1992; Tsing 2000; Oels 2005; Hulme 2010a), or by the construction of information needs (or 'demand') through iterative exchange across the 'social worlds' of science, politics and society (cf. McNie 2007; Sundberg 2007; Mahony & Hulme 2012).

In contrast to the rigidity and formalism of ANT, the *social worlds* framework provides a comparatively ecological perspective on social interaction. This is a symbolic interactionist approach to social inquiry (Blumer 1969) with roots in pragmatism (Clarke 2005, 124) and the Chicago school of sociology (Clarke & Star 2008, 114). A 'social world' can be understood as an assemblage of people and institutions united in a shared discursive space (Strauss, 1978), with "shared ideas about how to go about their business and conduct debates about both their own activities and those that may affect them" (Sundberg 2005, 28). However, the 'discursive space' referred to by Strauss should not be understood in a Foucauldian sense[10]. Rather, the social worlds approach focuses on *work* and shared meaning-making, and a social world can accordingly be considered a unit of analysis which cuts across formal societal organisations and institutions, to capture people 'doing things together' (Becker 1982). The focus is therefore on the actions and interactions of actors, and the performance of material practices (Gerson 1983; Fujimura 1987). Crucially, social worlds theorists see scientific knowledge (in the form of theories or facts) as socially constructed and as best viewed through the lens of the work, institutions and social relations which constitute scientific endeavour, which themselves cannot be separated from the cognitive aspects of science (Clarke & Gerson 1990; Sundberg 2005).

Social worlds are sites of disagreement and negotiation. The processes by which diverse actors come together within worlds or arenas do not naturally tend towards cooperation and consensus. Rather, social worlds theory "is a conflict theory; the generic social process is to be intergroup conflict unless and until the data prove

[10] Strauss uses 'discourse' in the more limited linguistic sense of the term (see also Sundberg 2005, 31).

otherwise" (Clarke 1991, 129). A particularly salient line of inquiry has focused on work that occurs at the boundaries of different social worlds or 'sub-worlds' (cf. Gieryn 1983; 1995). The concept of the *boundary object* (Star & Griesemer 1989) has been used to explore how certain ideas, objects or practices enable exchange to take place between social worlds (e.g. science and politics) in a manner that accommodates both theoretical coherency and local plasticity (Star 1988).

The social worlds analytic brings to the fore the problems faced in collective meaning-making and knowledge production when these activities are distributed across time and space. For knowledge systems to function, experiences must be combined with those gained in other space-times. Experience must therefore travel in the form of representations, but even "seemingly simple replication and transmission of information from one place to another involves encoding and decoding as time and place shift" (Bowker & Star 2000, 290). There are synergies here with the theorisation of mobility in ANT discussed above, although social worlds approaches offer greater scope for thinking about the mutability and interpretive flexibility of objects. The concept of the boundary object (in addition to the 'standardized package' - Fujimura 1992) provides an explanatory resource for thinking about how collective work and meaning-making is facilitated across social worlds, and in the process how 'facts' may come to be stabilised (Fujimura 1987; 1988; Fujimura & Fortun 1996), and how coherence across intersecting social worlds may be maintained in tension with local interpretive flexibilities (Fujimura 1992).

In contrast to more imperious articulations of ANT, the production of boundary objects should not be interpreted as an instance of a wholly unequal exercise of epistemic power through the imposition of one group's vision and assumptions on another[11]. Rather, boundary objects should be seen as bridges or anchors between groups, which are "plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (Star & Griesemer 1989, 393). Through studying the production and

[11] An interesting comparison can be made here with William James' warnings against 'vicious intellectualism' – the enforcement of certain abstractions or concepts that may not be shared or grounded in immediate experience (Heft 2005, 41).

evolution of boundary objects, it is possible to explore the question of how heterogeneity and cooperation coexist in complex strategic situations where objects and actors function as “vehicles of power” (Foucault 1980a, 98).

The social worlds tradition differs from anthropological approaches to social inquiry in that the initial unit of analysis is often defined by space or territory, rather than culture (Clarke & Star 2008, 114). As an ecological perspective, social worlds theorists are concerned with interactions and relations between people and nonhumans within a particular setting (such as the laboratory). The main thrust of early work in the Chicago tradition of sociology was to “make an inventory of a space by studying the different communities and activities of which it is composed, that is, which encounter and confront each other in that space” (Baszanger & Dodier 1997, 16). However, the territorial vernacular has increasingly given way to a concern for *shared discourses* and their role in demarcating boundaries, and the interactions of collective actors across multiple sites. Nevertheless, in concert with the geographies of science, the social worlds approach can draw attention to the demarcations, negotiations and shared practices which constitute ‘universes of discourse’ (Mead 1938), before leading us to the sites where these interactions occur.

While discourse and shared meaning-making are themselves constitutive of social worlds, there exists a need for an analytical unit which can account for such practices at a scale above the social world. For example, while the different groups involved with the Zoology Museum of Star and Griesemer's (1989) classic study were delineated by their *perspectives* on zoology, i.e. their organised sets of ideas and beliefs which orientate action and interaction (Becker 1961, 34; Sundberg 2005, 28; see also Mead 1938, 119; Shibutani 1955), they were nonetheless encompassed by a shared interest in natural history and its furtherance (Star & Griesemer 1989). This broader plane, where the meeting of diverse social worlds can occur, has been termed an *arena*, containing “multiple worlds organized ecologically around issues of mutual concern and commitment to action” (Clarke & Star 2008, 113). Sundberg (2005) depicts ‘climate change’ as an arena in which a wide collective of entities, such as modellers, research funders, politicians and activists interact, in part through the operation of boundary objects.

Such arenas are sites of intersection (Gerson 1983). "An intersection can involve more than two social worlds or segments...and consists of a system of negotiating contexts in which resources, skills or information flow between social worlds" (Sundberg 2005, 31). Gerson (1983) emphasises 'interpretive intersection' and the transmission of ideas between worlds, suggesting synergies with Callon's (1986a) 'sociology of translation', which has often been put forward as an alternative appellation for ANT. However, the concept also provides fruitful suggestions for exploring the spatiality of intersections, such as the operation of hybrid spaces of knowledge production where various social worlds meet in the service of policy-relevant scientific assessment (Miller 2001a; Petersen 2006).

Processes of legitimation (Gerson 1983) are considered central to the functioning of intersecting social worlds. These include "the sub-processes of discovering and claiming value for the social world (or subworld) and its products, distancing the world from others, setting standards, embodying them and evaluating them" (Sundberg 2005, 30; Strauss 2008). For Sundberg (2005), disputes over the techniques used to evaluate research are indicative of legitimacy conflict. Ryghaug & Skjølsvold (2010) illustrate this dynamic in their recounting of the controversy generated by the hacking of emails from the University of East Anglia's Climatic Research Unit (CRU). The study illuminates the centrality of methodological conflict to processes of legitimation, and the complex interweaving of personal and epistemic credibility in negotiations of scientific legitimacy. This echoes Strauss' (2008) argument that legitimation and boundary conflicts are often articulated through deliberations about whether certain individuals or practices should be considered properly representative of a given social world.

The boundaries of science

The social worlds approach has been largely overlooked as an example of interactional co-production. Although the notion of the boundary object has achieved wide recognition across and beyond STS (Star 2010), the social worlds tradition is largely overlooked by Jasanoff (2004c) as a means of grappling with the mutual constitution of, for example, science and politics in the ongoing construction of social and natural order. However, Gieryn's (1983) description of the 'boundary work' which goes into delineating science from its outsides (such as politics) has some resonance with, for example, Gerson's (1983) description of intersecting social worlds locked in battles for legitimation. Although the social worlds analytic is sociologically interested in science as a site of intersection – for example of professional scientists, laboratory technicians and amateur enthusiasts – and therefore in the question of how individuals come to be regarded as part of some social world or not, Gieryn's work is more interested in the broader cultural authority of science outside of conventionally delineated sites of knowledge production (Gieryn 1999). As opposed to essentialist arguments about the true nature of science and its boundaries (Popper 1959; Kuhn 1962), Gieryn emphasises the historical, cultural and spatial contingency of the settlement of science's boundaries in moments of epistemic controversy or emergence (Gieryn 1983). He builds on constructivist arguments that the form and content of scientific knowledge is under-determined by the physical world to suggest that the pervasive 'downstream' cultural authority of science is under-determined by the form and content of its knowledge claims (Gieryn 1999). The legitimation and authorisation of science is an ongoing social process. Boundary work occurs in contests over legitimate claims to represent the 'real', to denigrate opponents as unscientific, and to retain science's prominent position on the cultural map of modernity as a fount of epistemic authority (Gieryn 1995).

Gieryn's work sits firmly within the interactional tradition of co-productionist inquiry:

> In this view of co-production, human beings seeking to ascertain facts about the natural world are confronted, necessarily and perpetually, by problems of social authority and credibility. Whose testimony should be trusted, and on what basis, become central issues for people seeking reliable information about the state of a world in which all the relevant facts can never be at any single person's fingertips. At times of significant change...it may not be possible to address questions of the facticity and credibility of knowledge claims without, in effect, redrafting the rules of social order pertaining to the trustworthiness and authority of

individuals and institutions.

(Jasanoff 2004c, 29)

Gieryn's elucidation of the construction and contestation of scientific authority is thus one way of reading the *politics* of knowledge. Gieryn and other interactionists (e.g. Guston 1999; Hilgartner 2000; Miller 2001b; Doubleday & Wynne 2011) pull us largely out of the laboratory and into the broader field of public reason. In stressing the mutual constitution of science and politics, co-production invites us to consider the performance of public reason in situations where scientific knowledge becomes embroiled in questions of our living-together; where new social orders are sought through the pursuit of new knowledges, or when new knowledges themselves call forth new ways of ordering our collective existence. As such, the state has become a key object and site of co-productionist inquiry into the machinations of public reason. We may understand public reason as "the institutional practices, discourses, techniques and instruments through which modern governments claim legitimacy in an era of limitless risks" (Jasanoff 2012a, 5). This claiming of legitimacy forms part of an ongoing process of ordering. The state, like the scientific knowledge on which it so frequently draws as both buttress and model (Ezrahi 1990), is a constructed web: "a network that is partly held together by circulating technologies of representation and communication" (Jasanoff 2004c, 26; see also Sharma & Gupta 2006, 18).

Jasanoff (2005a) develops the notion of *civic epistemology* to describe the culturally-embedded, often institutionalised norms and practices by which reliable, objective knowledge is constituted in the public sphere (see also Miller 2004a; 2008)[12]. It is argued that "modern technoscientific cultures have developed tacit knowledge-ways through which they assess the rationality and robustness of claims that seek to order their lives; demonstrations or arguments that fail to meet these tests may be dismissed as illegitimate or irrational" (Jasanoff 2005a, 255). Civic epistemologies are constituted by the varying ways in which objectivity is constructed and performed (cf.

[12] Wynne (2003) uses the term 'civic epistemology' in a rebuttal to the efforts of Collins & Evans (2002) to erect new boundaries around different types of science and expertise. Wynne uses 'civic epistemology' to describe the public politics of expertise in processes of public reasoning, rather than to elaborate particular cultures of public reasoning (cf. Jasanoff 2003a)

Daston & Galison 2007), how public accountability is enabled, the processes through which citizens are invited into spaces of deliberation, how expertise is constituted, and how the visibility of processes of public reasoning is assured. For example, in the US the objectivity of public knowledge claims has historically been assured through practices of quantitative computation and risk analysis. For Porter (1995), quantitative risk management has offered US decision-makers an opportunity to transcend an otherwise fractious and agonistic political space, and to present allocative economic choices as decisions guided only by the cool hand of rational reason. Porter's detailed historical studies of public policymaking in the mid-twentieth century have shown that the numbers offered by quantitative cost-benefit analysis were rarely questioned in deliberative settings. They were instead taken at face-value, as economic truth, and thus as the dependable basis for rational policymaking (see also Kysar 2010).

However, an abiding US commitment to "sound science" in processes of public reasoning has, more recently, seen the deconstruction of numerical claims in public settings become more common, particularly in courtrooms and Congressional hearings. This has perhaps been most readily apparent in the case of climate science where, for example, claims about the historical uniqueness of current levels of global temperature rise have been subject to proto-constructivist charges of political interests shaping the construction of knowledge claims (Demeritt 2006). However, the agonistic unpacking of such knowledges serves to re-affirm the commitment to quantification as the source of objective reason – if a number is found to be tainted with interests, simply find a better, purer number. A commitment to objective quantification and to 'sound science' insulated from the polluting forces of politics is perhaps the only thing which unites the conflicting parties in debates about the veracity of historical and observational climatology (cf. Montford 2010; Mann 2012)[13].

Although quantitative risk assessment also carries great weight in European political contexts such as the UK and Germany, "in neither setting is the method alone seen as sufficient to establish the objectivity of regulatory judgements" (Jasanoff 2005a, 266).

[13] I return to this point in Chapter 9.

Calculative, numerical reasoning is not seen as being coterminous with the objectivist's 'view from nowhere' (Nagel 1989). Political representation thus takes on a significant role in the conduct of public scientific reasoning (Brown 2009). Diversity in scientific advisory committees is lauded in UK and German settings, with institutions such as the German *Enquete-Komission* (inquiry commission) prioritising the representation of diverse interests in knowledge making practices, with scientists sitting alongside political, industrial and civil society delegates. The view from nowhere becomes the view from everywhere, or at least everywhere that is taken to matter (cf. Dewey 1927). In the UK, Jasanoff has suggested that expert advisors are similarly equated with certain interests, but are judged according to individual excellence and personal discernment. Thus a community of trusted, experienced public knowledge makers dominate the conduct of public inquiries and advisory committees (Owens 2010). For Jasanoff (2005a, 266-7) "this faith in expert discernment could hardly exist in a cultural context where common norms of seeing and believing were felt to be lacking, as in the United States". Thus the attainment of an idealised objectivity – the separation of judgment from interests – is achieved in strikingly different fashions in different settings. In Chapters 6 and 8 I seek to develop this line of reasoning as a conceptual means for understanding the circulation of scientific knowledge claims as processes of ongoing interpretation, meaning-making and boundary work.

Jasanoff's elucidation of national civic epistemologies could be criticised for reifying the national in the contemporary geographies of science. By focusing on nationally-delineated 'styles' of public reason, civic epistemology might lead us into the 'territorial trap' (Agnew 1994) of taking the Westphalian nation-state as an historical *a priori* in social inquiry. This is a criticism Agnew makes of international relations scholarship, which overlooks the historic-geographic specificity of nation-state territoriality, assumes neat distinctions between the 'domestic' and the 'international', and presents state space as a container of distinctive societies. It is perhaps on this latter point that civic epistemology could be read as teetering on the edge of the territorial trap, in assuming distinctive cultures of collective reasoning which map neatly onto the geographies of the sovereign nation-state.

However, I would contend that when read in concert with the notion of co-production, civic epistemology can be employed as a resource for explaining the ongoing work of producing the nation-state as a historically and geographically contingent phenomenon. I read civic epistemology as an attempt to come to terms with the paradox that there clearly exist great diversities of ways of reasoning about something like climate change, even within a national context like the UK or US (Hulme 2009a). How, then, does collective reasoning happen? Civic epistemology emerges in Jasanoff's work as an empirical observation about the evident convergence of reasoning styles at the level of the national. Civic epistemologies are ways in which collectives have dealt with the shifting spatialities of knowledge and power which Agnew describes as challenging the foundational assumptions of international relations theories. In this way, civic epistemologies can be read in similar terms as Andrew Barry's 'technological zones' (Barry 2001; 2006) – sociotechnical constructs which decentre the state as the *a priori* unit of analysis, but which illustrate how "governments are constituted not purely on the basis of the demarcation of geographical territories, but also through the formation of *technological spaces* of compatible technique and procedure" (Whitehead 2011, 34, emphasis in original). Civic epistemologies enact particular deliberative spaces of compatible and culturally stabilised styles of reasoning, but spaces which are nonetheless co-produced with evolving technical commitments[14].

That said, the social construction of climate change is a process which occurs in a great diversity of deliberative spaces (Pettenger 2007; Stevenson & Dryzek 2012). The internet and new social media are key sites where the construction and contestation of scientific authority takes place (e.g. Koteyko et al. 2012). The communicative practices of public climate change deliberation may offer examples of the reach of the state into the everyday life-worlds of individuals through what Painter (2006) calls the 'prosaic geographies of stateness'. But an account of the epistemic geographies of climate change must be able to attend to spaces of knowledge production and

[14] For example, Jasanoff (chapter 3 in 2005a) and Barry (2001) both address how the governance of technology and innovation by the European Union (EU) has contributed to the broader project of shoring-up the legitimacy of the EU and enacting a new political space which stands in tension with conventional modes of governance by the nation-state..

interpretation which don't map onto national spaces of collective reasoning. In Chapter 7, I seek to build on this argument in order to critique an overriding focus on dominant, state-sanctioned institutions like the IPCC in our accounts of the politics of climate science. In exploring the epistemic geographies of two efforts which were made to collate scientific knowledge in advance of the ill-fated Copenhagen climate negotiations of 2009, I seek to illustrate how the ongoing negotiation of the boundaries of science and politics takes place in a diversity of settings. I suggest that the particular form which the debates took nonetheless represented a situated and contingent way of framing the science and politics of climate change, which can be attributed in part to dominant climate change discourses associated with particular constellations of state actors. However, these deliberative spaces were transnational and, like the IPCC, pose a challenge to how we understand processes of collective reasoning at the boundaries of science and politics.

In Chapter 8, I seek to bring the concerns with collective reasoning and national space into closer conversation by exploring how co-productionist understandings of knowledge and social order may contribute to the project of historicising territory as an epistemological category (Elden 2007; Elden 2010a). I offer a way to think about the currency of the national in global modes of knowledge production and about how that currency is at the same time continually re-worked and re-constituted through epistemological acts. In so doing, I illustrate how geographies of science can contribute to both interactional and constitutive strands of co-productionist thought. Throughout, the aim is to follow Foucault's direction to not abandon the state as an object of inquiry, but rather to decentre the state as an historical or spatial *a priori* mode of explanation (see e.g. Whitehead 2011, 215). Following Anderson (1991) and Scott (1998), the state (and the nation in Anderson's case) can be considered as constituted by particularly powerful modes of representation and vision. Objects like the map and national symbols, and techniques like the census and centralised planning, render the texture of modernity one of ongoing efforts to naturalise and to control through reciprocal relations between material technologies, epistemic constructs, and cultural meanings. The goal of co-productionist inquiry – of both constitutive and interactional variants – is to attempt to hold these various elements of collective world-making in creative tension; to observe the reciprocal relations between objects, spaces, institutions and meanings without taking any for granted as an explanatory *a priori*. Rather, through historically textured accounts of the cultures, practices and meanings of sociotechnical change, we can grasp how certain forms of social ordering have a peculiar persistence, while offering fine-grained accounts of social change which resist the temptations of determinism.

Epistemic geographies: spaces, boundaries and politics of knowing

What does this mean for the geography of science? The foregoing discussion has sought to demonstrate how our understanding of science's geographies may be enriched by engaging with substantive debates within STS about the different ways we understand knowledge, social order, truth and power to be co-produced. Research which self-identifies as 'geography of science' has offered important contributions to our understandings of how scientific knowledge is a situated accomplishment, born of locally-rooted practices and cultures and the enactment of privileged spaces of inquiry and social warranting. Geographies of science also pose telling questions about the role of mobility in the production of knowledge, and about the social contours of circulating knowledges and their impact on the reception of new ideas in different places. However, this work has largely drawn on theoretical innovations originating outside geography – from ANT, hermeneutics and the sociology of scientific knowledge, for example – while failing to substantively enlarge or contest these theoretical narratives. It is my contention that by engaging more readily with how these different theoretical strands implicate different understandings of how scientific knowledge and social order are co-produced, geographers of science may be able to make more ambitious contributions to social theory. In interrogating the geographies of co-production – for example in the participation of scientific knowledge in the transformation of the 'national' or the 'global' (e.g. Moore 2008) – we are drawn towards questions which go beyond the situatedness of knowledge to broader themes about the politics of a 'global knowledge society' (Willke 2007), of transnational expertise (Miller 2009) and of irreducible epistemic and normative uncertainty (Nowotny et al. 2001; Beck 2009)[15].

Although geographers of science have been sensitive to arguments about the cultural indeterminacy of what constitutes 'science', there is a risk of privileging science as an *a priori* packaging of techniques and assumptions, which then enters into the social life-world through processes of 'circulation' and is altered in processes of 'consumption'. Livingstone's use of Gadamer's philosophical hermeneutics begins to get at the need to reconfigure the spaces of knowledge production and circulation as being mutually constitutive, and to move beyond the language of a commodity which 'circulates' and is 'consumed' (cf. Hughes & Reimer 2004). I have suggested that by engaging with STS literatures which emphasise not only the objective indeterminacy of interpretation but also the variability of different styles of knowledge-making, we might cultivate a geography of science which does more than describe the curios of knowledge circulation – it might begin to describe and contribute understandings of the heterogeneous ways in which natural and social order evolve together in the circulation, contestation and stabilisation of various claims to represent the real. By engaging with the co-production of the spaces, boundaries and politics of knowing, geography of science can make important contributions to understanding the fate of scientific knowledge in contemporary societies.

In the next chapter, I present a survey of recent engagements by geographers and other social scientists with the processes by which scientific knowledge has been brought together in order to inform decision-making about climate change. Although based primarily on secondary sources, I use the material to begin constructing a picture of the epistemic geographies of climate change which provides a background and introduction to the subsequent empirical material.

[15] One topic of research where these considerations have begun to come to the fore is the history and geopolitics of polar science. Scientific constructions of and claims about the Arctic region have been co-produced with competing claims to political sovereignty (e.g. Powell 2008; Depledge 2013) and with new articulations of citizenship and solidarity (e.g. Bravo 2009).

Chapter 3

IPCC and the geographies of co-production

In the previous chapter I sought to develop an approach to the geography of science which takes seriously the co-production of knowledge and social order. The idea of co-production "calls attention to the social dimensions of cognitive commitments and understandings, while at the same time underscoring the epistemic and material correlates of social formations" (Jasanoff 2004b, 2). In this chapter I seek to show how this idea can be profitably applied to the recent evolution of debates about the science and politics of climate change. In particular, I engage with the Intergovernmental Panel on Climate Change (IPCC) as a site of co-production; as a site where "the ways in which we know and represent the world...are inseparable from the ways in which we choose to live in it" (ibid, 2). I seek to begin the work of addressing the overarching question:

> *How have the spaces and boundaries of climate change science been contested in the recent history of international environmental politics, and with what effects?*

In engaging with these epistemic geographies of climate change, it is clear that focusing solely on the IPCC would be insufficient. Conceptually speaking, the geographies of climatic knowledges are much greater than the sum of their institutional parts. Restricting our analysis to the confines of a given institution would be to commit the same essentialising fallacy of seeing 'science' as a hermetically sealed and insulated life world, cut off from the rough-and-tumble of politics and culture. As I explore how others have engaged with the IPCC as either a site of scientific knowledge-making or of co-production, I begin to trace a path through and around a variety of spaces where particular knowledge claims have intersected with the institutional identity of the IPCC, with expressions of different modes of collective reasoning, and with the will to act on climate change.

The IPCC is an experiment. It is an experiment in bringing-together knowledge on an international stage about a global problem of unmatched complexity. It is an experiment in the social organisation of knowledge production. It is an experiment in attaining political credibility and legitimacy for knowledge claims seen as having far-reaching implications for the organisation of contemporary and future societies. The IPCC is thus a site of co-production[16]. The Panel, while formally based in Geneva, is predominantly constituted as a decentred network of volunteer scientists who conduct most of their work remotely from both the organisation's centre and each other. A regular series of meetings at various levels of the organisation's vertical hierarchy facilitate progress and coordination, leading to the publication approximately every six years of a three volume report. Current knowledge about climate change is presented across three themes – the physical science relating to climate change (Working Group I), the potential impacts of a changing climate on human and natural systems (Working Group II), and the possible mitigation strategies that may be adopted (Working Group III). Draft chapters are produced by nominated authors according to a largely preordained structure, before being reviewed by fellow experts and government representatives and being subsequently accepted for publication. Four assessment reports have so far been published – in 1990, 1995, 2001 and 2007. These have been interspersed with periodic 'special reports' on more focused topics, such as extreme weather (IPCC 2011).

What does it mean to apply perspectives on the 'geography of science' to something like the IPCC? How can such a decentred organisation be analysed using the terms of the "socio-spatial school" of historians and geographers who are interested in the mutual constitution of the physical and social boundaries of scientific sites (Powell 2007a, 313)? The geography of the IPCC is highly ambiguous. As the organisation's own website explains, "[t]he Intergovernmental Panel on Climate Change is a huge and yet very tiny organization" (IPCC 2013a). Much of the work which goes into producing IPCC assessment reports is conducted via email, in cyberspace, rather than in the kind of regimented spaces which have conventionally captured the interest of

[16] As a form of intervention in the world, an experiment is "necessarily a temporal-spatial one, engaging with the transformation of spatial and temporal description, the framing of possible actions, and the preformatting of subject/object relations" (Davies 2010, 668).

historical geographers of science. However, I wish to argue that by introducing a co-productionist idiom into the lexicon of geography of science, we can gain fresh insights into the epistemic politics of organisations like the IPCC. The geographical interest in circulating knowledges has clear applications to the question of how 'IPCC knowledge' is a situated set of accomplishments which does not always translate easily into new contexts. However, I want to suggest that geographers of science also have much to say about the new spaces of scientific knowledge making which something like the IPCC is indicative of. Investigating these spaces may call for moving 'outside' of the formal organisational boundaries of the IPCC, to investigate how norms and practices associated with the Panel travel and yield influence in unexpected and perhaps unintended ways.

In this chapter I explore existing literature on the practices and politics of global assessments and the IPCC, and seek to start developing a geographic understanding of the co-production of scientific knowledge and forms of social order in such settings. This leads onto the development of the empirical questions to be addressed in the rest of the thesis. First, it is necessary to consider the place of global environmental assessments in the landscape of contemporary politics. To begin with, I want to build on insights developed in the previous chapter to explore how global scientific assessments transcend conventional understandings of science and politics being wholly distinct domains. In turning to the notion of 'governance', we can begin to see how assessments function as sites of co-production.

Assessment as governance

Global scientific assessments of environmental problems have become increasingly prominent actors in the international politics of environmental change (Farrell & Jäger 2006; Mitchell et al. 2006). In many ways, the rise of the global assessment continues but also modifies the twentieth century trend of liberal democracies drawing on scientific knowledge as a means of attaining credibility and legitimacy for their practices of governing (Ezrahi 1990; Hilgartner 2000). Particularly since the end of World War II, science has become an important means of governing – of negotiating and setting standards, of deliberating risk, and of pursuing diplomatic ideals of internationalism and multilateral cooperation (Miller 2001c; Krige 2006). The delegation of epistemic authority to bodies like the IPCC continues this trend. The increasing prominence of bodies like the IPCC, the Millennium Ecosystem Assessment (MA), the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) and the International Assessment of Agricultural Science and Technology for Development (IAASTD) means that states have, across a range of issues, largely "delegated the role of articulating and defending a shared epistemic foundation for global policy debates to a centralized, international institution" (Miller 2009, 142).

The notion of 'governance' captures the notion that the act of governing is not just associated with governments and the formal operations of the nation-state. "Governance, at whatever level of social organisation it may take place, refers to conducting the public's business – to the constellation of authoritative rules, institutions and practices by means of which any collectivity manages its affairs" (Ruggie 2004, 504). Unlike formal government, governance occurs at multiple, networked sites through which the political complexities of organising the common world are negotiated (Bulkeley 2005). In the context of climate change for example, the governance of risk, energy usage and human behaviour occurs at multiple sites – intergovernmental negotiation platforms like the UNFCCC, municipal councils (Bulkeley & Castán Broto 2012), corporate boardrooms (Cogan 2006; Lovell & Ghaleigh 2013), and the household (Dietz et al. 2009), to name but a few. But the political realism with which these de-centrings and innovations are described tends to separate knowledge from action – to detach processes of producing knowledge from the application of this knowledge in the service of governance. A co-productionist approach recognises the discursive power of these boundary-drawings (Gieryn 1999), but also challenges their empirical and conceptual foundations. If the production of knowledge is a part of the process by which evolving modes of political, social and moral order are negotiated and deployed, then the environmental assessment – often cast as a necessary but external bolt-on to the frameworks of 'Earth System Governance' for example (Biermann et al. 2012) – needs to be considered a site where societies collectively attempt to address the challenges of governing emergent and indeterminate risks (Miller 2007).

Understanding assessments as sites of governance and of co-production means engaging with the *epistemic constitutionalism* which they embody. Miller (2009, 142) defines epistemic constitutionalism as "the ways in which social and institutional processes for producing, validating, contesting and disseminating factual claims help to enable or constrain the exercise of power". He argues that global assessments have important consequences for democracy, particularly issues of representation and sovereignty. Centralised institutions of deliberation are not conventionally geared towards dealing with the demands of the decentred, networked and discursive forms of democracy which animate the field of climate change debates (Stevenson & Dryzek 2012). Indeed, the IPCC has been criticised as an institution which "functions at least as much as an institution for constraining debate in international governance as it does as a space for deliberating global policy ideas" (Miller 2009, 158). In producing dominant and persistent *framings* by which certain aspects or interpretations of the climate change problem are given analytic and communicative prominence (cf. Goffman 1972), IPCC reports have arguably restrained the possibility-space within which policy alternatives have been debated (Hulme 2009a; Grundmann & Stehr 2012). For example, in persistently framing climate adaptation as the marginal cost of failed mitigation, an impoverished politics of adaptation has ensued which relies on downscaled global climate modelling and the linear application of deterministic projections to the otherwise complex politics of societal vulnerabilities and environmental change (Beck 2011; Mahony & Hulme 2012). Similarly, the framing of climate change as a problem of carbon dioxide pollution has arguably precluded a broader politics of energy use and access, while other greenhouse gases have been overlooked as potential candidates for climate change mitigation (Prins et al. 2010)[17].

The IPCC has nonetheless been successfully positioned, by both scientific and political actors, as the most authoritative scientific voice on climate change (Hulme 2013). It is a voice which claims to speak both for and to the world. Climate change as a whole

[17] There is a risk that seeing frames as determinant of the scope of political debate reinforces a linear understanding of the relationship between knowledge (as frame) and action (as political debate). However, frames should be understood as being socially constructed and co-produced: they are forms of knowledge which evolve in tandem with forms of social order, such as the types of political action which are deemed feasible and necessary to tackle climate change. See for example Miller (2000).

has been framed “as a reconceptualization of the human environment in terms that can be analysed, assessed and responded to on scales no smaller than the globe itself” (Miller 2009, 157). Miller re-works Said’s (1979, 3) definition of *orientalism* to describe this *unitary globalism* as “the corporate institution for dealing with the globe [formerly the ‘Orient’] – dealing with it by making statements about it, authorizing views of it, describing it, teaching it” (Miller 2009, 156). Demonstrating the normative potential of co-productionist perspectives, Miller argues that it is not the ‘global’ which is necessarily the problem, but the ‘unitary’; the eliding of epistemic, geographic and deliberative plurality in the processes through which new knowledges and norms concerning the global environment are being co-produced (Hulme 2010a). In what follows, I explore the practices through which this co-production has occurred, and start to develop an interpretive account of the epistemic geographies of the IPCC.

Emergent orders: IPCC’s contested origins

The official constitution of the IPCC took place in Geneva, at the first meeting of the Panel in November 1988. The establishment of the Panel was a joint initiative of the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP), both subsidiaries of the UN, which itself formally recognised the action in Resolution 43/53, adopted by the UN General Assembly in New York on 6th December 1988.

The establishment of the IPCC was the outcome of a confluence of various concerns, interests and political manoeuvrings (Hecht & Tirpak 1995; Franz 1997; Agrawala 1998a; 1998b; Skodvin 2000a). Miller (2004b; 2007) argues that a number of conditions emerged in the late 1980s to create a space for the emergence of such a body. He cites the re-imagining of climate as a global object of scientific study[18], the growing epistemic power of earth system science and its attendant modelling strategies, and the increasing significance and visibility of global environmental politics, particularly in the context of the end of Cold War bi-polar politics. These conditions, Miller suggests, created the kind of atmosphere where a global scientific

[18] See Heymann (2010a) for an account of how the spatiality and temporality of the notion of ‘climate’ has evolved since its Classical origins.

assessment of this ostensibly global phenomenon was seen as not only possible, but was cast as the most appropriate means of generating the kind of scientific narrative deemed necessary to facilitate reasoned political action (Roe 1998). This line of argument is extended by Oels (2005), albeit through the lens of Foucault's notions of governmentality and biopower. Oels argues that the IPCC emerged as an 'administrative space' in which national governments could articulate a biopolitical desire to render the planet governable through the specific visibilities generated by climate science (particularly climate models, see e.g. Henman 2002). Governments thus "captured the scientific discourse by creating the [IPCC] as the main authoritative voice on the science of climate change" (Oels 2005, 197).

While theoretical understandings of the greenhouse effect now date back almost two centuries (Fourier 1827; Tyndall 1863; Arrhenius 1896), it was arguably the long-term monitoring of atmospheric carbon dioxide levels at the Mauna Loa Observatory in Hawaii which generated concerns about the anthropogenic modification of the atmosphere (see e.g. Keeling et al. 1984; Harris 2010). Before the identification of climate change as a pressing scientific and political issue, climatology was an unassuming, largely statistical discipline concerned with long timescale patterns in local and regional climates (Fleming 2005; Heymann 2010a). However, as the prospect of a global change in climate came to greater prominence in scientific debates, climate change science slowly emerged as an 'organised science', manifest in a loose network of researchers participating in conferences and debates on the matter from around 1970 (Agrawala 1998a; Weart 2008). Various reviews and assessments of the topic were conducted during the 1970s (e.g. SCEP 1970; SMIC 1971; Mormino et al. 1975; NRC 1977; 1979), with a decade of discussion culminating in the first World Climate Conference hosted by the WMO in Geneva in 1979. This in turn lead directly to the establishment of the World Climate Programme and its component World Climate Research Programme, which sought to further international trans-disciplinary understandings of the ontological space now occupied by the *climate system*[19].

[19] "The climate system is the highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere, and the

The 1979 conference also commissioned a series of scientific workshops under the auspices of the WMO, UNEP and ICSU (International Council of Scientific Unions) which were held in Villach, Austria in 1980, 1983 and 1985. At the latter workshop an international group of scientists, acting in their personal capacities, reached a consensus position stating that "in the first half of the next century a rise of global mean temperature would occur which is greater than any in man's history". To effectively respond to this challenge, it was recommended that "scientists and policymakers should begin active collaboration to explore the effectiveness of alternative policies and adjustments" (WMO 1985, quoted in Agrawala 1998a, 608). It was on the basis of these recommendations that momentum was built towards the formation of the IPCC.

Shardul Agrawala (1998a) suggests that four main actors were key to the formation of the IPCC: the WMO, UNEP, ICSU and the United States Government. Despite the consensus expressed at Villach (which Agrawala argues was as great as that which led to the Montreal Protocol on ozone-depleting substances), it was perceived by many that the political complexity of climate change was such that the Villach statements were insufficient to drive political action. In light of dissatisfaction with the Advisory Group on Greenhouse Gases (AGGG), a small advisory group set up in 1986 by WMO, UNEP and ICSU which was seen as underfunded and too distant from the policy process to be effective, calls were made – particularly by UNEP's Mostafa Tolba – for a more comprehensive international assessment effort. Following various formative interactions between the US and WMO's Executive Council (see Agrawala 1998a, 611) resolutions were made for WMO, in conjunction with UNEP, to work towards the establishment of an intergovernmental assessment body.

Why intergovernmental?

The 'intergovernmental' form of the assessment body was largely a result of US demands, which Agrawala (1998a) attributes to diverging opinions about climate change between various US government agencies and the Republican White House

interactions between them. The climate system evolves in time under the influence of its own internal dynamics and because of external forcings such as volcanic eruptions, solar variations and anthropogenic forcings such as the changing composition of the atmosphere and land-use change" (IPCC 2007a, 943-944).

administration. An intergovernmental mechanism emerged as a "common denominator agreement" (ibid, 612) between competing factions in the US[20]. Agrawala argues that the US administration (particularly the Department of Energy) was suspicious of any assessment conducted by experts who had not been governmentally accredited. The establishment of an intergovernmental mechanism also accorded with what appeared to be a reticence within the incumbent US administration to act on climate change immediately, and a desire to pursue more research before making political and economic commitments (ibid, 614).

After much backroom negotiation between agencies in the US, a proposal was put to the WMO for a panel consisting of "representatives of countries making major contributions to various aspects of...climate change", which should "allow for adequate representation of countries from all regions...(while)...representatives of...international organizations should participate as observers" (US Draft Proposal, quoted in Agrawala 1998a, 615). With terms of reference for the IPCC established tentatively by the WMO and UNEP in 1988, and the IPCC's comprehensive epistemic remit mandated by a resolution put forward by the Maltese authorities to the UN General Assembly (UNGA 1988), the body was ready to take shape.

Over its first assessment cycle (1988-1990), the IPCC operated in effect as *the* global setting for the negotiation of the science and politics of climate change. Working Group III was essentially a space for debating the merits of policy alternatives, whereas its next manifestation in 1995 was the more prosaically framed 'Economic and Social Dimensions of Climate Change'. A number of developing countries expressed a dissatisfaction at the first report's ambiguous positioning at the boundary of science and politics, and were wary of the IPCC becoming the only setting where a climate change governance architecture would be negotiated (Miller 2009). The Intergovernmental Negotiating Committee was thus established in 1990 under the auspices of the UN, and was the institutional setting for the drafting of the UNFCCC (Bodansky 2001). This act of boundary making strengthened the IPCC's self-

[20] Agrawala also suggests that that the US's insistence on such an organisation was a strategic move (by the US authorities and the WMO) to prevent UNEP's Mostafa Tolba from exercising the kind discursive and political leverage over the climate issue which he had over the science and politics of ozone depletion (cf. Grundmann 2006).

identification as a scientific body, with a clear discursive firewall established between deliberation which was “policy relevant” but “policy neutral” (Shaw & Robinson 2004).

While Miller (2004b) offers a co-productionist rendering of the mutual constitution of the political and scientific structures of the climate change arena, other studies of the IPCC’s origins have taken a more critical look at the convergence of science and politics in the IPCC. For example, Boehmer-Christiansen (1994a; 1994b; 1994c) interpreted the IPCC as the manifest convergence of scientific, political and business interests which represented a threat to the integrity and independence of science. She thus cautioned against the establishment of a single scientific voice for the climate debate in such a politically-charged atmosphere. Boehmer-Christiansen’s analyses came in for strident criticism (e.g. Moss 1995; see also Hulme & Mahony 2010). Shackley & Skodvin (1995) offered a careful rebuttal of Boehmer-Christiansen’s thesis, suggesting that while the IPCC of course represented the convergence of many scientific and extra-scientific forces, such a “conspiratorial” (ibid, 179) account of scientists seeking hegemony over policy mechanisms in order to secure further research funding failed to grasp the complexity of the unfolding epistemic politics. Shackley and Skodvin’s call for interpretative social scientists to play a greater role in understanding the dynamics of IPCC processes has been heeded by many in recent years (e.g. Elzinga 1996; Shackley 1997; Demeritt 2001a; Miller 2004b; Hume & Mahony 2010), and we now have greater understandings of the mutual constitution of the scientific and the political in the IPCC process which doesn’t grant undue agency or Machiavellian intentionality to any single group of actors participating in the process.

The symbolic politics of expertise

Hilgartner (2000) draws on notions of performance (following Goffman 1959) and staging to explore how legitimacy and authority are performatively established in science advisory processes. Hilgartner draws attention to the symbolic politics through which authority is enacted, and the ‘stage management’ through which identities of experts as objective, reliable spokespersons for nature are publicly established. The credibility of the stage – i.e. the science advisory panel – thus depends in many ways on the performative capacities and constitution of the cast of characters which populates it. The institutional history of the IPCC can be read as a history of performative stagings. The performative potential of broad participation has long been recognised in the governance and institutional design of the IPCC. Following the relatively low numbers of developing country experts present in the preparation of the first IPCC report (Jäger 2009), efforts were made to ensure better geographic representation. As early as 1989, action plans were drawn-up to widen participation, including the provision of financial support through an IPCC trust fund. The issue of participation was the only topic discussed at every IPCC Bureau session between 1989 and 1996, with the IPCC's first chair Bert Bolin famously remarking in 1991 that:

> right now many countries, especially developing countries, simply do not trust assessments in which their scientists and policymakers have not participated. Don't you think global credibility demands global representation?
>
> (quoted in Agrawala 1998b, 628)

This oft-cited question represents an instrumental linking of participation to trust and credibility. Participation is not presented as a means of widening the epistemic and deliberative profile of IPCC assessments by enrolling actors with diverse perspectives or worldviews, but as a means of ensuring governmental assent (cf. Fiorino 1990). The process of recruiting authors[21] has thus become an important element of the IPCC's efforts to attain international, public credibility. Although much of the recruitment process takes place 'backstage' (to use Hilgartner's metaphor), away from public and political eyes, the presentation of IPCC products on the public stages of the popular media and the internet increasingly featured statements and statistics describing the geographic diversity of the expertise represented in the reports[22].

[21] Authors are selected by Working Group chairs from lists of nominations prepared mostly by governments, but also by non-governmental observer organisations.
[22] See for example http://ipcc-wg2.gov/SREX/.

Despite efforts to the contrary, authorial participation from outside the richest nations has always been low. 45% of countries, all of them Non-Annex I countries in UNFCCC terms[23], have never been represented by an author of an IPCC report. The participation of authors from Non-Annex I countries is two-and-a-half times greater in the case English-speaking countries as compared to non-English-speaking countries (Ho-Lem et al. 2011). Between the Third and Fourth Assessment reports, the percentage of all authors and reviewers hailing from the Organisation for Economic Co-operation and Development (OECD) "remained remarkably constant at between 80% and 82%" (Hulme & Mahony 2010, 709). Although Kandlikar and Sagar's analysis spans only the First and Second Assessment Reports, their observation that participation is "heavily skewed towards some industrialized countries" still obtains (Kandlikar & Sagar1999, 134). Building on this analysis, Biermann (2001) suggests that under-representation of Indian experts has undermined the legitimacy and hampered the 'impact' of IPCC assessments in Indian environmental politics.

Related to the politics of participation and representation are the politics of the expertise (e.g. Ford et al. 2011). Bjurström & Polk (2011) offer the most comprehensive analysis to date of what many see as disciplinary biases in the IPCC corpus, through their study of the 14,000 references cited in the Third Assessment Report (TAR). It was found that of all the peer-reviewed sources used (62% of total citations), a mere 12% represented the social sciences. This figure falls to 8% if economics is excluded from the 'social science' category. The authors remark that this represents a powerful bias towards the natural sciences, which privileges understandings of the climate system and its impacts drawn from numerical techniques (e.g. climate models), rather than from work on the complex, situated interactions between weather and human livelihoods (Jasanoff 2010; Hulme 2010b).

However, the recognition of a bias towards the physical sciences is not new. Shackley & Skodvin (1995) criticised the IPCC's exclusion of any substantive contribution by the interpretative social sciences to the construction of 'IPCC knowledge' (Hulme &

[23] Annex I countries "include the industrialized countries that were members of the OECD in 1992, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States" (UNFCCC 2013).

Mahony 2010, 707). This criticism has been repeated by Cohen et al. (1998), Malone & Rayner (2001) and Yearley (2009), as the problems of disciplinary bias have persisted through the whole gamut of IPCC assessments. Godal (2003, 247) further bemoans the disciplinary skew of IPCC assessments, and criticises the rigidities of the Working Group structure, suggesting that it is based on "the understanding that the science of climate change follows a clear-cut 'disciplinary line' – from the natural sciences to the social sciences, where the latter is based on the former". The Working Group structure embodies this presumed linearity (Beck 2011), and enables deterministic framings of the links between the physical climate system and human behaviour (Hulme 2011; Nielsen & Sejersen 2012). However, I would argue that the forms of expertise given prominence within the IPCC are not just a function of eschewing a more 'integrative' approach to climate change research (Barry et al. 2008; Demeritt 2009). Rather, the study of the climate system involves numerous and constant acts of 'purification' (Latour 1993) by which the social and the climatic are rendered ontologically distinct. Unlike a Humboldtian phenomenological climate of human sensory experience[24], the global climate system functions vertically:

> the vertical is not one of the dimensions of space, it is the dimension of power. It dominates, rises up, threatens and flattens.
>
> (Foucault 2007c, 170)

The discursive dominance climate simulation gives rise to reductionist accounts of human behaviour and social change, which at once render future threats to future societies, and flatten the terrain of human choice and agency (Hulme 2011). Perhaps the most high-profile task of Working Group I has been the effort to *detect* a change in the climate system, and to *attribute* that change to human activities. It is this work of parsing-out the natural and the social in obsessively repeated simulations of the climate system which has given rise to the IPCC's headline claims, such as "[m]ost of the observed increase in global average temperatures since the mid-20th century

[24] Alexander von Humboldt (1845, 346) defined climate as "every change in the atmosphere which sensibly affects our organs", positing a locational logic bound to human experience but also a holism which parallels more recent thinking on the interconnectivity of human and nonhuman systems (Pepper 2002, 169).

is *very likely* due to the observed increase in anthropogenic GHG concentrations" (IPCC 2007b, 5). For Latour, this delineation of the natural and the social is deeply political:

> Researchers who establish a causal link between human action and global climate change 'do politics' in the sense of altering the associations – and thus directly the 'social' – that all beings establish with all other beings. They are thus engaged in a cosmology – a cosmopolitics – involving, in different ways, all the entities that previously did not count in the public understanding of problems.
>
> (Latour 2012, 72)

But the science of detection and attribution not only re-constitutes the social. It also plays upon the modernist boundary between the natural and the social and emphasises a renewed ontology of climatic hybridity (see also Latour 2013, 8). The cosmopolitical force of such claims is illustrated by the controversy which surrounded the detection and attribution chapter of the Second Assessment Report (SAR) in 1995, which was subject to criticism from actors concerned – sincerely or otherwise – that the IPCC's review process had been corrupted by authors making alterations to the chapter after its formal acceptance by government representatives (Edwards 1997; Edwards & Schneider 2001). Edwards & Schneider offer curious echoes of Polanyi's (1962) scientific republicanism in their defence of the IPCC's capacity for learning and development through 'self-governance'. Yet the IPCC's critics in this case embraced the quality assurance seemingly provided by governmental oversight, even though those sceptical of the reality and severity of climate change have often pointed to the intergovernmental nature of the IPCC as evidence of the political corruption of the scientific process (e.g. Laframboise 2012). In the symbolic- and cosmopolitics of the IPCC, we can see how solutions to the problem of knowledge are negotiated through acts of social ordering. This co-production can be considered both as constitutive (as in Latour's description of the cosmopolitics of detection and attribution studies) and interactional (regarding questions of who participates, what voices are represented, and where boundaries should be drawn between scientific autonomy and political oversight). In the next section I explore how the IPCC assessment process involves certain attempts at 'reasoning together' (Jasanoff 1998a). In reviewing extant literature on the politics of consensus, I look to characterise the hybrid spaces of the IPCC as sites of interactional co-production. In so doing, I aim to open-up the geographies of these hybrid spaces.

Constructing consensus

Scientific consensus is defined by Kim (1994, 23) as "the resolution of an issue of fundamental epistemological importance manifested in the scientific transformations of the structure of an evolving network of scientific allies and enemies within a specified period of time." Like many knowledge production and assessment activities at the science-policy interface, IPCC processes have always been directed towards generating and communicating a scientific consensus on climate change (Pielke Jr 2001; Sarewitz 2011). However, this pursuit of consensus has arguably "been a source of both strength and vulnerability for the IPCC" (Hulme & Mahony 2010, 711). Perceptions of the function and instrumentality of consensus vary. For example, Edwards & Schneider (1997) argue that the attainment of consensus has been politically instrumental in convincing the world of the need to act on climate change, and thus for the advancement of international climate policy (see also Guston 2006; Grassl 2009). In contrast, Horst & Irwin (2010) argue that the ultimate epistemological goal of consensus – the seeking of 'truth' – is perhaps equalled in importance by its function in constructing community identity, often in the form of what Haas (1992a) terms an 'epistemic community', i.e. a community or network of experts with authority in a certain field, who share beliefs regarding mechanisms of causality, standards of validity and certain normative commitments. Yearley (2009) presents IPCC consensus-building as a subjective exercise of Bayesian reasoning, i.e. about degrees of likelihood within an area of highly uncertain knowledge. However, due to the IPCC's unique position at the science-policy interface and the need to communicate findings to a wide spectrum of users (Weingart 1999), there often exists a trade-off between the push for consensus and full exploration of relevant uncertainties (Van Der Sluijs et al. 1998; Petersen 2006; Sarewitz 2011). For Oppenheimer et al. (2007, 1506), the saliency of the latter may now exceed that of the former: "[t]he establishment of consensus by the IPCC is no longer as critical to governments as a full exploration of uncertainty".

The pursuit of consensus has been widely critiqued in discussions about the performance of deliberative forms of democratic decision making, particularly in the context of environmental risk (e.g. Irwin 2006; Stirling 2008). In their critique of the attempted application of Habermasian ideas of communicative rationality and the 'ideal speech situation' to practices of collaborative spatial planning, Tewdwr-Jones & Allmendinger (1998, 1979) argue that efforts to mediate agreement must necessarily involve "not only an acceptance of ontological difference but also a desire to unify it", and that the drive for unification can only succeed through techniques of imposition and some measure of coercion. Similar arguments about the operation of power and discourse in the 'undecidable terrain' of postmodern politics[25] posit that the "creation of a consensus for a certain option cannot be reduced to simply identifying a shared opinion in the sense of a least common denominator, but rather describes an active process of coming into agreement through persuasion" (Torfing 1999, 67). These persuasive acts should be understood as attempts "to make somebody give up one set of beliefs in favour of another by offering a more or less thoroughgoing redescription of the world which...presents the new set of beliefs as the more suitable, appropriate or likely" (ibid, 68; see also Rorty 1989, 3-22; Lukes 2005). Thus, consensus cannot be achieved without exclusion (Mouffe 1996), and can only be sought in *political* situations through subversion, force, epistemological violence and even the undermining of social identities (Mouffe 2005; Sarewitz 2011). How does this antagonistic picture of consensus-building compare with the construction of consensus within the IPCC?

Despite positivistic arguments that truthful consensus is reached in science purely through direct correspondence with nature, Guston (2006) argues that the

[25] 'Undecidability' refers to the unresolvable dilemmas within discourse, attributable to the irreducible plurality of the social and the malleability of subject positions (Laclau & Mouffe 2001). Parallels exist here with the normative implications of post-normal (Funtowicz & Ravetz 1993) or 'wicked' issues (Turnpenny et al. 2009), particularly in terms of the problem of representation in participatory democracy: "the fragmentation of identities around issue politics requires forms of political aggregation whose constitution involves that political representatives play an active role in the formation of collective wills" (Laclau 1996,: 48).

aggregation of individual positions and preferences into group expressions necessarily involves some element of 'social choice' (cf. Arrow 1963). As much work in STS has made clear, "scientific views are constructed from a great deal more (e.g. material, social, psychological, ideological) than immediate compulsion from nature. Scientific views are thus compelled by many of the same elements as are pure political opinions and commercial preferences" (Guston 2006, 381). The exercise of social choice in science can take many forms, which may or may not seek to evoke democratic norms. The most explicitly 'political' or ostensibly 'democratic' means of exercising social choice include voting processes and procedures for producing consensus.

Consensus building within the IPCC is not about explicitly making a political decision or 'commitment' (Stirling 2008) to a particular course of action. Rather, it is an attempt to reach agreement on what can reliably and usefully be said about the climate system and human impacts on it. Thus, 'consensus' is presented as a state by which all substantive debate and disagreement is incorporated into a final knowledge claim. The 'consensus' is both an outcome and a *process*, the transparency of which is arguably central both to its instrumentality in political deliberations and its normative claims to democratic representativeness (Guston 2006; Beatty & Moore 2010). This dual status – as outcome and process – is reflected in statements that each consensus claim "reflects a lowest-common-denominator consensus view of the vast majority of scientists" (Edwards & Schneider 1997, 13), and the "IPCC *brings controversy within consensus*, capturing the full range of expert opinion" (Edwards 2010: xvii, emphasis in original)[26].

Although the IPCC's original mandating documents do not require it to produce consensus statements, the IPCC has from the First Assessment Report (FAR) "sought and rhetorically delivered a consensus on climate science" (Hulme 2013, 142). In his foreword to the Working Group I section of the first assessment, co-chair Sir John Houghton stated that:

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[26] The preponderance of a spatial parlance in discussions of the achievement of consensus – e.g. 'reach' and 'converge', or a "horizon that is never reached" (Lyotard 1995, 171) – emphasises the notion that actors must come together in a knowledge-space that is considerably smaller than the landscape of initial positions. The suggestion that consensus represents a "lowest common denominator" is problematic in this regard as it implies that the consensus can encompass at least some aspect of every initial position.

> Although … there is a minority of opinions which we have not been able to accommodate, the peer review has helped ensure a high degree of consensus amongst authors and reviewers regarding the results presented. Thus the Assessment is an authoritative statement of the views of the international scientific community at this time.
>
> (IPCC 1990, v)

The IPCC literally 'brings' together knowledges, as embodied in internationally mobile scientific actors, in pursuit of a consensual position. This resonates with Fuller's (1988) notion of 'essential consensus', i.e. agreement through a collective decision on theoretical, methodological or axiological matters[27]. Fuller posits two further types of consensus which are of relevance here. *Procedurally enforced consensus* "obtains in any group activity where the means of social interaction is highly constrained, say, by a technical language in which all claims must be expressed. These constraints serve to prevent any potentially debilitating disagreements from arising" (ibid, 213). The IPCC's framework for the communication of uncertainties (see Moss & Schneider 2000; IPCC 2005; Petersen 2006) – which is intended to encompass the uncertainty produced by expert disagreement – provides just such a 'technical language' to structure and constrain deliberations, and to foster consensual statements[28].

Fuller's other concept of *suboptimal essential consensus* accounts for the fact that the communicative and epistemic demands of reaching essential consensus – i.e. perfect knowledge amongst actors of others' positions and the standards used to validate scientific claims – can rarely be achieved in practice. Rather, a more common situation is that "those who arrive at a belief which they take to be justifiable engage other members in a public defence; those who either agree with a standing belief or have no strong views simply remain silent" (Fuller 1988, 214). The relevance of this

[27] This contrasts with the notion of 'accidental consensus' – agreement through "each individual deciding by himself [sic] to do the same thing" (Fuller 1988, 208). The phenomenon of multiple simultaneous discovery by unconnected scientists has long been held as an example of the indefatigable objectivity of scientific method, despite the historiographic problems with such claims (see e.g. Kuhn 1977; Lamb & Easton 1984)

[28] On uncertainty communication and interpretation, see Patt (2007) and Morgan et al. (2009). On the IPCC's handling of uncertainty, see Ha-Duong et al. (2007), Swart et al. (2009), and Gay & Estrada (2009).

concept to the IPCC lies in the micro-geographies of epistemic power which may enable certain actors to disproportionately direct consensus[29], and in the fact that consensual deliberations often take place in an open forum, or at least in contexts where the movements from dissensus to consensus are traceable (e.g. through the review process). If the relevant forum aspires to approximately democratic principles[30], Fuller suggests that the 'loudest' voices are often taken to be more representative of opinion than they actually are. This may lead to an amplification of scepticism if it is articulated stridently, while silent actors may fall in-line with what they perceive to be the trend of opinion among their colleagues – a trend which may be symptomatic of 'groupthink'[31].

The construction of consensus is thus of great sociological interest. In the context of the IPCC attention has been paid to how pre-formed consensus statements may be subject to conflicting or divergent interpretations (e.g. Patt 2007). Hulme & Mahony (2010, 711) draw attention to the problematic communication of the consensus-building process in arguing that statements such as "2,500 of the world's leading scientists have reached a consensus that human activities are having a significant influence on the climate" do not do justice to the social complexity of producing consensual knowledge. Claims about the significance of human influence on the climate arise from the work of perhaps a few dozen experts working in the subfield of detection and attribution studies, therefore to assimilate such claims into broad-brush accounts of the character and extent of consensus has the potential to mislead and to leave the Panel open to outside criticism (ibid; Sarewitz 2011).

In some instances the process of consensus-building has been criticised for being too conservative. The most prominent proponent of this argument has been Hansen (2007), who argues that the IPCC was too conservative in its judgement of the

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[29] IAC (2010, 23) makes an interesting observation about SPM preparation: "[a] complication could arise when Lead Authors are sitting side-by-side with their government representative, which might put the Lead Authors in the difficult position of either supporting a government position at odds with the Working Group report or opposing their government's position".

[30] Jasanoff (2003b, 160) takes a normative stance in this regard in arguing that "[e]xpertise, like other forms of democratically delegated power, is entitled to respect only when it conforms to norms of transparency and deliberative adequacy".

[31] 'Groupthink' is a "mode of thinking that people engage in when they are deeply involved in a cohesive in-group, when the members' strivings for unanimity override their motivation to realistically appraise alternative sources of action" (Janis 1972, 9). See also Sunstein (2009).

possible magnitude of sea level rise in its Fourth Assessment Report (AR4). Hansen suggests that the striving for consensus leads to a 'scientific reticence' to communicate more extreme possibilities[32]. Solomon et al. (2008) robustly defend the IPCC's position, claiming that the statement was not an example of a 'premature' consensus, but was rather a result of a lack of scientific understanding of the key glaciological processes. The inability to include these processes in the quantitative estimates precluded a consensus position towards the higher end of the range of sea level rise projections (e.g. Kerr 2007; Rahmstorf 2010). This case illustrates the consequences of a lack of agreement on the *standards* to be invoked in constructing consensual knowledge; a key characteristic of a suboptimal essential consensus situation (see O'Reilly et al. 2012).

Studies of the social-epistemological practices of the construction of consensus within the IPCC are rare, mainly due to the difficulties social scientists and philosophers face in obtaining access to the relevant deliberations[33]. We are thus largely dependent on accounts produced by interested participants (e.g. Edwards & Schneider 1997; Oppenheimer et al. 2007), which often do not engage with broader analytic themes of co-production and power. However, the IPCC is a prime site for the study of consensual practices, with particular interest generated by the complex social geographies of IPCC processes. The IPCC's hybrid spaces – populated by both scientific and political actors – of course complicate the picture of consensus-building offered by philosophers of science (e.g. Laudan 1984), while Fuller (1988) suggests that the spatial dispersion of a community creates further problems for the generation of ideal-type essential consensus (and presumably of procedurally-enforced consensus) as the friction of distance further precludes total understanding of others' beliefs and of the relevant epistemic standards. Fuller (1988, 230) thus calls on analysts to study "the 'phenomenological geography' of scientific interactions, that is, the effects that the spatiotemporal distances between scientists have on their ability to regulate their own activities". In the case of the IPCC, these 'spatiotemporal'

[32] Keller (2010) offers similar criticisms, from an ethical standpoint, of the IPCC's reticence to precisely define a temperature threshold whereby anthropogenic interference in the climate system can be considered 'dangerous' (cf. Liverman 2009; von Storch & Bray 2010).

[33] A notable exception is Petersen (2006), who gained access to sensitive negotiations through his attachment to the Dutch government delegation.

distances are arguably supplemented by cultural and disciplinary distances (e.g. Bjürstrom & Polk 2011), and by the role of national governments in not only shaping the governance of IPCC processes (Siebenhüner 2003) but also in actively contributing to knowledge-production through involvement in the review processes and the production and approval of the final Summary for Policymakers (SPM).

The contribution of government and expert reviews represents a significant part of the overall IPCC process (Petersen 2006). Government representatives play a central role in the reviewing of the second draft of each IPCC chapter (the first having been reviewed by nominated experts). Governments are asked to comment on the clarity, balance and accuracy of the draft chapter, in addition to its consistency with the mandate of the relevant Working Group. It is clear from archived review materials that particular 'styles' exist in the engagement of governments with this process. By exploring what motivates these different styles, it may be possible to engage with Fuller's 'phenomenological geography' and expand Livingstone's (2005b, 394) notion of "reviewing cultures" towards a cartography of 'textual reception', thus enabling exploration of "the constitutive significance of place in the production of the various meanings that become attached to even a single work" (Rupke 1999, 336). The review process thus offers an opportunity to study not only a site of IPCC knowledge production, but also a space where IPCC practices and knowledge claims interact directly with different political cultures or civic epistemologies (Jasanoff 2005a).

To investigate these questions, in Chapters 5 and 6 I explore the production and circulation of a particular framing of the global risks associated with climate change which emerged in the IPCC's Third Assessment Report. The 'reasons for concern' framework sought to synthesise knowledge about key social, ecological and physical vulnerabilities to climate change, and was popularised in a diagram which became known as the 'burning embers'. In the first instance, this study allows me to investigate the knowledge politics inherent to the production of IPCC assessment chapters. As suggested by the account above, the pursuit of consensus is by no means straightforward, and involves negotiations of profound disagreements and a sometimes tortuous pursuit of compromise. The IPCC review process offers a unique opportunity to study the interpretive geographies of circulating knowledges which challenge distinctions between spaces of knowledge production and knowledge consumption. By tracing the circulation of the reasons for concern and burning embers constructs through the processes of IPCC knowledge production and through broader networks of scholarly activity, I aim to address the question of how different epistemic spaces – such as a two-dimensional graphical representation and the IPCC review process – function as sites of co-production. Specifically, I seek to explore how the production and circulation of consensual knowledge claims proceeds in tandem with the ongoing negotiation of the cultural boundaries of science, as discussed in Chapter 2.

Governance of a 'boundary organisation'

Throughout its 23 year existence, the IPCC's governance structures and rules of procedure have evolved, often in direct response to both internal and external criticisms, or to moments of controversy. These organisational shifts can be considered though the lens of 'organisational social learning', which Siebenhüner (2008, 96) defines as "a change in an organisation's practices and strategies caused by a change in the knowledge of an international organisation on a collective level"[34]. Such changes can encompass alterations to organisational policies and strategies, to structures and hierarchies, or to the organisational culture (cf. Haas 1990). This conception of learning therefore goes beyond that employed by Doherty et al. (2009), who focus solely on the possible necessary changes to the substantive content of IPCC reports.

Siebenhüner (2002; 2003) and Tonn (2007) offer positive views of the IPCC's apparent capacity for reflexive and adaptive organisational learning. Siebenhüner (2003, 121) in particular suggests that the evolving structures and procedures of the IPCC have led to a "decreasing influence of national governments on the climate negotiation process through the assessment process", a change which Siebenhüner sees as a positive one for the maintenance of legitimacy and credibility. Edwards and Schneider (2001) praise the IPCC's capacity for "self-governance", with echoes both of Polanyi's

[34] For a more nuanced conception of learning and its links to reflexivity and organisational change, see Pallett & Chilvers (2013).

ideal of a scientific republic free from political interference and of Habermasian ideals of a deliberative space unburdened by webs of power. However, others (e.g. Grundmann 2007; Beck 2011) suggest that this strengthening of the boundary between the political and the scientific has "been achieved at the cost of greater procedural bureaucracy and complexity and hence loss of transparency and accountability" (Hulme & Mahony 2010, 710). Miller (2007) extends this line of criticism to urge organisations such as the IPCC, which exercise considerable power and influence in international political deliberations, to operate more democratically through the practice of greater openness and accountability (see also Demeritt 2001a; Yearley 2009).

Concerns for greater transparency, wider participation and reflexive governance are often articulated through the lens of post-normal science. Set in opposition to the Kuhnian notion of 'normal' science (Kuhn 1962) but variably described as theory, solution, practice, discourse or 'meta-method' (Yamineva 2010), post-normal science was originally formulated by Silvio Funtowicz and Jerry Ravetz as an approach to scientific inquiry when faced with situations where "facts are uncertain, values in dispute, stakes high and decisions urgent" (Funtowicz & Ravetz 1993, 744). Post-normal science builds on critiques of modernity and concerns about the insufficiency of traditional forms of expertise in dealing with complex, emergent problems, of which climate change is emblematic (e.g. Giddens 1990; Beck 1992; Healy 1999). Faced by such challenging and value-laden problems, it is argued that science must find new ways of ensuring quality and policy relevance. To this end, science must be opened-up to a range of different perspectives, values and opinions, as there can be no monopoly on competence, legitimacy or truth (Turnpenny et al. 2009; Turnpenny 2012).

Saloranta (2001) proposes that the IPCC is an embodiment of the philosophy of post-normal science. Writing in the context of the Second Assessment Report (SAR), it is argued that the employment of hundreds of expert authors and reviewers demonstrates that the IPCC is utilising an 'extended peer community' – a key means of quality assurance in post-normal situations (Funtowicz & Ravetz 1993). Additionally, the IPCC's careful management and communication of both methodological and epistemological uncertainties emulates the type of uncertainty management demanded by post-normal methodologies to facilitate effective decision making (Saloranta 2001). However, Yamineva's (2010) more comprehensive exploration of the IPCC's post-normal credentials yields criticism of, for example, the Panel's lack of reflexivity, the lack of transparency in the recruitment of the 'extended peer community' (IAC 2010), its continual efforts to reinforce boundaries between scientific and political actors (to the potential detriment of the assessment's comprehensiveness and wider societal usefulness), and its reification of the 'deficit model' of scientific communication which aims to correct societal waywardness through the straightforward provision of more and better scientific information (Irwin 1995; Gregory & Miller 2000; Nowotny et al. 2001; Irwin & Michael 2003)[35].

Major shifts in the IPCC's practices have often occurred in response to controversies and criticism. The IPCC's formal rules of procedure have undergone two major revisions, one in 1993 and another in 1999 (IPCC 1999; Skodvin 2000b). The 1999 changes were significant due to the introduction of review editors, the establishment of formal rules governing the adoption of Synthesis Reports, and for the clarification of the conditions under which the use of non-peer reviewed literature would be acceptable. These changes were partly driven by the detection and attribution controversy surrounding the SAR (Lahsen 1999; Edwards & Schneider 2001), in addition to a drive to accommodate a greater diversity of regional sources of knowledge in Working Group II's regionally-focused chapters (Hulme & Mahony 2010).

It was the incorporation of certain grey literature sources which was at the root of the controversies surrounding certain claims made in the AR4 Working Group II report (see e.g. Sarewitz 2010). The use of such sources has long been a cause for debate, and pits the IPCC's desire for scientific integrity often in direct opposition with demands for comprehensive assessment of all aspects of climate change which are politically relevant (Skodvin 2000a). Such debates are emblematic of the challenges faced by organisations which straddle the boundary between science and politics. Such 'boundary organisations' (Guston 2001; Miller 2001a; Pesch et al. 2012;

[35] See also Jasanoff (2005a, 249-255).

Boezeman et al. 2013) are charged with managing the flow of information across the science/politics boundary, and with negotiating the delegation of epistemic and normative authority between the two domains. Drawing on studies of interactional co-production, Guston (2001, 400-401) describes the processes through which boundary organisations achieve order at the science-policy interface:

> they provide the opportunity and sometimes the incentives for the creation and use of boundary objects and standardised packages [see Chapter 2];...they involve the participation of actors on both sides of the boundary, as well as professionals who serve a mediating role;...they exist at the frontier of the two relatively different social worlds of politics and science, but they have distinct lines of accountability to each.

The IPCC engages in all of these activities. Boundary objects like climate models (Shackley & Wynne 1996), climate sensitivity estimates (Van Der Sluijs et al. 1998) and temperature rise targets (Chapter 7) facilitate exchange and stability between science and politics. Scientific and political actors gather within the spaces of the IPCC to collaboratively produce and authorise knowledge (for example through processes of report scoping, reviewing and approving[36]), and 'lines of accountability' are enacted through the joint application of norms of scientific practices (like peer review) and democratic politics (such as broad participation and the production of consensus).

As a boundary organisation, the IPCC is mandated to provide scientific knowledge to participants in the UNFCCC process. The Panel is intended to provide knowledge that is policy-relevant (and 'neutral'), rather than policy-prescriptive (Moss 1995; IPCC 2013a). The provision of technical knowledge directly to UNFCCC participants is handled by the Subsidiary Body for Scientific and Technological Advice (SBSTA), which plays a more responsive mediatory role between the scientific and policy communities. For Miller (2001, 495), the UNFCCC's establishment of SBSTA was successful in constructing boundaries and conferring legitimacy, thus enabling the "maintenance of a productive tension between science and politics" (see also Oels

[36] For a detailed overview of these processes, see Agrawala (1998b).

2005, 198). Dahan-Dalmedico (2008) also argues that the existence of SBSTA enables the IPCC to avoid some of the criticisms associated with its challenging position at the meeting place of scientific advice and political action (see also Pielke Jr. 2007). The norm of 'policy neutrality' has functioned as a powerful means of ensuring stability at the science/politics boundary, as it reinforces a vision of science as being wholly 'value-free' (e.g. Betz 2013) and being capable of informing policy options without directing them. However, once science and politics are understood as being co-produced, and given the criticisms of how dominant scientific framings of climate change have hindered more productive democratic engagement with the issue (see above), this claim of neutral relevance appears hollow[37]:

> The IPCC claims to be both policy-relevant and policy-neutral. But those to whom the IPCC's knowledge is relevant compromises this stance. Different policy-makers want and need different things, so any one framing of a problem — be it scientific, economic or ethical — signals who will act and how. For example, by promoting 'global temperature' as the standardised unit to express the problem of global-warming, the IPCC deems only certain types of action relevant, whether it be mitigating climate change or manipulating the stratosphere. Such standardisation is good for modellers and funders, but it has failed to inform effective, diverse and local adaptation and mitigation policies and practices.
>
> (Turnhout et al. 2012: 455)

For these authors, the stability provided by the framing of climate change as a manageable problem of global average temperatures comes at the cost of constraining certain actions. More precisely, stability and 'relevance' are co-produced; the need for science-policy stability contributes to the construction of a particular kind of relevance. As Shaw (2005) argues, the ideals of objectivity and relevance are in constant tension, as determining and practicing what is 'relevant' means some reneging on the strive to be wholly 'disinterested' in the broader

[37] Cf. Latour (1987, 32).

connotations and meaning of scientific inquiry (Merton 1973)[38]. Boundary organisations like the IPCC are thus key sites of boundary work – of the constant regulation of where science ends and politics begins. In Chapters 5 and 6 I seek to open-up questions of how such boundaries are negotiated during the process of producing assessment reports. In spaces populated by both scientific and political actors, such as the review process and the plenary sessions where SPMs are negotiated, accepted and approved, it is possible to trace the 'hybrid management' (Miller 2001a) of the science/politics boundary discursively and materially.

The plenary negotiations of Working Group and Synthesis Report SPMs have become iconic examples of such hybrid management[39]. Draft SPMs, prepared by scientists, are subjected to line-by-line and word-by-word approval by government representatives. A *Microsoft Word* document with Track Changes turned on looms over the delegates, and every word is subjected to hermeneutic struggle. Like UN treaties and conventions, the diplomatic process of square-bracketed disagreement and free-text agreement structures the exchanges (Scoones 2009, 561), and where disagreements can't be resolved in open discussion, break-out groups provide a space for authors to persuade dissenting voices of the veracity of their claims (see e.g. Edwards & Schneider 2001; Petersen 2006; and the discussion of *suboptimal essential consensus* above). One UK delegate to an IPCC plenary described the scene like this:

> having started in a very organised fashion with songs about the future from children's choirs . . . the meeting came close to a breakdown. It finished at four o'clock in the morning, one day late, with most of the delegates having abandoned their chairs in the conference hall to gather

[38] Mulkay (1976) argues that the collective norms identified by Merton (1973) have been effective in institutionalising a particular image of science as detached and asocial, but that norms of, for example, emotional disinterestedness and epistemic universalism exist in a functional interplay with norms such as emotional commitment and epistemic particularism.

[39] Miller (2001a, 486) uses the term *hybrid* "to refer to people, artifacts, and institutions that mix elements from scientific and political forms of life", bringing Latour's (1993) notion of ontological hybridity into conversation within an interactional perspective on contemporary environmental politics. Boundary organisations "need to be able to manage hybrids — that is, to put scientific and political elements together, take them apart, establish and maintain boundaries between different forms of life" (Miller 2001a, 487).

on the front podium and shout at each other.

(quoted in Agrawala 1998b, 627)

In responding to the epistemic geographies (and very bodily antagonism) of such hybrid spaces, it is important not to over-emphasise the functional valence of designated ‘boundary organisations’ like the IPCC. In Chapter 7, I seek to begin the ontological decentring of the organisation in our accounts of science-policy boundary work by exploring how the practices, norms and discourses of the IPCC’s boundary-managing activities have inflected debates about the science-policy relationship beyond the institutional confines of the IPCC itself. By stepping into the institutional margins of the IPCC, it is possible to get a firmer grip on the politics of the epistemic, political and cultural space which the Panel occupies. I develop the notion of ‘boundary spaces’ to account for the multiple settings in which the negotiation of the science-policy boundary takes place, and illustrate this empirically through a study of two efforts which were made to bring-together scientific knowledge to inform the high-stakes international climate negotiations of 2009. In exploring these ‘alternative’ spaces of collective reasoning, I aim in part to follow the classic constructivist path of showing how, with reference to the practices and design of the IPCC, things could have been (or could still be) otherwise (Law & Singleton 2000). But I also seek to show the overlapping of different boundary spaces, as norms and discourses of how to relate knowledge to action circulate about the hybrid social worlds of science and politics, creating a palimpsest of historically textured boundary formations.

The historical moment within which this particular empirical foray is situated was an especially pertinent one in which to explore questions of how scientific knowledge is presumed to relate to political action. In November 2009, a few weeks before the Copenhagen climate talks, a batch of emails acquired, leaked or stolen from the University of East Anglia’s Climate Research Unit (CRU) were released onto the internet. Some commentators read from these emails evidence of serious scientific misconduct in the compilation of instrumental and historical records of global temperatures over the last 1,000 years. There were accusations that data had been massaged to exaggerate recent warming; that scientists had refused to share primary data and the computer codes used to analyse it; that the peer review process had been manipulated to keep dissenting publications out of key journals; and that key scientists had sought to ensure that IPCC reports reflected only their own interpretations of the temperature record (see e.g. Pearce 2010). A number of public inquiries subsequently cleared the scientists of major scientific misconduct. STS analysts have pointed to how the episode reveals a small community of scientists anxiously trying to engage in a fractious political debate for which they are professionally unprepared (Ryghaug & Skjølsvold 2010; Skrydstrup 2013), and to the problematic valence of classical norms of scientific disinterestedness and purity which do not do justice to the empirical reality of scientific practice (Grundmann 2012; 2013; Lahsen 2012). Calls for greater institutional transparency in the negotiation of policy-relevant scientific knowledge has thus been a common refrain (e.g. Beck 2012; Grundmann 2013).

The so-called 'climategate'[40] affair also touched the IPCC directly. Around the time of the CRU email release, a mistake was identified in the WGII report of AR4. It had been stated that Himalayan glaciers could melt away by the year 2035. A very public controversy ensued when a journalistic report in *Science* (Bagla 2009) was picked up by newspapers around the world. The IPCC was brought 'under the public microscope' (Beck 2012) as the knowledge claims contained within AR4's pages were subject to scrutiny across a diversity of epistemic spaces – weblogs, the popular press, and governmental institutions (e.g. PBL 2010). A number of other mistakes were identified, including erroneous statements about the proportion of the Netherlands which lies below sea level and the productivity of anchovy fisheries off the west coast of Africa (ibid). Although many dismissed these mistakes as inconsequential and not unexpected given the expansiveness of IPCC reports, others saw evidence of malpractice, low levels of quality control, and even alarmism. Even Bob Watson, former chair of the IPCC, expressed concerns:

> The mistakes all appear to have gone in the direction of making it seem like climate change is more serious by overstating the impact. That is

[40] On the nomenclature of climategate, see Norton (2010).

> worrying. The IPCC needs to look at this trend in the errors and ask why it happened.
>
> (quoted in Webster & Pagnamenta 2010)

Although the episode gave some actors cause to challenge the reality and seriousness of climate change, it also generated a space to debate the organisation of the science-policy interface. For the head for the Netherlands environmental assessment agency (PBL), "[w]hat was at stake was not only the authority of IPCC as an example of an institutional interface between science and politics. The question was whether the very set up of global 'science (IPCC) for policy (UNFCCC)' was still credible" (Hajer 2012, 77). In March 2010 the InterAcademy Council (IAC) – an international organisation of national science academies – was commissioned by UNEP to conduct a formal review of IPCC processes and procedures (see IAC 2010, 75). Although stating that "the IPCC assessment process has been successful overall" (ibid, xii), the IAC report, published on 1st September 2010, made a series of recommendations designed to improve the assessment process. These included:

- The establishment of an elected Executive Committee;
- The election of an Executive Director to head the Secretariat;
- Extra vigilance by Review Editors to ensure that review comments are adequately considered, and the reflection of any controversy in the final report;
- A more targeted process for responding to reviews, including a more appropriate division of labour between Review Editors and chapter authors;
- The use of the qualitative level-of-understanding scale in SPMs and Technical Summaries;
- The use of quantitative probability scales only where the evidence allows it;
- The enactment of a comprehensive communications strategy which could help avoid public statements "perceived as advocating specific climate policies" (ibid, 5); and
- The adoption of a 'rigorous' conflict of interest policy covering the IPCC leadership, authors, review editors and technical support staff.

The recommendations of the IAC were broadly accepted (see IPCC 2010), and work is ongoing within the organisation to formally enact the IAC suggestions. However, the mandate, questions and recommendations of the IAC were restricted to a familiar instrumentalism which positions 'sound science' as separate from, but determinate of, good public policy. Minor institutional reform is seen as sufficient for re-gaining lost credibility. This defence of the 'science for policy' s*tatus quo* described by Hajer (2012) highlights the strong investment made by both the scientific and diplomatic community in the structure and organisation of this kind of assessment process, and thus the dominant problem framings to which it has given rise. More fundamental questions – like the scalar politics of knowledge-making, epistemic pluralism and the need for institutional spaces geared towards a more resolutely deliberative form of engagement with climate change – were conspicuously absent from the IAC agenda. Although increased transparency and accountability were recognised as a "growing obligation" (IAC 2010, vi; Beck 2012), this was the only real concession to the changes in the nature of political deliberation in the quarter-century since the IPCC's establishment. New communications guidelines, developed *in lieu* of the IAC report, have renewed the commitment of the IPCC to communicating with its "primary audience" of national governments, with a clear firewall enacted between the IPCC and broader global publics. Although other assessments like the IAASTD have attempted to enact deliberative spaces responsive to new, distributed systems of public deliberation (Scoones 2009; Stevenson & Dryzek 2012), the IPCC clings to a conventional understanding of political representation and delegation, with publics defined as those who are tied to and contained by a sovereign nation-state (Brown 2009).

Impact and influence: beyond 'epistemic communities'

There has been little empirical work on how the IPCC has altered the 'where', 'how', and 'why' of climate change science. Some evidence exists of scientific practices in the climate field being radically altered by the presence of the IPCC (Shackley & Wynne 1996; Shackley et al. 1998; Shackley 2001; Sundberg 2006; Edwards 2010; Yohe & Oppenheimer 2011), and of the IPCC acting as a legitimating and at times 'custodial' force in the performance of policy-facing science in national contexts

(Mahony & Hulme 2012). Yohe & Oppenheimer (2011) argue that the IPCC's creation of a number of what might be termed 'epistemic things' (Rheinberger 1997), such as the 'Reasons for Concern' and greenhouse gas emissions scenarios which have inspired much further research, illustrate how the IPCC is engaged in developing new conceptual resources which have fundamental impacts on the broader field of climate science and climate change impacts studies[41].

The IPCC has undoubtedly had a significant impact on the knowledge, discourse and politics of climate change (Dahan-Dalmedico 2008; Hulme & Mahony 2010). Since the late 1980s, the IPCC has been instrumental in shaping and consolidating an international 'epistemic community' (Haas 1992a; 2004) united in a shared interest in and concern with climate change. It was this work of consolidation which was recognised by the awarders of the 2007 Nobel Peace Prize, who praised the Panel (and fellow recipient Al Gore) "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change" (The Nobel Foundation 2013). Haas (1992b, 187) defines an epistemic community as a "knowledge-based network of specialists who share beliefs in cause-and-effect relations, validity tests, and underlying principled values and pursued common policy goals". Within a specific field of inquiry, epistemic communities exercise an "authoritative claim to policy-relevant knowledge", and thus act as agents for the diffusion of consensual scientific knowledge at international and national levels of decision-making (Haas 1992a, 3). The impact and influence of the IPCC's work could be argued to have resulted from the efforts of key actors to synthesise and diffuse scientific knowledge, which has led to at least a partial 'cognitive convergence' among political actors, thus enabling the development of climate policy at national and international levels (Elzinga 1996). More broadly, the IPCC may be said to have contributed to the constitution of an extensive epistemic community spanning scientific and civil society actors, who have

[41] Yohe & Oppenheimer (2011, 633) argue that the creation of these objects by the IPCC also contradicts the "unwritten" rule that the "IPCC shall perform no original research". When one examines the products of assessment activities, the boundaries between assessment and research become significantly blurred.

been united in their efforts to persuade political actors of the need to take action (Gough & Shackley 2001).

The epistemic communities model of knowledge diffusion is, however, deeply problematic. The assumption that scientific knowledge is more authoritative when it is consensual and insulated from ideology and normative inclinations (Hulme 2013) ignores the politics of scientific knowledge production while overestimating "the cognitive capacities of epistemic communities and their influence on public policy" (Grundmann & Stehr 2012, 12). "The view that a consensus on the part of climate science could provide the solution to climate policy has failed spectacularly" (ibid, 178), and like other theories of 'cognitive convergence', the notion of epistemic communities posits "the emergence of shared ideas as causal variables without exploring in detail the question of how particular ideas acquire credibility and authority among diverse audiences and therefore come to be shared in the first place" (Miller 2001b, 248).

While the notion of epistemic communities has been persistent in political science and international relations accounts of knowledge diffusion (e.g. Adler 2005), it conforms to 'linear model' understandings of science-policy relations which have long since been debunked within STS (e.g. Jasanoff & Wynne 1998; Grundmann & Stehr 2012, 6-14). The critique is both conceptual and empirical. Conceptually, the linear model reinforces an understanding of science and politics being wholly distinct, with the former determining the scope of action in the latter. As my outline of co-productionist understandings of science and politics showed in Chapter 2, this distinction is untenable. Scientific knowledge-making, despite the best efforts to enact socio-spatially insulated sites of knowledge production (Shapin & Schaffer 1985; Shapin 1994), does not proceed in a vacuum. Ideas and interests are mutually constitutive, as in Foucault's discursive formations which tie together material interests and systems of thought (Foucault 2002; Grundmann & Stehr 2012). The notion of epistemic communities in part captures this co-production of the epistemic and the normative, as the 'community' is defined by actors united by shared epistemic and normative commitments. But the assumption that this consensual position then drives the formation of political consensus overlooks the fact that policy consensus often pre-exists scientific consensus (Grundmann 2006), and that the development of politically robust public policy is a process of compromise and negotiation, which often "requires next to nothing by way of technical information" (Collingridge & Reeve 1986, quoted in Grundmann & Stehr 2012, 15). Thus, the processes by which shared understandings and commitments give rise to action are much more complicated than the linear "transmission belt" model described by Haas (2004, 576)[42].

Echoing such critiques of agent-based models of knowledge diffusion, Livingstone (2002, 26) asserts that "scientific ideas and instruments, theories and techniques do not diffuse evenly across a flat isotropic plane. In different settings, works of scientific scholarship are differently received on account of cultural, political, ecological and other particularities". Jasanoff's (2005a) notion of civic epistemology (see Chapter 2) offers a way of thinking about such particularities in the situated construction of shared understandings and commitments. However, with few exceptions (e.g. Miller 2005; Jasanoff 2011a), this notion is yet to be applied empirically to the question of how climatic knowledges circulate and are (re)constructed in different cultural contexts (Hulme 2008). Wilson Rowe (2012) and Lahsen (2004) both illustrate the empirical inadequacy of the epistemic communities model in their studies of the knowledge politics of climate change in Russia and Brazil respectively. In both cases, changing political stances were not determined by the technical knowledge of a 'global' epistemic community, but by changing local commitments. Lahsen reports scepticism among Brazilian scientists of the veracity and relevance of 'Western' IPCC science to their own needs, while Wilson Rowe clearly shows from Russia how the relationship between epistemic and normative convergence can be the polar opposite of that posited by the linear model. "Rather than facilitating political change, international knowledge and the experts behind it gained a more prominent role after key political decisions had been made" (Wilson Rowe 2012, 5), particularly the

[42] The model of epistemic communities also posits that "the power of transnational networks lies in their ability to influence nation-states, which remain the location of governance. Thus, these approaches reinforce an interpretation of global environmental governance where 'government' is at the heart of the analysis and in which the nature of the state is effectively 'black boxed'" (Betsill & Bulkeley 2006, 148).

signing of the Kyoto Protocol – a decision largely attributable to economic considerations (Harrison & Sundstrom 2007).

It is in this sense that we can say that IPCC knowledge travels far and wide, but does not always 'travel well' (Howlett & Morgan 2010). The challenges and difficulties in the circulation of IPCC knowledge (e.g. Grundmann 2007; Hulme 2008) have been attributed to variegated responses to the perceived epistemological hegemony of the IPCC (Hulme & Mahony 2010)[43], or its 'monopolistic' position in the field of climate change assessment (Tol 2011). Lahsen's (2004) reading of a geographic disconnect between the IPCC community and Brazilian scientists echoes Biermann's (2001, 299) suggestion that many Indian experts "are wary of prejudices in the framing of assessments", and therefore watch the IPCC "with 'great suspicion' and argue that IPCC is a 'political-scientific' institution with little transparency and inherent Northern intellectual supremacy". Biermann suggests that IPCC assessments have had little substantive impact on government policy, due largely to the low participation rates of Indian experts, mistrust of Northern problem framings, low government interest in international assessments and greater scientific concern for issues of local and national importance. However, despite a lack of 'cognitive convergence', the IPCC has had significant 'impacts' on the structure and activities of Indian expert communities, including increased scientific capacities and the formation of new research networks, coalescing for example around the production of various "counter assessments" (ibid, 302), and the re-shaping of research agendas in response to gaps in IPCC discourse such as monsoonal and climatic variability. The corollary of Biermann's analysis, recalling Agnew's (2011) discussion of place (see Chapter 2), is that the *relations between* sites of knowledge production have a fundamental impact on the settings of scientific work and the local structuring of social relations and practice. The web of relations also influences a *sense of place*, with the relationality of scientific sites contributing to the reconfiguration of senses of local and national identity and ideas of how scientific work should be prioritised according to the existence of problems at different spatial scales.

[43] This may have also been what Bruno Latour was suggesting in his branding of the IPCC as an "epistemological monster" (quoted in Dahan-Dalmedico 2008, 71).

In Chapter 7 I seek to build on Biermann's insights to develop a fuller account of the epistemic geographies of Indian climate politics. I take as a starting point the unearthing of the error in the 2007 IPCC report about the likely imminent melting of Himalayan glaciers. I ask how the knowledge politics of this controversy related to previous moments of epistemic contestation between experts in India and experts in the global North. This enables me to raise a broader question of how the 'national' is carved out of the international spaces of climate change, such as IPCC assessment reports and global climate models. Specifically, my interest is in bringing together constitutive and interactional strands of co-productionist thought to explore how national territory is continually reconstructed in the deliberative space of international climate politics. By taking territory and the state as objects which have to be continuously constituted and performed through representational practices, I seek to enlarge Biermann's implicit critique of Haas by showing how expert and governmental engagements with climate change do not conform to linear model understandings of the relationship of knowledge and action. In investigating the co-production of new epistemic geographies and evolving political commitments to climate change, I argue in opposition to agent-based models of scientific diffusion and join Livingstone (2002, 10) in arguing that "science does not transcend our particularities; it discloses them. Science is not a disembodied entity; it is incarnated in human beings… [it is] a social practice earthed in concrete historical and geographical circumstances."

Chapter 4

Methodology and research design

In this chapter I set out a research design and methodology geared towards addressing the following question, introduced in the preceding chapter:

> *How have the spaces and boundaries of climate change science been contested in the recent history of international environmental politics, and with what effects?*

In seeking to understand contestation, I situate my work in the interpretive tradition of social scientific inquiry. This approach to engagement with the social world focuses on the subjective meanings which actors construct and attach to particular situations (Goffman 1959; Geertz 1993), allowing analysis of the occurrence of contestation when competing meanings meet, clash and, potentially, change. Participants in the research process are constituted not as objects but as subjects – knowledgeable, agentive actors whose behaviour is not determined solely by structures and power external to themselves. In seeking to reconstruct and interpret these meanings, the subjectivity of the researcher is also emphasised. The researcher's account of a situation is a similarly situated, contingent and inevitably partial engagement with the social world, constructed through relational interaction with the research subject. An interpretive orientation resonates with constructivist understandings of the nature of knowledge. In emphasising the social, material and historical contingency of knowledge claims, constructivism urges the analyst towards reconstruction and understanding of the multiple and sometimes competing interpretive resources which are brought to bear on the production of knowledge (Guba & Lincoln 1994; Demeritt 1998; Law 2004b).

In pursuing this research question I adopted a multiple case study design, with cases selected for their potential to offer illustrative insights into the politics of climate change knowledges. Flyvbjerg (2006) suggests, following Kuhn (1962), that case studies can offer important exemplars in the ongoing mediation between theory and data. Case studies can be generative of hypotheses, they can test hypotheses, and can function as reference points "that highlight more general characteristics of the societies in question" (Flyvbjerg 2006, 232). Although generalisation is often reified as a key goal of natural and social scientific inquiry, exemplary or paradigmatic cases, even if they represent the extremes of expected phenomena, can function as critical nodes in the development of knowledge (cf. Popper 1959). To this end, I selected three cases which can in some sense be considered representative of the kind of knowledge politics I discuss in the preceding two chapters. However, this 'representativeness' is not conceived in terms of direct and equal correspondence to broader characteristics, but rather in terms of what Flyvbjerg terms 'variation' among 'critical cases'. Critical cases "can be defined as having strategic importance in relation to the general problem" (Flyvbjerg 2006, 229). The 'general problem' here, delineated by shuttling between conceptual interests in the geographies of science and in the politics of climate, is the contestation over the spaces and boundaries of knowledge making.

Thus the case selection was guided by these concerns, but also included personal, intuitive judgments about the nature of the contestations in question and the ability of subsequent findings to speak to (and ideally advance) my theoretical interests (see also Ragin 1992; Curtis et al. 2000)[44]. My interest was less in a proto-statistical form of representativeness (Small 2009), and more in the representation, through my own interpretive practices, of a *diversity* of ways in which the spaces and boundaries of climate knowledge making have been recently contested. Although not selected to be directly comparative through the holding constant of a set number of 'variables' (Jasanoff 2005a, 19-20), the diversity of the cases offer interesting threads of comparison which, as I aim to show over the coming chapters, offer new and perhaps unexpected contributions to empirical and conceptual development. Although 'critical cases' are often selected for their ability to generate logical deductions (Flyvbjerg 2006, 230) I have, through my selection and analysis (see below), been able

[44] "Like other good craftspeople, all that researchers can do is use their experience and intuition to assess whether they believe a given case is interesting in a paradigmatic context" (Flyvbjerg 2006, 233).

to make inductive claims which have guided the conceptual arguments which I then develop more fully in the concluding chapter.

Broadly, the case study of the burning embers is considered representative of the discursive significance of visualisation and mobility in scientific practice, and of the epistemic politics of the IPCC. The Copenhagen study is considered to offer a representation of broader assumptions about the relationship between knowledge making and political action, which are rendered particularly acute and visible by the sense of urgency which often animates climate change debates. The India case study is considered representative not only of a history of epistemic contestation in Indian climate politics, but also of the kind of scalar tensions inherent to climatic knowledge making. Below I provide further rationales for selecting the particular cases, and then discuss my general methodological strategy. However, the case-specific details of data collection and analysis are left to the empirical chapters themselves, as this enables my analyses to be more tightly coupled to their methodological contexts.

The case of the IPCC's burning embers diagram was selected on the basis of a previous research interest (see Mahony & Hulme 2012) in 'following' the materially mobile objects and tools of scientific work (cf. Latour 1987), and investigating how practices, norms and discourses of scientific inquiry and political action travel with them on their journeys between sites. This earlier study also piqued an interest in the rhetorical power of scientific visualisation, and a desire to dig further into the practices and negotiations which lie behind the myriad 'immutable mobiles' of the visual discourses of climate change (Latour 1990; see also Manzo 2010; Hamblyn & Callanan 2009; Schneider 2011). The publication of an updated version of the diagram during my Masters research brought the burning embers to my attention, and my supervisor's knowledge of the diagram's epistemic history prompted me to begin exploring its production and circulation. Although the case was initially selected following a line of conceptual reasoning about travelling visualisations, my analysis reveals the case as being partially representative – or at least indicative – of broader patterns of contestation in the IPCC.

The case study which constitutes Chapter 7, like that of Chapter 8, was selected following Biermann's (2001) empirical observation about the emergence of 'alternative assessments' of climate change science. This observation connected to my conceptual interest in the diverse settings of scientific practice and in the enduring importance of place in the politics of climate change. The prospect of 'alternatives' implied either contestation or claims of shortcomings in the IPCC process. Like the burning embers study, my analysis of the science-policy debates preceding the Copenhagen climate talks of December 2009 was retrospective, with the case selected on the basis of my own knowledge of the expectations and subsequent disappointments of the international negotiations. The selection of two empirical units within the case produced an element of comparison which enabled broader themes concerning the relationship between scientific knowledge and political action to emerge.

I learnt about the emergence of the Indian Network for Climate Change Assessment (INCCA) during 2010. Its emergence connected immediately to Biermann's observation about alternative assessments, and the discursive linking of INCCA to recently discovered errors in the IPCC report was readily apparent. I immediately sensed the opportunity to study a 'critical case', with a strategic potential to speak powerfully to "the general problem" of my research (Flyvbjerg 2006, 229). I allowed the bounds of the case to remain open to theoretical sampling (Clarke 2005) in response to initial findings during a six-week fieldwork period in New Delhi in February and March, 2012. Theoretical sampling enabled me to gain a broad understanding and coverage of the case in relation to themes which emerged in the early stages of analysis during the fieldwork itself. As I argue in Chapter 8, analytically 'bounding' climate politics in India is a particularly difficult task. This early observation permitted me to develop a sampling strategy which could capture some of the epistemic and normative diversity of climate policy debates in that particular context.

On almost doing an ethnography, or doing an almost-ethnography

Within STS, case study research has often been informed by the ethnographic tradition of inquiry (Hammersley & Atkinson 2007), and as such participant observation has frequently been employed (Beaulieu 2010). However, researchers in the field have often encountered difficulty in successfully observing the esoteric material practices of climate science, such as computer modelling and climate simulation (Lahsen 1998; Sundberg 2005). In the context of the IPCC, knowledge is produced in Panel and Lead Author meetings, collective processes of literature reviewing, individual writing, and final plenary meetings where the reports are approved. The compilation and combination of fragments of knowledge, borne by individuals, into a collectively-accepted whole is thus a deeply social process, as explored in Chapter 3. Recognition of this meant that the initial research design featured an element of observation, with attention focussed on the Chapter 19 writing team in Working Group II of the Fifth Assessment Report. This chapter is essentially the continuation of the work which previously produced (in the TAR) and then excluded (in AR4) the burning embers diagram.

In an attempt to facilitate ethnographic access, my supervisor and I initially approached the Coordinating Lead Authors (CLAs) of the chapter by email, explaining our intentions and motivations and asking whether such a study would be possible. Initial responses were positive, with the CLAs expressing an interest in such work and recognising its potential importance to the IPCC. A teleconference was then organised between my supervisor and I, one CLA, one of the Working Group co-chairs and a member of the technical support unit. A variety of issues were discussed, with much conversation revolving around the practicalities and attendant ethical considerations of observing one sub-set of individuals (the chapter team) within a much larger body (the Working Group) in situations where 'the observed' would be interacting heavily with the ostensibly 'non-observed' (e.g. at Working Group meetings). This would raise difficulties pertaining to issues of informed consent and *a priori* definitions of what is and what is not to count as data.

As far as we are aware discussions then took place between the co-chairs of Working Group II and the higher echelons of IPCC management. After several weeks, we were eventually told that an ethnographic engagement would not be possible owing to unresolved concerns over the observational ethics of studying a complex process with multiple actual and potential research subjects. However, some two years later we received another communication from the chair of the IPCC expressing much more support for the idea and encouraging us to put together a formal research proposal which the IPCC Bureau could consider. It was strongly implied that the Bureau would look positively upon such a proposal. Inquiring what had led to the new response, we were told that another conversation had taken place between the chair and the CLA of the chapter we were interested in, the latter being very supportive of an ethnographic study of the kind we were proposing. When we inquired further about the delay, we were told that 2010 had been a particularly difficult year for the IPCC, implying that the bureaucratic response to the epistemic controversies and subsequent IAC review had taken precedence over dealing with our request.

While it would be possible to speculate about an institutional unwillingness to open up to external scrutiny and become ethnographically 'complicit' (Marcus 1998) in a time of controversy and organisational flux, the relatively diminutive administrative structure of the IPCC equally suggests that the existence of different priorities may have led to our proposal slipping from view. The present research design was thus developed, with data collection beginning in May 2011. However, these interactions with the IPCC may themselves be considered a small part of a larger, multi-sited engagement with the IPCC and its diverse spaces and boundaries.

The research design could perhaps be characterised as a form of multi-sited ethnography (Marcus 1995; Marcus 2007; Falzon 2009). Responding to the notion that the conventional field site is always a construction (Amit 2000), multi-sited approaches or imaginaries (Marcus 1998) trace and describe connections between places, and emphasise the agency of the researcher in determining the focus and path (e.g. Krauss 2009). Multi-sited approaches offer up "the possibility of crafting a research object specifically designed to engage in a particular argument, or to be significant to an identified context of concern" (Hine 2007, 656). Such an approach recognises the fluidity of space (Mol & Law 1994) and responds to the contemporary cultural significance of mobility (Sheller & Urry 2006). It also seeks explicitly to connect localised practices and identities to histories and meanings which overflow the boundaries of particular sites and which may lead the researcher in unexpected directions, textually or physically (e.g. Cook 2004; Cook & Harrison 2007).

Within STS, multi-sited ethnographies have recognised textual, virtual and conversational spaces as sites for ethnographic engagement, such as websites, online forums, scientific journals, emails, and informal discussions (Hine 2007; Ellis & Waterton 2005). Through engagement and immersion in such spaces, an ethnographic sensibility can offer a level of understanding and depth of interpretation which transcends purely textual analysis of documents and interview data. Multi-sited ethnography offers the researcher a way to comprehend their own form of engagement with the fluid, iterative and generative spaces of contemporary knowledge politics (Davies 2010), and to navigate the crumbling boundaries between previously discrete methodologies of inquiry (Law 2004b). This ethnographic imagination is perhaps most pertinent to the work presented in Chapter 8 which drew on a period of study during which I relocated to India. However, Chapters 5 and 6 present what we might think of as an ethnography of diagrammatic space which, in concert with Chapter 7, constitutes a multi-sited following of a *thing* (Cook 2004). The study of Copenhagen's science-policy debates in Chapter 7 also raises questions about the potential for an ethnographic sensitivity to a space which one has not personally visited. Through close textual and visual analysis, I aim in part to reconstruct and interpret the affective and interpersonal properties of the epistemic geographies under consideration. It was this attempt to mobilise an ethnographic sensibility which enabled the conceptual argument about 'boundary spaces' to be developed.

The relational construction of elite interviews

A key data collection method has been the conducting of interviews with key actors in each of my case studies. Despite the dialogic connotations of the term 'interview' (which suggests an exchange of viewpoints between interviewer and respondent), orthodox approaches to interviewing as a research methodology in the social sciences often present the technique as a means of extracting information from a respondent in a unidirectional fashion (e.g. Bryman 2001, 313). This information may be factual, or it may concern the respondent's values, interests or subjective experiences of an event or other object of interest. However, this image of a linear, unmediated flow of information is at odds with the acknowledged relationality of research methods under interpretive and constructivist paradigms (Guba & Lincoln 1994; Mauthner & Doucet 1998). "Relationality recognizes connectedness between the researcher and the participant... It provides an opportunity to account for such reciprocal relationships, the effects of the investigator's discipline... and expectations from participants about reciprocal relationships in the research process" (Hall & Callery 2001, 268).

In accordance with a trend across the social sciences towards 'studying up' – i.e. turning attention to actors who may be more powerful, yield greater influence or have a higher status than the researcher (e.g. Nader 1972; Aguiar & Schneider 2012) – my research involved engaging with a particular kind of *elite*. Elites can be defined in either relational terms to the researcher, or to the population as a whole (Conti & Neil 2007). In the case of this research project, the majority of my respondents were middle- to high-ranking academics, and thus constituted an elite group in both senses. In the interview situation, it has been stressed that sensitivity to both social differences and commonalities is important to not only establish rapport, but also to facilitate adequate reflection on the effects of these divergences and convergences on the type of account that is eventually produced by the respondent and the questioner (Stephens 2007; Hall & Callery 2001). In many cases, the interview respondents and I shared either an academic background or research interests, or both. Despite the consistent disparities in status and seniority, this eased the establishment of good rapport. Having studied geography at undergraduate level, for example, was a frequent source of common interest when visiting academics in geography departments (particularly at my *Alma mater*). However, these convergences also had important substantive influences on the form and content of the interviews, which raises important questions about the interviewer-respondent relationship and its social and epistemic relationality.

My study of the social construction of the burning embers diagram involved particularly interesting negotiations of positionality. One well-known climate impacts specialist had published an article which critiqued the epistemic assumptions of the diagram, and they were thus selected for interview under a theoretical sampling strategy. Upon opening the discussion of the diagram with an introductory question, having already discussed some other topics, the respondent asked "are you going to use actor-network theory to study this?" This question represented a rupture in the conventionally conceived interviewer-respondent relationship. The theoretical resources which a researcher will use to interpret and make sense of their data are generally left 'black-boxed' in the interview situation. Theory is left in the university office when the researcher is out in the field, only to be returned to once data has been assembled, ordered and made ripe for interpretation. Of course, many schools of thought rightly hold that research should be an ongoing process of iteration between theory and data, rather than a purely inductive process which leaves theorising to the latter stages of the process[45].

The reply of this interview respondent brought my interpretive scheme into the interview room, and theory was confronted with data even as the data were in the process of being brought into being. As I showed in Chapter 2, actor-network theory is one of the theoretical resources which I have used to both delineate my research questions and settle on particular case studies, and as I set about my data collection I was reasonably sure it would figure in my analysis of the case to some extent. This I freely admitted to my respondent, thinking that any attempt to steer the conversation away from her question about social theory might appear impolite and have negative impacts on rapport. This prompted the respondent to recount how she uses the example of this image in her teaching to illustrate how certain 'visual icons' of climate change have emerged in science-policy discourse, taking on a role similar to the immutable mobiles described by Latour (1990).

This kind of epistemic convergence seems to be rare in social science research, if the methodological literature is to be believed. For example, Stephens (2007) reports that his study of the social construction of macroeconomics inevitably involved a large degree of commonality between researcher and respondent in terms of shared experiences and expectations of the research process, but he still recounts his interviews as being a largely extractive process, with small visual and verbal cues

[45] The split between the former and the latter stance is that which has pulled the 'grounded theory' approach into two opposing schools (see below) which are so divided that the use of common nomenclature seems problematic, although of course both schools claim to be the true inheritors of grounded theory's Chicago School intellectual lineage.

helping to construct the narrative, rather than any broader instances of shared interest in telling the story in a particular way.

Stephens (2007) reports that in many instances the social structure of his interview situations took on a supervisor-student feel. This is a common trait within the field of elite interviewing, where disparities of status can lead the respondent to feel that they need to ‘teach’ the interviewer a certain amount of technical information. This is perhaps particularly pronounced where interviewees are scientists or technical specialists, and in some cases a perceived lack of expertise on the part of the interviewer can make the respondent reluctant to answer questions (Zuckerman 1996; Merz & Cetina 1997).

This disparity in technical expertise, perceived or real, can also lead to forms of relational construction, as respondents make particular efforts to regulate the information flow and to advise the researcher on its subsequent correct presentation. For example, during an interview in India, a government climate scientist at one point told me to stop taking notes and ‘just listen’, as he stressed the importance of recognising and studying cross-sectoral impacts of climate change. Soon afterwards, he tapped his finger on the page of my notebook to make sure I had written down “biosphere impacts”. During this interview we were sat on a three-piece suite in a corner of his large, ministerial office. Our proximity to each other enabled this physical interaction, while our positioning on either side of his desk would have precluded it as he may not have been able to observe my note-taking so readily. This is a reminder that the physical space in which an interview is conducted can be an important influence on its form and on the type of interactions which are enabled (Anderson et al. 2010).

Other examples of relational construction I encountered included respondents suggesting further strategies and methodologies for investigating my research interests. This ranged from respondents suggesting that I carry out survey work to establish how particular scientific claims – often those generated in part by the respondent – were received and used by policymakers, to a respondent actually suggesting a collaborative project between the two of us to further explore one of the questions I had raised with him. In such situations it is necessary to make conscious efforts to maintain some semblance of the orthodox interviewer-respondent relationship in order to keep the interview on-topic, and also to ensure that the discussion revolves around the respondent's perspectives rather than her or his interest in finding out the perspectives of others. However, such a response is indicative of good rapport and the clearest possible sign of the interest of the respondent in the interview, so I did react positively to the proposal and suggested that we discuss it further at a later date.

The verbal exchanges of an interview thus produce deeply dialogical texts – not just because they feature the direct interaction of two parties, but because the resultant text is a complicated product of the researcher's empirical intentions and the research subject's attempts to regulate the form of the data and its possible interpretations (cf. Bakhtin 1981; Goffman 1981; Hammersley 2010). This relational construction of empirical data is also perhaps a function of the unique interdisciplinary logic of climate change research (Barry et al. 2008), and the commitment of broad and diverse epistemic communities both to collaborative inquiry and to ontological transformation of the object in question (i.e. finding effective 'solutions' to climate change – cf. Hulme 2009a, 330). For example, an Indian climate change negotiator sought, in exchange for the interview with me, contacts with academics in the UK (particularly those at my well-known university) who specialise in technology transfer mechanisms and who could thus aid the Indian government's efforts to attain particular forms of financial and technological concessions from Western nations through the international climate policy regime. I thus became a node within the ongoing spatial politics of climate change; an agent of travelling knowledges and political exchange. In researching the topic of climate change, the impossibility of constructing oneself as a subject detached from the object of research is rendered all the clearer. Negotiating this relationality involved careful reflexivity about my own role and position, and about the expectations seemingly held by my respondents about the significance and potentials of their interactions with my research (cf. Hall & Callery 2001).

Analysis

Analysis of documents and transcribed interviews began in September 2011[46]. This process was partly inspired by the techniques of grounded theory generation (see Charmaz 2006; Bryant & Charmaz 2010) whereby categories, concepts, and ultimately theories are allowed to emerge from the data rather than being wholly pre-determined. Under this approach, textual data is coded word-by-word or line-by-line, in a process known as open coding (Strauss & Corbin 1998; Corbin & Strauss 2008). Codes are then grouped into themes, categories and sub-categories, following Strauss (1987, 28), with the aim of producing "concepts that seem to fit the data". Despite this inductive style of analysis it is of course impossible, even undesirable, to suspend one's own theoretical dispositions, reference frames, and epistemological commitments. This point has been recognised and embraced by grounded theorists working in the tradition of Anselm Strauss (1978; 1987) who emphasise the interpretative action of the analyst in the generation of codes and categories, and recognise that the researcher's interpretation of a given reality may conflict with those of their respondents. This constructivist position stands in contrast to the largely positivistic claims of grounded theorists in the tradition of Barney Glaser (1978; 1992) who claim that the inductive conceptualisation of data can offer a neutral, transparent window onto social reality. For example, Holton (2010, 268) naively suggests that grounded theory methodology is "epistemologically and ontologically neutral", and can offer conceptual insights free of theoretical or epistemological imposition – itself of course an epistemological position.

Following Adele Clarke (2005, xxxiii), I recognise that "epistemology and ontology are joined at the hip", and that our methodological commitments are the result of that union. "[A]ll aspects of human being and knowing are *situated*" (McCarthy 1996, 107, emphasis in original), including both knowledge claims of the researcher *and* the researched – situated in time, in space, in social situations. Attempting to objectivise the claims of the researcher regarding the situatedness, or constructedness, of the

[46] It wasn't possible to record and transcribe all interviews. In such cases, detailed notes were made during and after the interview, and these were then subject to analysis. A sample of an interview transcript is presented as Appendix 4.

claims of the researched would be to commit an act of great epistemological contradiction, not to mention hubris.

Like Sundberg (2005) I have therefore employed a hybrid approach which seeks to find a middle ground between inductive coding on the one hand, and a complete dependence on *a priori* theoretical frameworks on the other. Facilitated by Nvivo data analysis software (Richards 1999), coding has therefore been a constant process of iteration between the codes and concepts emerging from the data (Strauss & Corbin 1998), and the theoretical ideas presented in Chapter 2. The analysis has therefore involved "following an inductive approach in identifying themes, but also the use of theories to guide the articulation of meaningful themes" (Sundberg 2005, 74). The case-specific details of the data collection and analytical strategies are discussed in the subsequent empirical chapters. This includes discussion of how documents and interview respondents were selected, along with illustration of how the aforementioned analytical techniques were operationalised in each case.

Prospective interviewees were initially approached by my supervisor with an email detailing the general interests and rationales behind my study. Those that agreed to an interview were then provided by me with a set of interview topics (see Appendix 1) and a consent form (Appendix 2). Interviews were conducted in person where possible, or by internet telephone[47]. The interviews were semi-structured and based on an interview schedule prepared beforehand (Appendix 3), but with sufficient flexibility to be able to respond nimbly to topics which emerged during the conversation (Bryman 2001). All interview extracts are presented anonymously, but with an interview number which refers to the list of respondents in Appendix 5. Likewise, extracts from documents a given with a number which refers to the list of analysed documents in Appendix 6.

[47] On the relative merits of face-to-face and telephone interviewing, see Stephens (2007) and Holt (2010).

Chapter 5

The colour of risk

An exploration of the IPCC's 'burning embers' diagram

This chapter is based on[48]*:*
Mahony, M. & Hulme, M., 2012. The colour of risk: an exploration of the IPCC's burning embers diagram. *Spontaneous Generations,* 6(1), pp.75-89.

Seeing climate change

How can climate change be visualised? The anthropogenic modification of the atmosphere's radiative properties through the emission of greenhouse gases and aerosols is an almost impossibly intangible, abstract and remote phenomenon, distant in both space and time in many people's perceptions (O'Neill & Nicholson-Cole 2009). While the human-caused depletion of the planet's protective ozone layer became manifest in the figuratively visible 'ozone hole' over the Antarctic (Grundmann 2006), the complex causation and uncertain present and future impacts of climate change have generated "a mess of competing visual narratives characterised by suggestive shapes drawn by the plotted lines of story-laden graphs" (Hamblyn & Callanan 2009, 43). The notion that graphical representations of climate change are "story-laden" is not to undermine their relationship to physical realities. Rather it points both to the social processes of their construction and to their appropriation of culturally-embedded representational conventions in the ongoing struggle to render climate change meaningful (Schneider 2011; Doyle 2011; O'Neill 2013). While graphic data representations have proven to be useful heuristics for coming to terms with the complex dynamics of the atmosphere, photographs have often been employed to visualise the possible impacts of climate change. Common tropes of stranded polar bears, flash flooding and parched soil can be found

[48] The data collection, analysis and writing of these publications and this chapter were conducted by me under the guidance of Professor Hulme.

accompanying media coverage of climate change (Doyle 2007; Manzo 2010). Such discursive coupling is suggestive of direct causal relationships between climate change and the pictured impacts, even as the scientific debate over the attribution and prediction of extreme weather events appears irresolvable with any certainty (IPCC 2011).

It is into this representational milieu that the Intergovernmental Panel on Climate Change (IPCC) introduced the so-called 'burning embers' diagram in 2001 (figure 5.1). The diagram seeks to summarise a number of "reasons for concern" linked to the prospect of rising global temperatures. The left hand side of the figure, which appeared in the Working Group II *Summary for Policymakers* (IPCC 2001a), shows projections of global mean temperature (GMT) change up to 2100 based on various emissions scenarios and the results of numerous climate simulations. It is suggested that GMT could rise by up to 6°C by 2100. The right hand side of the figure schematically represents the level of danger associated with these rises in mean temperature above 1990 levels for five categories of concern. The change in colour from white to yellow to red is taken to denote risks of increasing magnitude, severity or geographic spread, and it is this colour pallet which gave rise to the moniker 'burning embers' among the diagram's creators.

In this chapter, I offer an initial exploration of the key assumptions, contestations and meanings which would come to animate the social life of the burning embers diagram. I introduce the themes which allow me, in the following chapter, to dig deeper into representational politics and interpretive geographies of the diagram. In an auto-ethnographic sense, the path I tread from this chapter to the next also diagrams the evolution of my thinking about the utility of bringing co-productionist and geographical understandings of science into closer conversation – an evolution which has occurred through my coeval engagement with all of the case studies which make up this thesis. In Chapter 6 I explore the cultural spaces in which the burning embers form has travelled, in the language of interpretive geographies and civic epistemologies. Here, I seek to lay out how I see the burning embers as fitting into broader debates about the representation of climate change, about risk and expert judgment, and about the aesthetics of modernity. Drawing predominantly on interpretive readings of the scientific literature, along with 13 interviews with scientists who were involved in the development of the diagram between 1999 and 2009[49], I suggest that the burning embers has become something of an icon of the climate change debate through its engagement with a historically-textured set of cultural resources which, as a result of the work and decisions of its authors, are quietly manifested in this diagrammatic space.

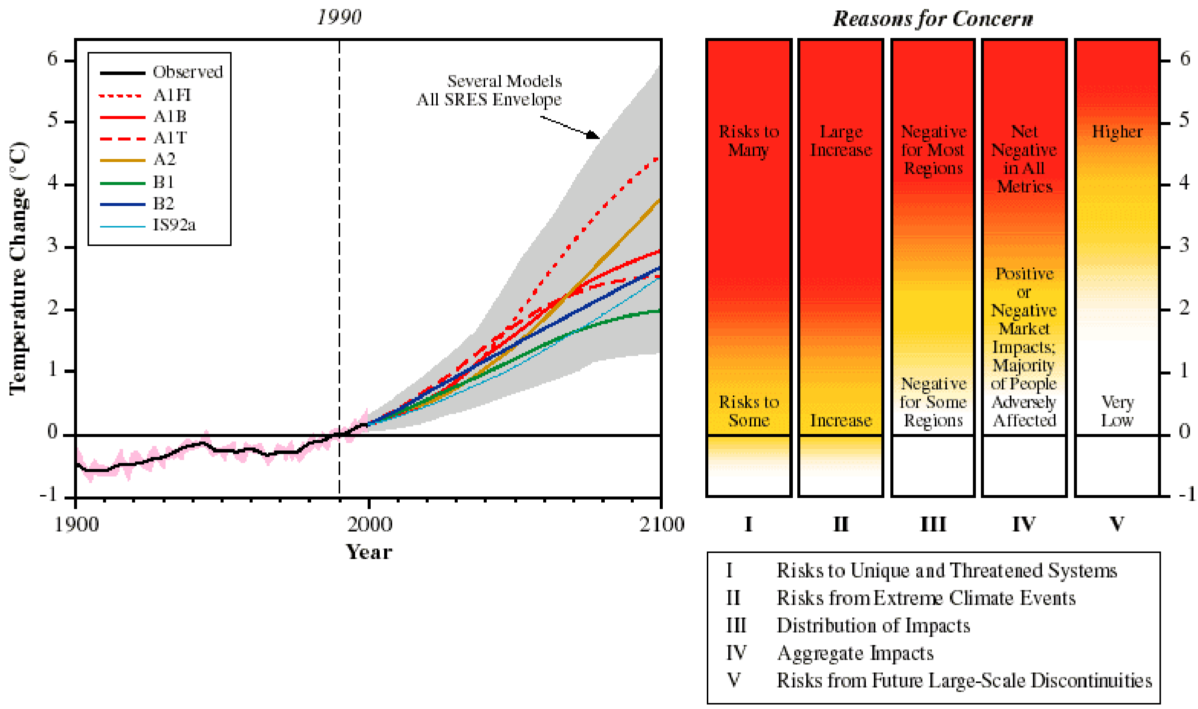

Figure 5.1. Projected temperature changes under different emissions scenarios (left) and 'reasons for concern' or 'burning embers' (right). Reproduced with permission from IPCC (2001a, 5).

The colour of risk

The burning embers diagram is "underpinned by a large number of scientific analyses and legitimated through publication and republication" (Liverman 2009, 285). As is shown below, the diagram has found traction among both scientific actors and non-governmental organisations, and has also surfaced in governmental settings such as submissions to the *Stern Review on the Economics of Climate Change*, produced for

[49] As I draw more directly on interview data in Chapter 6, the methods of respondent selection, analysis and interpretation are discussed on page 124-125.

the UK Government (document 23). The diagram has functioned as a powerful boundary object (Star & Griesemer 1989), facilitating exchange and interaction between the worlds of science and politics – a function which has defined the broader institutional history of the IPCC (Miller 2004b).

As I argued in Chapter 3, the IPCC occupies a unique position at the science-policy boundary and constitutes a hybrid space where scientific and political actors together regulate the flow of information across that boundary (see Hulme & Mahony 2010). IPCC reports are charged with being "policy-relevant and yet policy-neutral, never policy-prescriptive" (IPCC 2013b; Moss 1995), and thus IPCC authors face a constant challenge in regulating the boundary between epistemic statements of what *is* and normative statements of what *ought to be* (Walsh 2009). The chapter which gave rise to the burning embers sought to address the question of what might constitute "dangerous anthropogenic interference with the climate system" (UN 1992) – a question which the authors acknowledged to be loaded with potential value judgments. This diagrammatic form thus offers an opportunity to study how the interpenetration of the epistemic and the normative – long recognised by STS scholars – is handled under the rubric and norms of relevance and neutrality.

In its original form in Chapter 19 of Working Group II's contribution to the IPCC's Third Assessment Report (TAR), the diagram appeared in greyscale (as did all diagrams in the main body of the report) and laid-out horizontally. This original version of the diagram was based on months of work by individuals on the writing team, who assessed the literature on climate change impacts across the five reasons for concern. This categorisation of impacts was a result of earlier deliberations within the team which led to a desire to synthesise the textual information in the form of an accessible visualisation. The diagrammatic format demanded that projected impacts be tied to specific temperature points and, as literature on climate change impacts was sparse at the time, the authors had to exercise personal judgment in determining where the colour shifts should take place.

This kind of risk visualisation was not without precedent in the climate change literature. A decade earlier, Rijsberman and Swart (1990) and Vellinga and Swart

(1991) presented the ‘traffic light’ system of risk visualisation and management (figure 5.2). This employed three discrete blocks of colour – green, amber and red – to represent increasing rates of GMT and sea level rise and their risk corollaries (although again, printing practices reduced the colours to shades of grey). The aim of this visual device was to propose targets for temperature stabilisation. The transition from green to amber occurs with a 1°C rise above pre-industrial levels, while the red light is associated with a 2°C rise. The authors argue that the:

> goal of our effort must be, therefore, to go for the green light, and in any case, to fully avoid the red light. To avoid the red light means that we want to limit the GMT rise to well below 2°C with respect to the pre-industrial level and that we want to limit the sea level rise to well below 50cms.
>
> (Vellinga and Swart 1991, 131)

This was the first time that maximum temperature change was used as a means of normatively framing a target-based approach to global climate policy (cf. Nordhaus 1977), and was a key moment in the establishment of the 2°C target as an anchoring device for scientific and political discussions of climate change (Randalls 2010).

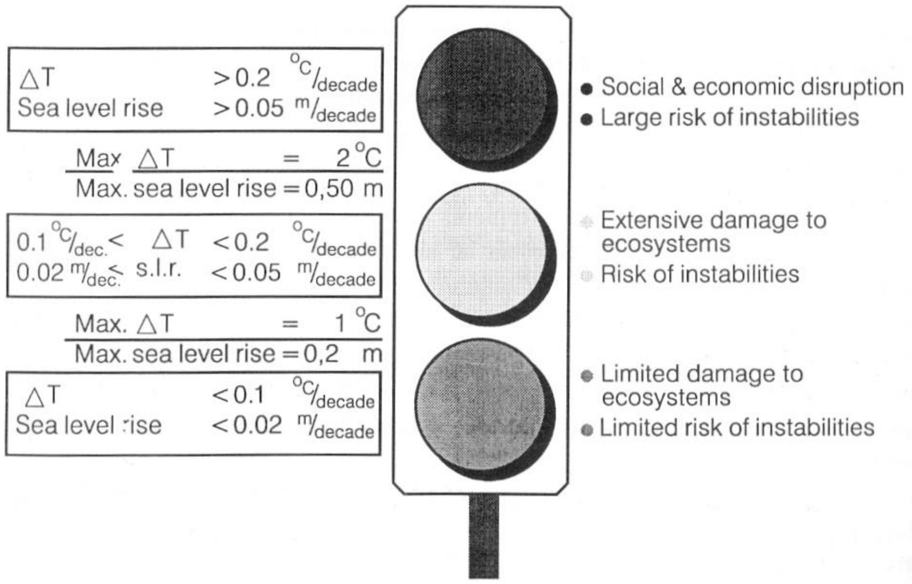

Figure 5.2. The 'traffic light' approach to risk management from Vellinga and Swart (1991, 131). Copyright (1991) World Meteorological Organization. Reprinted with the permission of Cambridge University Press.

Diagrams such as these combine expert judgments of observational evidence, future predictions, and normative judgments of risk. Unlike quantitative scientific visualisations which commonly aim at an ideal of unmediated representation or an analogue of physical reality (Daston & Galison 2007; see also Barthes 1977), here the viewer's interpretation is guided explicitly by the design choices and their attendant normative elements. The desirability of the bottom scenario is prefigured in the green traffic light; likewise the undesirability in the red. The normative content of the temperature and sea level rise scenarios is not left to the viewer's interpretation. The familiarity of the traffic light – and the images it conjures of momentum continued, tempered or abated – directs interpretation towards this seductively linear notion of pathways and targets. This notion has since been criticised for its reductiveness and its tendency to distract from the politically and ethically complex task of reducing emissions (Randalls 2010). According to this construction, it is science which is almost literally directing the traffic and showing the way.

The traffic lights had a direct influence on the development of the burning embers diagram. During the early stages of the writing team's deliberations, a diagram was proposed which employed a similar transition from green to red along each "line of evidence" column, as they were known before "reasons for concern." However, this pallet was dismissed, as it was thought that the green element indicated an absence of risk or even safety for some levels of climate change – something which the authors took as being contrary both to their own understandings of the risks and to the message they sought to convey (see Chapter 6). The neutrality of white was thus employed as the baseline on which to build the negativity of red. The ordering of the columns was also decided based on a combination of epistemic and aesthetic considerations. Neither fundamentally scientific nor axiological reasons are given for the ordering. Rather, this composition was deemed the most visually appealing, producing an upward-trending diagonal in the emergence of yellow, from column two to column five (interview 7, environmental scientist). It is a graphical design choice, but one which provides visual and rhetorical echoes of the rising forms of many high-profile climate visualisations, from Michael Mann's famously controversial 'hockey stick' temperature chart on the pages of IPCC reports to Al Gore's dramatically exponential CO_2 concentrations in the film *An Inconvenient Truth* (Hamblyn 2009; Schneider 2011).

As in the traffic lights, a sense of danger is pre-figured in the burning embers' colour pallet. The colour red has been graphically associated with high temperatures since the 19th century (Schneider 2011), but its connotative associations with danger, fear, violence and passion have a much longer and more engrained lineage in Western cultures (Gage 1999). The embeddedness of this scientific diagram within these political discourses and cultural conventions is the source of its meaning. It is also the locus from which it has achieved mobility as an actant within the networks which tie together science, politics, culture and ethics, further blurring their already permeable boundaries while undergoing a number of epistemic transformations.

Epistemic transformations

The burning embers diagram achieved a great deal of visibility following its publication in 2001 and has arguably become one of a few iconic scientific visualisations giving illustration to the climate change debate (Liverman 2009)[50]. In a particularly interesting use of the burning embers diagram, Mastrandrea and Schneider (2004) use the image as a foundation for a probabilistic assessment of the chances of avoiding "dangerous" climate change under certain policy initiatives. A cumulative density function of the threshold of dangerous anthropogenic interference (DAI) is constructed by placing a data point at the level at which each column turns red (see figure 5.3). The authors justify this strategy by stating that each column represents the judgment of "dozens of IPCC lead authors' examination of climate impacts literature," and therefore that the red zones represent "a consensus estimate of DAI" (Mastrandrea and Schneider 2004, 572). The authors later argued that:

> we view the increasing scale and intensity of impacts represented by the colour gradient in each category as an estimate not only of physical climate impacts, but also of societal perceptions of danger from those impacts. Interpreted in this way, increasing temperatures will progressively exceed thresholds in each metric and cumulatively contribute to the likelihood that the climate change occurring will be perceived to be dangerous by humanity as a whole. In other words, as warming intensifies, more and more stakeholders will perceive that DAI thresholds are being exceeded (based on their own value-driven assessments of what constitutes DAI in various metrics).
>
> (Schneider & Mastrandrea 2005, 15728)

These thresholds of combined physical and psycho-social manifestations of "dangerous" are then used to explore the sensitivity of projections of DAI to three model parameters[51] enabling the authors to claim that the probability of DAI can be reduced from around 45% to near zero with increasing "policy controls."

---

[50] See e.g. West Coast Climate Equity (2010); Vincent (2009); Climate Change Food Security (2012); UNEP (2009); Yohe (2010)

[51] The model parameters investigated are the estimated climate sensitivity to a doubling of CO_2 concentrations, projected economic damages, and the discount rate, i.e. the way present costs and benefits are weighed-up against future costs and benefits.

Mastrandrea and Schneider's analysis transforms the burning embers' blurred, uncertain judgments of future climate impacts into a quantitative profile of risk and danger as the global temperature moves up the scale from its late 20th century baseline. The temperature thresholds for radical changes in social and natural systems, drawn initially from climate impacts studies and then amalgamated and obscured in colour, re-emerge as new points; average thresholds, calculated not from the collected-together numbers of the impacts literature, but from the shifting colours of their graphical approximation. Point becomes blur, blur becomes point.

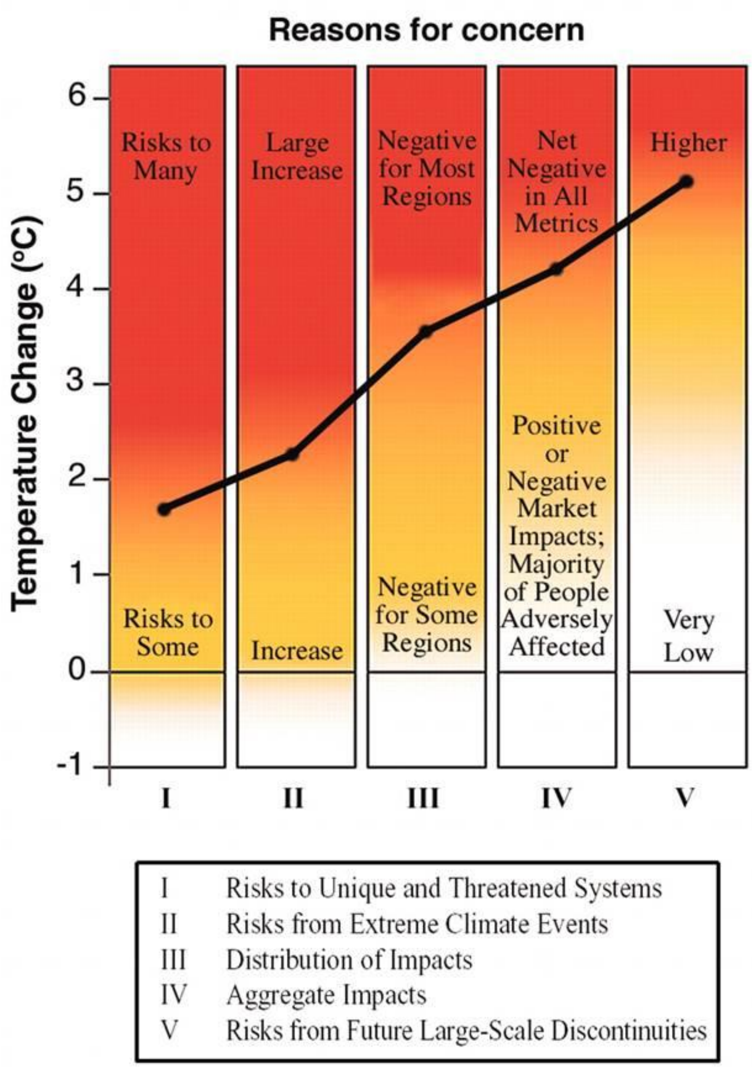

Figure 5.3. Schneider and Mastrandrea's adaptation of the burning embers diagram. The thresholds of dangerous climate change are marked by the black points and connecting line, positioned where each column begins turning red. From Schneider & Mastrandrea (2005, 15729). Copyright (2005) National Academy of Sciences, U.S.A. Reproduced with permission of the National Academy of Sciences.

This epistemic transformation illustrates both the challenges of visualising risk, and the power of consensus in addressing complex environmental issues. The visualisation of risk involves not only an attempt to capture and represent physical processes and phenomena. It also represents their interaction with social systems, certain interpretations of the meaning of that interaction, and the social and political capacity to respond to an emerging danger, should it be deemed to be of sufficient magnitude and urgency. The calculation of risk is thus often a task bestowed upon those with the necessary technical expertise to comprehend the complex, multi-faceted nature of anthropogenically "manufactured risks" (Giddens 1999). The concept of 'risk' itself "has come to stand as one of the focal points of feelings of fear, anxiety and uncertainty" pertaining to the future (Lupton 1999, 12). Its calculation must therefore involve grappling with the epistemological, ontological and ethical uncertainties which are constitutive of any effort to project what is known into the future, and then to draw on such projections to reflect on how society should be directed in the present (Beck 1992; Felt & Wynne 2007). Such knowledge will always be incomplete and partial—it will vary between experts, social constituencies, and cultures (Lupton 1999). The social organisation of knowledge therefore becomes a key source of epistemic authority, with assessment, synthesis and consensus being central strategies for the application of scientific expertise to questions of societal risk. Although gaining authority through its representation of a form of consensus, the burning embers diagram has not always attracted a broader consensus beyond the epistemic community which innovated and developed the diagram.

The IPCC chapter which gave rise to the original burning embers was re-mandated for the Fourth Assessment Report (AR4), albeit with many new authors. Although the 'reasons for concern' framework persisted and was updated textually in the IPCC's *Synthesis Report* (IPCC 2007b), the burning embers diagram was absent in the final report. In interviews, authors of the chapter reported a reluctance to wholly import the analytical framings from the TAR, as the AR4 team was required to assess a rapidly evolving and expanding literature. However, towards the end of the writing process, it was decided amongst some authors that an update to the burning embers diagram would be appropriate. An updated version of the burning embers diagram was thus presented for inclusion at the Working Group II plenary session. However, the lack of a version of the diagram in the underlying chapter later opened space for procedural objections from government delegations, with the late Steve Schneider, Coordinating Lead Author of the chapter, reporting that "four fossil fuel dependent countries accepted the text but refused the figure," seemingly on the grounds that it was "too much of a judgment" (quoted in Revkin 2009). A combination of these governmental protestations, the tight timescales of IPCC drafting processes, and certain objections to this particular analytical framing within the Working Group II hierarchy conspired to see the updated embers excluded from the AR4. The updated diagram was eventually published by a group largely consisting of chapter authors in the *Proceedings of the National Academy of Sciences* (Smith et al. 2009; see figure 5.4).

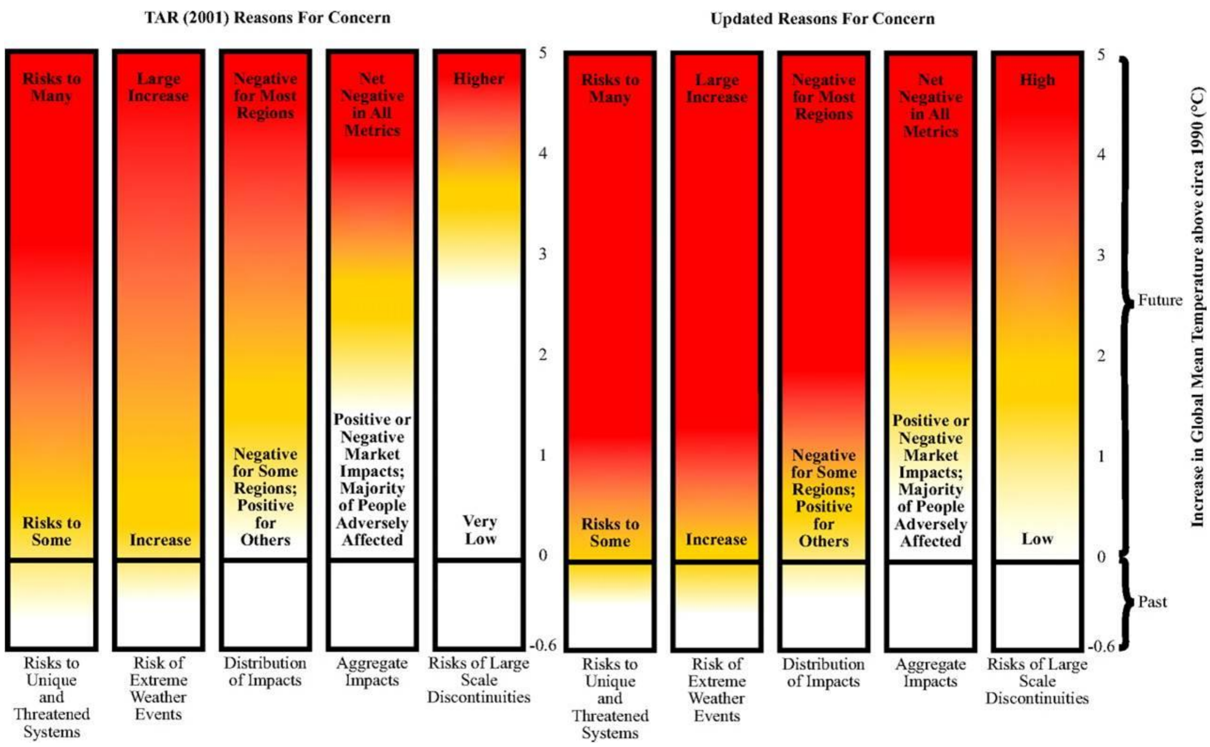

Figure 5.4. Updated 'Reasons for Concern'. Reproduced with permission from Smith et al. (2009, 4134) and IPCC (2001a, 5).

As I show in the next chapter, Schneider's claim that the diagram represented too much of a "judgment" for some parties emphasises the challenge of negotiating the boundary between description and prescription. The preservation of this boundary is inscribed both in the IPCC's mandate and in the norms of much contemporary scientific practice (Shapin 2008; Walsh 2009). The shift from the left- to the right-hand side of figure 5.4, with the visually-striking descent of the red, does not portray a change in the ontological status of the risks between 2001 and 2009, but rather maps the changing content of scientific understandings and judgments. The diagram seeks to represent the consensual amalgamation of these judgments, and the authors openly relate the potential for subjectivity in this mode of knowledge production and synthesis (Smith et al*.* 2009). However, the cognitive and social-epistemological processes which are generative of such judgments are largely indiscernible to the outside observer.

An icon of late modernity

The burning embers diagram is a collage of space and time (Schneider 2011) with GMT standing-in for an indeterminate temporality, while the global is collapsed into the limited dimensionality of graphematic space. This level of abstraction has been a source of criticism. For example, Liverman (2009) argues that the diagram elides the complex geographies of climate change impacts in its effort to present a globalised conceptual space. The dominant 'global gaze' of climate science is not an epistemological inevitability, but is rather the result of the complex intertwining of science and politics (e.g. Miller 2004b; Oels 2005). For instance, since its inception the reasons for concern framework has sought to address the principle enshrined in Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC) – the avoidance of "dangerous anthropogenic interference with the climate system" (UN 1992).

While attempting to avoid overt policy prescriptiveness, the "reasons for concern" framework has sought to provide illustrative guidance on what might be considered a dangerous level of global mean temperature rise. However, the framework seeks to address only the dangers associated with anthropogenic climate change, rather than those associated with natural climate variability. For example, it is suggested in all versions of the diagram that at some point below 1990 temperature levels the risks associated with extreme weather events were "virtually" zero or "neutral." Of course extreme weather happened long before 1990, but the "reasons for concern" framework seeks to address only that which may be attributable to human actions. This inverse purification of the “human” from the “natural” (cf. Latour 1993) is a function of the diagram’s direct engagement with the policy question of “dangerous anthropogenic interference.” It thus functions as a heuristic for the dangers associated with an imagined, human-made climate of linear trends and direct causalities, rather than a complex, hybrid climate where cycles, trends and social trajectories interact chaotically in perhaps unknowable ways[52].

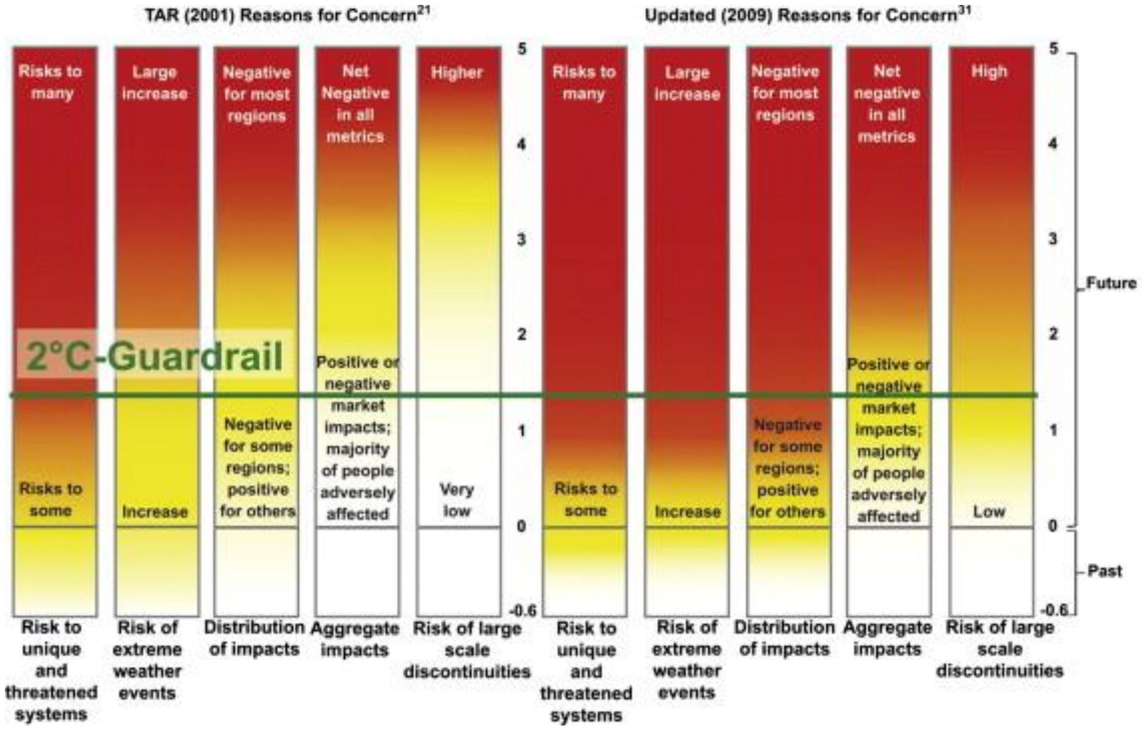

Figure 5.5. The burning embers as they appear in Richardson et al.'s (2009, 16) synthesis of an international scientific conference which took place in the run-up to the Copenhagen climate negotiations of December 2009 (see Chapter 7). The positioning of the “2°C guardrail” at around 1.4°C represents the discrepancy between pre-industrial and 1990 temperature baselines, the latter being preferred in IPCC assessments. Copyright and reproduced with permission of the University of Copenhagen.

As an “epistemic thing” (Rheinberger 1997) the burning embers diagram does not simply fulfil a representational role, but rather functions as an object *within* a system of enquiry; and object which is “open, question-generating and complex” (Knorr Cetina 2001, 190). In figures 5.3 and 5.5 for example, the diagram has formed the basis of new knowledge claims about the prospect and complexity of “dangerous”

[52] See Hulme et al. (2011) for an example of the political implications of this purification.

climate change. However, instead of Rheinberger's tightly bounded and regulated laboratory spaces, the burning embers functions in a much wider arena. There the conditions "of the possibility of things becoming epistemic things" (Rheinberger 1998, 297) are as much political and discursive as they are determined by the materiality of scientific enquiry (Jasanoff 2004c; Foucault 2007a). The burning embers diagram is thus a hybrid form: representational and heuristic, forensic and epideictic;[53] the outcome of an institutionalised yet indeterminate encounter between object and subject. This hybridity, while posing challenges to certain scientific norms, is emblematic of the complex interweaving of competing epistemologies with the challenges of intractable uncertainty which characterises late modern "risk societies" (Beck 1992).

For theorists such as Ulrich Beck and Anthony Giddens, industrialised societies are experiencing conditions of late modernity. This represents a continuation or radicalisation of the institutional, economic and cultural changes wrought by modernisation to a point where socioeconomic processes generate hazards of a scale which require modernity to reflect on itself; to challenge its assumptions of progress and interminable growth (Giddens 1990; Beck 1992). Late modern societies are thus preoccupied with the future. This preoccupation most often takes the form of the calculation of hazard probabilities and of the social acceptability of risks in order that they may be managed or controlled. However, late modernity is also characterised by risks of a sort which belie easy calculation, spatio-temporal delineation or straightforward democratic appraisal. The blurring, evocative colours of the burning embers exemplify this paradoxical societal relationship with risk as an object of scientific enquiry and political concern; the semiotic functions of the colours suggest that significant dangers confront humanity, while their blurred transitions point to the irrevocable uncertainties which accompany such threats.

It is in the distinctive societal milieu of late modernity that the burning embers diagram may be said to function much like an expressionist painting. During the early twentieth century the expressionist movement pursued an artistic style which prioritised subjective experience, meaning and emotion in a direct rebuttal to realist

[53] See Walsh (2009) for a discussion of climatological imagery through the lens of rhetoric theory.

and naturalist representational paradigms (Willett 1970). Likewise, the burning embers seeks not to figuratively represent a phenomenon (the changing climate), but rather its intangible effects[54]. These effects, be they heightened levels of danger or risk, are quickly translated into affect through the use of literary and visual conventions such as the emotionally charged colour pallet. The expressionist movement arose in Germany in part in response to conditions of social crisis and upheaval (Whitford 1970). The burning embers too feed certain anxieties about the future; we can sense ourselves walking powerlessly into the red heat, a fate made all the more inevitable as the red zone creeps towards the colourless safety of the baseline. In the case of this diagram, scientific visualisation is not the disinterested gaze of technical apparatus. Rather, it is a suite of social-epistemic practices situated within a set of cultural discourses in the uncertain, reflexive time-space of late modernity. The semiotic, epistemic and social elements of such constructions cannot be understood in isolation, or even analytically delineated. Here they are mutually constitutive; combining and re-combining in a particular graphematic space to produce a mobile and evolving visual convention.

Conclusion

The case of the burning embers diagram raises the question of whether the exercise of subjective expert reasoning is compatible with the demands of diagrammatic reasoning. It has been argued that the notion of risk is highly complex in epistemic and normative terms, especially when considered in the context of climate change (Hulme 2009a). A perfectly 'objective' assessment (in the sense of wholly restrained subjective evaluations) of the risks posed by a changing climate would be impossible, and the authors of the burning embers diagram are right to acknowledge the inevitable subjectivity of such judgments. As a *heuristic* tool, the diagram functions well in its suggestion of when (or, more precisely, at what temperature) danger might be encountered under a changing climate, as evidenced by the variety of uses to which the diagram has been put. As *representation*, the diagram is weakened by the

[54] Coincidentally, one of the most famous examples of expressionist architecture – Erich Mendelsohn's Einstein Tower in Potsdam – lies just a few yards from the meeting room where the burning embers diagram was first conceived by IPCC authors.

opacity of what exactly is being represented. In the translation from assessment of scientific literature to diagrammatic form, a wide body of scientific knowledge is condensed into a suggestive array of colour with the somewhat inevitable loss of what Latour (1999) terms "reference"— the traces, marks and symbols which tie together mind and world.

Despite the widespread rhetorical policing of the boundary between description and prescription, this case makes clear that the communication of climate change through visualisation relies not only on translation, but also on what Walsh (2009) terms a "performance of continuity" across the is/ought divide. Highlighting the normative underpinnings of this continuity is perhaps incompatible with the demands of diagrammatic reasoning and the limitations of graphematic space. Knowledge of the complexity of the climate system is growing and different normative stances on climate change are proliferating (Hulme 2009a), for example in judgements about what might constitute a "reason for concern". In this context, scientists working at the science-policy interface face difficult decisions in finding creative ways of communicating their findings. Recognising and communicating epistemic uncertainty and normative diversity may be central to the success of such efforts.

In the next chapter, I dig deeper into the history of the production and circulation of the burning embers diagram. This involves looking at how the authors of the original diagram made their way through a number of alternative versions before arriving at the manifestation reprinted here as figure 5.1. I then seek to explore the spaces through which this diagram has circulated, which include the review and approval processes for IPCC reports, and the adaptation of the diagram for various local needs and purposes. In so doing, I seek to engage in debates which I introduced in Chapters 2 and 3, including the interpretive geographies of circulating scientific texts, and the place of 'styles' of governmental reasoning in the transnational spaces of the IPCC. Through these discussions, I am able to develop a fuller account of how and why the burning embers diagram challenged conventional boundaries between *is* and *ought*, *relevance* and *prescription*, *science* and *politics*.

Chapter 6

'Too much of a judgment'

Interpretive geographies of risk at the boundaries of science

This chapter is based on:
Mahony, M., (under review). 'Too much of a judgment': interpretive geographies of risk at the boundaries of science. Transactions of the Institute of British Geographers.

Introduction

As I outlined in Chapter 2, geographers have recently shown considerable interest in the diverse cultural settings where scientific knowledge is produced, and the varieties of reception which such knowledge encounters as it circulates through different political, social and cultural milieux (Livingstone 2003a; Powell 2007a; Meusburger et al. 2010). In accordance with work in science and technology studies (STS), geographers have explored the interaction of scientific knowledge with other modes of thinking and acting – such as politics, ethics and theology (Hulme 2009a; Demeritt 2001a). Epistemological distinctions between different 'ways of knowing' have been problematised at the same time as ontological divisions between knowing, cultured human subjects and the brute materiality of the 'natural' world have come under question (Latour 1993; Whatmore 2002). New geographies have therefore emerged of hybrid human/non-human collectives, and of contingent cultural boundaries between different modes of attaining and communicating knowledge of the world (Lorimer 2012).

The argument that the boundaries between science and other cultural spaces are not an *a priori* product of science's foundational characteristics has been most cogently developed by Gieryn (1999). Through practices of 'boundary work' (Gieryn 1983), distinctions between science and its outsides are continuously redrawn in moments of epistemic or political controversy and emergence. Thus, the space of science on the cultural map of modernity is contingent upon broader cultural circumstances which shape the ways in which distinctions are made between legitimate and illegitimate claims to knowledge and objective authority (Jasanoff 1987; Miller 2004b).

Scientific visualisation plays an important role in constructing “the objective authority of science” (Burri & Dumit 2008, 299). The persuasiveness of scientific images “depends on their being regarded as the simultaneous voice of technoscientific authority and as expressions of nature” (ibid, 305). However, the interpretive flexibility and semiotic openness of scientific imagery means that visualisations frequently become a site where the authority of science is contested (Demeritt 2006) and where the boundaries between science and politics are negotiated (Walsh 2009; Yusoff 2009). Such boundary conflicts, it will be argued here, may be particularly acute when visualisation techniques are used to construct and communicate other forms of ontological boundary, such as between the normative concepts of ‘safety’ and ‘danger’ in the context of anthropogenic climate change.

The epistemic and political complexity of climate change poses distinct challenges to the culturally pervasive norms of scientific disinterestedness, objectivity and neutrality in political debates (Merton 1973; Turnpenny 2012). Articulations of what might constitute “dangerous anthropogenic interference” (DAI) in the climate system (UN 1992) involve interactions of quantitative scientific knowledge with value-based judgements of the meaning and implications of the label “dangerous” (Dessai et al. 2004; Oppenheimer & Petsonk 2005). The debate about how to define and ultimately avoid DAI has become a central element of science-policy discourse around climate change (Randalls 2010; Shaw 2010), while encapsulating the deeper challenges of scientific and democratic engagement with an object – the climate – which is defined as a global, hybrid compound of human and nonhuman agency (Hulme 2010a). In the face of deep ambiguity and uncertainty about observed and predicted changes, science-policy ‘boundary organisations’ (Guston 2001) like the Intergovernmental Panel on Climate Change (IPCC) have developed new methodologies for ascertaining and compiling the judgements of individual experts on questions of the likelihood and potential severity of climate change impacts (Hulme & Mahony 2010). Meanwhile, the IPCC has also developed new ways of ensuring democratic accountability and political legitimacy through the incorporation of governmental actors in the processes of scoping and reviewing assessment reports (Miller 2004b). It is in this sense, as I argued in Chapter 3, that the IPCC can be considered a site of co-production where new knowledges are created alongside the development of new forms of political and social order (Jasanoff 2004a).

In this chapter, I build on the interpretive account of the production and circulation of the burning embers diagram which I presented in Chapter 5. In that account I suggested that the diagram has, since its first iteration in 2001, become a particularly prominent part of the visual discourse of climate change. Here, I seek to show how the processes of the diagram's production by an IPCC chapter-writing team and its circulation around the social worlds (Gerson 1983) of climate science and politics reveal the varied and contested practices of expert judgement at the science-policy boundary. These practices highlight the ongoing construction of the boundaries between science and politics in the production and circulation of knowledge.

The chapter proceeds through an outline of the conceptual and methodological resources employed in the study, followed by a detailed exposition of the production and circulation of the burning embers diagram. However, in attending to the influence of distinct political cultures (as represented by governmental actors) in determining the fate of the diagram, I argue that distinctions between the spaces of knowledge production and circulation are rendered problematic (cf. Livingstone 2003a). The hybrid spaces of the IPCC process (Petersen 2006) are also spaces where scientific knowledge and evolving forms of social order are co-produced, for instance in the boundaries which are drawn between science and politics. The chapter therefore ends with reflections on what the implications of this cultural, epistemic and ontological hybridity may be for the institutionalisation of expert judgement and policy-relevant science in global organisations like the IPCC.

Visualisation and the boundaries of science

Scholars of the social practices of science have devoted much analytic attention to processes of scientific visualisation (e.g. Lynch & Woolgar 1990; Pauwels 2006; Burri & Dumit 2008; Gross & Louson 2012). In laboratory settings, images are central to processes of reasoning and discovery (Knorr-Cetina 1981). Technical apparatus transforms the messiness of the natural world into 'docile objects' of investigation (Lynch 1985), while craftsmanship is invested into the transformation of objects into durable, mobile visual inscriptions (Latour & Woolgar 1979; Latour 1990). For Latour, it is the ability of science to accumulate masses of inscriptions – infinitely combinable, comparable and transportable – which gives it a unique power. Such accounts transcend understandings of scientific objectivity as being achieved through the disinterestedness of mechanical observation (Daston & Galison 2007). Rather, the production of inscriptions is a deeply social act – disciplined by conventions, constitutive of agonistic struggles between actors over the meaning of epistemic objects, and a source of power (Latour 1990).

Other studies offer more hermeneutic readings of scientific visualisation (cf. Livingstone 2002). Taking inspiration from Anderson's (1991) account of the participation of visual imagery in the formation of shared national consciousness, Jasanoff (2001; 2004d) has explored how images of the earth from space have contributed to the formation of a global environmental consciousness. However, in line with criticisms of the idea that new knowledges linearly determine new horizons of action (cf. Haas 1992a; Grundmann & Stehr 2012), Jasanoff explores how discourses of fragility and universal communalism were already in existence before their association with images of a blue and green planet floating serenely in the infinite darkness of space. However, these discourses were mobilised and transformed by the circulation and interpretive flexibility of the images (Jasanoff 2001). For example, the ideal of a borderless world of political cooperation which became articulated in light of the images was interpreted in some contexts, such as Indian environmental movements, as representing a dangerous depoliticisation of questions of social and environmental justice (Jasanoff 2004d; see also Yusoff 2009).

These arguments about the complex and contested circulation of visualised knowledge accord with historical work on the 'geographies of reading' (Livingstone 2005b; see also Secord 2000; Daston 2004). By focusing on the hermeneutic moment of encounter between reader and text, insights can be gained into the role of space and place in the construction of scientific meaning. Conceptualised as a dialogic meeting of new knowledge and individuals' intellectual histories (Beer 1985) or collective modes of interpretation and understanding (Fish 1980), the act of reading and reviewing (Rupke 1999) represents not just a migration of knowledge and ideas but a transformation of meaning according to local hermeneutic conditions (Said 1983). Reading therefore is an act of knowledge production, rather than knowledge consumption (Livingstone 2005a). As Jasanoff (2004c) notes, the ways in which knowledge claims are interpreted in different places is radically under-determined by the solidity of immutable mobiles and the size of the networks through which they circulate (cf. Latour 1990), as evinced by her study of the circulation of earth imagery. The semiotic formalism of Latour's account of epistemic mobility overlooks the complex geographies of textual and visual interpretation. In engaging with contemporary spaces of scientific meaning-making, it is profitable to turn towards the idea of co-production (Jasanoff 2004a) and the related concept of civic epistemology – the culturally-embedded norms and practices by which authoritative scientific knowledge is constituted in different political contexts (Jasanoff 2005a).

In concert with the suggestion that knowledge and social order are co-produced, the argument that there exist distinct civic epistemologies in different political settings (often delineated nationally) points towards geographic differences in the settlement of the boundaries of science. For example, Jasanoff observes in her study of the politics of biotechnology distinct ways by which expertise, objectivity, accountability and public demonstration are constituted and evaluated in the UK, US and Germany (Jasanoff 2005a). Despite their differences however, these Western democracies all adhere to a vision of science and politics as being fundamentally distinct, and to the idea that careful boundary work must be conducted to preserve social order in the face of challenging hybrid entities like biotechnology or climate change (Jasanoff 2011b; Whatmore 2002). It is therefore worth briefly inquiring into the historical origins of the culturally pervasive and powerful idea that science and politics exist on a continuum, but as fundamentally distinct entities.

Lynda Walsh (2009), in her study of IPCC efforts to negotiate the boundary between description (what *is*) and prescription (what *ought to be*), draws on the theory of the stases to delineate conventional understandings of the relationship between knowledge and action. Developed initially by Roman scholars to describe the idealised functioning of democratic discourse, the theory holds that debate proceeds through five stases: 1) *fact*; 2) *definition*; 3) claims of *cause and effect*; 4) *value*; and 5) *action* (Fahnestock & Secor 1988). For example, a debate about the effects of smoking would begin with statements about the conditions of subjects' lungs, followed by the question as to whether the condition would be classed as 'damage'. Causal mechanisms would then be evaluated, before discussion of whether the causal agents are worthy of preventive regulatory action given the severity of the observed effects. Finally, the means of regulatory action are debated. According to students of political rhetoric, the "stases exert an irresistible upward pull on the discourse surrounding a particular issue because the answer to a question at one stasis generates a question at the one above it" (Walsh 2009, 42). This argument brings us back to the question of boundaries: where does the role of the scientist conventionally end in the progression from *fact* to *action*?

In the pre-modern era the question of who was justified in speaking at different stases was answered by an ethos of the scientist as a "priest of nature" (Lessl 1989). Possessed of an unprecedented access to God's will, the scientist was *expected* to draw conclusions at the higher stases about how society should be shaped in an image of divine order (Walsh 2009). By contrast, approximately since World War II, the professional ethos of the scientist has been largely restricted to the first three stases. Pre-dated perhaps by Weber's characterisation of scientific work as fulfilling a Puritan ethic of discovery as reward for diligent, isolated yet civic application (Weber 1958), the new ethos removed normative questions from the purview of science. Restricted to stases 1-3, the scientist was placed at the start of a linear chain of knowledge production and societal debate about political action (Merton 1973; Shapin 2008). However, the irresistible pull of the stases places the scientist in an ethical bind, as questions of cause and effect immediately become questions of value (Walsh 2009; also Foucault 1980b, 126-129). In addition to the personal quandaries which can result from this ambiguous positioning in public life (Russill 2010; Keller 2011), the intertwining of the epistemic and the normative in the warp and weft of public life destabilises accepted boundaries between science and politics and necessitates the ongoing re-settlement of boundaries in the pursuit of social order (Gieryn 1999).

The IPCC is a space where the boundaries of science are continually negotiated. Charged with periodically providing "policy-relevant" but not "policy-prescriptive" scientific assessments to the political community, the IPCC process features close interaction between scientific and political actors in the framing, reviewing and accepting of reports (Shaw & Robinson 2004). The epistemic complexity of climate change means that the need – actual or perceived (Mahony & Hulme 2012) – for detailed knowledge of future changes to inform political action (particularly climate adaptation policy) is often met through the exercise of qualitative reasoning and judgements about the severity or likelihood of certain outcomes (Petersen 2006). Thus, 'expert judgement' has been institutionalised within the IPCC as a means of ascertaining, compiling and communicating uncertain knowledge based on tacit combinations of empirical assessment, theoretical knowledge, and perceptions of what knowledge is 'relevant' to the political community (Jasanoff & Wynne 1998; O'Reilly et al. 2012; cf. Helmer & Rescher 1959). For Walsh (2009), efforts to visualise claims and judgements about the likelihood and desirability of future events in an explicitly policy-facing fashion can be read as integrations of epistemic commitments to what *is* and normative commitments to what *ought to be*. However, these integrations take place in a setting where the boundary between relevance and prescription, and between science and politics more generally, is carefully regulated. In the case of the IPCC, scientific visualisation can therefore be seen as a site of co-production both through the interpenetration of the epistemic and the normative, and because the creation of new knowledge proceeds hand-in-hand with the negotiation of the cultural boundaries which aim to keep science and politics at an orderly distance (Miller 2004b). In what follows, these dynamics are explored in the context of the production and evolution of the burning embers diagram between 1999 and 2010. In line with this thesis's broader goal of bringing STS notions of co-production into greater dialogue with geographies of science, attention is focused on the hermeneutic geographies of the diagram, its associated analytic framings, and their perceived implications for the ordering of science/politics relationships.

Methods

The first part of the analysis, which focuses on the production of the burning embers diagram, draws primarily on 13 interviews with scientists who were involved with producing the various iterations of the diagram. These include Coordinating Lead Authors, Lead Authors and Review Editors in the IPCC process, selected on the basis of their proximity to the production process as determined through earlier interviews or documentary analysis, which included archival materials held at Harvard University pertaining to the preparation of the IPCC's Third Assessment Report (TAR). In the second part of the analysis, which focuses on the circulation and reception of the diagram, the focus switches to documentary sources as the diagram is followed (cf. Latour 1987) through a textual network of interpretation and revision in scientific publications, press releases, weblogs and conference proceedings. Most significantly, government reviews of the relevant IPCC chapters are used to reconstruct the hermeneutic conditions of the diagram's reception in governmental settings. Although it is not possible to identify the authors of individual comments and to determine whether they are formal government employees or experts solicited by governmental actors to undertake a review on the government's behalf, their positioning in a quasi-public space as representative governmental voices[55] means that they perform a role of "community-constituted interpreters" (Fish 1989, 141). For example, the US Government review of the 4th Assessment Report (AR4) solicited "comments by US experts and stakeholders to inform development of an integrated set of US Government comments on the report" (USCCSP 2006). These comments were compiled "in development of the US position" (ibid).

For literary theorist Stanley Fish, the interpretation of new knowledge is a communal act guided by understandings of shared conventions, norms and goals. As sources of interpretive meaning which transcend the objective text and the subjective individual reader, interpretive communities can thus exhibit distinct epistemological commitments (Fish 1980). In what follows, the links between this understanding of collective meaning-making and the notion of civic epistemology will be explored in

[55] Since the IPCC's 2007 report, review comments and author responses have been made public. TAR review comments were obtained for this study from the WGII Technical Support Unit in the US.

the context of the IPCC government review process. The review comments were coded both for their substantive content (e.g. whether they engaged in conceptual critique or identifying grammatical errors) and their thematic content (such as concerns about the authors over-reaching their mandate as scientific actors). The thematic coding allowed linkages to emerge with the interview and documentary data which was subject to a parallel coding process, as explained in Chapter 4 (see also Charmaz 2006). Interview extracts are presented anonymously as agreed with the respondents, although indications are given of disciplinary backgrounds as this is considered relevant to the analysis of the dynamics of the author group.

Igniting the 'burning embers'

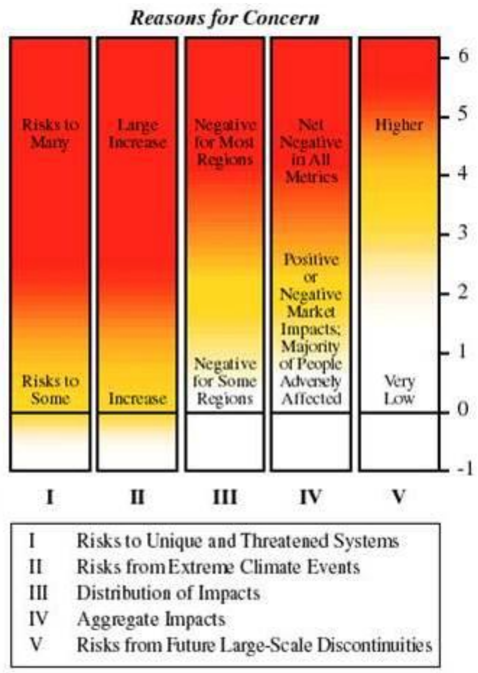

Figure 6.1. The 2001 'reasons for concern' diagram. Reproduced with permission from IPCC (2001a, 5).

As I explained in Chapter 5, the "reasons for concern" (RFC) framework was initially developed in Chapter 19 of the Working Group II contribution to the IPCC's Third Assessment Report (TAR). The WGII report assesses knowledge of the impacts of climate change on social and ecological systems, and the potential for adaptation. In turn, Chapter 19 sought to further synthesise information on climate change vulnerabilities and to delineate significant "reasons for concern" (IPCC 2001b). The aim was to address the question of what might constitute "dangerous anthropogenic interference” (DAI) and to “enable readers to evaluate the relationship between increases in global mean temperature and impacts.” The RFC framework was presumed to “aid readers in making their own determination about what is a ‘dangerous’ climate change” (IPCC 2001b, 915). The compiled judgements about the severity or risk of particular impacts were visualised in the ‘burning embers’ diagram – as it came to be known – with each column corresponding to a single RFC and the shifting colours denoting increasing severity or risk as global mean temperature rises from a 1990 baseline.

The goal of aiding readers (particularly policymakers) in determining their own definition of DAI situates the RFC construct at the conventional boundary between statements of causation and judgements of value (Walsh 2009). The framework seeks to communicate the causal mechanisms of the potential damage to be wrought by climate change, while also engaging with the definition of *dangerous* impacts and the corollary questions of whether such impacts are worthy of aversive or adaptive political action. The burning embers diagram is, quite literally, a composition of a “matter of concern”, as opposed to a “matter of fact” (Latour 2004a 22-25; Latour 2010). It engages with the complex, rhizomatic entangling of human and nonhuman systems through a compilation of knowledges drawn from, for example, the atmospheric sciences, ecology, and economics. At the same time, the diagram seeks to contribute to the construction of a deeply normative ontological threshold of dangerous human interference with the climate system. How did the authors manage this complexity in the development of the burning embers visualisation?

Early iterations of the diagram featured a homogenous threshold of harm across the “lines of evidence”, which later became RFCs (figure 6.2):

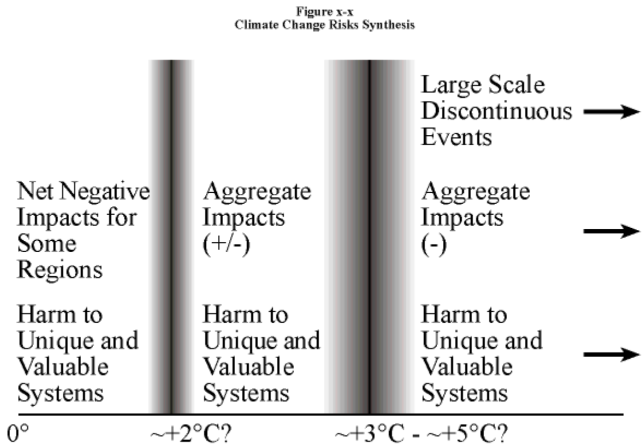

Figure 6.2. A diagram included in the first-order draft (FOD) of Chapter 19, which was reviewed by experts (document 9). The diagram posits a common threshold of harm across the RFCs.

Later in the process, more RFCs were developed with their own independent thresholds. To communicate this, a colour transition from green to red was used, influenced by the 'traffic lights' approach to visualising the risks of climate change which was used in the early 1990s (see Chapter 5). The evolving embers diagram came to more closely resemble figure 6.1 in its composition. However, the green element was soon jettisoned:

> There were many incarnations of the whole figure and one was a different colour scheme with green, yellow, red. The green – a lot of people interpreted it as 'no risk'… which is a little bit of a different message. The colour scheme actually makes a very big, big difference in that diagram.
>
> (interview 7, environmental scientist)

The implication of 'no risk' was thus seen as being contrary to the message which the authors sought to convey, even though the white of figure 6.1 was stated to denote "no or virtually neutral impact or risk" (IPCC 2001b, 958). For another of the authors, the epistemic concerns were supplemented by a feeling that the green colouring "was aesthetically less pleasing" than the yellow-to-red colouring (interview 3, environmental economist). The alteration of the colour scheme was a product of complex negotiations within the chapter-writing team which also concerned the positioning of the colour transitions. The authors, both in interviews and in print (e.g. IPCC 2001b, 941), acknowledge the role of "value judgements" in these decisions. Although the authors use this term to distinguish scientific *evaluation* of the risks from political *judgments* of the acceptability of risks (indicating boundary work between the stases of *cause and effect* and of *value*, e.g. IPCC 2001b, 917), "value judgements" are also reported as being central to the chapter preparation itself:

> I guess the *robust* thing to say is if you're looking for an algorithm, a piece of analysis that calculates the number, we didn't have that. We were looking at the evidence *and then* using value judgements, and portraying that by being cloudy and making the colours sort of mesh into each other.
>
> (interview 3, environmental economist, emphasis added)

This quotation highlights the awareness that existed within the author team of the somewhat awkward position in which they found themselves. The qualifying "robust" portrays the insecurity felt about being compelled to exercise subjective judgements as opposed to more conventional modes of scientific reasoning, such as calculation using mathematical algorithms. The statement that "[w]e were looking at the evidence *and then*" indicates a continuity across the *is/ought* divide, while the contrasting picture of ambiguity inherent to normative judgements – "cloudy", meshing colours – is contrasted to the ideals of precise, detached and quantitative scientific enquiry. This author does not go so far as to stress a complete interpenetration of the epistemic and the normative, but suggests continuity across that divide – what rhetoricians describe as an ineluctable pull from fact to value (Walsh 2009). But this cloudiness was not just a means of representing epistemic uncertainty. It was also, for some, a means of communicating the ambiguities of control of such uncertain *cause and effect* relationships:

> the chart is sort of skilfully blurred to make sure you don't have an on-off switch. [We] deliberately didn't want that, because we weren't able to say '1.9 degrees good, 2.1 degrees bad'. It doesn't work that way, so we

blurred it.

(interview 3, environmental economist)

The use of the metaphor of an "on-off switch" in part re-states the aforementioned concerns within the author team about communicating the ambiguities they found in the scientific literature and the indeterminacy of the personal judgments they were exercising. But the metaphor of a switch also suggests a concern about offering an epistemic construct to policymakers which, like the traffic lights of Chapter 5, implies an undue level of purposeful control. As Judge (1990) argues, metaphors of switching often animate modernist framings of complex social problems. Ambiguity is disavowed (Levine 1988) in favour of dualistic thinking which splices problems into opposed categories, with the goal of public policy being to push or 'switch' individuals or collectives from one to the other (e.g. Jones et al. 2013).

A category like "dangerous" climate change invites a similar conflation of knowledge and control. This can in part be read as confirmation of Foucauldian arguments that knowledge and power are internally related, and that modern empirical sciences have developed "within a methodological frame of reference that reflects the transcendental viewpoint of possible technical control. Hence the modern sciences produce knowledge which through its *form* is technically exploitable knowledge" (Habermas 1970, 99). This can be read alongside pragmatist and Heideggerian arguments about the internal relations between truth and the capacity for productive intervention in – and interpretation of – the world (e.g. Rouse 1987). For Yusoff (2009, 1021), animations of visualised climate simulations – often rendered in the same palette as the burning embers – transpose the immensity of pixelated, pointillist data into fluvial images of "atmospheric streams, ice flows, bodies of sea temperature, and intensities of CO_2 accumulation". This shift from an overwhelming immensity of data to an aesthetics of movement and flow represents an instantiation of Kant's mathematical sublime (Kant 1987; Yusoff 2009), or perhaps of Heidegger's mathematical projection of nature: "nature is projected in modern physics as something about which certainty can be had" (Glazebrook 2000, 52). For Yusoff:

> The conceptual movement from the landslide of immensity to the pleasure of asserting the control of reason (from a distance) can be seen as a form of transcendence, albeit one that restores the originary condition of control. The movement is from `form' to `formless' then back to `form'. The mathematical sublime can be seen as a negative moment between two forms of ordering, that of immensity and that of reason. If we transpose this ordering onto atmospheric climate models, we can begin to see how atmospheres are atomised through their encoding as data, accumulated, then mobilised as an aesthetic experience, then rearticulated as data again.
>
> (Yusoff 2009, 1021)

This conceptual and aesthetic movement is evident in Mastrandrea & Schneider's (2004) treatment of the burning embers as a means of experimenting with the possibility of avoiding certain atmospheric outcomes through the hypothetical instantiation of certain forms of 'policy control' (figure 6.3). The aesthetic experience of the burning embers diagram, with its intention to "grab [people's] attention and really focus their minds on the intellectual issues" (interview 15, environmental scientist), was rearticulated as data – as technical knowledge offering a transcendental view of the globe and its politics of human intervention and control.

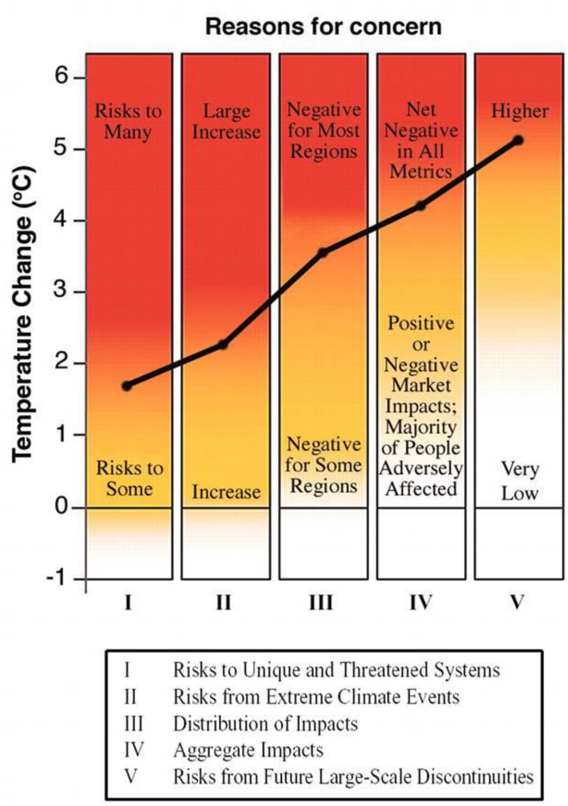

Figure 6.3. From aesthetic experience to reasoned control. From Schneider & Mastrandrea (2005, 15729). Copyright (2005) National Academy of Sciences, U.S.A. Reproduced with permission of the National Academy of Sciences.

The resistance to imputing a "switch" by 'skilfully blurring' the colours of the original embers represents a pre-emption of the kind of diagrammatic reasoning that would read from the diagram a level of precision unsupported by our capacity to reason about the future interactions of the climate with various human and nonhuman systems. The diagram was arguably intended to fulfil a more heuristic function, enabling a cognitive shortcut between the immensity of predictive data of climate change impacts and the desire to reason holistically about a range of possible global futures. To facilitate this heuristic move, the authors of the diagram were compelled to rely on their own personal judgments in locating the blurry transitions from white to yellow to red.

The decisions about the locations of the colour transitions were complicated by the relative scarcity of scientific evidence available to the authors. For Maarten Hajer, director of the Netherlands Environmental Assessment Agency which extensively reviewed the AR4 report following the discovery of a number of errors in 2009, such evidential gaps were often negotiated with recourse to “expert judgment”, which was:

> constantly referred to as a magical formula. In many cases IPCC had come to judgments in the [course] of its proceedings yet without spelling out the reasoning that led to a particular stance... in cases where the existing literature was inconclusive it employed expert judgement to fill the gaps.
>
> (Hajer 2012, 88)[56]

These gaps were physically expressed by one interviewee as he moved his index finger around a printed copy of the diagram, pointing to areas of the composition where data was scarce:

> we had a few data points here and we had no data points here at all… it’s like you have a picture and you de-focus and then you get shades only.
>
> (interview 1, earth system scientist)

These exercises of expert judgment meant the particular expertise and experience of the authors played an important role in determining what forms of knowledge were represented (cf. O’Reilly et al. 2012). For example, “Large-Scale Discontinuities” was a category added to the range of the RFCs, largely as a result of the contributions of one of the authors to the emerging science of earth system “tipping points”. Likewise, before the colour palette was moved entirely to the red end of the spectrum, a blue hue was added to the “aggregate [i.e. economic] impacts” column, to show:

> where there might be a positive effect. We actually had one draft early on and it ended up being controversial with the aggregate impacts having blue up to a degree or two, because a number of studies show net gains from a small amount of warming. We changed that because

[56] Hajer (2012) also suggests that expert judgment and observation constitute a dominant epistemology of WGII, which may be looked down upon by scientists in WGI where experimentation on theoretical models is favoured as an epistemic practice.

> not all the studies show that. Nordhaus did one of the more prominent studies … that showed losses right from the beginning.
>
> (interview 14, climate policy analyst)

However, a prominent climate change economist on the author team had conducted studies which countered Nordhaus' findings and posited some economic benefits at low levels of warming. The blue section represented this argument – a lone indication of positive impacts across the RFCs. However, a collective decision was eventually made to remove the positive colouring. Although it was suggested in some interviews that the colour transitions represented "extremely conservative" readings of possible impact thresholds, the economist proposing the representation of positive impacts pointed to the "heated debates" (interview 3) around the colour gradients:

> we changed things to a bit more red than we actually had agreed on, but everybody was so exhausted of fighting about this that we all just said "fuck it, nobody's going to take this seriously", which was a big mistake because people did take it seriously.
>
> (interview 4, environmental economist)

Taking the embers seriously: a geography

Following its publication in the IPCC's 2001 report, the burning embers diagram became a significant feature of the climate change debate. It occupied a prominent place in the high-profile IPCC *Summary for Policymakers* and travelled as what we might call an "immutable mobile" (Latour 1990) around the worlds of climate science, policy and advocacy. For example, Environment Canada, a government department, used the diagram to illustrate the argument that some negative impacts of climate change are already occurring, and that the frequency and severity of these impacts will increase with rising temperatures (Environment Canada 2008). A Greenpeace-Australia article (Vincent 2009) presented the diagram as a means of seeing "clearly and simply the level of risk we're taking on with different temperature increases". The article invites the reader to "run your finger along the 3 degree line on the right hand side graph", in order to see "where current policy is taking us". It is concluded that “[c]urrent policy has us placed well and truly in the danger zone, leaving us standing flat-footed on burning embers.”

This invitation to engage corporeally with the physical space of the diagram illustrates the conjoined epistemic and aesthetic transformation of the space from the porous amalgamation of data points and judgments gestured at by the finger of one the diagram’s creators, to a reified consensus statement of escalating global risks. The transformation of the ‘burning embers’ into a metaphor for a sensation of burning, immobile feet heightens the affective properties of the interpretive act. Although scholars of scientific practice have begun to come to terms with the embodied and constitutive nature of vision and with the political effects of different ‘lines of sight’ (cf. Foucault 1979; Latour 1990; Jasanoff 1998b), the affective corporeality of diagrammatic reasoning has arguably not yet been fully considered by students of the social practices of visualisation and interpretation.

In its wide circulation the burning embers diagram also became a mutable mobile, as other analysts used it as an object with which to construct new knowledge claims (cf. De Laet & Mol 2000). Mastrandrea & Schneider’s (2004) use of the diagram to construct a quantitative characterisation of DAI is one such example, as discussed above. By 2010, the global gaze of the original diagram (Liverman 2009) had been narrowed in a version portraying the risks and impacts of climate change in the United States (figure 6.4, Yohe 2010). Perhaps most significantly, a new RFC was added – “National Security Concerns”. This information was compiled from and in collaboration with the US Department of Defense. The conceptual framing of *risk* was seen by Yohe as segueing with the modes of governmental rationality employed by the military[57], particularly the unique concern of defence planners with low-likelihood but high-magnitude future events. Through John Holdren, Director of the Office of Science and Technology Policy since 2009, the diagram found its way into the sightlines of President Obama, with Holdren showing the short paper to the President following its publication in the journal *Climatic Change*.

[57] On the relationship between *danger* and *risk* from a governmentality perspective, see Castel (1991).

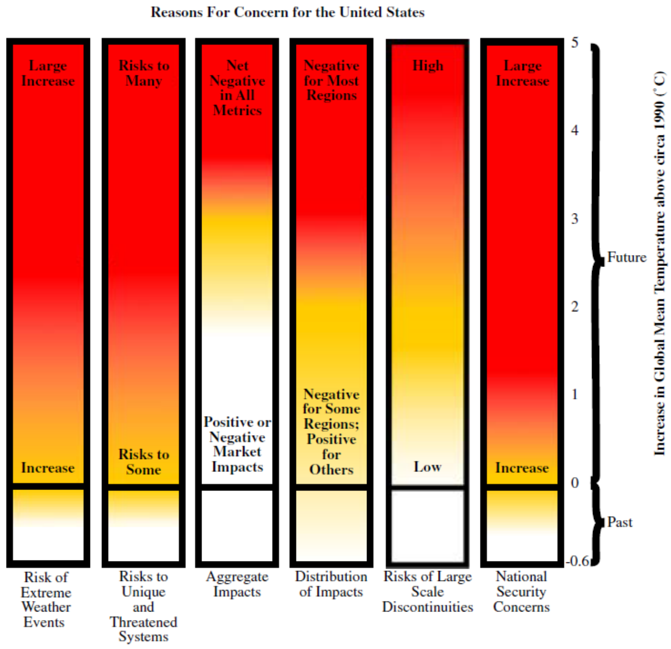

Figure 6.4. The US version of the burning embers. Reproduced with permission from Yohe (2010, 297).

The national security RFC draws on military research into climate change as a potential "threat multiplier" for social instability "in the most volatile regions in the world" (Yohe 2010, 299). Yohe acknowledges the potential for lapsing into environmental determinism in such accounts of geopolitical risk (Barnett 2009), but argues that because the defence community is demonstrably concerned about climate change, the new RFC can contribute to the project of aiding readers in making their own determination of DAI. He argues that science "cannot make value judgements but it can… direct decision-makers to critical issues… This was the intent of the five original RFCs, and it is equally true even if it was the decision-makers themselves who began the conversation" (Yohe 2010, 300-301). Again, there is an ambiguity between the "value judgements" employed in positioning the colour transitions, and those which are argued to reside outside science, in the domain of politics. In seeking to "direct decision-makers to critical issues", Yohe's work is an example not just of how scientific problem-framings are culturally embedded, but also of an attempt to negotiate a local science-policy boundary by entering into dialogue with a mode of reasoning seen as having a particular traction within a specified interpretive community.

Reviewing cultures

To further explore the interpretive or hermeneutic geographies of the burning embers, I will now turn to the IPCC government review process. Reviews of the TAR and Fourth Assessment Report (AR4) versions of WGII Chapter 19 offer an opportunity to study how governmental actors responded to the analytical framings employed by the authors, often while seeking to regulate the boundary between science and politics. The IPCC review process has expanded with each iteration. The AR4 WGII report, for example, received 37,078 comments from experts and government reviewers (IAC 2010), each of which must be responded to by the relevant chapter authors. 274 government comments were received for Chapter 19 from 16 governments. 39% of the comments came from the US, 18% from the European Union[58] and 8% from Pakistan (document 26). The US dominance of the process is further evident in the word count, with the US contributing 54% of the 12,136 words of comment received by the authors. The average length of a US comment was 60 words; for Pakistan, 16 words. Whereas US comments often engage in detailed conceptual critique, smaller nations with fewer institutional resources characteristically make more limited comments concerning grammar or style, or make requests for greater attention to be given to local ecosystems and vulnerabilities[59]. Of the 16 comments referring to specific places, only one was penned by the US (which was a critique of European authorities' apparent lack of 'adaptive capacity' during the 2003 summer heatwave). While smaller countries like Argentina, Pakistan and Sweden refer to knowledges of specific places (e.g. "Magnitude: For Latin America the most reliable indicator of the magnitude of climate impacts must be *the number of people affected*" – Government of Argentina, document 26), the US government reviewers prefer to speak to and of the globe (cf. Miller 2009). For example:

> Biospheric positive feedbacks: This entry is misleading. It should be replaced by one titled "Biospheric feedbacks" because these feedbacks

[58] The EU submits comments independently of its member states, although the prominence of the EU in the process may explain the relative obscurity of some individual EU states in the review process.
[59] See Biermann (2001) and Kandlikar & Sagar (1999) on the participation dynamics of Indian experts in the review and other IPCC processes.

> may be negative particularly if global temperature increases are low and CO2 concentrations are higher than today's. We note in passing that the biosphere seems to be absorbing more now than it did a few decades ago, particularly in the northern latitudes.
>
> (Government of USA, document 26)

By digging further into the content of the reviews, patterns emerge which point towards distinctive modes of reasoning and interpretive commitments. To illustrate this point, I will focus mainly on US and German contributions. This is in part due to the empirically distinct styles of interpretation which are illustrative of broader diversity, but also due to the existence of relevant comparative work on the civic epistemologies evident in the environmental politics of the US and Germany (Jasanoff 2005a; Jasanoff 2011a; Beck 2011; Vogel 2012).

The US review of the TAR WGII Chapter 19 featured a discourse about the sufficiency of extant scientific knowledge in informing and directing policy. For example:

> We recommend that the goal of the chapter…be restated, so that it no longer implies that the current state of knowledge about the relationship between greenhouse gas concentrations and impacts is sufficient to *inform policy-makers* and, by implication, *draw policy recommendations*… the nature of the evidence compiled by the research community on the potential impacts of climate change remains very speculative.
>
> (document 14, emphasis in original)

The link made between *informing* and *recommending* stands in contrast to the distinction made repeatedly by the chapter authors between judgements made to inform and perhaps direct policy-makers, and judgements as to what might constitute DAI and an appropriate policy response. The authors place these two modes of judgement on either side of the science/politics boundary. For the reviewer, the link between the two (by "implication") cannot be severed so easily by the careful boundary work of the assessment authors, thus risking the formulation of deleterious policy on the basis of “speculative” evidence.

By contrast, the German government’s engagement with the nascent burning embers diagram suggests a very different way of interpreting the knowledge contained in the draft text and the embers graphic:

> Massive coral bleaching and recession of glaciers are occurring at the actual temperature level (including its variation e.g. by ENSO). So do we need a global temperature increase of 1-2°C to state, that substantially adverse impacts begin? (Of cause [sic] the impacts at higher temperatures would be much more severe, but the beginning is here already)… The blackening pattern of [the embers] if copied black-white[60] creates the impression, that serious effects are only arising at [a] temperature [increase] of 2-3°C at least.
>
> (document 14)

Here the German government reviewer suggests that the colour transitions of the burning embers offer a false impression of when serious impacts of climate change are to be encountered. By offering two examples of “unique and threatened systems” (IPCC 2001b, 957) already undergoing change, the reviewer is concerned that the present state of knowledge, as communicated in the diagram, may offer a false sense of security and a temporal reprieve from the need for strident policy measures. This stands in contrast to the US concerns for the misapplication of “speculative” research in the formulation of environmental policy.

The German concerns about the embers did not immediately result in their alteration. However, the passage of time and the accumulation of new knowledge did, with an updated version published by Smith et al. (2009) in the *Proceedings of the National Academy of Sciences*, following attempts to publish the paper in *Nature* and *Science* (figure 5.4). Criticisms in the review process for the latter two journals included “the subjective nature” of the work (interview 14, climate policy analyst) and calls for

[60] The embers appeared in greyscale in Chapter 19, as colour printing was only available for the *Technical Summary*.

greater “traceability” (ibid) and “robust support for the various decisions that were being made, and clarity” (interview 9, climate impacts scientist).

The update had been intended for publication in the IPCC AR4 in 2007. WGII Chapter 19 was re-mandated in 2004 to update the RFC framework and to assess evidence of “Key Vulnerabilities” to climate change under the theme of DAI. The RFCs were initially updated textually, with the TAR version of the burning embers appearing in the Second Order Draft of the chapter which was sent out for government review. The Government of Australia remarked that the figure “is helpful, could be more useful if paired with a new figure updated for the new findings of AR4” (document 26). The authors responded by claiming that they could “defend” the “qualitative discussion” of the RFCs in the text, but implied that a new figure would require waiting for the “overall AR4 findings” to be “determined”. Later in the process a small group of US authors with previous links to the diagram decided, over dinner, to propose a visual update to the burning embers. It was by then too late to incorporate the new figure into Chapter 19, so the authors planned to put the diagram forward for inclusion in the *Summary for Policymakers*. However, even prior to the development of the new visualisation, familiar themes were emerging in the government review of the draft chapter which pre-empted later contestations over the updated embers. For example, a US government reviewer argued:

> This chapter strays too far from the science into normative policy judgements, adds little value scientifically, and should be deleted unless it is significantly rewritten… The authors sometimes use value judgements as to which impacts indicate “dangerous interference.” Judgements of what may constitute “dangerous interference” are inappropriate for a chapter in an IPCC assessment, as the authors themselves argue on page 2 of this chapter. The authors should refrain from using the term “dangerous interference” but, rather, stick to explicit description of what the key vulnerabilities might be in a form that is useful for policy-makers to make DAI judgements.
>
> (document 26)

The authors responded to this devastating review by emphasising the "care" that had been taken in distinguishing between "scientific and normative judgements", before reminding the reviewer of the authorial mandate to address the UNFCCC concept of DAI. The Governments of Finland and China both praised the authors for stating that a "definition of DAI cannot be based on scientific arguments alone, but must incorporate value judgements", with the Government of China remarking that "[t]his sentence is very important, please keep it in future". But the US government reviewer quoted above goes further by engaging in vigorous boundary work which seeks to define what appropriate content for a scientific assessment is, and to define the appropriate cultural space (i.e. politics) for the exercise of normative judgment. Similar arguments were made by the US government delegation to the IPCC plenary session where the WGII SPM was approved. It is worth quoting at length an extract from the *Earth Negotiations Bulletin* account of the meeting:

> the US, supported by Saudi Arabia, and opposed by the Russian Federation, Belgium, Austria, the UK and others, called for deleting a sentence explaining that assessment of potential key vulnerabilities is meant "to provide guidance to decision makers, for example, for identifying levels and rates of climate change that, in the terminology of the UNFCCC Article 2, could result from 'dangerous anthropogenic interference' with the climate system." Several formulations were proposed by the US and Co-Chair Parry trying to avoid the reference to anthropogenic interference and to UNFCCC Article 2. A Lead Author, supported by the Russian Federation and others, and opposed by the US and Saudi Arabia, quoted the mandate of WGII to specifically address UNFCCC Article 2. Given lack of consensus on the reference, delegates agreed to a proposal by the UK stating "to help decision makers make appropriate responses to the risks of climate change." Reference to the UNFCCC was removed.
>
> (IISD 2007, 8)

This parsing-out of the political from the scientific echoed the criticisms made by the US government reviewers of Chapter 19. It also resonates with the governmental negotiations following the First Assessment Report which led to the deliberation of policy options being moved to a new institution, the Intergovernmental Negotiating Committee (see Chapter 3). In the latter case, the governments of developing countries were wary of the political process being captured by countries with greater scientific capacities. These negotiations over the content and wording of the WGII SPM illustrate how efforts to delineate the stases of collective reasoning have been recurrent features of the IPCC's institutional history. 'Guidance', with its connotations of close interaction and the directing of a passive subject by another, more active actor, was replaced with the vaguer notion of 'help'. 'Risk' appeared as an object of political concern in place of a definition of DAI, again inviting a more active role for political judgment, but judgment which must take place elsewhere. By contrast, the German government review of Chapter 19 invited a more direct engagement between what are taken as scientific and political questions in urging more attention to be paid to impacts occurring up to a 2°C increase from pre-industrial temperatures:

> On the one hand, at this temperature change already severe impacts for example for ecosystems are expected… on the other hand this is an important threshold to look at since it is discussed in the political arena.
>
> (document 26)

In the previous decade the German government, through the German Advisory Council on Global Environmental Change (WBGU), was a key actor in the process of establishing the 2°C temperature rise target in EU climate policy (Shaw 2010, 109). The 2°C target is taken as a threshold of dangerous climate change, and much political and scientific effort – a lot of it European – has therefore been applied to determining how it can be met. The 2°C temperature rise limit was adopted as a goal of EU climate policy in 1996 (EEA 1997), and was reaffirmed in 2005 (EU 2005; Randalls 2010). However, the authors of Chapter 19 responded to the German suggestion by stating that "specific mention of individual policy goals is beyond the scope of this chapter" – a response which would likely have met with approval from the US reviewer.

In the Second Order Draft of Chapter 19 (document 21), a graph was presented which plotted the probabilities of exceeding a DAI threshold under different emissions scenarios. The threshold given was "DAI-EU", i.e. 2°C above pre-industrial temperatures, with the probabilistic data drawn from Schneider & Mastrandrea (2005) – a paper which also presented figure 6.3 as a means of constructing an alternative metric of DAI[61]. In the figure caption, the DAI-EU nomenclature was justified by stating that "the European Union has endorsed this level of climate change as their climate policy target". However, the Government of Australia remarked in the review of the Second Order Draft that:

> Figure 19.3 is useful and clearly presented, however, we suggest removing references to DAI-EU, as it is not relevant that the EU has endorsed a specific level of climate change as this is a political, as well as scientific, judgement.
>
> (document 26)

The authors responded by saying "[y]es, we agree, and have revised Figure 19.3 to remove specific references to DAI-EU". In the final version of the chapter, the same threshold remained on the graph, but the name had been changed to "representative threshold of 1.4°C" (IPCC 2007c, 802)[62]. The chapter thus no longer referred to specific policy targets by name, but offered this particular target as an object which could facilitate collaborative reasoning across scientific and political communities. This move functioned as an acknowledgement of the interdependency of scientific and political reasoning, even as efforts were made – under the direction of governmental representatives – to purify this ostensibly scientific assessment of political inference or argument[63].

[61] The estimate of DAI developed from the 2001 burning embers diagram comes in at about 1.5°C higher than the EU threshold of 2°C above pre-industrial temperatures (Schneider & Mastrandrea, 2005).
[62] The threshold stands at 1.4°C above 1990 temperature levels, which the IPCC commonly uses as a measurement baseline. The EU's target of 2°C refers to a rise from pre-industrial levels, a baseline approximately 0.6°C lower than the1990 baseline.
[63] I further explore the operation of the 2°C target as a boundary object in the next chapter.

In a broader fashion, US government reviewers repeatedly remonstrated with the authors about venturing definitions of DAI. One reviewer even quoted a 2003 speech by Rajendra Pachauri, the chair of the IPCC, in which he stated that:

> at no stage must any part of the AR4 cross the storm front that would inappropriately take us into policy prescriptive territory. This would be a difficult but critically important requirement, and one that is at the core of the scientific credibility and effectiveness of the IPCC ... Purely as an example, I would like to refer to the need for treading carefully on the issue of Article 2 of the Framework Convention on Climate Change, which refers to the level of stabilization of greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system ... It is for others to determine what constitutes dangerous levels of interference with the world's climate system and what actions should be taken ... Such value judgments do not reflect scientific assessment, and can at best be facilitated by an objective assessment of risks, impacts and key vulnerabilities of the systems thus affected and their relationship with specific mitigation options.
>
> (document 15, quoted in document 26)

Pachauri's comments were described as "pertinent" by the US reviewer. Other comments urged the removal of all references to DAI, echoing the comment about the 'inappropriateness' of DAI judgments quoted above. Further governmental boundary work concerned a passage which sought to explain the close ties between "scientific assessment" and "value judgments" in the context of climate change vulnerabilities, while suggesting that they can be successfully kept apart. The final sentence read "[w]hile value judgments are necessarily subjective, they may be informed by ethical, moral or religious arguments", followed by references to moral philosopher Alasdair MacIntyre and the Forum on Religion and Theology (document 21). The Government of France responded with:

> Delete the last sentence which is out of place in an IPCC report which should deal with scientific knowledge only. Ethical, moral, and religious arguments are indeed subjective (some people do not even believe in any religion) and cannot inform subjective value judgment, in the same sense as scientific knowledge.
>
> (document 26)

Similarly, the US government urged the authors to delete the second clause of the sentence, stating that:

> these [‘ethical, moral or religious’] arguments – and more importantly – the force that should be given to these argument[s] is itself subjective. In fact, it is a good argument for avoiding such judgment, because otherwise one will get into discussions of theology. We urge that the IPCC stick to science instead.
>
> (document 26)

Amongst other arguments for scientific “neutrality” (e.g. from the Government of Japan), the chapter authors trimmed their text of normative implications and erected rhetorical fences between description and prescription, objectivity and subjectivity, *is* and *ought*. This bedrock of boundary work would go on to provide the foundations for the heated negotiations which would eventually see the updated burning embers diagram excluded from AR4.

The updated diagram was put forward for inclusion in the final WGII Summary for Policymakers (SPM), to communicate the RFC assessment of Chapter 19. However, at a fraught plenary session in Brussels in April 2007 where government representatives and authors together sought agreement on the report contents, the diagram was excluded from the SPM. In the early stages of the four-day meeting, the updated embers were presented to a contact group which was discussing the tabular presentation of climate change impacts

> following requests in plenary by Germany, Austria and Spain. Switzerland said the diagram was too vague. Italy supported its inclusion noting that it is a TAR figure familiar to policymaker[s]. The US requested time to consider the diagram and proposed its inclusion in the AR4 Synthesis Report instead. Spain noted the different audiences of the Synthesis Report and SPM and advocated keeping the diagram in the SPM. On Thursday [the next day] WGII agreed not to include the diagram.
>
> (IISD 2007, 11)

The Co-ordinating Lead Author of Chapter 19, the late Steve Schneider, offered this account of the incident which imputes motives to the intransigence of the US government and its allies in this negotiation:

> Although a central feature of the 3rd AR, it was left out of the 2007 report. The main opposition comprised officials representing the United States, China, Russia, and Saudi Arabia. Some scientists from other countries thought the diagram's bright orange gradients of levels of risk from increments of warming were too subjective. In its place the report used written descriptions of levels of risk. Because words are less powerful than a colourful, iconic chart, many from Europe, Canada, New Zealand, and small island states demanded to include it. Unfortunately, governments of the four big fossil-fuel dependent and producing nations opposed it.
>
> (Schneider 2009, 187)

Schneider told Andy Revkin of the *New York Times* that “China, the US, Russia and the Saudis said it was too much of a “judgement”. But in the TAR it also was a judgement and this was just an update… so their logic was faulty” (Revkin 2009). These broader governmental objections were given traction in part by the procedural objection that could be levelled against the inclusion of a diagram in the SPM which was absent from the underlying chapter, while the tight timescales of the meeting precluded a fuller negotiation between the diagram’s supporters and its detractors. In his autobiography, Schneider (2009, 193) offers a colourful evaluation of the Brussels meeting and the interminable tussles over content and meaning:

> I can't say I was shocked, but I was sometimes disgusted how national interests trump planetary interests and the here-and-now overshadows long-term sustainability. I remembered my "five horsemen of the environmental apocalypse": ignorance, greed, denial, tribalism, and short-term thinking. At least three of them were riding at the Brussels Plenary.

This striking evocation of the science/politics boundary equates the former with planetary interests and the latter with 'apocalyptic' forces of governmental *realpolitik* running amok in what was meant to be a space of scientific rationality. On this reading, had appropriate checks been in place to constrain the malign influence of self-interested governmental reasoning, then the perception of the burning embers as an "essential diagram" (Schneider, quoted in Revkin 2009) may have been more widely shared and the diagram may again have brightened the pages of the IPCC's SPM. As it happened, the circulation of this evolving diagrammatic form left the contested science/politics boundary spaces of the IPCC, and entered instead the network of academic journals and the discourses of environmental advocacy.

Interpreting interpretive geographies: objectivity, risk and governmental reason

How can we explain the divergent interpretations which the burning embers and the RFCs construct received in different political settings? Appealing to economic interests is a common means of explaining divergent attitudes to scientific evidence – see for example Oreskes & Conway (2010) and Schneider's citing of fossil fuel dependence in the extract above. But such accounts treat science as a monolithic entity with pre-ordained boundaries (Demeritt 2001); they regard power as something only possessed by political and economic actors rather than as something which pervades any attempt to represent and to intervene in the world (Rouse 1987); and they overlook the different ways in which evidence, objectivity and accountability are constituted in the public sphere (Gieryn 1999; Jasanoff 2005a).

Historians have shown 'objectivity' to be much more complex than the Cartesian ideal of the extraction of the analytical mind from the brute mechanics of nature and the human body. Daston & Galison (2007) show objectivity to be a historically-contingent ideal; a combination of ontological, epistemic and moral commitments which have changed alongside changes in scientific knowledge, technology and social concerns. In certain epochs, the mathematical delineation of the structural mechanisms of nature has been lauded as the height of objectivity. Other ages have championed the exercise of trained expert judgement and intuition as the surest way to reliable knowledge. Disjunctions in the constitution of objectivity are also observable across political cultures when it comes to the norms by which scientific knowledge is handled in the public sphere. For example, Jasanoff (2005a) and Porter (1995) identify an abiding commitment to quantification in US political culture. Since the early 20th century, numbers have been a key means of attaining credibility in political debate, with techniques like cost-benefit analysis functioning as a means of creating "a basis for mutual accommodation" in an agonistic political sphere marked by "suspicion and disagreement" (ibid, 149). The numbers of quantitative risk analysis could unite an emergent polity riven by ideological conflict and regional disparities. However, the cloaking of risk assessment in a language of quantitative objectivity obscures the underlying incommensurability of the objects of analysis, while value judgements – in the form of 'risk management' – are pushed downstream in the deliberative process; separate to, but dependent on, the numerical assessments which precede them (ibid, 157).

This characteristic is evident in the US response to the RFCs. The government charge that judgements of DAI were "speculative" and even "inappropriate" for a scientific assessment is indicative of an interpretive community guided by the civic-epistemological norm of objectivity as the numerical cloaking of expert judgement and the careful elimination of subjectivity from public reason (Jasanoff 2005a, 265). By contrast, Jasanoff has observed that in German environmental debates, objectivity is sought though the incorporation of all interested viewpoints into knowledge-making process. The 'view from nowhere' (Nagel 1989) becomes the 'view from everywhere' through "a belief that it is possible to map the terrain of reason completely" in knowledge-making processes (Jasanoff 2005a, 269). The German concerns with the burning embers were thus less about the exercise of situated, subjective reason and more about whether the framing diluted a broader feeling of political urgency. Against the visualisation of future impacts, the German reviewer worried that “the beginning is here already”.

This interpretation, a combined product of the reviewer’s extant knowledges and the knowledge presented in the burning embers, evokes a commitment to a style of environmental regulation influenced by the precautionary principle, which is strongly evident in European attitudes to climate change and biotechnology (Jasanoff 2005a; Shaw 2010; Vogel 2012). The principle was originally developed in German environmental law “in reaction to the dominant regulatory standard, which requires affirmative evidence of harm before regulatory action can be taken” (Gross 2010, 3). A precautionary approach instead displaces the burden of proof onto the proponents of risky activities thus, in theory, giving greater regulatory credence to the early warning signs of risk.

The precautionary principle, “rooted in the civil law tradition of precisely defining the state’s responsibilities toward citizens” (Jasanoff 2010, 242), does not sit comfortably in political settings – like the US – where common law is more dominant and where the legal system is “reluctant to prohibit any human activity unless dangers [are] imminent and foreseeable” (ibid). Indur Goklany, a science and technology policy analyst at the US Department of the Interior, has often represented the US government at the IPCC. Goklany has been a critic of the precautionary principle, most notably in a 2001 book published by the libertarian Cato Institute (Goklany 2001) in which he argues that the principle, traditionally conceived, overlooks the potential harms to economic growth caused by regulatory action while discounting the potential for economic and technological growth to offset potential future harms. Instead, he argues, risk analysis should be employed to better capture the range of possible harms (Goklany 2002). As a prominent expert reviewer of the AR4 WGII report, Goklany succeeded in getting his own work cited in Chapter 19 (IPCC 2007c, 785). However, his thinking is also indicative of broader currents of US political thought which place the burden of proof onto the proponents of regulation, discount “speculative” or emergent evidence of risks, and carefully regulate the boundary between the objective sciences of risk and the subjective application of value judgements (Brown 1996; Demeritt 2006). The US governmental response to the burning embers and, more broadly, to the various manifestations of Chapter 19 can therefore be read not just through the lens of economic interests, but in relation to a civic epistemology which is generative of particular modes of collective reasoning and interpretation at the boundaries of science and politics.

The fate of expert judgement

I have argued that the IPCC’s burning embers diagram was a product of complex processes of expert judgement influenced not only by the available scientific evidence, but also by group dynamics, aesthetic considerations, and a desire to draw political attention to significant objects of normative concern (i.e. certain ‘key vulnerabilities’) while navigating shared but sometimes contradictory understandings about the nature of scientific assessment. Outside the team of authors, the diagram met with a mixed reception which included concerns that the diagram risked diluting the case for urgent political action, and arguments that the constitutive processes of expert judgement were inappropriately subjective for a scientific assessment which should leave normative considerations to the political community. Although the authors were initially successful in defending their construct from these criticisms, the updated diagram was eventually excluded from AR4 amid arguments which mobilised interpretive norms of objectivity and conventions of risk assessment which constitute, *inter alia*, a dominant US civic epistemology.

The fate of the burning embers highlights the ongoing processes through which the boundaries of science are negotiated. As a boundary organisation, the IPCC is a space where the juncture of science and politics is continually negotiated alongside and, as shown here, within the processes of knowledge production (cf. Miller 2004b). Although the spaces of knowledge production and circulation are often considered neatly distinct, here we can see how the hybrid spaces of the IPCC problematise such distinctions. The interpretive geographies of the diagram’s construction and circulation – particularly within the review process – illustrate the situated hermeneutics of climate change knowledge, and point to interpretive acts as processes of dialogic knowledge production, rather than of passive consumption or disinterested reflection (Livingstone 2005a). Integral to this knowledge production is the boundary work of delineating science and politics, 'relevant' and 'prescriptive', objective and subjective. This study suggests that these boundary questions become particularly acute when ontological questions – such as the meaning of 'danger' – are addressed, and when such questions are explicitly intended to inform or direct political action.

The history of the burning embers diagram also prompts reflection on the nature of consensus. Firstly, the valorisation of the diagram as a "consensus statement" represented an overt claiming of authority and credibility which could in turn justify the diagram's use in new exercises of reasoning, such as the generation of probabilistic estimates of avoiding "dangerous anthropogenic interference" with the climate system. This highlights how consensus itself has come to be valorised as a source or perhaps marker of epistemic authority, even as the notion of 'expert judgment' itself remains ill-defined (cf. Helmer & Rescher 1959; Hajer 2012). The broader cultural authority of consensus – assumed or otherwise – is perhaps attributable in no small part to the IPCC's high-profile pursuit and delivery of consensus statements[64]. Secondly, the history of the diagram may be read as an example of Fuller's (1988) *suboptimal essential consensus*. This notion seeks to account for the fact that when consensus is sought, there often exists imperfect understanding between actors of others' positions and of the epistemic standards used to validate claims. My argument is that the trajectory of the burning embers diagram has been marked, like the IPCC process more broadly, by constant struggles to define the appropriate local boundaries between 'scientific' and 'political'

[64] A number of recent studies have sought to widen the scope of consensus, to enable claims about the reach of agreement among the scientific community more broadly (e.g. Cook et al. 2013; Doran & Zimmerman 2009; Oreskes 2004). Such exercises appear to rest on the assumption that, as Cook et al. (2013, 1) put it, an "accurate perception of the degree of scientific consensus is an essential element to public support for climate policy". Such studies have been critiqued for failing to do justice to the range of scientific opinion about the details of climate change, which itself is highly relevant to public policymaking (e.g. Bray 2010). It seems that many such exercises aim at arresting the bipartisanship of US climate debates in particular, with numbers like 97% (Cook et al. 2013) being used to try and unite a deeply divided polity, thus supporting the arguments of Porter (1995) and Jasanoff (2005a) about the valence of quantification in US political culture.

judgment. The dissensus on the location of these boundaries represents a lack of mutual understanding and agreement which Fuller posits as a hallmark of a suboptimal essential consensus situation. Thirdly, following Fuller, it is important to attend to the micro-geographies of the social construction of consensus. In this case, representatives of the US government were able to exercise a significant amount of power in shaping and directing the knowledge production process, especially in contrast to governments which made minimal or no comments on the relevant sections of the draft IPCC report. Likewise, the knowledge claims themselves – particularly the burning embers – were products of negotiations within a relatively small group of authors who led the process, and who were able to inflect the various iterations with their own interests, concerns and assumptions.

Some might respond to these observations by calling for a higher firewall to be erected to between governments and scientists, or for clearer definition of the "storm front" between description and prescription. Others might argue that analytically reconstructing the processes by which consensus is reached could do damage to the authority and credibility of IPCC science in the public sphere; boundary questions beget boundary questions. I will deal with such issues in Chapter 9, following further excursions around the spaces and places of climate change knowledge production. For now, I can just remark that further work is required to fully explore the role of scientific visualisation practices in science-politics boundary disputes. Relatedly, future research could profitably explore the mutual constitution of civic epistemologies (Jasanoff 2005a) and interpretive communities (Fish 1980), particularly beyond the usual analytic orbits of Europe and North America.

Insights into the contemporary geographies of scientific knowledge can offer useful contributions to debates about the institutional fate of expert judgement in scientific assessments. The observed divergences in modes of governmental reasoning about risk and environmental change pose challenges to the international credibility of bodies like the IPCC which aim to locate and relate to a global polity receptive to claims of international scientific consensus (Hulme 2010a; Jasanoff 2011). Although the burning embers diagram was valorised by some as a consensus statement, its international circulation was neither smooth nor uncontested. However, the example of the US embers (figure 6.4) suggests that credibility and traction may be more readily gained by attending to local contexts. This example highlights how the success of the burning embers (in Latourian terms of productive circulation) can be attributed in no small part to its mutability – i.e. its function not as a fixed, mimetic representational form, but as an expressive framework adaptable to new contexts and demands. Yet the dominant, global version of the burning embers may be said to obscure the geographic complexity of climate change risks and impacts (Liverman 2009), and the fragile globalism (Miller 2009; Hulme 2010a) of such constructs has led some to argue that climate change knowledge production might be better served through a partial regionalisation of assessment processes (e.g. Nature Opinion 2010). While this would offer better representation of local environmental conditions and knowledges, it also means that the kind of complex interpretive geographies explored here may be better negotiated in locally accountable and credible ways. Exercising expert judgment of the course and impacts of global climate change, in the service of a global politics, is a demonstrably fraught task. The ongoing debate about the future direction of global knowledge-making arguably requires a greater geographic sensitivity to the spaces, boundaries and politics of science.

In the next chapter I seek to move this geographic sensitivity to a new site. I follow the burning embers diagram and the 2°C target to Copenhagen and the anxious efforts to effect a new global political deal on the mitigation of climate change in 2009. In studying two distinctive efforts made to bring-together scientific knowledge in service of political decision making, I again examine struggles over the boundaries of science and over the distribution of epistemic and normative authority on the cultural map of international climate politics.

Chapter 7

Boundary spaces

Science, politics and the epistemic geographies of climate change in Copenhagen, 2009

This chapter is based on:

Mahony, M., 2013. Boundary spaces: science, politics and the epistemic geographies of climate change in Copenhagen, 2009. *Geoforum,* 49, pp.29-39.

Introduction

Despite widespread societal agreement on the need for political action to address climate change, so far the achievements of global climate governance have been limited to the rather modest ambition of the Kyoto Protocol. Signed in 1997 following negotiations under the United Nations Framework Convention on Climate Change (UNFCCC), the Protocol committed developed countries (with significant exceptions such as the US) to around a 5% cut in emissions of climate-warming greenhouse gases during the period 2008–2012, as compared to a 1990 baseline (Grubb et al., 1999). The 15th Conference of the Parties to the UNFCCC (COP15) meeting in December 2009 was a crucial moment in political efforts to negotiate a successor treaty to the Kyoto Protocol which would legally commit countries to further emissions reductions post-2012. During the months leading up to the December conference, the city of Copenhagen therefore became a microcosm of the global climate change debate, with a diverse array of actors fuelling a sense of urgency, expectation and hope; Copenhagen became 'Hopenhagen'[65]. Part of this anticipation saw the city acting as a key site of science–policy interaction, as a number of scientific actors sought to bring together new and emerging knowledge about the state of the climate, the potential impacts of climate change and possible political and societal responses, with the aim of informing and shaping the political debate.

[65] http://www.hopenhagen.org

The issue of climate change poses unique challenges to the norms and practices of science and democratic politics. Complex mechanisms of physical causation, intractable uncertainties about future changes, the seeming inability of political institutions to deal with global risks; these factors, among others, have seen conventions of expertise, representation and political authority called into question as societies have collectively or otherwise sought a 'solution' to the problem of anthropogenic climate change (Beck 2009; Hulme 2009a; Jasanoff 2010). The physical sciences have exercised a great deal of 'definitional power' (Beck 2009, 32) in the climate debate, with organisations such as the IPCC playing a central role in shaping discourse on causation, hazardousness, responsibility and potential solutions. The scientific construction of climate change as a global environmental problem rooted in the universal physical properties of the greenhouse gases has shaped the political space within which actors have responded in technocratic terms of global environmental managerialism (Demeritt 2001; Miller 2004b; Oels 2005). Yet political contestations over climate change have often focused on scientific arguments, as various actors have sought to shed doubt on the scientifically-delineated need for strident political action (see Oreskes & Conway 2010), while others have called for the insulation of science from the polluting forces of politics (cf. Montford 2010; Mann 2012).

Such arguments reveal tensions inherent to the modernist settlement of science and politics as being wholly separate domains, with the former able to provide the latter with value-free knowledge on which political decisions can be based (Ezrahi 1990; Latour 1993). As I argued in Chapters 2 and 3, work in STS and cognate disciplines has problematised the notion that science operates as an autonomous 'republic' (Polanyi 1962), and has instead emphasised the co-production of knowledge and social order. The notion of co-production emphasises how our knowledge and representations of the world are inseparable from our choices about how to live as collectives of human and nonhuman actors (Jasanoff 2004a). Attempts to draw sharp distinctions between the worlds of science and politics therefore tend to mask the complex interpenetration of epistemic claims and normative commitments (e.g. Demeritt 2001). However, such 'boundary work' (Gieryn 1983) can itself be seen as a mode of social ordering, for example to delegate certain forms of authority to science or politics (Ezrahi 1990) in contexts – such as climate change – where complexity and indeterminacy preclude problems being comprehended or 'solved' by the activities of any one set of authorised actors (Turnpenny et al. 2009).

This chapter seeks to further explore the boundary dynamics of climate science and politics. The notion of 'boundary spaces' is developed to facilitate consideration of the epistemic geographies (the objects, actors, spaces and discourses) of science–politics interactions beyond the conventionally-delineated organisational spaces in which such interactions are subject to formal management. By drawing together literature from STS, geography of science and the geography of organisations, an account is given of the contested spaces of the science–politics relationship in the run-up to the ill-fated international climate change negotiations in Copenhagen. In the following section, the notion of boundary spaces is developed in relation to literatures on the spaces and boundaries of science, with particular reference to examples drawn from the climate change debate.

The geography of science–policy interactions

The lively field of 'geography of science' (see Chapter 2) has drawn attention to the significance of locality in scientific knowledge production and to the varied reception supposedly universal knowledge receives in diverse places. For Livingstone (2003, 123), "in the consumption of science, as in its production, a distinctive regionalism manifests itself." Yet such arguments have a tendency to reify a distinction between spaces of knowledge production and consumption and may overlook the forces of co-production which problematise such distinctions. Along with a "spatially sensitive social constructivism" (Withers 2010a, 67), geographies of science also implicitly adopt a phenomenological spatiality which conceives places as a "distinctive coming together in space" (Agnew 2011, 317) of diverse socio-cultural trajectories (Massey 2005). Place is thus a unique assembly of phenomena and actors where actions unfold through the mobilising of "distant actants that are both present and absent" (Callon & Law 2004, 6); actants that are connected in material networks of sociotechnical relations which enfold together otherwise distant spaces. As will be argued below, this spatial imaginary may help conceptualise ‘boundary spaces’, where the spaces of knowledge production and consumption intermingle in processes of social ordering.

Social forms at the science–policy interface

For the last 25 years the interaction between science and politics on the issue of climate change has been dominated by the IPCC. Charged with offering scientific knowledge to the nation-state signatories of the UNFCCC, the IPCC has exercised considerable epistemic and definitional power (Hulme & Mahony 2010; Tol 2011; Bjurström & Polk 2011). For many observers the periodic, authoritative consensus statements of the Panel have been instrumental in driving forward the global political process (Edwards & Schneider 1997; Tonn 2007) and public debate (Boykoff 2011). For others, the knowledge mobilised by the IPCC is inflected with localised problem-framings which raise questions about how trust in distant or international scientific practices is to be achieved in diverse political contexts (Biermann 2001, Lahsen 2004, Hulme 2010a; Jasanoff 2011a). The assumption that the IPCC represents disinterested, neutral scientific knowledge (Moss 1995) which can be used to legitimate political decisions has been critiqued by analysts wary of ‘linear model’ understandings of science–policy interactions (e.g. Sarewitz 2004; Carolan 2008). As discussed in Chapter 3, the linear model holds that authoritative scientific knowledge must always precede effective decision-making, and that the latter is wholly dependent on the former (Beck 2011; Grundmann & Stehr 2012). The linear model thus also reinforces an understanding of science and politics as occupying wholly distinct cultural and physical spaces.

Work in STS has emphasised the diversity of organisations, discourses, and networks which nonetheless straddle the boundaries between science and politics, thus challenging the implicit spatiality of the linear model. In disputing earlier notions of science as a neutral, value-free exercise which can generate wholly impartial yet policy-relevant knowledge, and thus ‘speak truth to power’ (c.f. Wildavsky 1979; Jasanoff & Wynne 1998), studies of the operation of advisory panels (Jasanoff 1990), regulatory science (Jasanoff 1990; Irwin et al. 1997), ethno-epistemic assemblages (Irwin & Michael 2003), and networks at the science–policy interface (Chilvers & Evans 2009) have contributed to understandings of these social processes and forms as instances of co-production. This proposition challenges the notion that sharp distinctions can be drawn between science and politics by drawing attention what Jasanoff calls “the social dimensions of cognitive commitments and understandings”, without losing sight of “the epistemic and material correlates of social formations” (Jasanoff 2004b, 3).

Boundary spaces

The work of facilitating and managing flows of knowledge, resources, people and material things across the boundary between science and politics has often been bestowed upon what have become known to STS scholars as ‘boundary organisations’ (e.g. Guston 2001; Miller 2001a; Boezeman et al. 2013). The IPCC in many ways fits the description of such organisations, which “exist at the frontier of the two relatively different social worlds of politics and science, but … have distinct lines of accountability to each” (Guston 2001, 401). Drawing on principal-agent theory, the concept of the boundary organisation highlights the work of authority delegation according to normative principles which may differ across the boundary in question. “The success of the organisation in performing these tasks can then be taken as the stability of the boundary, while in practice the boundary continues to be negotiated at the lowest level and the greatest nuance within the confines of the organisation” (ibid, 401).

The interest in stability as an achievement of ongoing work directs analytic attention towards internal organisational arrangements and practices (Boezeman et al. 2013). But such work arguably also resides within the interactional tradition of co-productionist inquiry (Jasanoff 2004c). This tradition emphasises that “science and politics operate against a backdrop of an extant natural and cultural order, and highlights the conflicts between competing epistemologies. Under this perspective reliable, credible and authoritative science (and policy) depends on solving problems of social order” (Chilvers & Evans 2009, 358). Boundary organisations are sites where the work of social ordering takes place in ongoing processes of negotiation, translation and accommodation.

This mode of work corresponds to the 'boundary work' described by sociologist Thomas Gieryn (1983). In a series of influential studies of the efforts made to define the boundaries of science and to ground the criteria of demarcation between legitimate and illegitimate claims to represent the 'real', Gieryn has emphasised the historical, cultural and spatial contingency of settlements of such boundaries (Gieryn 1995; 1999). This points to the never-ending tasks of boundary work in moments of political or epistemic conflict. Using the methodology of what he terms 'cultural cartography', Gieryn (1999, xii) suggests that "science is a cultural space: it has no essential or universal qualities. Rather, its characteristics are selectively and inconsistently attributed as boundaries between 'scientific' space and other spaces [e.g. politics] are rhetorically constructed."

Boundary work often coalesces around 'boundary objects' which function as bridges or anchors between different cultural spaces and which are "plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (Star & Griesemer 1989, 393). A persistent consensus around climate sensitivity estimates (van der Sluijs et al. 1998) and the target of limiting the global mean temperature rise to 2°C to avoid "dangerous" climate change (Shaw 2010; Randalls 2010) have functioned as objects of boundary negotiation in the climate debate, particularly – as will be shown below – in the boundary spaces enacted in Copenhagen in 2009.

The operations of boundary organisations and boundary objects thus contribute to the construction of science–politics boundaries, while reifying the very possibility of their existence. However, Gieryn's work encourages us to recognise that boundary work is not confined to formalised institutions charged with the management of science–politics boundaries. Rather, the sites and spaces of boundary work are diverse, often spontaneous, and frequently unexpected. The concept of boundary organisations largely arose in studies of scientific advisory processes in the United States (e.g. Guston 1999; 2000). The concept has now gained a particular popularity among students of comparable processes in the Netherlands (e.g. Pesch et al. 2012; Boezeman et al. 2013). As Miller (2001a) points out, this tying of the concept to nation-state contexts may limit its applicability to transnational or intergovernmental spaces. The "theory has not fully escaped conventional patterns of thought that circumscribe the institutional landscape inhabited by these institutions" (ibid, 484) to what Guston (2000, vx) describes as a "fine, bright line". The concept thus arguably recapitulates elements of US political culture which seek to identify clear dividing lines between pure science and pure politics, as suggested by Jasanoff (2005a) and as I discuss in Chapter 6. This "overly static view of science and politics" (Miller 2001a, 484) elides differences between institutions in the respective cultural domains – differences which may "stand out more distinctly in international settings…where the scientific and political institutions of myriad countries are brought into immediate contact with one another (ibid, 483). As I argued in the previous chapter, the IPCC is a space where competing understandings of the boundary between scientific and political reasoning have been brought to bear on the production and circulation of scientific assessments. Such diversity in the 'lines of accountability' (Guston 2001) enacted between the assessment process and multiple scientific and political communities is not adequately captured by the concept of the boundary organisation, which assumes largely homogenous cultures of science and politics.

Furthermore, in the context of climate change, the diversity of networks and assemblages of political and scientific actors engaged with the issue means that the ongoing processes of boundary work are not restricted to the boundaries of organisations like the IPCC. The profusion of various 'alternative' scientific assessments of climate change (e.g. Biermann 2001, 302), heated public debates in new social media platforms (Koteyko et al. 2012) and the more fundamental disconnect between a global climate science and locally-embedded forms of meaning and action (Hulme 2010b; Jasanoff 2010) suggest that the boundaries between climate science and politics are contested in a diversity of spaces.

Recent work on the geographies of organisations has sought to destabilise conceptions of organisations as neatly-bounded, homogenous entities which should be studied in terms of their procedural outputs (Beyes & Steyaert 2011). A turn towards practice has emphasised networks, embodiment, materiality and affect as being constitutive of 'organisational space' (e.g. Conradson 2003; Dale 2005). Moving beyond conceptions of space as a passive container of organisational activity, organisational spaces are associated with and constituted by particular associations of actors and objects coalescing around certain goals, imaginaries (Taylor 2002) and practices (Conradson 2003). Drawing variously on Lefèbvre (1991), actor-network theory (ANT) and non-representational theories, work on the production and generative potential of organisational space (e.g. van Loon 2000; Beyes & Steyaert 2011) draws attention back to the often banal and habitual processes of ordering, as opposed to order-as-product. The concept of the boundary organisation to a large extent shares this concern with the contingency of practice and process. Yet it potentially deflects attention away from the multiplicity of spaces and processes in which the organisation of the science–politics boundary is accomplished (Chilvers & Evans 2009; Irwin & Michael 2003).

We might then emphasise the importance of *boundary spaces* – the spaces and spacings (Derrida 1981; Beyes & Steyaert, 2011) in and through which the work of organising and negotiating the boundary between science and politics is conducted. This focus has the potential to transcend the latent state-centric functionalism of existing literature on science–policy boundaries (Miller 2001a). It might also respond to the diversity of empirical settings and networks through which such boundaries are contested in the context of a complex issue like climate change (Hulme 2009a; Chilvers & Evans 2009). Following the non-representational critique of the socio-material rigidity of ANT (Thrift 2007), the concept of boundary spaces directs us towards the epistemic and political geographies of boundaries in their emergence and contestation. It also places emphasis on the embodied forces of event and conjuncture over the progressive institutionalisation of stability (Bingham & Thrift 2000). In problematising conventional organisational boundaries, the notion of boundary spaces permits us to consider the interpenetration of different organisational spaces in particular space–time configurations. For example, the dominant position of the IPCC at the science–policy interface has effected a complex geography of connected boundary spaces as norms, procedures, bodies and objects associated with the IPCC have circulated widely through the worlds of scientific assessment and policy advice (e.g. Hulme & Mahony 2010; Perrings et al. 2011).

Boundary spaces should be conceived of as spaces where the co-production of scientific knowledge and social order occurs. Boundaries, as a form of social order, are co-produced with the very knowledge they are mandated to contain and signify (Jasanoff 2004c). In considering boundary spaces, we therefore encounter one example of how geographies of science and ideas about co-production may be brought into fruitful conversation. In a generative and performative sense, boundary spaces are co-produced along with scientific knowledge, political commitments, and normative allocations of authority on the cultural map of late modernity (Gieryn 1999; Chilvers & Evans 2009). This co-production of space resonates with a growing interest among geographers of science in going beyond a simple localism in accounts of scientific practice towards a fuller treatment of the mutual constitution of the epistemic and social spaces of science (cf. Shapin 1998; Powell 2007a; Livingstone 2010).

Science for Copenhagen: two cases

Throughout 2009 the word "Copenhagen" took on a number of new connotative, one might even argue denotative, functions (Barthes 1977). Phrasings such as "the road to Copenhagen" and "countdown to Copenhagen" – common in media coverage of COP15 – elide space and time in anticipation of a particular event[66]. "Copenhagen" became synonymous with the COP15 meeting; the name of a city became the name of a gathering of political actors at a particular time and place. A new, transient sense of the city's political salience thus took shape through these constructions of a particular time-space; one of scientific deliberation, political wrangling, and popular protest. Copenhagen became a key site for the political deliberation of climate change, and the events of December 2009 will likely continue to be seen as a critical discourse moment (Carvalho & Burgess 2005) which led to the transformation of discursive and political positions among political and scientific actors (Bailey 2010).

[66] See http://www.roadtocopenhagen.org/ and http://www.actionaid.org.uk/102001/countdown_to_copenhagen.html

These transformations included a newly prominent scepticism about the efficacy of top-down, multi-lateral climate policy initiatives (e.g. Prins et al. 2010) and, as will be argued below, changes in how scientific actors perceive and respond to political processes.

The following analysis investigates the epistemic geographies of two boundary spaces which were enacted in the run-up to COP15. Two groupings of scientists and political actors sought to bring together new and emerging scientific knowledge in order to inform the anticipated political debates about climate change mitigation and adaptation. In the months and weeks leading up to the COP15 meeting, two particularly high-profile documents were produced[67]. The *Synthesis Report* (document 72) arising from a scientific conference entitled "Climate Change: Global Risks, Challenges and Decisions" (also known as the 'Climate Congress') held at the Bella Center in Copenhagen from 10th to 12th March 2009 presented key findings and 'messages' from an interdisciplinary collection of 58 conference sessions, which were later presented to the Danish Prime Minister.

The *Copenhagen Diagnosis* (document 114) was a 64-page document produced by 26 prominent climate scientists to communicate the latest policy-relevant findings to decision-makers at COP15. The document, published in November 2009, covers observations of atmospheric greenhouse gas concentrations, extreme events, changes in land use, the cryosphere and oceans, the prospect of "tipping points" in the earth system, and the most up-to-date projections of future changes and emissions trajectories. The central theme of media coverage of the report's publication was that across these variables, the effects of climate change are occurring faster than estimated in the 2007 IPCC report[68].

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[67] These cases were selected due to their high-profile media coverage (see e.g. Boykoff 2011, 20-28 on corresponding spikes in media coverage of climate change) and for the significant scientific and political debates which ensued, as discussed below.

[68] The scientific findings of *Copenhagen Diagnosis* were also used by newspaper commentators to argue against the thesis that the unfolding 'Climategate' episode undermined the case for urgent policy action. For more sceptical writers, the association of many *Diagnosis* authors with the IPCC meant they could be dismissed as part of the same supposedly discredited cabal – "a score of official UN scientists", as they were described by the editor of the Canadian *Financial Post* (Corcoran & Cary 2009).

Both of these initiatives can be studied as boundary spaces as not only did they seek to influence the flow of information across the science–politics boundary, but also to negotiate the normative status and political authority of scientific knowledge within the climate change debate. As is demonstrated in the following analysis, these boundary spaces became sites of epistemic and normative contestation despite their relative distance from the conventional sites of boundary organisation in the climate debate, such as the IPCC. In the following section, the methods used to explore the epistemic geographies of these boundary spaces are outlined.

Methods

Data collection and analysis began with a document search for items directly linked with the two projects (such as the published reports and website texts), media coverage of the reports' findings[69], and academic commentary on the proceedings and outcomes of both the scientific and political events. In the case of the Congress, indirect access to the proceedings was offered by video footage made available on the event's website of the opening, plenary and closing sessions. Verbal interactions between scientific and political actors were therefore vicariously observable, albeit through the limited gaze of a video camera. Sixteen interviews were conducted across both cases with key actors such as the main organisers, those subsequently identified as influential participants through a snowball sampling strategy (Bryman 2001), and actors associated with the development of a version of the burning embers diagram (figure 7.1) which functioned as a prominent boundary object in exchanges between scientists and political actors[70]. Interviewees were selected based on their influence in developing the epistemic claims or objects in question. Many of the respondents' perspectives were clearly influenced by the subsequent "climategate" controversy, meaning that the opinions expressed in the interviews may have been quite different from those held in early 2009. As Pitts and Miller-Day (2007) argue,

[69] Facilitated by the LexisNexis web-based database of English-language newspaper and online news reports. The search terms "Climate Congress", "Global risks, challenges and decisions", "Copenhagen" and "Copenhagen Diagnosis" were used to identify news reports and press releases from March 2009 to February 2010. 98 unique articles and press releases were identified.

[70] Interview extracts are presented anonymously, along with an indication of the respondent's disciplinary background.

retrospective interviewing can prompt reflexivity in respondent's evaluations of particular events and relationships. The Climategate events and the perceived failure of COP15 generated much reflection on the science–policy relationship which was of great benefit to this analysis.

The analysis of the documents, video transcripts and interviews drew on elements of discourse analysis and grounded theory (see Chapter 4). Close thematic coding preceded the development of categories, following Corbin and Strauss (2008). For example, emergent codes such as "elite universities" and "peer review" were grouped under a category of "credibility/status". This strategy allows thematic linkages to emerge, albeit without the claim to complete inductivism demanded by some schools of grounded theory (e.g. Holton 2010). Theoretical concerns such as "authority" or "boundaries" were used as sensitising concepts to guide the development of categories and the identification of themes (Blumer 1969) in an ongoing iteration between emergent elements in the data and the theoretical interests introduced above.

The epistemic geographies of the Congress and Diagnosis

The Climate Congress event was governed by a Scientific Steering Committee consisting mostly of representatives of the International Alliance of Research Universities (IARU) – a recently-formed elite grouping of prominent universities including for example the Australian National University, the University of Oxford and Peking University. This elite grouping was:

> looking for a common cause. And the idea of trying to run that kind of a congress … the rectors of all those universities thought it was a good way to try and put this new alliance on the map.
>
> (interview 10, oceanographer)

The rector of the University of Copenhagen thus took the initiative to instigate the event and to allocate the necessary resources. Like the Steering Committee, the conference was avowedly multi-disciplinary (see O'Neill et al. 2010), with 58 parallel sessions held in addition to plenary sessions with high-profile speakers. For one member of the Steering Committee, the broad disciplinary scope and design of the event aimed to:

> make better connections between the science and a lot of other aspects of climate change that we touched on...economic instruments, economic approaches to dealing with it, adaptation issues, issues of equity, developing country issues, technology issues and so on. And so we wanted to have a broader conference, if you like, a knowledge-mix of climate change that would complement the government and business perspectives on the issue.
>
> (interview 13, earth system scientist)

Here, the Congress is presented as an epistemic exercise with the goal of integrating, or at least bringing into dialogue, diverse perspectives on climate change. This was achieved through a programme which progressed from sessions on recent climate observations through to discussions on equity, adaptation, policy responses and behaviour change. For another of the organisers, this desired interdisciplinary conversation presented itself in an embodied form:

> I just really enjoyed this conference because of the interdisciplinarity and the cross-conversations and the fact that there were physical scientists sitting in the cultural session…and vice versa.
>
> (interview 12, environmental geographer)

The epistemic geography of the Congress featured the enactment of a multi-disciplinary space in which collective exchange and individual discovery could transcend conventional disciplinary boundaries. The common topic of climate change and in particular the sense of urgency surrounding the forthcoming political negotiations offered the normatively unifying pull amongst this diversity of actors, discourses and epistemic claims. For another of the organisers, the ability to gain "a broader understanding" of climate change through participation in diverse conversations had distinctive affective properties, giving “a sense of belonging to something, something really big” (interview 10, oceanographer).

This interplay between normative unity and epistemic diversity is evident in the processes by which the conversations of this large conference were translated into a coherent and targeted written narrative. Prior to the conference, session chairs were requested to submit a summary of the abstracts of the papers which were to be presented, to “provide us [the organisers] with detailed background information…and in their professional judgment, what were the main points that were coming out” (interview 13, earth system scientist). The abstracts thus functioned as mobile inscriptions (Latour 1990), substituting for the *Synthesis* authors’ absence from the majority of the verbal discussions they sought to synthesise. The synthesis document was published on 18th June 2009, following a review process involving “eminent scholars” from IARU and the International Council for Science (ICSU) Global Change programs.

The *Synthesis Report* is structured around six ‘Key Messages’ entitled:

- Climatic trends.
- Social and environmental disruption.
- Long-term strategy: global targets and timetables.
- Equity dimensions.
- Inaction is inexcusable.
- Meeting the challenge.

The Key Messages were arrived at before and during the conference itself through deliberations within the Scientific Steering Committee based on the compiled summaries of the sessions. These deliberations – a lot of them “conducted in the corridors or on email” (interview 12, environmental geographer) – proceeded quickly and urgently, and the Key Messages were announced in a press release on the final day of the conference. The six messages also constituted the backbone of discussions in the final plenary session, at which the findings of the conference were presented to the Danish Prime Minister, Anders Fogh Rasmussen. The urgency of the compilation and the subsequent review process meant the results, for one of the organisers, were "probably as good as we could have done",

> given the timeframe we had and the nature of the Congress, [and] given the quite severe time constraints that the Danish government was putting on us to get this done.
>
> (interview 13, earth system scientist)

The Danish government had played a significant role in the enactment of the Congress. As explained by one of the organisers, the initial push for the Congress event came from the government:

> the major motivating factor was the fact that Denmark was the host for the COP15. And Denmark is a very small country and getting the COP15 to Denmark was something that was a political initiative that many different ministries worked on at different levels. And when it became a reality, it really became a – I wouldn't say 'national sport' – but certainly a national goal…And obviously our Congress was something that we have total responsibility for…it wasn't run by the government…However, at the Prime Minister's office they had sat down and said "well, what do we need to keep the dialogue going in the media and getting all parts of society along?" And they decided that they needed three things: one, they needed to have the research results, the knowledge, in the news; and two, they needed to have good business cases in the news; and three, they really needed to have a good contact to the international press.
>
> (interview 10, oceanographer)

The respondent is keen to emphasise the independence of the scientific activities from the government and its "national goal"; "total responsibility" lies with the scientists who convened the conference. The extract reveals the complex boundary negotiations which would characterise the project overall. The phrase "our Congress" situates the normative authority of the project within the realm of science. Yet responsibility for the genesis of the project – and for the pressure placed on the organisers – lies predominantly with the Danish government and its desire to generate an ongoing "dialogue" between scientific knowledge, business, media and, by extension, the public[71]. The Congress was one setting at which this broad societal dialogue could be enacted – other settings included separate conferences for businesses and for local governments in the run-up to COP15.Yet this instigation of dialogue competed with a desire to deliver information to the decision-makers of COP15, in a fashion more linear than dialogic – a point returned to below. The initial steer from the Danish government offered a sense of urgency in the face of the looming political "showdown" (interview 1, earth system scientist). The same respondent reporting the personal enjoyment above also relates a very different sense – one of pressure and hectic activity:

> the urgency was having something to tell the Danish Prime Minister, you know? He wanted to hear a synthesis of the conference and of course given how large the conference was, it was very stressful to try to come up with some messages, but it was good that we'd done the homework reading everybody's abstracts I think.
>
> (interview 12, environmental geographer)

This desire for urgent synthesis was in part a function of the identification of a discursive space left open by the timings of the IPCC process. With the AR4 having been published in 2007, it was considered "timely" to produce an alternative forum where the latest research could be shared:

> climate change science is a fast-moving field, and the IPCC 4th Assessment Report had come out in 2007, which was two years earlier than that conference in Copenhagen. In fact the cut-off for a lot of the literature was probably around 2006. So given that the field moves very

[71] (Kysar 2010, 284) suggests that ''Danish officials and citizens felt significant responsibility for the success of negotiations for a post-Kyoto climate agreement, in light of the talks being held in Copenhagen . . . quoting Angela Anderson [of the Pew Environment Group]: 'They want their name on this agreement. They want it to go down in history as the moment the world really got on top of this problem'''.

> fast, it was timely to update those sciences as well as we could put it running in to the COP15.
>
> (interview 13, earth system scientist)

As discussed below, this particular rationale was shared by the *Copenhagen Diagnosis* authors. The recognition of and response to this gap in scientific discourse – generated by the 6-year assessment cycle of the IPCC – also contains within it perceptions of the role of scientific knowledge in political and societal debate. Although references to the forthcoming COP15 are prominent in the *Synthesis Reports,* respondents all conveyed a sense that the project "wasn't really directed to the negotiators" (interview 12, environmental geographer). Evaluative statements focused on the epistemic achievements of the event (rather than any political achievements), and respondents' reflections on their personal enjoyment of the event focused most often on its multi-disciplinarity and the possibility to encounter knowledge from outside one's own disciplinary territory.

Immediately after the close of the Congress, a group of physical scientists met in a single side-room at the Bella Center to scope-out a separate project – the *Copenhagen Diagnosis*. Much more limited in scope than the Congress *Synthesis*, the *Diagnosis* surveys recent findings in physical climate science, as outlined above. The document was prepared following the identification of potential contributors who had expertise in the planned topics. The writing tasks were then completed remotely, an internal and *ad hoc* external review process was conducted, and a copy of the final published report was sent to all COP15 delegates. The geographies of both of these projects were thus very distinct from the IPCC, where large teams of authors collaborate in assessing extant literature. Working often independently but with frequent contact and meetings with colleagues, IPCC authors prepare chapters over several years and through several iterations of expert and government review. For one *Diagnosis* author, the IPCC's protracted, iterative process enables authoritative consensus statements like "warming of the climate system is unequivocal" (IPCC 2007b, 2) to be carefully constructed. The *Diagnosis* did not achieve the same level of epistemic integration and internal coherency, due largely to the organisation of the writing tasks and the informal review process (interview 6, climate and ocean scientist).

The original idea to prepare a report such as the *Copenhagen Diagnosis* came not from government ministers but from a group of scientists who, together with an anonymous funder, were keen to fill the void left by the IPCC's discursive dormancy since the publication of its 2007 report. A related group of scientists had helped instigate the *Bali Declaration by Climate Scientists* in 2007. A key author explains the linkages:

> the background to that Declaration was that we had seen the UNFCCC meetings come and go without a lot of reference to the basic science, which surprised me…the UN obviously puts a lot of effort into the FCCC…or the COP meetings, and we're up to about number 17 or 18 of those meetings which I find staggering. You know, there's been an international effort for twenty years up at the UN to make some progress on this issue. But one of the things that concerned us, despite all the good efforts of the COP meetings, and all of the huge efforts of the IPCC, a group of us felt that we needed to start making statements about what's a safe level of emissions for the planet's future…I was glad to see at one of these UN meetings the science brought back to centre stage, even if it was just for one one-hour press conference. And the *Copenhagen Diagnosis* was basically the core group of researchers who were behind the *Bali Declaration*. We got together and we felt that there was the chance to make a scientific statement for Copenhagen.
>
> (interview 11, oceanographer)

While the organisers of the Congress are reluctant to draw direct linkages between their efforts and the UNFCCC process, here the connections are plainer. The respondent expresses disappointment at the perceived shortage of scientifically-informed discussion and political progress at the highest level of international climate governance – "up at the UN". The implication is that there is a causal connection between these "surprising" and "staggering" shortfalls, and that bringing the science "back to the centre stage" could motivate the desired political action. Thus the *Copenhagen Diagnosis* was a "statement for Copenhagen" – an intervention in the debate with the intention of re-ordering the map of epistemic authority within the political space of the UNFCCC.

When other respondents were asked about the motivations for the project, answers alternated between explanations of the political import of COP15 and of the discursive gap left by the IPCC's protracted assessment cycle. An additional rationale is evident in the report's particular coverage of a number of topics perceived to be the source of major misconceptions about the scientific understandings of climate change. Such "mistruths" (interview 11, oceanographer) were identified in public discussions of recent temperature trends, the role of solar forcing, and Antarctic sea ice extent, for example. The misconceptions are dismissed as being the product of erroneous causal judgments which misconstrue the magnitude or significance of particular observed patterns.

> There's all sorts of conspiracy theories, some of them very wild and exotic and we didn't really feel the need to go there. But some of them, we thought, were – let me say – not so wildly exotic at face value. So for a politician or somebody in the general public, they could hear this statement and kind of guess that it might be true…And so we felt that those kinds of issues, that really needed a scientific answer and a precise scientific answer, we should focus on...we ended up trying to pick a selection that we thought were the most significant at the time. And in some sense we didn't want to diffuse the main findings of the report with these distractions, because they kind of are a distraction. But because so many people in the public get taken in by them we thought it would be a nice opportunity to dispel some of those myths.
>
> (interview 11, oceanographer)

While the dispelling of certain "myths" was not an original motivation for the report, it reflects a broader desire to influence public debate beyond the "centre stage" of UN climate politics. The *Diagnosis* could provide a vehicle for this, perhaps owing to an expectation of high public interest in the document because of its timing and its relatively high-profile attempt to bridge scientific and political debate at a time of peaking political interest[72]. The carefully planned participation of these scientists in such public debates is reflected in the concern about potentially distracting from the main messages of the document (cf. Ryghaug & Skjølsvold 2010). However, the authors believed it possible to engage multiple audiences at a time of political "frenzy" (interview 1, earth system scientist) through the tailoring of information to what were perceived to be key discussion points, from what might constitute a "safe level of emissions" to dispelling myths and misunderstandings of the science. Like the Congress, the *Diagnosis* can therefore be read as an exercise designed to influence and direct public and political discourse by locating the climate as a scientific object in Copenhagen alongside the climate's presence as a political object in the run-up to COP15.

As Gieryn (1999) and Jasanoff (2012b) have argued, scientific peer review processes often function as sites of boundary work where competing interests seek to (de)legitimate epistemic authority in the context of political contestation.
The *Diagnosis* authors drew on recent peer-reviewed publications to construct their synthesis although, like the authors of the burning embers diagram, they acknowledged the 'value judgments' involved in deciding which findings to promote as significant, and which to ignore. Papers were selected on criteria of "impact", of the esteem of the journals, and the "maturity" of the results":

> we thought, as scientists, "OK, let's provide all the evidence we have in a format like the *Copenhagen Diagnosis*", which is peer reviewed, first rate literature – *Nature*, *Science*, what have you, *PNAS*, but provided in a digestible way.
>
> (interview 1, earth system scientist)

[72] This expectation proved to be well-founded, with the *Diagnosis* website receiving over one million visits since its launch. The Congress website received around 141,000 hits between February 2009 and November 2011.

> I think a lot of times scientists are accused of cherry-picking the scariest data. In fact what we cherry-picked…was the most reliable publications. The publications that, say, were based upon the most number of IPCC models or were, you know, synthesising the most amount of data. There were definitely occasions where papers were perceived to be relatively premature, if you like, in their findings. And that's a value judgment.
>
> (interview 11, oceanographer)

The epistemic basis of the Congress was rather different. While *Diagnosis* authors faced the challenge of narrowing their assessment without inviting a charge of improperly excluding certain scientific claims from consideration, Congress organisers encountered greater difficulty in ensuring the credibility of their sources. Owing to the design of the process which saw the *Synthesis Report* compiled from collected conference abstracts, the sources did not have the tacit credibility afforded by peer review (Jasanoff 2012b). In the heightened political atmosphere of 2009, this proved troubling to the organisers:

> already at this point we were starting to get into trouble. Because obviously at the meeting, I mean, we didn't get into trouble but we saw a black cloud emerging on the horizon. And that is people were beginning to criticise the IPCC for various things. And when you have a meeting like that and present new knowledge at the meeting, then obviously it's not always peer-reviewed literature. And, while our idea was to have done a review of what was presented, we got a little shaky on that one because we didn't want to be blown off the field because we weren't using peer-reviewed literature.
>
> (interview 10, oceanographer)

During the COP15 negotiations themselves, a sub-section of the *Synthesis* writing team met to put the finishing touches to a book version of the report (Richardson et al. 2011):

> partly as a result of the debate about peer review and IPCC, we decided that we couldn't just cite conference abstracts, because conference abstracts are only modestly peer-reviewed. So at the last minute [we] went through every single citation, to try to replace a citation to an abstract to a citation to a refereed journal article in the book.
>
> (interview 12, environmental geographer)

These efforts to avoid "trouble" reflect a concern to legitimate a set of scientific messages which would be deemed credible and authoritative (Gerson 1983). The striking image of a "black cloud emerging on the horizon" offers a distinctly negative reading of the events of late 2009 which would come to be known as "climategate", which saw a variety of the norms of scientific practice brought into public debate (Grundmann 2013). Issues such as methodological transparency became subjects of public discussion and objects of criticism, along with the norm of basing high-profile assessments only on peer-reviewed source material (e.g. IAC 2010). This episode represents an interesting response to the environment of criticism, in the form of a very conscious effort to shore-up and legitimate the epistemic foundations of a scientific document. This effort did not involve the alteration of the contents of the *Synthesis* as such, but rather an attempt to ensure that the content could not be undermined by accusations that it did not meet the foundational norms being stridently and publicly demanded of other scientific documents, particularly those of the IPCC.

Overlapping boundary spaces: the absent presence of the IPCC

While both projects were motivated in part by the disjoint between the IPCC and UNFCCC timescales, in both cases the influence of the IPCC is apparent in the norms, practices and claims to credibility which were employed. Participants in both projects were keen to stress that their respective efforts were in no way an imitation or a replacement of those of the IPCC. For the Congress organisers, a sense of mimicry was to be avoided:

> I have to say, when we decided to do it the way that we did, there was some concern that it would look like we were trying to be an alternative to the IPCC, and that we were in competition with the IPCC in some way. And that would have been very unfortunate for the whole process. But fortunately because Yale was a part of this alliance [IARU] and [IPCC Chair] Pachauri has a position at Yale – in fact it was announced that he was getting this position at Yale at the meeting in Copenhagen – the President of Yale was able to help us get Pachauri to come to our meeting which certainly didn't, I mean, that helped it not look like we were in competition with the IPCC. But I was very, very, very, very, very, very, very, very careful in the way that I presented what we were doing to the outside world, because we could do more harm than good by maintaining or some ways saying that the IPCC wasn't good enough.
>
> (interview 10, oceanographer)

Here the IPCC is presented as an institution with a potentially fragile reputation and status at the science–policy interface which should not be undermined – a view undoubtedly influenced by the controversies of late 2009 and 2010. It is suggested that mimicry would imply the existence of shortcomings in the IPCC process and thus a need for change or alternatives, whilst also perhaps weakening the trust placed in the IPCC as an arbiter of scientific information. The contested epistemic landscape which the organisers of the *Diagnosis* responded to with efforts to clarify substantive scientific "mistruths" and "myths" (such as the role of solar forcing in climate change) is manifest here in a defence of the institution (IPCC) through which authoritative consensual statements are periodically constructed and communicated. The symbolic presence of the IPCC chair at the Congress is offered as an embodied example of cooperation and mutual reinforcement in place of the potential image of the Congress offering a competing forum for the deliberation and construction of scientific claims.

In both cases, the IPCC offered an informal template with which to negotiate the structure and boundaries of different epistemic claims. The language of IPCC Working

Groups was used to describe the disciplinary reach of the two projects, with the *Diagnosis* described as “more or less following the IPCC framework and ‘here’s the big highlights of the climate science of the Working Group I’, so the physical basis” (interview 6, climate and ocean scientist). Another contributor describes the content of the *Diagnosis* as covering Working Group I in addition to some coverage of “emissions pathways, which is kind of Working Group II or III really” (interview 11, oceanographer).

However, the Congress was seen to cover the whole sweep of the IPCC’s tripartite structure more comprehensively. The event sought to convene “all the scientific disciplines, the topics relevant for climate change, like in IPCC lingo IPCC Working Group I, II and III” (interview 5, climate impacts scientist). However, epistemic boundaries did not go uncontested. One of the Congress Key Messages stated that “inaction is inexcusable”. Such a statement would arguably violate the IPCC’s claim to be “policy-relevant” but not “policy-prescriptive” (Moss 1995). Congress organisers reported regret at the particular wording of the statement. The argument they sought to make was that scientific uncertainty and technological incapacity could not excuse political inaction – a point which is lost in the statement “inaction is inexcusable”, which suggests that all possible reasons for inaction are invalid, given the risks reported in the *Synthesis Report*[73]. Hulme (2009b) criticised the dressing of such “political prescriptiveness” as “scientific unanimity”, and suggested that the top-down process by which the Key Messages were arrived at was ineffective at capturing the epistemic and normative diversity on show at the Congress. Hulme thus urged the *Synthesis* authors to be more forthright about their own political preferences, if political statements are to be made.

For *Diagnosis* authors, the experience of participating in IPCC assessments offered a form of procedural expertise which could contribute to the credibility of the report:

[73] A clearer formulation of the message was offered by the Steering Committee chair in *The Guardian* (13 March 2009, document 94).

> The authors primarily comprise previous IPCC lead authors familiar with the rigor and completeness required for a scientific assessment of this nature.
>
> (*Diagnosis* website, document 115)

Here and in interviews, personal experiences and knowledge of the IPCC process are drawn upon to claim "rigor and completeness" for a related yet ostensibly independent assessment. Congress organisers are perhaps keen to emphasise the independence of their process from the IPCC because of the occasional similarities – the production of a *Synthesis Report* and the participation of a great number of experts from a variety of disciplines (covering the three IPCC Working Groups), for example. The *Diagnosis* authors are however more willing to emphasise commonalities with the IPCC process where this can lend credibility to the assessment process:

> it was an aim to produce something like the IPCC *Summary for Policy Makers*, but without all of the processes and protocols the IPCC needs to go through…one of the things we had to emphasise many times was that we didn't want to cut across the agenda of the IPCC, but we were a group of scientists who had contributed to IPCC reports, most of the authors had either been lead authors or convening lead authors of past IPCC reports. And the goal was just to write yet another report, if you like, on the state of the science.
>
> (interview 11, oceanographer)

This particular respondent seems much more at ease with IPCC similarities than their counterparts at the Congress. While careful not to "cut across" the IPCC's "agenda" – which may be interpreted as both the Panel's unique mandate and its reputation or status – the notion of producing an IPCC-like product is not seen as problematic. The personal links add credibility, while the document itself is merely "yet another report" in what was suggested to be a cacophony of scientific voices. The overlapping of these distinctive boundary spaces highlights the contingency of the norms which govern the negotiation of science–politics boundaries. The IPCC is an organisation which, of necessity, has innovated a number of norms and practices of scientific assessment, having operated largely in unchartered waters around the contested boundaries of climate science and politics (Miller 2004b). The norms of "rigor and completeness", for example, can therefore be imported without "all of the processes and protocols" which characterise the IPCC assessment process. Rigor and completeness are therefore norms placed on the scientific side of the boundary, while the processes and protocols which seek to assure governmental assent (and a measure of democratic legitimacy) to IPCC statements are located – for these actors – in the realm of the political.

Despite the clear (and varied) influence of the IPCC on both of these projects, the norms and practices of different boundary spaces are evidently open to constant revision and renegotiation. For most of the *Diagnosis* authors, a rigorous presentation of scientific knowledge could achieve political value without the IPCC's mechanisms for constructing epistemic and political authority. Meanwhile, the Congress organisers grappled with the broader indeterminacy of the norms by which complex, interdisciplinary knowledge claims should be condensed and communicated to political actors. The *Synthesis Report* authors saw their activities as being too distinct from the IPCC for them to be judged according to the norms of UN-mandated scientific assessment. Thus, the boundary between the scientific and the political could be constructed in a new place through negotiations between the demands of a large academic conference and the perceived need to communicate succinctly to policymakers. Through formal and informal boundary work, new forms of knowledge and social order were co-produced; the latter in the form of a local settlement of the boundaries of the epistemic and the normative.

The (linear?) geographies of science and politics

These local boundary settlements point to the importance of attending to the location of boundary spaces. With the by-line removed, the title *Copenhagen Diagnosis* does not immediately suggest "climate change". However, the medical connotations of "diagnosis" were taken to accord with the document's authoritative scientific status, while the presentation of new observed data meant the document could be considered "like a report card on the state of the planet" (interview 11 oceanographer). It was considered important by the organisers to tie the document to the site of the upcoming political meeting:

> we'd seen the success of the *Bali Declaration* and naming something associated with the place and a meeting of such gravity…I thought given the timing of the meeting, and there was a tremendous focus on Copenhagen globally. I mean we've seen nothing like that for the meeting in Mexico or in Poland and this one in South Africa. I mean, ask somebody to name the cities they were in and people wouldn't remember, let alone even that they existed as meetings. So there was a huge focus on Copenhagen even six months or a year out. It was sort of seen as "this is the meeting where finally this problem's going to be solved". And I mean, ironically, it wasn't…But, the title, I think in the end enough of the authors said "yeah, let's go with the place name as key, Copenhagen's key, it ties in with the meeting".
>
> (ibid)

The "gravity" of the meeting and the potential for a "solution" to the problem of climate change motivated the nominal connecting of the document to the site of the COP15 gathering. As in numerous other examples, "Copenhagen" stands-in for "COP15" while functioning as a rhetorical signifier to persuade a particular audience of the time- and place-specific relevance of the report[74]. Such ordering of scientific information and political decision making implies a linear science-policy relationship, by which it is assumed that scientific knowledge must always precede rational decision making. Here the linearity is both temporal – in that the documents were released at strategic times to contribute to the decision-making, and spatial – for

[74] The title also resonates with the *Copenhagen Consensus*, a project convened by the 'sceptical environmentalist' Bjorn Lomborg (Lomborg 2001) to prioritise global problems using economic analysis. Climate change has frequently been dismissed by Lomborg as an urgent political problem. While Lomborg's project was not acknowledged as a motivation for the *Diagnosis* nomenclature, the two projects stand in interesting opposition as voices from the city.

example in the distribution of print copies of the *Diagnosis* to the national agencies which would be attending COP15, and in the geographical linkages forged between both projects and the Copenhagen UNFCCC meeting.

The influence of particular urban settings and cultures on scientific practices has been well documented in historical works on the geographies of Enlightenment- and Industrial Revolution-era science (e.g. Inkster & Morrell 1983; Withers 2007; see also Gieryn 2006). In his study of the itinerant British Association for the Advancement of Science (BAAS), Withers (2010a) documents how the urban settings of the Association's annual public meetings played an important role in delimiting and legitimating the civic science which was staged before the scientific community and the interested local public. Late modern aspirations to 'global' knowledge and political forms (Hulme, 2010a) mean the itinerancy of the BAAS is evident today in the spatiality of institutions such as the IPCC and the "passing caravan of international diplomacy" which constitutes the major annual UNFCCC negotiations (Rayner & Prins 2007, 37).

The city of Copenhagen exercised varying influence over the form of these two scientific exercises. While the *Copenhagen Diagnosis* perhaps would have been named after any city hosting a meeting like COP15, the Climate Congress happened because of the desires of the Danish national government to promote dialogue between academia, industry and government in the run-up to the international negotiations. This desire for cross-sectoral dialogue reflects a shift in Danish (and much northern European) climate discourse during the late 2000s which reframed climate change as an issue of technological innovation, economic opportunity and societal co-benefits (Whitehead 2007). The city of Copenhagen itself has come to embody and perform this commitment to ecological modernisation in the city authority's ambition to become "the eco-metropolis of the world" by 2015 (City of Copenhagen 2007, 2). The city has spawned a mobile design paradigm – *Copenhagenization* – which seeks to enhance the accessibility and sustainability of urban spaces and transport systems. The Bella Center itself – host both of the Congress and COP15 – presents itself as a pioneer of sustainable urban architecture and practice, such that its "extensive green programme" and "Copenhagen's strong position as a green city makes Bella Center a natural choice for environmental events such as the United Nations climate conference", which was certified as a "sustainable conference" (Bella Center 2012).

Many interview respondents portrayed the strengths of the linkages between the governmental, business and academic sectors as a key factor in the very possibility of an event such as the Congress taking place. The networks existing between academia and industry are evident in the range of sponsorship which the University of Copenhagen was able to attract[75], and the commitment of the Danish government to the exercise was embodied in the presence of Anders Fogh Rasmussen, then Prime Minister, in the conference hall for the final plenary.

Like in the title of the *Copenhagen Diagnosis,* a performative sense of place was mobilised by the Danish Prime Minister in his address on the final day of the Congress. Standing in Hall A of the Bella Center, Prime Minister Rasmussen referred frequently to the spatial coincidence of the Congress and COP15 to performatively link scientific knowledge to political action. For example:

> your contribution is an essential part of the preparations for the climate change conference, as an input to the negotiations within these very walls in December…I will carry your paper with me when I engage with other leaders to let them know what science says.
>
> (quoted in Baer and Kammen 2009, 7; document 105)

With these statements Rasmussen draws a direct line between the scientific and political events, with their shared location adding a rhetorical strength to his model of how scientific information can inform policy-making. The messages of the Congress will accompany him in his interactions with other politicians before he leads them back to the Bella Centre "to make the final decision" on international climate change policy (ibid, 12). Rasmussen's assumptions about the science–policy relations are made plainer in the following statement, which brought his address towards a close:

[75] Sponsoring companies included wind turbine manufacturer Vestas and Maersk Oil.

> But understand me correctly; at the end of the day, here in Copenhagen, we have – as politicians – to make the final decision, and to decide on exact figures, I hope. And this is a reason why I would give you this piece of advice, not to provide us with too many moving targets, because it is already a very, very complicated process. And I need your assistance to push this process in the right direction, and in that respect, I need fixed targets and certain figures, and not too many considerations on uncertainty and risk and things like that.
>
> (quoted in Baer and Kammen 2009, 12)

This statement refers back to an exchange between Rasmussen and Stefan Rahmstorf, a prominent climate modeller and panellist for the plenary discussion. The latter had suggested that a global temperature rise target of 2°C might not be correctly considered 'safe'. Rasmussen retorted that he took his understanding of the desirability of a 2°C target from IPCC, and had expended much political capital in persuading other UNFCCC delegates to support a push for just such a target. Other panellists explained that Rahmstorf's statement should not be considered as an absolute, but rather as a personal understanding of the risks associated with certain levels of global mean temperature rise. However, Rahmstorf's judgment was also one which was present in the *Synthesis Report* itself (figure 7.1).

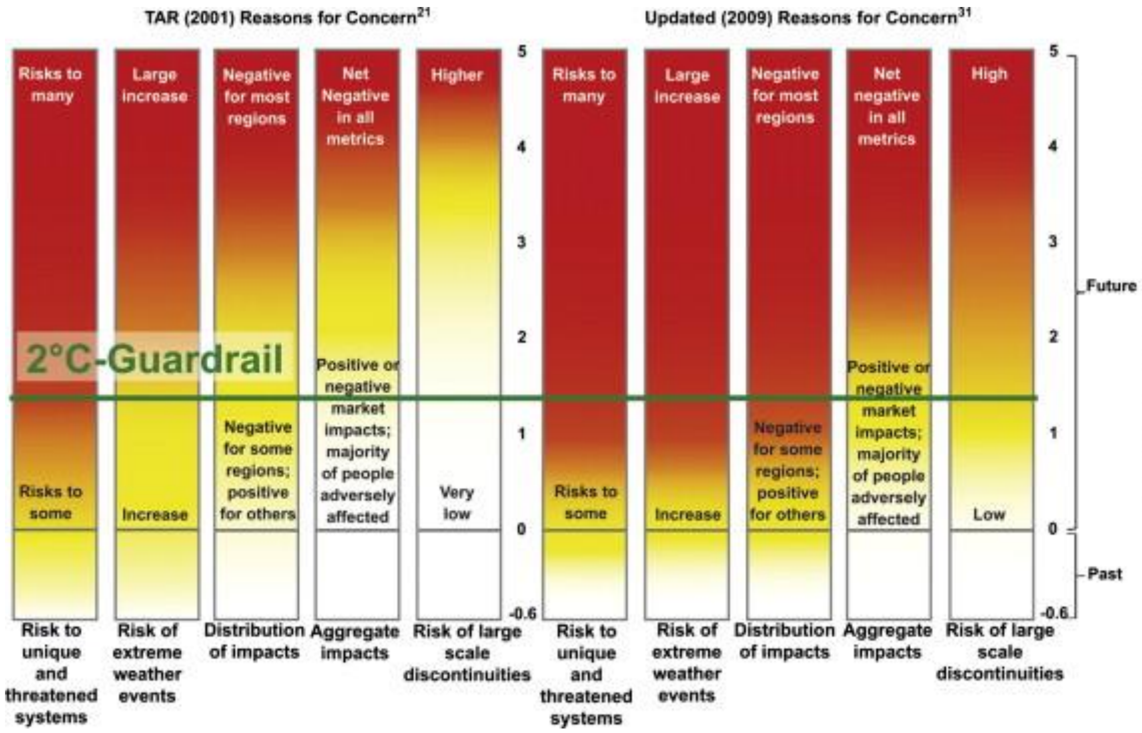

Figure 7.1. This updated version of the IPCC's burning embers figure appeared in the Synthesis Report *to illustrate the thesis that, based on new knowledge, the 2°C temperature rise target cannot be taken as sufficient to fully avoid "dangerous" climate change. Copyright and reproduced with permission of the University of Copenhagen.*

The text accompanying figure 7.1 emphasises the changing scientific understandings of the prospect of "dangerous" anthropogenic climate change. It is argued that:

> a 2°C guardrail, which was thought in 2001 to have avoided serious risks for all five reasons for concern, is now inadequate to avoid serious risks to many unique and threatened ecosystems and to avoid a large increase in the risks associated with extreme weather events.
>
> (Richardson et al. 2009, 16)

The risk of large scale discontinuities or 'tipping elements' in the climate system is also reported to have moved from 'very low' to 'moderate'. The authors conclude that the 2°C target, despite being "commonly quoted…nevertheless carries significant risks of deleterious impacts for society and the environment". As I showed in the preceding two chapters, the burning embers diagram has had a complex history of interaction with the 2°C target. The origins of both can perhaps be traced to the 'traffic lights' analysis of the early 1990s (see page 106), but the 2°C target became a significant object of governmental interest before the burning embers diagram appeared. In the mid-2000s, the burning embers analysis was taken as offering an alternative reading of the meaning of "dangerous" climate change to the 2°C threshold (Schneider & Mastrandrea 2005). However, in the science-policy boundary spaces of Copenhagen these two widely-circulating objects of climate change discourse crossed paths once again, with the new burning embers offering another alternative rendering of the meaning of danger. For one of the diagram's creators, placing the two objects into such close conversation was mistaken:

> one person approached me at one of the COPs, I think in Copenhagen, and said "the burning embers shows that 2 degrees is too high", so I said "no, no it does not." 2 degrees in the new one – I think it's within the range of where we describe that transitions could occur…I actually think that maybe it does suggest that it's hard for policymakers, maybe it's a little too complex – you're essentially putting out several numbers that are nuanced, that aren't hard numbers. And the policy process seems to want *the* number, you know, a single number.
>
> (interview 14, climate policy analyst)

This extract, in comparison to Rasmussen's "advice" to his scientific audience, reveals much about the tensions inherent to science–policy relationships. While the interviewee quoted above and the authors of the Congress synthesis document stressed that inevitable uncertainties should not preclude political action, the Prime Minister's preference was for "exact" and "fixed" targets which could function as stable boundary objects between the domains of scientific enquiry and climate diplomacy. As discussed in the previous chapter, the 2°C target is a distinctly European boundary object (Star & Griesemer 1989)[76]. The target has origins in scientific research and debate among European scientists and in the political manoeuvrings of European politicians, particularly at the level of the European Union. It has functioned as an interface and organising principle between science, policy and

[76] See also Randalls (2010), Shaw (2010), Cointe et al. (2011).

society, particularly as a central tenet of EU climate diplomacy on the international stage[77].

Boundary objects are characterised by the simultaneous existence of both theoretical coherency and local plasticity. In the case of the 2°C target, its coherency lies in its precision and the metrological stabilisation of degrees Celsius as the scale on which climate change is judged. This enables exchange between diverse social constituencies (Bowker & Star 2000). The plasticity of 2°C exists in the ability of these social constituencies to interpret the target for their own needs, for example as a guiding principle of climate activism (Stop Climate Chaos Coalition 2012), or as an object of enquiry into possible mitigation pathways. In the *Copenhagen Diagnosis* and associated media coverage, the 2°C target anchored discussions of the required trajectory of emissions reductions. In this case, 2°C was 'black-boxed' (Latour and Woolgar 1979) as a political imperative, while at the Congress, the assumptions underlying the target were publicly unpacked.

The exchange at the Congress plenary illustrates the challenges of the plasticity inherent in any such boundary object. For Rahmstorf, the 2°C target can be destabilised by changing scientific understandings. For Rasmussen, for whom the target has functioned as a tool for political coalition-building within and beyond the EU, its destabilisation risks the consequent destabilisation of the political process[78]. He acknowledges the scientific instability of such targets in his advice about avoiding "moving targets" and considerations of "risk and uncertainty", and urges the

[77] van der Sluijs et al. (1998) introduce the term 'anchoring device' – a subcategory of boundary objects – to describe the stabilisation of science-policy discourse around estimates of climate sensitivity ("the model-calculated potential global surface air temperature change in equilibrium following an instantaneous doubling of atmospheric CO_2-concentration" – ibid, 296). A consensus estimate of potential climate sensitivity values (1.5-4.5°C) has remained remarkably constant over the four IPCC assessment reports, thus fulfilling a similar function as the 2°C target in offering stability amid scientific and political flux (see also Knutti & Hegerl 2008). Yet I would suggest that the role of sensitivity estimates in managing scientific uncertainty at the science-policy interface (see also Shackley & Wynne 1996) differs from the kind of horizontal interaction and actor coalescence facilitated by the 2°C target. The latter is less about managing scientific uncertainty and more about navigating political plurality. The broad range of the sensitivity estimates highlights the epistemic ambiguity of the 2°C target.

[78] This resistance to re-evaluation of the figure mirrors the resistance among the scientific community to wholesale re-evaluation of the climate sensitivity estimates, as described by van der Sluijs et al. (1998).

scientists to focus on fixity and precision. Such scientific certainty is required in order to “push this [political] process in the right direction”.

The notion of a boundary object generates an image of concurrent and ongoing negotiation, mutability and exchange between and within science and politics. This picture would seem to be at odds with the claim that a linear model of interaction is here being constructed and performed between science and politics. However, conceiving of the 2°C target as a boundary object begins to highlight the empirical inadequacy of linear understandings of science–policy boundary spaces. The demand by the Prime Minister for scientific certainty to drive forward the political process is a result of the investment in constructing political stability on a foundation of reductive epistemic stability. This construction assumes the political to be dependent on the scientific, which in turn assumes that the scientific is independent of the political. Such an understanding reflects Mertonian norms of scientific practice and an assumed existence of a clear fact/value distinction (Merton 1973; cf. Moss 1995). Such assumptions appear erroneous when epistemic and normative commitments have been shown to be inextricably intertwined and equally agentive in their mutual construction (Jasanoff 2004c; Cointe et al. 2011). The notion that the political should be wholly dependent on the scientific also short-circuits democratic governmental norms while abdicating responsibility for instigating open and participatory deliberation on issues such as climate change mitigation.

The staging of the interaction between the climate scientists and the Prime Minister gave a unique visibility to the challenges of science-policy relationships. Video footage of the exchange was available online and a transcript was published in an editorial in a prominent environmental science journal as a “remarkable” and “important” insight into “the interaction between research, science and the political process” (Baer and Kammen 2009, 1). The exchange was variously described as “interesting”, “fascinating” and “shocking” by my interviewees. This science-policy spectacle suggests that the knowledge generated at the Bella Center pertained not just to the future direction of climate change, but also to the nature of the relationship between science and politics through the public display of epistemic tensions usually hidden to all but select participants in, and ethnographers of, scientific advisory processes.

The particular alignment of objects, actors and discourses in Copenhagen's boundary spaces may be said to have had some success, in that the Copenhagen Accord, hastily agreed at COP15, recognised "the scientific view that the increase in global temperature *should* be below 2 degrees Celsius" (UNFCCC 2009, document 173, emphasis added). However, the outcome of COP15 was largely decried as a failure of multilateral governance as no concrete agreement was reached on how such a target would be met (e.g. Vidal et al. 2009, Dimitrov 2010; Kovel 2010). The political achievement was simply recognising the "scientific view" of what "should" be, rather than a resolutely political articulation of the "should" – its implications, its normative content, and a means of moving towards this vision of a desirable future. The ensuing pessimism was captured by a senior scientist who was involved in both the Congress and *Diagnosis*, and who has extensive experience of scientific advisory processes. Although he evaluated both as successful scientific events and publications, his reflections on "this frenzy of scientific evidence" and the epistemic and normative authority of science were more negative:

> the naivety of that was simply that evidence counts in the political world. And it doesn't. I mean, simply, everybody has this insight in the end.
>
> (interview 1, earth system scientist)

Conclusion: boundary spaces and the geographies of truth and power

This chapter has argued that the concept of 'boundary spaces' can help capture the contingency and indeterminacy of interactions between scientific knowledge and political action. By focusing on emergence and conjuncture rather than institutional stability, the analyst is drawn to the localised negotiations of the objects, norms and discourses of late modern 'techno-politics' (Mitchell 2002). The examples of the *Copenhagen Diagnosis* and the Climate Congress illustrate the place-bound co-production of scientific knowledge and social order, as voices from the scientific community sought to influence the distribution of epistemic and normative authority across the science–politics boundary.

Where boundary objects such as the 2°C target are polysemic "in the case of notions and statements" (Callon 1995, 59), scientific sites are "polysemic with overlapping layers of different spatial formations" (Livingstone 2002, 16).The city of Copenhagen in 2009 became a site of intertwined knowledges and political hopes, with certain formulations of the science–policy relationship played out in the enactment of these two boundary spaces. The Congress was politically motivated in a literal sense in that the Danish government provided the initial rationale amid an apparent commitment to a targets-based approach to climate change mitigation. Somewhat conversely, the event itself combined epistemic concerns for the integration of diverse knowledges with arguments that political progress was not dependent on scientific certainty. The *Diagnosis* sought to more directly regulate political and public discourse through the physical delivery of text-bound scientific knowledge to the political negotiations and through efforts to address key public misunderstandings of climate science.

Ophir and Shapin (1991, 9) invite students of scientific practice to consider the social and spatial relations "that render the knowledge in question either authentic, safe and valuable, or fraudulent, dangerous, and worthless". The responses to the credibility challenge of the unfolding climategate events highlight how the root of scientific value no longer lies simply in individual virtue but rather in the materiality of scientific practices and their social legitimation (Shapin 1995). The spatial ordering of knowledge in Copenhagen contributed to a sense of value in the form of relevance and applicability through the spatio-temporal alignment of the social worlds of science and politics, and the performance of a linear relationship by which science was hoped to speak truth to power, to the latter's betterment (Jasanoff and Wynne 1998). This lends support to David Livingstone's assertion that "the knowledge claims that manifest themselves in particular settings are the compound product of nature's agency *and* cultural hermeneutics" (Livingstone 2010, 10 emphasis in original). The "cultural hermeneutics" in this case include the perceived need to update the knowledge claims of the IPCC, specific assumptions about the relationship between scientific knowledge and decision making, the sense of political urgency in the run-up to COP15, the agency and intentions of the Danish government, and the local resources available in the wealthy northern European country which facilitated such exercises – the lack of which elsewhere might have precluded knowledge-making on the scale seen in Copenhagen.

With echoes of the often strained processes by which governmental actors regulate, contest and approve IPCC documents (Chapter 6; see also Petersen 2006), the negotiation of the 2°C target – although conducted in a language of linear science-policy relations – illustrates the ontological and epistemic hybridity of boundary spaces such as the Congress. Despite Prime Minister Rasmussen's desire to recount "what science says" to his political colleagues, his overt regulation of what scientists can usefully say to political audiences highlights not only the boundary-spanning negotiation of useful and credible knowledge, but also the tacit co-production of knowledge with a commitment to a particular mode of governing the climate. This mode of knowing and governing through targets arguably precludes a more robust democratic engagement with the causes and consequences of climate change (Shaw 2010; Knopf et al. 2012, 122-125). In this particular moment of epistemic and normative conjuncture, Rasmussen's efforts to exclude considerations of uncertainty and ambiguity from discussion echoed the discursive privileging of the physical sciences over other epistemic claimants (O'Neill et al. 2010) and foreshadowed the physical exclusion of thousands of non-state delegates and activists – each with their own epistemic and political commitments – from the over-full Bella Center during COP15 itself (Fisher 2010). As the boundaries of the COP15 negotiations were strengthened by force, inside, negotiations were interrupted by a Tuvaluan delegate breaking into tears as the 2°C temperature rise target was favoured over a 1.5°C target (Farbotko & McGregor 2010); an affective response to a science–policy translation which momentarily ruptured the carefully constructed 'rational' spaces of climate diplomacy.

The 2°C discussion highlights the need to attend to the location of boundary spaces. The investment of much European and Danish political capital in the target gave it a particular prominence in the Copenhagen discussions. Rhetorical references to place (both to Copenhagen and the Bella Center as the shared stages of climate science and politics) functioned as performative spacings; bringing science and politics into closer relation – discursively and materially – even as the form and location of the boundaries between the two remained unsettled. Following Gieryn (1999), we can see how such boundaries are contingent on local contexts and overlapping boundary spaces, and thus how their negotiation is not restricted to "the confines" of formal boundary organisations and intergovernmental bodies like the IPCC (Guston 2001, 401).

These processes of representing and ordering function on different and often conflicting timescales. The disjoint between the timescales of IPCC assessments, a rapidly changing climate and the UNFCCC process was generative of new boundary spaces, while the perceived urgency of the political situation (and the emergence of Climategate) placed strains on the conventional norms and sources of scientific credibility. A hybrid climate subject to both 'natural' and human agency itself delivers challenges in the form of uncertain outcomes and unknowable timescapes of change (Adam 1998). In Copenhagen this gave rise to the emergence of boundary spaces defined by varying degrees of epistemic plurality where exchange between social worlds could be publicly performed, including the strained concomitant negotiation of the scientific veracity and political utility of the 2°C temperature rise target, in an effort to provide the epistemic basis for a complex political negotiation. This underscores the understanding of science and politics as essentially hybrid domains engaged in local acts of constant co-production and mutual re-alignment.

Most work characterised as 'geography of science' is historical in orientation (see Powell 2007a; Meusburger et al. 2010). Bringing geographical perspectives to bear on contemporary scientific practices offers the opportunity to study the tremors and rifts of emergent spatialities; the co-production of knowledge and socio-spatial order as boundaries, linearities, and hybridities emerge performatively in the service of 'good' science or 'authoritative' governance (Hajer 2009). The 'spatial turn' is arguably yet to fully inflect the theoretical language of STS, where spatial parlance most often fulfils a metaphorical function in relation to institutions and textual discourse. In attending to the production and practices of boundary spaces such as those explored in this chapter, we might therefore obtain a fuller picture of the complex epistemic geographies of late modernity, where classical distinctions between science and politics – or truth and power – are challenged by the intractable intertwining of knowledge and action. In turn, such research will be well-placed to contribute to discussions about how the space–times of scientific advice-giving may be reformed. Modes of organisation are needed which embrace the hybridity of science and politics and which facilitate iterative interaction rather than linear reductionism. The IPCC, in its current form, arguably does not match this prescription. The Congress and the *Diagnosis*, despite their own shortcomings, offer two indications of what more nimble processes of collating and negotiating knowledge could look like.

In the next chapter, I seek to extend this interest in the boundaries and hybridity of science and politics. The climategate episode – which figured here as a 'black cloud on the horizon' and which, for some, had a significant impact on the failed Copenhagen negotiations[79] – can be read as a *critical discourse moment.* For Carvalho & Burgess (2005, 1462), critical discourse moments "entail a potential for transformation in understandings of a problematique and constitute a test for 'established' discursive positions" in the cultural circulation of knowledges and political commitments. In following such circulation, I now move my analysis to India in order to examine the responses to an event which coincided with many of the events described here – the discovery of an error in the 2007 IPCC report concerning the possibility that Himalayan glaciers could disappear by the year 2035. Following this controversy and the diverse responses to it enables to me to further explore the place-bound co-production of science and social order, and to more closely examine the role of the state in the constitution of climate science and politics. Boundary questions therefore transform into questions of geopolitical borders, and the assumed linearity of science and politics is challenged in a context where questions of sovereignty are interwoven with questions of scientific credibility (Shapin 1995a). It is therefore an opportunity to look more closely at practices and performances of

[79] For example, Mooney & Kirshenbaum (2010, xi) argue that "because climategate occurred just before the critical United Nations climate conference in Copenhagen, Denmark, it knocked the whole event off rhythm in the media sphere". On the eve of the summit, the lead negotiator for Saudi Arabia told BBC News that "[i]t appears from the detail of the scandal that there is no relationship whatsoever between human activities and climate change" (BBC 2009).

collective reasoning, and to investigate the complex spatial politics by which the 'national' is carved out of the transnational spaces of climate science and politics.

Chapter 8

The predictive state

Science, territory and the future of the Indian climate

This chapter is based on:
Mahony, M., (forthcoming). The predictive state: science, territory and the future of the Indian climate. *Social Studies of Science.*

Introduction

In late 2009, it emerged that a statement that had been made in the Working Group II report of the IPCC 4th Assessment Report was incorrect. The report stated that "glaciers in the Himalayas are receding faster than in any other part of the world and, if the present rate continues, the likelihood of them disappearing by the year 2035 and perhaps sooner is very high" (IPCC 2007d, 493). This probabilistically-hedged prediction was found to have been made on unreasonable grounds. Indeed, it emerged that the year 2035 had originated in a glaciologist's statement in a magazine interview in the late 1990s, and had found its way into the IPCC report via a number of non-peer reviewed publications (or 'grey literature'; for a detailed account see Banerjee and Collins 2010).

The claim appears to have caused a mixture of alarm, unease and puzzlement in scientific and political circles in India. A summary statement about glaciers decaying rapidly by the 2030s was removed from the Working Group II *Summary for Policymakers* following a comment from the Government of India that "[t]his is a very drastic conclusion. Should have a suppoting [sic] reference otherwise need [sic] to be deleted" (document 27). The statement was thus removed from the summary document, and did not make it into the summary of the overall *Synthesis Report.* However, the underlying claim about glaciers disappearing by 2035 remained in the underlying chapter on climate change impacts in Asia, and garnered a significant amount of media attention on its publication. Newspapers reported on visual artists who used the claim to frame creative efforts at environmental awareness-raising in India[80]. John Kerry, then the chair of the US Senate Foreign Relations Committee, gained media attention when he argued in a 2009 speech that rapidly melting glaciers risked inflaming military tensions on the India-Pakistan border. Environmental change such as rapidly melting glaciers, he suggested, could potentially undo the recent diplomatic gains that had been made in the perennial border conflict (e.g. *Hindustan Times*, June 17 2009, document 344).

The importance of glacial meltwaters for agriculture, industry and human livelihoods across northern India positions the Himalayan region as a key site of scientific and political concern (e.g. Moors et al. 2011). The journalist involved with breaking the IPCC story in the news section of *Science* was born on the banks of the Ganges, perhaps India's most famous glacier-fed river.[81] He stated in an interview with me that:

> there is a deep connection in my personal life for the Ganges and for Gangotri glacier. And when this [IPCC] report came out I was aghast. I was taken aback, thinking "how can this happen?" And then I started hearing murmurs from Indian glaciologists saying 'the IPCC has got it wrong'. But remember, IPCC is 2,500 of the top-notch scientists so they are looked upon as a very august body. So nobody was going to come on record. Glaciologists... they work very slowly. Glaciers move slowly, glaciologists also move slowly. It took them time before that murmur became a little louder. And then we started looking at it carefully. In 2009 I started looking at it very vigorously. Then the murmur became a little louder.
>
> (interview 26, science journalist)

[80] For example, director Sudhesh Unniraman opened his 2008 documentary *The Agony of the Ganges* with a young man gazing down on the plains and glaciers of northern India from a spaceship orbiting the earth. Futuristic text flashes onto the screen, proclaiming the year to be 2035.
[81] On the links between rivers, religious thought and environmental science and politics in India, see Haberman (2006) and O'Reilly (2011).

The “murmurs” were also picked up by Jairam Ramesh, then Minister of Environment and Forests. Apparently sensing not only some perplexity about the 2035 claim, but also a measure of disagreement within the glaciological community about the true status and prospects of the Himalayan glaciers, Ramesh commissioned a review of existing knowledge produced by Indian scientists. A prominent glaciologist was persuaded out of retirement to conduct the review, which concluded that there is a mixed picture of receding and advancing glaciers in the Himalayan range, and that no trend can be attributed to anthropogenic climate change (Raina 2009). This conclusion was reported in *Science* in the context of refuting the IPCC claim about Himalayan glaciers melting by 2035 (Bagla 2009).

The same journalist who narrated the story of these counterposed scientific assessments in *Science* also filed a report for New Delhi Television, a major English-language television channel in India. In response to the news segment, the chair of the IPCC, Indian scientist Rajendra Pachauri, famously dismissed the Indian government report as “voodoo science”, questioning the evidential basis and scientific rigour of the report.[82] The term “voodoo science” functioned as an instance of boundary work, an effort to delineate what is to count as legitimate scientific knowledge, and what is to count as mere belief, superstition, or ideology (Gieryn 1983)[83]. This controversy sparked important re-framings of the relationships between the IPCC, the Indian government, and national and international modes of political knowledge-making and action. The so-called ‘Himalayagate’ or ‘glaciergate’ incident[84] re-animated a history of scientific and political contestation that has shaped the relationship between climate politics and national space in India. This relationship informed the emergence of a new national assessment body, the Indian Network for

[82] See also *The Guardian*’s interview with Pachauri: ‘India “arrogant” to deny global warming link to melting glaciers’, 9 November 2009.

[83] Pachauri’s denigration of the Indian government’s report in this register led Silke Beck (2012) to criticise the IPCC leadership’s tendency to position themselves as gatekeepers in the climate debate, dismissing uncomfortable questions as politically-motivated attacks, while often failing to engage with the substantive issues being raised. Beck argues that this tactic, of dismissing the messenger before engaging with the message, is ironically reminiscent of the agonistic tactics which climate sceptics or deniers are accused of using.

[84] The controversy quickly garnered these labels in media coverage and on blogs written by commentators sceptical of the reality or severity of anthropogenic climate change. As Norton (2010) has shown, the ‘climategate’ nomenclature emerged through complex iterative processes enabled by new social media, rather than being a concerted, strategic discursive act.

Climate Change Assessment (INCCA), under the direction of Jairam Ramesh. As STS scholars have shown, moments of controversy can bring the contested practices, norms and politics of knowledge-making into the open, as various actors seek to translate emergence and flux into stability and order (e.g. Jasanoff 2004c; Whatmore 2009). Himalayagate and INCCA thus offer an opportunity to study the relations between international and national modes of knowledge production, and the potential of international science, such as that represented and mobilised by the IPCC, to travel and be translated into diverse national contexts and political cultures (Lahsen 2007; Hulme 2010b; Jasanoff 2010). These political cultures bear upon the evolution of the forms of knowledge from which national governments draw certain understandings of and commitments to the climate change issue. In India, INCCA is a site at which scientific prediction and the governance of a national space have been brought into conversation with each other. I analyse this development in relation to a broader history of national environmental knowledge-making that points towards a distinctive civic epistemology (Jasanoff, 2005a). I suggest that regional climate prediction constitutes a new form of governmental gaze, with both its own effects and its own potential blind-spots. Therefore, this predictive knowledge arguably represents an important juncture in the history and use of the notion of 'territory'.

Knowing and producing territory

Climate change, understood as an epistemic and political object defined by globality and the pursuit of a transnationally enlightened polity (Jasanoff 2010; Hulme 2010a), generates frictions with conventional modes of ordering the relationship between science and politics in the system of territorially-bounded nation-states. In the history of the modern nation-state, territory has been both a central object and means of governing. In conventional discourses of international relations, both academic and public, territory is often conceived as the bounded space over which nation-states exercise a unique sovereignty (e.g. Weber 1946). However, a strand of work in political geography and related disciplines has sought to dig deeper into this notion of territory. The effort here is to not take national territories for granted as spatial units (a move characterised by John Agnew (1994) as the 'territorial trap'), but rather to problematise and historicise territory as both political object and political technology. That is, ‘territory’ is understood to refer to both a thing to be known and controlled, and to a means of achieving certain goals which precede territory-as-object (Braun 2000; Elden 2007; 2010a). Territory can therefore be seen as being constructed, perhaps most visibly through calculative and representational techniques such as cartography (e.g. Winichakul 1994; Edney 1997; Crampton 2010). The well-worn adage of the critical cartographer – “the map precedes the territory” (Baudrillard 1983, 2) – captures the notion that the will to map space, often with the aim of, for example, better organising the network of property rights, is central to the emergence of the territorially bounded nation-state (Wood 1992; Pickles 2004; Elden 2010b).

Elden (2010a) has argued that the concept of territory needs to be decoupled from the notion of ‘territoriality’ and its connotations of an innate social (Sack 1983) or even biological (Ardrey 1969) drive to dominate space. Through acts of territoriality, Sack and others argue, territory is extracted from space. Yet Elden contends that the analytical primacy of territoriality in political science and geography erroneously presupposes the category – territory – for which an explanation is sort. It also erases the historic and geographic specificity of territory and the forms of representation, appropriation and control through which territory is constructed. Territory therefore must be considered logically prior to territoriality (Elden 2010a). In his analysis of the recent evolution of international climate politics, Kythreotis (2012) productively explores territoriality as the relational effect of uneven economic power and the articulation of interests and differences within and between state borders. However, he doesn’t fully engage with the politics of spatial organisation or with territory itself as a relational effect of networked practices of calculation (Painter 2010). In this paper, I seek to explore the co-evolution of practices of territorial calculation with the shifting norms and discourses of Indian climate politics. Thinking territory and politics together in this way may be aided by turning again to the notion of co-production.

As I outlined in Chapters 2 and 3, the notion of co-production broadly suggests that “the ways in which we seek to know and represent the world … are inseparable from the ways in which we choose to live in it” (Jasanoff 2004b, 2). In this understanding, knowledge and forms of political order mutually construct one another. Epistemic commitments to what ‘is’ are inseparable from normative commitments to what ‘ought to be’ (e.g. Hulme 2009a). The co-productionist approach can help make sense of how the cognitive, institutional, material and normative elements of a society are interlinked (Jasanoff 2004c), thus offering explanatory resources for observable changes in the configurations of science and politics (cf. Miller 2004b; Lövbrand 2011). As I demonstrate below, an understanding of science and politics as being tightly coupled has had particular traction in recent Indian environmental politics. The events I describe highlight how the boundaries can become blurred between co-production as an analytic lens and as a strategic instrument wielded by powerful and knowledgeable actors (Jasanoff 2004e: 281).

The state is a key site of co-productionist inquiry, and such an approach offers a number of synergies with theories which emphasise the roles of representation and spatial standardisation in the development and functioning of the state (Anderson 1991; Scott 1998; Mitchell 2002; Goswami 2004). In such terms, the nation-state can be conceived as “a network that is partly held together by circulating technologies of representation and communication” (Jasanoff 2004c, 26; Sharma & Gupta 2006). For example, in his history of forestry in colonial eastern India, Sivaramakrishnan (1999) argues that the project of state-making was intimately bound with the politics of knowledge and expertise. Although the history of colonial forestry can be read as the straightforward imposition of a ‘Western’ science on the complex social ecologies of Indian woodlands, Sivaramakrishnan argues that the spatial rationalities of scientific forestry were, in fact, confounded both by local ecological realities and by political resistances to the colonial state (see also Gadgil & Guha 1993).

The idiom of co-production, when brought to bear on Sivaramakrishnan’s analysis, highlights the emergent quality of political rule. Colonial power is not simply applied unilaterally, but rather made to conform to the local particularities with which it is confronted. Turning from the national to the international, contemporary climate change offers new cosmopolitan networks of knowledge production in the form of transnational spaces like the IPCC (Hulme 2010a; Beck et al. 2013) and globally circulating tools of climate prediction (Mahony & Hulme 2012). Seen from a certain normative standpoint, the international coordination of climate science-for-policy can be interpreted as a "cosmopolitan moment" (Beck 2009, 47) that challenges national forms of epistemic and political sovereignty by presenting global risks, knowledges and political power (Whitehead et al. 2007; Beck 2009). However, it would be wrong to suggest that global climate science and politics erase local specificities. Indeed, work in STS has highlighted the complex translation or localisation of knowledges that claim universal reach (e.g. Jasanoff & Martello 2004; Jasanoff 2005a; Wilson Rowe 2012).

Evident in the above is that political orders are never entirely stable, nor are they ever simply 'given'. Rather, they emerge out of the interplay between material and discursive resources in ways that are not necessarily predictable but are nonetheless amenable to empirical analysis. In what follows I aim to make such an empirical exploration of the tensions between transnational networks of knowledge production, the localisation of global climate science, and the ongoing co-production of territory and climate politics.

Despite clear synergies, co-productionist accounts of social ordering have not yet been brought into conversation with emerging geographical understandings of the nature and enduring political import of territory. Indeed, with a few exceptions (e.g. Miller 2004a; Jasanoff 2004d), the self-described co-productionist strand of STS has yet to fully embrace questions of space and spatial organisation. In taking a symmetrical approach to the evolution of epistemic and political forms, the lens of co-production offers a powerful way of comprehending territory not as a historical *a priori*, but as a contingent product of particular forms of cognitive and normative development; a compound of economic, legal, strategic and technical forces whose changing interrelations lend territory its historic and cultural specificities (Elden 2010b). By studying a moment of both controversy and emergence at the science-policy interface in India, I aim to illustrate the local co-production of climate science and politics and to unpack the continuing significance of national territory in the face of cosmopolitan challenges to the territorial logics of the modern nation-state.

Sources and methodology

This chapter is based predominantly on fieldwork conducted in New Delhi in February and March of 2012. I carried out 27 interviews with scientists participating in both IPCC and INCCA, and with journalists, politicians and non-governmental organisation (NGO) actors. Previous characterisations of Indian environmental politics describe a space of multiple voices and competing epistemic and normative commitments (e.g. Jasanoff 2007; Dubash 2011). As illustrated below, the evolution of the Indian government's position on climate change has not occurred in an institutional vacuum (see also Atteridge et al. 2012). Rather, a diverse array of actors has participated in the process of defining and deliberating the knowledge to which governmental actors have deferred in climate change debates. Responding to this diversity through a sampling strategy which traversed networks of scientific, political, NGO and media actors was therefore a response to the particular characteristics of Indian environmental knowledge-making, but also an attempt to operationalise the co-productionist stance on the relation between the epistemic and the normative. If scientific and political concerns cannot be neatly distinguished from one another, it follows that the scientific and political work of responding to climate change happens in a number of different settings. By identifying prominent actors through documentary analysis, lists of IPCC participants and notes on recent national climate change conferences, for example, I gained a measure of heterogeneity within my field of analytic vision.

Documents were collected through internet searches and from the library of the New Delhi-based environmental NGO the Centre for Science and Environment (CSE). A survey of the major English-language daily newspapers was also conducted through the LexisNexis online database of news reports. The search terms "climate", "global warming", "IPCC", "Himalaya" and "glaciers" were used to identify relevant articles. In searching for articles with the term "INCCA", I broadened the scope of my search beyond the major English-language dailies. As Billett (2009), Boykoff (2010) and Jogesh (2011) have shown, the print media has been a key site of climate change debate and deliberation in India, with certain discourses about risk and responsibility (particularly their geographic distribution) becoming dominant (Billet 2009), while also being subject to challenge and destabilisation (Jogesh 2011)[85]. As Jogesh shows, media coverage of climate change in India peaked around the time of the 2009 Copenhagen negotiations and the concurrent scientific controversies[86]. 102 articles were returned by the LexisNexis search and, along with the other documents and interview transcripts, these were subject to interpretive content analysis which drew on the tools of grounded theory (Charmaz 2006). As in previous chapters, this involved close thematic coding of the texts and the building-up of conceptual categories (such as "credibility") through iteration between the data and the conceptual interests introduced above. While attention was paid to the dominant framings employed by the newspaper reporters (cf. Billet 2009), my guiding research interest in the spatial politics of climate knowledges directed me more towards interpretive analysis of the utterances of key actors which were quoted in the news reports.

I also analysed 31 transcripts of parliamentary debates and questions submitted by members of the Lok Sabha and Rajya Sabha – the lower and upper houses of the Indian parliament respectively – to various government ministers. In searching the online depositories of parliamentary debates and questions I employed the same search terms as in the media study. This analysis was benefitted by the transcriptions provided by Prabhu (2011) of key parliamentary debates before and after the Copenhagen climate talks, which are otherwise unavailable publicly.

In the next section I situate the IPCC glacier controversy within a longer history of national environmental politics and epistemic contestation. I then explore how this incident and this history informed the emergence of INCCA, before offering conclusions about the co-production of new territorial knowledges and new forms of climate politics.

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[85] On the broader significance of the print media in Indian political culture, see Sonwalkar (2002).

[86] Interestingly, Jogesh (2011) categorises articles dealing with the glacier controversy as "global politics and not science, as they dealt less with the science of climate change and more with the politics of recrimination and retaliation over the mistakes made" (ibid, 271). A pragmatic and understandable choice perhaps, but one which assumes that media coverage of the science of climate change can be neatly purified of politics. Only 10% of Jogesh's sample fitted her 'science' category.

A lineage of contestation

The controversy over melting Himalayan glaciers points towards a longer history of occasional antagonism between epistemic claims made in the global North and claims made in India. In what may have been the first popular presentation in India of the climate change issue, a contestation over the science and its implications took centre-stage. In 1982 CSE produced its first *Citizens' Report* on the "State of India's Environment", the first of a series of reports that sought to present the Indian environment as a national object through the lens of political economy and an overriding concern for environmental and social justice. In introducing the topic of climate change, the report took issue with a statement by British scientist John Gribben in *New Scientist* magazine that:

> although the third world countries will produce the greenhouse problem by the early 21st century…they will suffer little adverse consequences themselves, and may even benefit as a result. Meanwhile, their traditional enemies in the rich North will suffer the worst consequences of the developing world's carbon pollution.
>
> (quoted in Agarwal et al. 1982, 87)

This position was challenged by the marshalling of a range of evidence, including emerging modelling studies which suggested that the tropics and sub-tropics would see perturbed rainfall patterns that would put the region's agriculture at risk. The CSE authors also took issue with Gribben's characterisation of the shifting responsibility for climate change. The authors foregrounded arguments about the historic responsibility of the North and the need to allow developing countries to continue on the path of industrialisation:

> Rich countries should not be allowed to argue in the future that the fuel consumption of developing countries ought to be kept in check to control the increase in carbon dioxide, regardless of their own contribution in the past.
>
> (Agarwal et al. 1982, 90)

This was the first manifestation of an argument that would come to define not just CSE's position on climate change, but also the Indian government's. In a highly influential volume in 1991, CSE directors Anil Agarwal and Sunita Narain famously argued against a World Resources Institute (WRI) report by stating that emissions should be counted on a per capita basis in order to work the differential historic responsibility for climate change into global calculations of how the mitigation burden should be shared (Agarwal & Narain 1991). They also argued for a distinction to be made between 'luxury' and 'survival' emissions, suggesting that a molecule of carbon dioxide in the atmosphere does not have a universal status. That is, carbon dioxide produced in a wood-burning stove in rural India has a profoundly different ethical (and therefore, the authors suggest, legal) status from that expelled from the exhaust pipe of an oversized vehicle in the United States.

This notion of common but differentiated responsibility based on per capita emissions became a cornerstone of India's negotiating position in the UNFCCC and the rationale behind the refusal to accept binding emissions cuts (Stevenson 2011; Atteridge et al. 2012). However, I want to draw attention to the episode's entangling of the epistemic and the normative; to the intimate relation between assertions of what *is* and conceptions of what *ought to be*. This is a widely-reported characteristic of much environmental knowledge making in India (e.g. Jasanoff 2004d; 2005b; 2007; Lele 2011), with bodies like CSE foregrounding their arguments for social and environmental justice in any analytic descriptions of the state of the environment.

Contestations such as these continued, for example in the deeply normative struggle over the economic valuation of an individual human life in the IPCC's Second Assessment Report (Masood 1995), and in the contestation between US and Indian scientists over how much methane was estimated to be emitted from India's rice fields (Parashar et al. 1996).

The Indian government and the IPCC

Incidents such as the aforementioned moments of contestation have led some observers to claim that the attention of the relevant arms of the Indian government has been focused on the UNFCCC negotiations and the preservation of the norm of differentiated responsibility, rather than on the process of producing IPCC assessments. For example, in 2001 Frank Biermann reported a lack of government interest in fostering greater participation of Indian experts in the IPCC process, both in terms of helping scientists to take part as authors (e.g. by publicising the recruitment process or offering financial support for travel to international meetings[87]), and in terms of ensuring wide participation of Indian experts in the review process (Biermann 2001; see also Kandlikar & Sagar 1999).

A persistent sense of the government's relative lack of concern for the IPCC process was also offered by my interview respondents. In relation to the Indian government's modest effort at garnering review comments and public scrutiny of IPCC documents, an Indian environmental economist working on the current IPCC report surmised:

> The fact that not much of this is done to me reveals that probably the government doesn't feel that there's much point in doing it, you see? I mean it could be lack of capacity but it could simply be a lack of interest or, as they say, you put your money where your mouth is. So this is [revealing a] preference.
>
> (interview 19)

An ocean modeller I interviewed at one of New Delhi's elite universities revealed a similar perception based on his experiences of trying to foster national-level activities to support Indian input into IPCC. He said that in response to a research proposal he submitted to an Indian science funding body, a reviewer wrote,

> "So what if your science project, you want it to feed into the IPCC process, nobody reads the IPCC report". It was an Indian reviewer…my suspicion is fairly senior. For you to hear that, it sort of confounded a lot of things…I mean sure enough it's too thick for any one person to sit and read it all. But to say what they said indicates that it's not taken like it's

[87] The IPCC has a trust fund to support the participation of scientists from developing countries, but other financial and bureaucratic constraints – like visas and working time – still preclude fuller participation, alongside broader issues of language barriers and the diverse nature of climate expertise. See Biermann (2001) and Ho-Lem et al. (2011).

important for this country. And you know, all of us had our suspicions on foreign…[laughs] and thanks to you guys [referring to my British nationality and the legacy of British colonialism in India] well,…be that as it may, it may or may not be real but at least it plays well.

(interview 25)

This account begs comparison with Mikaela Sundberg's (2006) analysis of climate science research proposals in Sweden, where she found that linking proposed research to the assessment practices of the IPCC, however tangential the link might be, was seen as an essential strategy for attracting government attention and hence funding. It is apparent that this strategy is not as effective in India. Indeed, there is reason to think that linking work to particular national concerns such as the monsoon might be a more effective strategy for attracting funding.

My interview subjects indicated that many Indian actors regard the IPCC as being of little relevance to Indian concerns. Indeed, in broader terms, the IPCC tended to perceived as a Western institution that challenges the epistemic sovereignty of countries like India that take a distinctive normative stance on climate change (cf. Lahsen 2007). This framing is evident in the mainstream English-language media's coverage of the Himalayan glacier controversy in India[88], in statements such as:

For the first time, the Indian government has challenged western research that says global warming has hastened the melting of Himalayan glaciers.

(*Hindustan Times,* 10 November 2009, document 237)

and:

[88] Jogesh (2011, 273), in a sample drawn from 9 English-language newspapers and business dailies, found 85 articles dealing with the glacier controversy, "80 of which were critical in their tone". This was nearly double the number of articles which were critical of the UEA email controversy, a discrepancy which Jogesh attributes to the geographic proximity of the glaciers. Jogesh found only 5 articles written by Indian journalists or commentators which challenged the broader reality of anthropogenic climate change.

> The western countries, [Environmental Minister Jairam Ramesh] felt, used the IPCC report to pressurise India to come on board to accept mitigation targets, which was successfully rejected.
>
> (*Hindustan Times,* 16 March 2010, document 321)

The language of challenging and rejecting scientific claims emanating from outside India situates this particular moment of controversy in the longer lineage of epistemic contestation discussed above. The sense that the IPCC and climate science as a whole is a space where the epistemic and the normative are deeply intertwined – with the IPCC for example acting as a didactic tool to put pressure on the Indian government – is a theme voiced by a variety of different actors in Indian climate debates (see below). In her analysis of Brazilian climate politics, Lahsen (2007) challenges the kind of instrumental linking of IPCC participation to trust and credibility that I discuss in Chapter 3. She argues that in Brazil, institutions like the IPCC have often been read as vectors of hegemonic power; a power which is co-produced with, and a locus of, the economic and political dominance of Northern states. Yet she argues that trust in the IPCC cannot be straightforwardly achieved through the broader participation of actors from states like Brazil and India. Indeed, she reports some governmental actors being sceptical of their participating scientific compatriots and their potential to be co-opted into ways of thinking about and framing climate change which may run counter to national interests. In the relative intransigence of the Indian government towards fostering broader participation in the IPCC process, similar concerns may be at work.

The use of the label “western” with reference to the IPCC process cannot, of course, be understood without reference to the legacy of British colonialism and the politics of national autonomy which guided much pre- and post-independence political thought in India (Zachariah 2005). Industrial import substitution and science-led developmentalism were flagship policies of the post-colonial government, with economic independence and scientific knowledge seen as central to an autonomous and enlightened state (Kochhar 1999; Chakrabarty 2002). The periodic use of the leitmotif of *Western* science plays upon concerns that the IPCC is an institution which challenges the epistemic and political sovereignty of the Indian state. It re-articulates a framing of climate change which stratifies risk and responsibility along a 'North-South' divide (Billett 2009; Joshi 2013). The motif is a reminder that the delegation of epistemic authority from the nation state to international institutions of scientific assessment and regulatory politics (Miller 2009) is far from being an inevitable, complete or uncontested process.

The complex relationship between participation, power and trust described by Lahsen (2007) is further evidenced by the positionality of Rajendra Pachauri, the Indian chair of the IPCC, in the controversy surrounding the melting glaciers claim. A former high-level policymaker with a long involvement in climate policy told me that "Pachauri is not very well received in India", due to what my respondent described as "several manipulations" (interview 24). The 2035 melting glaciers claim was offered as an example. Yet when asked whether Pachauri should step-down as IPCC chair, my respondent argued that having an Indian voice in such a prominent position in an international body was too valuable to lose. Here we can see echoes of Lahsen's (2007) argument that trust in individuals (cf. Shapin 1995a) is not neatly determined by nationality, particularly in the case of government actors and their scientific compatriots. Pachauri sought to staunchly defend the territory of a trans-national, autonomous science by denouncing the Indian government's challenge as "voodoo science" and "arrogant", and accusing the author the Indian glacier report of engaging in "schoolboy science" and in media tactics reminiscent of "climate change deniers" (*The Guardian*, 9 November 2009, document 236). Yet in media interviews Pachauri also played upon his own subjectivity. In seeking to link the tirade of criticism to which he was subject in late 2009 to powerful corporate interests, he told the *Hindustan Times* (25 January 2010, document 286) that "I am the easiest target as I represent the poor and the most vulnerable". Although listings of IPCC contributors are accompanied by statements of nationality, it is wrong to assume that credibility in national political contexts flows unproblematically from national representation in the IPCC process. Personal subjectivities may not always map onto the kind of 'national interests' defended and pursued by national governments (see also Scoones 2009). However, by March 2010, the Indian government threw its weight behind

Pachauri in the face of widespread calls for his resignation, with Jairam Ramesh telling Parliament that he had “full confidence” in the “Indian chairperson” of the IPCC, despite the government’s objections to the glacier claim being “upheld…we were vindicated” (quoted in *Times of India,* 16 March 2010, document 322).

Defining the space of science and politics

For over a decade, calls have come from various NGOs in India for the government to pay greater attention to the IPCC process. Such arguments have been advanced by CSE and parts of the People’s Science Movement such as the Delhi Science Forum (DSF). The People’s Science Movement is a collective term for a number of civil society organisations that emerged after India’s independence, with aims ranging from the popularisation to the democratisation of science and related policymaking (Varma 2001; Visvanathan 2005).

The DSF largely resides in this latter category. For its founder, writing in 2011, the Indian government’s lack of engagement with the science of climate change has hindered its ability to gain geopolitical advantage and assert its own sovereignty in international climate debates:

> Certainly as far as India goes, poor understanding of the science combined with poor geopolitical understanding and tactics, has meant ceding the upper hand to the USA and its allies to the detriment of global climate control.
>
> (Raghunandan 2011, 170)

This argument echoes one put forward by CSE in 1999. Writing in a volume on “Green Politics”, the Centre’s directors argued that:

> Developing countries will continue to allow industrialized countries to lead them astray unless they learn the importance of science in global climate negotiations…Western scientific institutions have a monopoly over climate science, a fact that has often worked against developing

countries in climate negotiations.

(Agarwal et al. 1999, 31)

In these examples we have two scientific/environmental NGOs critiquing the forms of knowledge to which the Indian government defers in international climate politics. While both the DSF and the CSE have been critical of Western scientific framings of climate change, that hasn't prevented them from presenting science in general as a potent analytic tool in developing climate policy. Both organisations draw on the perception that the science and politics of climate change are deeply intertwined, and that to succeed in the politics, one must be proficient in the science.

The emergence of INCCA

The responses to the IPCC glacier error drew upon a history of contested knowledge claims and of articulations of epistemic and political sovereignty. These themes also animated an institutional innovation regarded by some as the emergence of an 'Indian IPCC' (see below) which could offer independence from the under-fire science of the international body. On October 14, 2009 a national workshop was hosted by the Ministry of Environment and Forests (MoEF) to lay out plans for a comprehensive programme of climate change assessment. This led to the constitution of the Indian Network for Climate Change Assessment (INCCA), a nationwide network of scientists and institutions engaged with climate change research. Most of the scientists who have thus far contributed to reports are linked with government research institutions, while those residing in the more autonomous university sector have had less involvement. This is important to note, because government scientists are more disposed to participating in scientific projects that reflect and respond to national interests than university scientists, who are more likely to engage in international collaborative projects which transcend national borders.

In May 2010, an INCCA-branded greenhouse gas emissions inventory was published (INCCA 2010a). This was followed in November of the same year by what was known as the "4x4 Assessment" (INCCA 2010b), a study of the impacts of projected climate changes on four sectors (water resources, agriculture, forests and human health) in four regions of India (the Himalayan region, the North-East, the Western Ghats and the coastal region). Impacts were assessed based on national climate projections produced for the 2030s by a regional climate model run at the Indian Institute of Tropical Meteorology (IITM) in Pune.

The IPCC glacier incident happened between the official establishment of INCCA and the start of the work for the 4x4 assessment. It is therefore important to consider the impact that these events had on the framing and indeed the rationale for this assessment. A 2009 MoEF document outlines the steps being taken to conduct national climate change assessments. It states:

> The [IPCC] AR4 projects wide ranging implications and adverse impacts on developing countries for reasons of their lack of capacity to respond to rapid change. Alarmed by the findings, the government[s] of the countries across the world are engaged in working out the impacts and associated vulnerabilities of their economies to impending projected climate change.
>
> (MoEF 2009a, 7)

In the foreword to the 4x4 assessment by Jairam Ramesh, released around one year after the Himalayagate affair, a subtle shift in discourse is evident:

> we need to make the '3 M's' – Measure, Model and Monitor – the foundation of our decision-making and we need to build indigenous capacity for this. We should not be dependent on external studies to tell us for example about the impact of climate change on our glaciers, on our monsoons, and indeed even on sea level rise. Indeed, recent evidence suggests the 'scientific consensus' on many of these is debatable.
>
> (INCCA 2010b, 9)

The shift is from a picture of developing countries responding uniformly to the threatened impacts by bringing together knowledge about national vulnerabilities, to a language of autonomy and of the need to be in some sense self-sufficient when it comes to evaluating the available evidence on climate change impacts.

The language of “our glaciers” and “our monsoons” is significant in that here is a minister of state using terms of collective national experience and territoriality to describe masses of frozen water and features of atmospheric circulation (cf. O’Reilly 2011). Rhetorical constructions of the national are of course common to any political project (Anderson 1991), and the wider cultural, political and environmental significance of these particular objects within (and beyond) India cannot be overstated. This mingling of the national and the nonhuman thus serves to introduce borders and territory into the supposedly borderless worlds both of science in general (Shapin 1998) and more particularly of the study of an object constructed as quintessentially global, the climate (Miller 2004b; Hulme 2010a).

Jairam Ramesh has offered such sentiments on numerous occasions, and often echoes the arguments put forward by the NGOs outlined above, that the science and politics of climate change are inextricably interwoven, and that to cede scientific sovereignty is to cede political sovereignty. For example, a report in an Indian daily newspaper cites the Minister as saying:

> Declaring that “science is politics in climate change; climate science is politics”, Union Environment Minister Jairam Ramesh has urged Indian scientists to undertake more and more studies and publish them vigorously to prevent India and other developing countries from being “led by our noses by Western (climate) scientists who have less of a scientific agenda and more of a political agenda”.
>
> (*Indian Express,* 9 June 2011, document 382)

Particularly striking here are the echoes of CSE’s description of developing countries being “led astray” by the science-laden developed countries. This open mixing of the scientific and the political, or the epistemic and the normative, is something that Sheila Jasanoff (2005b) has noted as being a characteristic of dominant modes of public knowledge making in India, or civic epistemology: the political and cultural norms by which knowledge claims within a particular political context come to be counted as authoritative and reliable bases for collective action.

This empirically-observed coupling of the epistemic and the normative parallels the STS and social constructivist insistence on the interdependence of fact and value. While STS scholars have suggested that the concealment of such entangling is characteristic of many Western political cultures or civic epistemologies (e.g. Ezrahi 1990; Porter 1995; Jasanoff 2005a), the recent history of environmental politics in India may offer illustration of the bridging of "the gap between co-production as an analytic approach and co-production as a strategic instrument in the hands of knowledgeable social actors" (Jasanoff 2004e, 281). For example, Jasanoff has observed a tight coupling of the epistemic and the normative in the aftermath of the Bhopal tragedy, where an industrial gas leak in 1984 caused the deaths of an estimated 16,000 people. In this case, epistemic closure about the causes and consequences of the disaster could not be attained prior to normative closure about the patterns of responsibility and blame, and science was just one voice among many in the process of achieving closure (Jasanoff 1988; 2007). A similar patterning of the epistemic and the normative is evident in the approach of bodies like CSE to environmental knowledge-making, particularly in the emphasis on responsibility in climate change debates, and also in Ramesh's response both to the IPCC glacier incident and to what he saw as being shortfalls in the Indian government's ability to both know and manage climate change. In what follows, I will give further illustration of how co-productionist understandings of order and change can function as strategic resources *within* the co-production of knowledge and social order.

Jairam Ramesh and the re-ordering of climate science and politics

Although a number of NGO actors have been sceptical about Ramesh's approach to the international climate negotiations, the majority of my respondents viewed Ramesh quite favourably, particularly his grasp of scientific issues. He was widely perceived as being competent in dealing with conflicting scientific opinions on matters such as the state of the Himalayan glaciers, and an individual who worked closely with MoEF for a decade described him as having "the mind of a scientist" (interview 42, government analyst). In a similar vein, a prominent NGO actor stated in an interview that he felt that whereas scientists or other specialists may be consulted on policy issues, "ultimately it is a clutch of politicians and bureaucrats who take policy decisions according to their own preferences and compulsions, particularly since they themselves do not have a sound understanding of the subject or where the specialists are coming from" (personal communication, January 2013). In contrast he characterised Ramesh as "a highly educated engineer and management science guy, so he was confident in dealing with the scientific community" (interview 37, science and technology NGO director; see also Agarwal 2001).

Ramesh's reputation for changing the epistemic foundations of climate governance in India has in part been enhanced by INCCA, which was largely his own innovation. However, much of the network of scientists and data that constituted INCCA was in existence prior to 2009, in the form of the network that put together India's first *National Communication* document under the UNFCCC; this document included climate projections and some impact analysis for the last few decades of the 21st century. Although INCCA was to some degree a re-packaging of already existing knowledge and capacity, for another NGO representative it represented a "substantive and productive effort" to draw attention to the climate issue. In this sense INCCA in part reflected other examples of Jairam Ramesh instigating political initiatives on particular issues which did not necessarily "represent a deliberate departure from past policy positions", but which "drew attention to issues through creating new fora and discussion" (interview 17, climate policy analyst; personal communication, January 2013).

If INCCA represents a partial continuation of existing developments in climate science in India, then the framing and promotion of the 4x4 assessment can offer insights into the changing configurations of climate science and policy in the country. Media coverage was particularly interested in the idea that INCCA represented something of an 'Indian IPCC' and an indication of India's increasing autonomy in scientific matters pertaining to climate change (see e.g. *Indian Express*, 13 October 2009, document 232). As discussed above, this was a framing evident in the minister's foreword to the report.

Politics of time and space

It is particularly instructive to explore the framing of the scientific study itself, particularly its spatial and temporal coordinates. Climate change as a global risk issue poses distinct challenges to the territorial logic of the modern nation state. Posed as a question of global impacts and international responsibility, climate change knowledges have been most prominently pursued through transnational spaces like the IPCC. However, it is important not to lose sight of the processes through which climate change has been rendered a governable entity at the national scale through the pursuit of knowledges that accord with and extend the historical project of knowing and governing a national territory (cf. Oels 2005; Whitehead et al. 2007, 203-206). The temporal and spatial coordinates of the INCCA assessment offer insights into how territory and climate change are being brought (and thought) together in a governmental setting.

The INCCA 4x4 assessment presents projections for the 2030s, an unusual strategy in regional climate prediction, where answers are usually sought for 2050 onwards (Hulme & Dessai 2008). The desire for projections for the 2030s came from Ramesh himself, and not from the scientists running the regional climate model[89]. It could be surmised that projections for the 2030s were an attempt to reclaim that decade of India's future from the erroneous clutches of the 2035 melting glaciers claim. However, it seems that by locating climate change impacts on a timescale of more human proportions, Ramesh was attempting to inculcate a sense of political urgency amongst his fellow political actors. He offered an additional motivation in a speech he gave in New Delhi in November 2010:

> The important thing of this assessment is that it is for the year 2030. It's very important. I want to stress this, because all assessments of climate change are for the year 2060 or 2070, when none of us will be around. So that's why we are safe when we make all these projections. I told these guys "you have to make studies and assessments for periods in

[89] How the years 2050 and 2100 came be stabilised as future-visioning horizons at the science-policy interface is an interesting empirical question. In regional climate modelling, near-term projections (e.g. for the 2030s) can be problematic due to the prevalence of uncertainties relating to the internal variability of regional climates. See Hawkins and Sutton (2009).

> which you will be alive to be held accountable" [murmuring and laughter in the audience].
>
> (document 362)

This language of accountability and of not being "safe" in the temporal distance of one's epistemic claims accords with the co-production of the epistemic and the normative that is clearly evident elsewhere in the episode. Despite the scientists' residing in a government research institution, trust in their predictions is not automatic or given, and the implication is that the scientists would not only be accountable for the accuracy of their predictions, but also in part for the political actions that are taken on the basis of the predictions. Questions of knowledge and of political action thus converge at the temporal horizon of the year 2030 (cf. Beck et al. 2013, 10).

The spatial coverage of the impacts assessment also reveals certain logics of relating predictive knowledge to political action. The initial climate projections used in the INCCA assessment were generated for an area covering the nation as a whole. However, the impacts analysis, for human health and agriculture for example, is conducted for four regions (see figure 8.1). This zooming-in was in the first instance an effort to save time, as it is clear that Ramesh wanted a report published quickly. However, the selection of these four regions reveals an interesting territorial logic. The regions don't correspond to conventional climatic or agricultural zones, but rather represent regions of particular natural resource wealth and vulnerability, for example the forests of the North-East and the water resources of the Himalayan region. The tacit metrics of vulnerability by which the regions were selected don't speak of fragile human livelihoods, but rather of national economic and broad-scale ecological security.

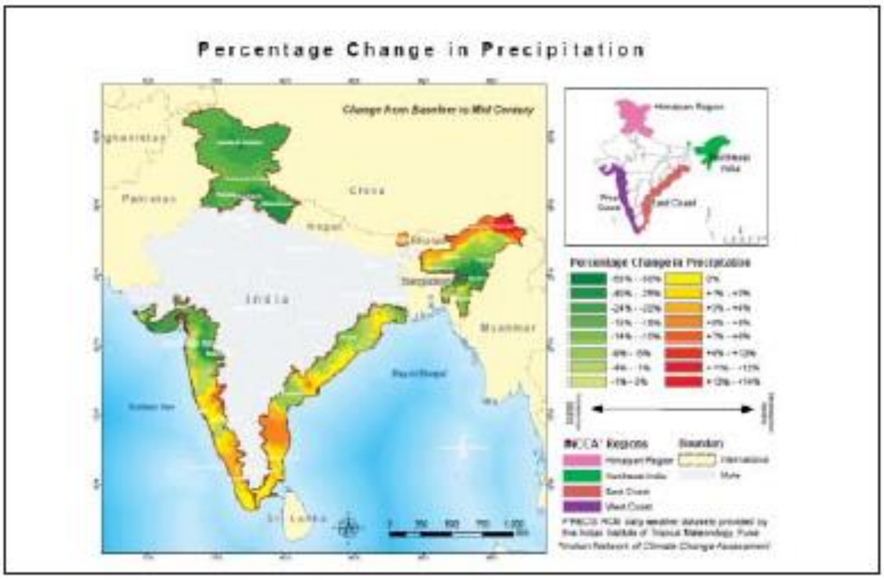

Figure 8.1. Projected changes in precipitation in the four regions. Reproduced from INCCA (2010b, 122).

The projections used in the INCCA assessment were generated by scientists at the IITM in Pune, which reports to the Ministry of Earth Sciences. The scientists there use a regional climate model called PRECIS which was developed by the UK's Met Office Hadley Centre with the expressed aim of enabling developing countries to produce regional climate scenarios to support adaptation policy making.

PRECIS, which includes a regional climate model and software that enables it to run on any personal computer, is now at work in over 100 countries, and has formed the basis of many national communications under the UNFCCC and other analytic exercises. As a transnational community of actors united by shared epistemic commitments, the PRECIS network illustrates the geographic complexity of climate change knowledge production. Although used here alongside assertions of national scientific autonomy, the model's global spread depends on its association with the prestigious Hadley Centre and on its links with the largely European and North American infrastructures of global climate simulation (Mahony & Hulme 2012)[90].

[90] Mahony & Hulme (2012) argue that the wide application of PRECIS has been achieved by the packaging of the model into a 'black box', meaning that users are unable to see or change the computer code which underlies the model, and thus they are unable to consider the sensitivity of their regional scenarios to the unique characteristics of the model. This is a problem which some philosophers of science have called 'epistemic opacity' – raising the question of whether one needs to

In the case of Indian knowledge-making, this itinerant climate model has become enmeshed in a new network of epistemic accountability and in articulations of national scientific autonomy. It thus functions as a powerful boundary object between the worlds of science and politics, much like the global models from which it is descended (Shackley & Wynne 1996). Miller (2004b) argues that the global gaze offered by climate science and global atmospheric models developed in tandem with the increasingly globalist imagination of a political solution to the knowing and managing of climate change. The exchange of globalist visions of scientific and political order can explain how climate models came to occupy such a prominent position at the science-policy interface, as described by Shackley & Wynne (1996), Demeritt (2001), Oels (2005) and others. In this case, however, the gaze is no longer just global; it is regional or, more precisely, national. A regional model is positioned over the Indian subcontinent and is used to generate national cartographies of environmental change. The question therefore becomes: how is this emergent and increasingly popular means of viewing climate change being co-produced with evolving forms of political order?

Governmental knowledges and national space

The task of addressing this question can be started by considering the broader epistemic landscape within which this predictive knowledge sits. Ramesh, whenever he has spoken of the need for India to act on climate change, has made the claim that India is the country most vulnerable to the effects of climate change. He has described this vulnerability in terms of four facets: the monsoon, the vulnerability of India's forest cover to the demands for mineral resource extraction, the Himalayan glaciers, and coastal vulnerability to rising sea levels.

In the same speech in which he spoke of the accountability of the climate modellers, Ramesh offered a glimpse of the epistemic underpinnings of this claim. The monsoon vulnerability he describes by discussing a correlation between GDP growth rates and

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know what's going on inside a model in order to make sense of what comes out of it (e.g. Humphreys 2009).

monsoon variability[91]. On forests, he depicts a spatial correlation between forest areas and areas of mineral wealth. On glaciers, he notes the dependence of many millions of people on the water that springs from the Himalayan range, but, like Raina (2009), he does not offer a particular sense of the glaciers' future under climate change. One Indian NGO grouping deemed this ambiguity as tantamount to 'climate denialism' (CCI Coalition 2008)[92]. On coastal vulnerabilities, Ramesh states that "if there is one robust scientific conclusion that has been reached after 20 years of research on climate change, the one thing on which there is no controversy is the rise in mean sea levels" (cf. O'Reilly, et al. 2012).

Together, these claims constitute an archetypal collection of government knowledges – variously ambiguous and certain international science, the oscillations of the national economy as measured by a single metric that seeks to capture all the productive activity taking place within a pre-defined national space, and the spatial coincidence of two types of resource – mineral and arboricultural, as observable on a map of the country's resource richness. The latter two examples represent the kind of the governmental gaze described by James Scott in *Seeing Like a State* (1998); the homogenizing and ordering eye of political power (see also Sivaramakrishnan 1999). The construction, especially by the state, of forest areas in particular as collections of resources for national exploitation rather than spaces of human habitation and ecological interdependence is a long-standing object of critique in India (Guha 2006, 90-124).

This collection of ways of knowing a national space suggests that when climate change and its implications come to be known at the national level, the process is much more complex than just downscaling the results of global climate projections. Rather, 'downscaling' climate change means that the idea comes into contact with a number of political and cultural norms and ways of knowing that, this episode suggests, will be unique to particular national and even sub-national contexts.

[91] On the links between the monsoon, an emergent meteorology and colonial political economy in India, see Anderson (2005).

[92] In responses to parliamentary questions around this time on the state of the Himalayan glaciers, the Minister of Environment and Forests was much more cautious in attributing trends to anthropogenic causes than his counterpart at the Ministry of Science and Technology.

Climate change predictions are integrated into longer stories of national progress, of collective experiences and risks, and different logics of relating economy, government, environment, and national space (cf. Jasanoff and Martello 2004).

These logics have informed and reinforced India's approach to international climate negotiations, with the norms of per capita responsibility and the right to development informing India's resistance to binding emissions targets since the inception of the UN negotiations (Dasgupta 2011). However, in the period in which this study is situated, a noticeable shift in India's stance took place. This began in 2007 with Prime Minister Manmohan Singh announcing that India's per capita emissions would never exceed those of industrialised countries, essentially introducing for the first time the idea of a national emissions cap. Jogesh (2011) reports that media coverage of climate change in the period 2007-2009 gave increasing space to accounts which challenged dominant narratives of a clear 'North-South' divide in the responsibility for emissions cuts (cf. Billett 2009). By the time of COP16 in 2010, Ramesh had introduced the notion of "equitable access to sustainable development", which can be seen as an attempt to mediate between the long-institutionalised concerns for equity and material development and an apparent desire to be seen to play a more constructive role in international negotiations (Dubash 2009; Stevenson 2011; Atteridge et al. 2012).

Indian negotiators, along with their US counterparts, were at the forefront of moves to inculcate a "pledge-and-review" system of emissions cuts, whereby nation-states would voluntarily pledge mitigation actions that would then be monitored by international bodies (see Hare et al. 2010). These moves led to fierce debates in parliament between the minister and those who saw Ramesh as ceding sovereignty to outside actors, or as one Member of Parliament put it, "gifting away our carbon space". However, Ramesh countered such concerns by re-affirming his vision of India's unique vulnerability, and by arguing that incidents when Indian science has countered the received wisdom demonstrate that the country does not need to be defensive when it comes to the international monitoring of domestic mitigation efforts (Prabhu 2011).

For some commentators, the policy shift between 2007 and 2010 resulted from a fear of isolation on the global stage. At the same time, many domestic actors and campaigners, such as those at CSE, criticised Ramesh for what they perceived as an attempt to align India's position with that of the US, and for uncritically embracing neoliberal approaches to mitigation such as market mechanisms and transnational carbon abatement (e.g. D'Monte 2009; CSE 2010). Ramesh's manoeuvrings were seen as running counter to the demands of poverty reduction, livelihood protection, and economic sovereignty, while extending the government's embracing of a neoliberal, globalist discourse and economic paradigm (Atteridge et al. 2012).

The focus of many Indian environmental campaigners on questions of poverty and justice perhaps explains why the policy goal of limiting global temperature rise to 2°C above pre-industrial levels has been a rare feature of climate change discourse in India. Like the refusal to accept binding limits to emissions, the eschewing of abstract planetary limits serves to foreground a framing of climate change which emphasises the place-based entanglement of human livelihoods, environmental change, and the developmental ambitions of a government committed to economic growth as a means of ensuring human security at various levels of collective activity. However, India's endorsement of the Copenhagen Accord in 2009 – with its 'recognition' of the need to limit the global temperature rise to 2°C – was indicative of Ramesh's efforts to reformulate the Indian government's approach to the governance of a global climate. For climate change campaigner Manu Sharma, founder of Climate Revolution, this shift owed more to geopolitical strategizing than an acknowledgement of the science of dangerous climate change. In a series of Right to Information[93] requests, Sharma challenged the epistemic basis of the government's approach to the governance of global climate thresholds. In response, MoEF officials wrote that "no information exists in our records with regard to research being commissioned by the Ministry to validate if 2 degree centigrade of warming is a safe target for India" (document 239), and that MoEF "does not have any view on the safe concentration of CO_2 in the atmosphere and the Government discussions are being held based on IPCC

[93] Like the UK's Freedom of Information Act, the Right to Information Act (2005) enables any citizen to request information from public authorities, and requires such authorities to retain digital records and to pro-actively publish selected categories of information.

Assessment Report IV – Vol. 1" (document 238). For Sharma, this represented an ignorance of new research which problematised the definition of 2°C as a threshold of danger (see Chapter 7) and an eschewing of the government's responsibility to its poorest citizens:

> It is of tremendous significance that the government admits of not knowing what is safe for its citizens…If our policymakers aim even slightly wrong on climate targets today, it is easy to conceive that hundreds of million people might end up outside the climate protection boundary tomorrow. And if we are way off target, no one can predict how many will survive to see the next century.
>
> (Sharma 2010)[94]

The tensions between the responsibilities of government towards its citizens, the global climate and the national economy were manifest even within the government's climate negotiation team, with several veteran members only agreeing to go with Ramesh to the 2009 Copenhagen negotiations after eleventh-hour efforts at reconciliation. However, Ramesh also at times offered readings of the relationship between the national and the international which accorded more directly with the political narratives which had dominated Indian climate politics since the early 1990s (Dubash 2013). For example, in stressing a need to "de-link" domestic policy actions from the international proceedings, Ramesh stated in 2010 that:

> Unfortunately, our approach to climate change has been unduly influenced by international negotiations. We need to de-link what we do from international negotiations. We need to ask ourselves the question

[94] Sharma also criticises the government for failing to embrace new research which posits carbon budgets as the most effective way to calculate how much carbon can be emitted before certain climatic thresholds are reached, and to allocate national allowances on such a basis (see also Raghunandan 2011). By contrast, government-sponsored calculations of national emissions focus on per capita contributions, rather than on the relationship between national emissions and global thresholds (see MoEF, 2009b). This insistence on per capita calculation has been criticised by some as being tantamount to 'hiding behind the poor' in international policy debates (Chakravarty & Ramana 2011).

> "what is in our interest?" and mount the appropriate response.
>
> (document 362)

Statements such as these illustrate arguments put forward by Kythreotis (2012) that the re-assertion of nation state territoriality in the recent evolution of the climate change debate challenges the commonly idealised vision of a post-political consensual environment of international collectivism (see Swyngedouw 2010). The concept of territoriality, conceived by Kythreotis as the relational effect of uneven economic power and the articulation of interests and differences within and between state borders, offers a powerful way of understanding the partial fragmentation of the global climate governance regime and the groundswell of support for more 'bottom-up' approaches to climate politics (Biermann & Pattberg 2009; Kythreotis 2012).

The 'pledge-and-review' approach can be read as an attempt to articulate territoriality within a policy architecture that has historically been geared towards multilateral agreement (cf. Hare et al. 2010). State-based processes of emissions accounting such as the INCCA inventory (INCCA, 2010a) produce "a peculiar situation whereby a territorial substance…which contributes to a change in the operation of natural systems at a post-territoriality scale, is conceived of, classified, and managed through its association with the persistent territorialities of nation-states" (Whitehead et al. 2007, 205; see also Lövbrand & Stripple 2011). Like INCCA's (2010b) predictions, this act of measurement and classification reconstitutes territory as a form of political order in the face of the deterritorialising potential of the carbon dioxide molecule (cf. Agarwal and Narain 1991).

Ramesh's characterisation of Indian domestic policy being "unduly influenced by international negotiations" restates and responds to criticisms of the government's overriding focus on the UNFCCC process and its eschewing of other ways of knowing and acting upon climate change. INCCA has informed the arguments for delinking domestic and international policy action. Predictive knowledge of national territory is seen as offering the Indian government the means to pursue mitigation and adaptation policies independently of the international scientific and political processes. With the addition of renewed knowledge of national emissions, national territory becomes a newly governable object with which particular forms of political action can be exercised by a government sensitive to criticism that it has ceded nation-state sovereignty over the Indian economy and environment. However, the resistances to Ramesh's efforts to alter the terms of India's engagement with international climate mitigation negotiations, particularly efforts to enmesh the state in a new, highly disputed form of neoliberal globalism, are reminders that the redefinition of what, as Ramesh put it, is "in our interest", is a contested terrain. Territoriality and territory are not pre-given in such debates. Rather, like the nation-state itself, they are constituted through networks "held together by circulating technologies of representation and communication" (Jasanoff 2004c, 26; see also Elden 2007). The participation of climate models in these processes marks an important extension and re-casting of longer traditions of national knowledge-making (Edney 1997; Scott 1998; Sivaramakrishnan 1999).

Conclusions

Jairam Ramesh's claims about India being the epitome of vulnerability to climate change direct us to an earlier episode in the history of the relationship between prediction and national space. In the 19th century British meteorologists were engaged in trying to piece together synoptic – or large-scale – patterns of atmospheric behaviour. This work was complicated by these scientists' location on a small grouping of islands off the north-west coast of mainland Europe, and they grew increasingly frustrated by the seemingly faster progress of American meteorologists in putting together convincing descriptions and explanations of synoptic weather patterns. Attributing this to the Americans' access to a vast continental space over which the atmosphere could be observed, the British meteorologists saw in India a similar opportunity to add scale to their activities (Anderson 2005).

In addition to India's vastness, they viewed the subcontinent as the "epitome of meteorology" (ibid, 248), in that contained within its apparently natural geographical borders was a seemingly self-contained climate which traversed mountains, glaciers, deserts, tropical vegetation and a coastline visited regularly and seemingly predictably by that characteristic atmospheric phenomenon – the monsoon. In Anderson's study of the history of British weather prediction, she argues that the meteorologists – such as Henry Francis Blanford and later Gilbert Walker – along with their imperial backers saw in India a natural laboratory not only for the emerging science, but one in which to demonstrate the political importance of science and rational, centralised management of a territory which was seen as being inherently chaotic and unruly. By 1878, seasonal forecasts of the monsoon were being produced in order to anticipate what were seen as being environmental determinants of political unrest, specifically in response to emerging correlations between monsoon failure and famine. In this historical case, we can see an example of the co-production of scientific knowledge and a particular form of social and territorial order.

Territory, as a form of social order, is both premised on and generative of certain kinds of governmental knowledge-making, particularly the measurement and calculation of space and spatial relationships. In the more recent case offered here we can see a re-emergence or perhaps re-coding of territory as an epistemic object. That re-coding is evident, for example, in new temporal coordinates. Specifically, there is an emerging concern with the *future* of territory, in efforts to induce a new anticipative approach to problems of resource management and human development, and in order to persuade and convince other political actors of the need to transform the state's engagement with both domestic and international climate politics. Territory is mediated through a didactic futurology, by which it comes to figure as an object of combined epistemic and normative contestation (cf. Beck et al. 2013, 9-12).

A further observation that should be made about the spatial re-working of territory is that practices of regional climate prediction in contexts such as this contribute to the extension of a territorial consciousness from the horizontal plane to the vertical (Braun 2000; Elden 2013); supplementing the two dimensions of the cartographic map with simulations of the sky-bound hurrying of atmospheric matter and energy. The result is a kind of multidimensional 'cartography of the future'[95]. But like

[95] Rose (2007) proposes the development of 'cartographies of the future' which would map possible ways of knowing and governing which stand as alternatives to modern biopolitics (Foucault 2010) and biocapital (Sunder Rajan 2006). I use the notion here in a more prosaic and literal way, although

conventional cartographies, these emerging forms can be studied as situated, contingent, and always-already political means of seeing and representing the world (cf. Cosgrove 2001; Wood & Fels 2008; Sloterdijk 2009). As I've sought to demonstrate, these new cartographies have come about amid a set of very particular responses to the nature of international science and the changing nature of international climate politics. Although many countries across the world are now pursuing what we might think of as territorial knowledge of the future (see e.g. Jenkins et al. 2009 for the UK; MoST 2011 for China), in India the form of this emergent knowledge has been shaped by the context of a complex and at times antagonistic relationship with the so-called 'Western' science of the IPCC. The controversy over the melting glaciers claim reanimated themes of epistemic and political sovereignty which have long informed climate politics in India. A persistent pattern of epistemic and normative intermixing situates predictive knowledge claims within a framework of scientific accountability and national autonomy, in a powerful illustration of how the science and politics of climate change are mutually constituted. This is the quintessential co-productionist understanding of climate change. But I have suggested that in this case, the co-production of the epistemic and the normative has a particular valence, to the point where a co-productionist understanding of science and politics becomes a strategic instrument in the ongoing construction of social order.

It is in this sense that we might begin to think about the agonistic co-existence of different co-productions, particularly in the different strategies of reproducing the nation-state in the putative global space of international climate science and politics. Recalling the incident with which I opened the chapter, the Indian chair of the IPCC rebuffed the Indian government's challenge to IPCC claims by dismissing them as "arrogant" and "voodoo science". In defending the space of global science against governmental attack, Rajendra Pachauri sought to discredit the government's scientific claims by painting them as politically-driven and scientifically disreputable. A number of Indian environmental NGOs have similarly argued for the subordination of

interesting questions are raised about the participation of such predictive knowledges in broader forms of biopolitical or subversive imaginings of collective futures.

the nation-state to the authority of global science, although bodies like CSE have long argued for the strident defence of national sovereignty in the international politics of climate change. In his own response to the glacier error, Jairam Ramesh sought to re-inscribe the national in the global space of climate science and politics by articulating (and practicing) an epistemic sovereignty alongside moves to re-order the relationship between national and international climate policy. Ramesh's political 'internationalism' (Dubash 2013) was thus distinct from the kind of epistemic globalism (Miller 2009) mobilised by Pachauri. Ramesh's efforts to re-inscribe the national in international climate politics (through embracing strategic alliances and voluntary pledges) did not, however, sit comfortably with the way CSE articulated the relationship between knowledge and action, and national and global (CSE 2010). These different co-productions of knowledge and social order co-exist in dynamic and agonistic tension, with science playing different roles in each. Disentangling such articulations of space, knowledge and power may be aided by renewed empirical and conceptual exchange between STS and critical human geography.

My observations about the re-emergence of territory as a political object in climate debates concur with a number of arguments that have been advanced regarding the fragmentation of the global climate governance architecture and the seeming re-assertion of nation state territoriality and sovereignty in questions about ethics, responsibility and development rights (Biermann & Pattberg 2009; Prins et al. 2010; Kythreotis 2012). However, the way in which the climate becomes a knowable object in national contexts is contingent both on transnational knowledge networks, such as the PRECIS system, that challenge assertions of national scientific autonomy, and on local modes of authorising and acting upon knowledge, or civic epistemologies. In turn, the ways in which the climate re-emerges as a local object, described in terms of national space, may begin to shape how states conceive their very sovereignty and responsibility to their own citizens and to others (Jasanoff & Martello 2004; Beck 2009).

It is in this sense that it is vital to further explore the co-production of territory in the complex relationship between climate science and politics. Through the study of controversy and emergence, insights can be gained into the processes by which the epistemic and the normative mutually shape and condition each other in the ongoing construction of political order. The idiom of co-production therefore has the potential to contribute to the project of historicizing the role of scientific rationalities in the production of particular forms of spatial organisation, such as territory, and to offer new insights into the evolving spatiality of science and the nation-state in an era of apparent epistemic and political globalisation.

Chapter 9

Conclusions

Epistemic geographies of climate change

A key theme of this thesis has been that our understanding of the geographies of science might benefit from renewed engagement with both constitutive and interactional modes of co-productionist inquiry. Constitutive co-production draws attention to the attainment of ontological stability at certain privileged sites of knowledge production in the form of, for example, constitutional settlements of the distinction between nature and culture (Latour 1993; Castree & Braun 2001; see also Whitehead 1920). Interactional co-production by contrast draws our analytical gaze towards the never-ending struggles to define the authority upon which certain actors may base their claims to adequately represent and govern the form of metaphysical order achieved through processes of constitutive co-production. Here, the interest in constitutional settlements lies in "the ways in which social and institutional processes for producing, validating, contesting and disseminating factual claims help to enable or constrain the exercise of power" (Miller 2009, 142). Boundaries between science and politics become objects of inquiry in addition to boundaries between nature and culture (Gieryn 1999). Struggles over the determination and definition of meaning transcend questions of representational realism and are reconceived as constitutive elements of the entangling of knowledge and power (Rouse 1987; Beck 2009). In this concluding chapter, I seek to revisit such insights in light of my own empirical findings. I aim to show that in attending to the spaces, boundaries and politics of knowing, geographers of science can make important new contributions to our knowledge of the interactional co-production of knowledge and social order. However, I will also argue that this has implications for how we understand the constitutive co-production of broader constitutional orders – of nature and culture, of the global, the national, the climatic and the anthropogenic. I will situate this argument within the present debate about the existence or definition of the 'Anthropocene', and will make a case for geographers of science to attend to the emergent spatialities of anthropocenic knowledge politics. In the first instance though, let us turn back to my own explorations of the spaces, boundaries and politics of climate change knowledges.

In Chapter 3 I introduced the research question which has guided my subsequent empirical work:

> *How have the spaces and boundaries of climate change science been contested in the recent history of international environmental politics, and with what effects?*

Beginning in Chapter 5 with the colourful epistemic collage of the burning embers and continuing through to Chapter 8 and the spatial politics of predictive knowledge in India, I have explored moments of contestation, negotiation and (de)stabilisation in efforts to collectively reason about the future course and consequences of global climate change. It is in such contestation that I locate the politics of knowing, and I have suggested that such politics cannot be separated from questions of spaces and boundaries. I will now turn to each of these concepts in turn, to draw together insights arising from my empirical investigations.

Spaces

I have explored the politics of knowledge making across a diversity of spaces; diverse not just in location, but in form. The diagrammatic space of the burning embers graphic was a political space – not in the sense of being 'unscientific', but in the sense of being a site of both contestation and power (Torfing 1999). The city of Copenhagen in 2009 became a political space in a rather conventional sense, in that it became the site of political negotiation, intrigue, and frustration. Within this political milieu new spaces were carved-out for the delivery of scientific information to political decision-makers. These textual and deliberative spaces were marked by varying degrees of epistemic plurality which was often eschewed in favour of a pragmatic politics of reductive targets which was seen as being generative of political consensus[96]. In my

[96] The pragmatism of the Danish Prime Minister is distinct from the political pragmatism proposed by the Hartwell group of climate policy analysts (Prins et al. 2010).

final case study, the national space of India became an object of epistemic contestation as new territorial knowledge emerged amid tussles over the future both of nonhuman objects such as glaciers, and of the human-nonhuman assemblage which constitutes a national economy and sovereign state.

In his study of the governmentalisation of the atmosphere in nineteenth-century Britain, Mark Whitehead (2011) argues that, following Foucault, attending to the relationship between scientific knowledge and political power requires attending to the multiple ways in which space comes to feature as a mediator in the co-production of science and social order[97]. Following Whitehead, we may identify three ways in which space features in my analysis of climatic knowledges. C*onstitutive space*[98] refers to the "geographical constitution of knowledge" and "the role of culturally meaningful space (or *place*)… [and] of meaningful movement (or *mobility*)" in the constitution of scientific knowledge and its interpretive geographies. (ibid, 213, emphasis in original). S*pace-as-epistemology* denotes the spatial conditioning of knowledge and the role of knowledges *of* space as "explanatory context[s] for air [or climatic] interpretation" (ibid, 214). S*pace-as-rationality* refers to the "association between space and rationalities (or the balanced reasons) of and for government", in the "dialectical relation" between *space-as-epistemology* and the rationalities of particular modes and forms of government (ibid)[99]. These three analytical themes offer a way of unpacking the diverse spatialities I have encountered. By exploring them each in turn, I seek to develop my argument about the utility of a co-productionist approach to understanding the epistemic geographies of climate change.

Constitutive space

Methodologically, I was drawn to contexts where meaningful spatialities played a role in the constitution of knowledges. In Copenhagen, I argued that the city took on a

[97] Whitehead does not frame his analysis in co-productionist terms but his arguments certainly resonate with the idiom, as pointed out by Sam Randalls in a review forum (Coe et al. 2012).
[98] Whitehead frames this according to his own analytical *method* of tracing the places and mobilities of knowledges. I find that the notion of *constitutive space* better captures the conceptual specificity Whitehead alludes to.
[99] Whitehead uses Foucault's notion of governmentality to discuss the changing modalities of atmospheric governance and their associated assumptions, subjectivities and spatial relations.

range of meanings associated with the hope of a political deal at the UN climate talks. This inflected the knowledge making activities of the Climate Congress and the *Copenhagen Diagnosis* with a palpable sense of urgency. For the *Diagnosis*, this played-out through arguments about the urgency of political action in light of rapid timescales of change in the climate system. For the Congress, this urgency was supplemented with a need to rapidly and succinctly communicate to the Danish Prime Minister "what science says" (see page 181). There was a strong political commitment within the Danish polity to the achievement of a political deal in Copenhagen: "They want[ed] their name on this agreement. They want[ed] it to go down in history as the moment the world really got on top of this problem" (Angela Anderson, quoted in Kysar 2010, 284). This ambition was channelled into a commitment to the target of limiting global temperature rise to 2°C as a focal point of political negotiation – a product of over a decade of European science-policy debates. The exchange between leading climate change scientists and Prime Minister Rasmussen on the final day of the conference should be read as a moment of knowledge production – of hermeneutic encounter (Livingstone 2005b) – rather than of linear (mis)communication. This knowledge production was inflected with the demands of its spatial setting; with the particular form of politics being pursued by the hosts of the climate talks. With the Copenhagen Accord, the city will go down in history as the place where global leaders 'recognised' the importance of limiting warming to 2°C, even if little was achieved in the form of plans to meet such a target.

The case of the burning embers offers an example of meaningful mobility (cf. Cresswell 2006; Merriman et al. 2013). The mutability of this mobile object (cf. Mol & Law 1994; de Laet & Mol 2000) gave it an iconicity in climate change debates as it became a useful tool for different actors to construct new arguments and diverse interpretations. When this roving representation arrived in Copenhagen in 2009, it was mobilised by some as evidence for the increasingly questionable assumptions of the 2°C target. For some of its creators, the diagram couldn't offer sufficient certitude to make such political judgments. Yet, as Jasanoff (2010, 234) argues, it is "this very capacity to make ideas and objects that travel, spilling over the limits of lived experience, that students of the scientific enterprise have taken as the foundation of science's special cognitive authority". The burning embers was a powerful object bearing a number of consequential ideas, concerning for example the prospect of economic damage, the spectre of climatic extremes, and even the possibility that human actions may tip the climate system into a new, unforeseeable and potentially dangerous new state. The rendering of such ideas into a visually striking red haze drew on a cultural lineage shared by the sciences and liberal democratic cultures which positions visualisation as a central means of knowledge production and as a medium of political action (Ezrahi 1990). Such visualisations and their attendant forms of vision (Cosgrove 2008) are always situated (Haraway 1989; 1991), yet their mobility and discursive power stems in large part from the elision of geography; from the packing of the world into the limited dimensionality of a graphical representation (Latour 1990).

Chapter 8 continued this interest in meaningful mobilities by tracking the circulation of particular objects of climate change discourse. Like the diverse responses to the burning embers framework in the IPCC review process, the responses to the IPCC's erroneous melting glaciers claim highlight how scientific claims "bearing on the global environment never take root in a neutral interpretive field; they are dropped into contexts that have already been conditioned to produce distinctive cultural responses to scientific claims" (Jasanoff 2010, 24). In both Chapter 6 and Chapter 8 I used the notion of civic epistemology to characterise these contexts of "cultural responses". The glacial error met with a lineage of epistemic contestation which places scientific attempts to render the world as it *is* into close concert with efforts by particular groups to render the world as they think it *ought to be*. The travelling knowledges rolled into the Himalayan glacier claim took on a particular meaningfulness associated with a history of contested 'Western' science. Thus the travelling knowledges of the IPCC took on associations of travelling political power, of economic sovereignty ebbing away from the state, and of travelling codes of political action which challenged established, local modes of relating knowledge to action.

The place of the Himalayan glaciers played a key role in the moral economy of this particular controversy, allowing arguments of territorial ownership ("our glaciers") to entwine with arguments for epistemic sovereignty in the slippery space between domestic and international climate politics (cf. Agnew 1994). This sovereignty was sought in part through engagement with another prominent mobile actor of contemporary climate change discourse – the PRECIS regional climate modelling system. The model participates in the production of governmental knowledges the world over, and can be critiqued for the assumptions which travel with it about the centrality of prediction to robust climate adaptation (Mahony & Hulme 2012). Yet in this case, we can see how this tool has also participated in the generation of new national governmental knowledges which point to the inevitable cosmopolitan diversity of climatic knowledges (Hulme 2010b; Beck et al. 2013) even in the face of powerful epistemic communities and networks like that assembled around the PRECIS model.

Space-as-epistemology

The constitutive significance of space in the Indian case study is closely associated with the role of space as an epistemological category and as a mode of interpretation. The Indian environment minister's reference to "our glaciers" and "our monsoons" reminds us of the importance of affording agency to landscape in our accounts of the location of science (Livingstone 2010), without of course falling into the trap of environmental determinism in explaining locational patterns (e.g. Dorn 1991)[100]. The Indian subcontinent constituted a distinctive knowledge space – an "assemblage of linked sites, people and activities…given coherence through the social labour of creating equivalences and connections" (Turnbull 2000, 20)[101]. This coherence worked for the Victorian meteorologists, who a perceived an almost self-contained climatic laboratory ripe for meteorological investigation and theorisation (Anderson 2005).

In 2009, the Indian climate again became an object of coherence through the social labour of responding forcefully to the IPCC glacier error, of positioning a regional

[100] Interestingly, Steve Schneider (see Chapter 6) reviewed Dorn's *Geography of Science* in the journal *Climatic Change*, prompting interesting reflections on the pure/applied science distinction and the nature of interdisciplinarity (Schneider 1993).

[101] See also Turnbull (1996). Turnbull speaks often of the 'coproduction' of knowledge spaces, but seems to refer more to the collaborative efforts of states and scientists *within* processes of generating spatial knowledges, rather than to the conjoined evolution of broader, culturally-situated epistemic and normative commitments *through* processes of producing spatial knowledges.

climate model over a codified representation of the subcontinent, and of publicising new knowledge claims as an example of a renewed epistemic sovereignty. To say that the carving-out of this national knowledge space was a *political* act would be to risk suggesting that science which is not so tightly bound to the activities of national governments possesses a greater distance from 'politics', and that politics only resides in the government of nation-states. This knowledge space nonetheless had its own unique political and moral coordinates, drawn from a history of competing representations of national space. As Turnbull (2000, 20) argues, knowledge spaces are "polysemous and are capable of many possible modes of assemblage and of providing alternative interpretations and meanings. Hence all knowledge spaces are potential sites of resistance." In the recent history of environmental politics in India, constructing knowledge of 'the national' has been a contested affair in a poly-vocal field of actors with diverse interpretive and moral commitments.

In the case of the burning embers diagram, the mode of spatial representation employed was that of global aggregation. The authors of the diagram were aware of the elision of geographic specificity which their framework was engaged in, and struggled with the pull between situated, local framings of climate change impacts and the desire to represent the risks of global-scale transformations in the functioning of the earth system. The global climate was an ever-present object of concern – a function of the engagement with the question of what might constitute "dangerous anthropogenic interference" with the climate system. This small, rectangular space on the page of an IPCC report thus ostensibly came to stand for the combined risks and ambiguities of climate change impacts across the world and into the future, even as the underlying knowledge base itself carried a geographic skew towards regions where climate change research was more generously funded (Liverman 2009).

The patterns of interpretation of the diagram and its associated analytic framework, as evident in the IPCC review process, point to the situatedness of epistemic constructions of the global. Peter Sloterdijk (2009, 29) describes the "affair of Western reason with the totality of the world" and locates it in the development of Greek geometry and a subsequent metaphysical and representational fixation with the globe and with processes of globalisation (see also Heidegger 1977; Cosgrove 2001). Constructs such as the burning embers are arguably situated in this tradition, as are the simulation models which aim at a totality of representation with reference to the earth system and its various, interlocking components. This particular way of constructing the global through simulation – this uniquely panoptic 'eye of power' (Foucault 1979; Ashley 1983) – has its own geography: "the elite world of global climate simulation still includes no members from South or Central America, Africa, the Middle East, or Southern Asia" (Edwards 2010, 171). In the government reviews of the burning embers' chapter, it was governments such as the US, Germany and Australia who took the greatest concern with the scientific veracity and political implications of such global constructions. Like the knowledge space of the Indian subcontinent, this global space was a construction open to constant challenge, but challenges which were conspicuous by their geographical moorings. While the epistemological space may be global, it is a spatial construction which cannot be severed from the constitutive, local spaces of its production, circulation and contestation.

In Copenhagen, another set of situated constructions of the global emerged through the social labour of a diversity of scientific and political actors. Most significantly, the 2°C temperature rise target functioned as a means of assessing aggregated global emissions pathways while at the same time being challenged as an accurate threshold of 'dangerous' climate change. Local processes such as melting ice sheets posed challenges to this abstract figure, but the commitment of European diplomats to the target meant that it eventually took a prominent position in the final political agreement. Answers to the question of whether 2°C rightly represents 'dangerous' climate change are mediated by local knowledges. The designers of the burning embers sought to stress this by emphasising the value-ladenness of such judgments, and by acknowledging the judgments which they themselves had to employ in making their own global aggregation. The moment of hermeneutic encounter between the Danish Prime Minister and the Congress scientists further underscores the interpretive flexibility and contingency of responses to this metrological abstraction. The global temperature index stands "as a motif of a wider globalising instinct in the contemporary making of knowledge about environmental change" (Hulme 2010a, 560). Yet it is a motif which resides in its own web of situated meanings and interpretive commitments.

Space-as-rationality

These epistemic constructions of space cannot be understood without reference to the particular forms of governmental rationality with which they are co-produced. The discursive prominence of the 2°C target is a product both of a long process by which global temperature has been co-produced as a means of stabilising the science and politics of climate change (Miller 2004b; Hulme 2010a), and of a situated set of commitments to a targets-based approach to global climate governance (Shaw 2010). The aim of the latter is the rational management of anthropogenic climate change through the limiting of the deviation from a steady-state or even 'natural' global climate. Through legally-binding commitments to reduce emissions by a given amount, individual countries can contribute to the limiting of anthropogenic climate change to a level deemed to be the threshold of unacceptable danger. The burning embers diagram sought to contribute to the definition of this threshold, and its various iterations stood in a complicated relation to the cycle of stabilisation and destabilisation which the 2°C target endured. The aim of the diagram was to enable policymakers to decide for themselves what 'dangerous' might mean. The Danish Prime Minister abdicated some of this interpretive responsibility in demanding a single, unambiguous number from scientists with which he could continue his coalition building. This particular form of global rationality is thus a hybrid product of scientific abstraction and political strategy and one which, judged on its own terms, is yet to yield the kind of outcome to which it is orientated.

In Chapter 8 I sought to further articulate how these global rationalities can be contested. The carving-out of national territory from the simulated globality of the future climate proceeded in lock-step with the continued reassertion of nation-state territoriality in climate change debates (Kythreotis 2012). In the period in which I situated the majority of my study of Indian climate politics, there were transformations in how this territoriality was articulated. The long-established refusal to countenance legally binding emissions cuts morphed into a preference for a system of voluntary initiatives which could then themselves become levers for transnational negotiation. This politically controversial change in the relation between the national and the international was stage-managed by Jairam Ramesh through his insistence on epistemic sovereignty – on the need and capacity of the nation's scientists to produce new knowledge which could help guide the government through these unchartered waters of international negotiation and arbitration. New studies of India's current and future greenhouse gas emissions thus emerged alongside projections of future climatic changes, while Ramesh argued that the lineage of successful challenges to the dominant 'international' and 'Western' sciences of climate change meant that Indian policymakers should have no fear in subjecting the nation's accounts to the potentially prejudiced eye of outside scrutiny.

It is in such instances that we can see the root of the tensions inherent to the kind of global rationalities described above. Debates about climate change in India are framed not in relation to an abstract global ceiling of allowable change, but in relation to questions of human poverty, social injustice, local environmental degradation and economic sovereignty. This framing asserts the "nation's sovereign political right to imagine the future for its citizens" (Jasanoff 2010, 248). The spatial rationalities of national territory thus figure larger than the spatial rationalities of a climate system devoid of specificity and detached from local meanings (Hulme 2010a). These global rationalities – dubbed by Miller (2009) a 'unitary globalism' – strive to separate "the epistemic from the normative, divorcing is from ought." The dominant globalism "detaches global fact from local value, projecting a new, totalizing image of the world as it is, without regard for the layered investments that societies have made in worlds as they wish them to be" (Jasanoff 2010, 236). In the recent evolution of Indian climate politics, new epistemic articulations of territory were co-produced with shifting commitments to the modalities and mechanisms by which the national should be integrated into the international space of global climate politics. *Space-as-epistemology* and *space-as-rationality* exist, as Whitehead (2011, 214) suggests, in a complex dialectical relation with each other, profoundly altering our ways of living together as assemblages of human and nonhuman actors.

Until now, much of the work which can be categorised as 'geography of science' has focused on the constitutive spaces of science. Likewise, constitutive space has a "thematic presence" (Turnbull 2000, 40) in work on the sociology of scientific knowledge (e.g. Shapin 1995). It is my contention that exercises in writing geographies of science are incomplete without attention to the co-production of constitutive space, space-as-epistemology and space-as-rationality. It is the combined attention to these three modalities of space and their attendant and constitutive objects, actors and discourses which I see as enabling consideration of the *co-production of space* in the *epistemic geographies* of an object, debate or phenomenon like climate change[102]. Through studying such epistemic geographies, we may find new ways of thinking about the shifting relations between societies and their climate(s), and about the shifting spatialities of knowledge and power.

Boundaries

In my discussion of space-as-rationality I began to touch upon some questions concerning the boundaries between epistemic and normative, science and politics, fact and meaning. Throughout this thesis, I have sought to show how the boundaries which are erected between such entities – particularly science and politics – are contingent cultural products of local negotiations over authority and credibility. Eschewing essentialist definitions of science and objectivity, I have shown how their positions on the cultural map of modernity (Gieryn 1999) are not pre-given and are subject to change in moments of controversy and emergence. Particular formulations of the map are no more than local and episodic. Gieryn's reference to a singular map ('*the* map') is a deliberate conceptual move – he argues that boundary negotiations do not proceed through the development of wholly new discursive resources. Rather, like a dog-eared old roadmap pulled from the glove box of a car, conventional and shared understandings of the 'proper' boundaries of science are drawn upon to offer direction even in the most unfamiliar territory. However, my analysis of the interpretive geographies of the burning embers suggests that, to stretch the

[102] The only previous use of the term 'epistemic geography' that I know of is in an article which tracks the sources of knowledge with which theories of physical education are built (Ross 1981). The 'geography' of this article is essentially textual, although it overlaps with my interest in tracking the sources and circulations of particular knowledge claims.

metaphor a little further, different drivers in different terrain may have different maps to turn to. The notion of civic epistemology, like Gieryn's metaphorical map, offers a way to comprehend the persistence of certain forms of collective reasoning across different political spaces. The proper constitution of science's boundaries is one such commitment which is directed by culturally pervasive and situated norms.

The IPCC has been a site where contestation over the boundaries of science has been especially acute. It is an institution which has been forced to innovate new ways of mediating between scientific and political actors, of attaining credibility through virtual witnessing, and of dealing with palpable epistemic and political diversity. The history of the burning embers formulation thus functions as an informative microcosm of the IPCC's efforts to aggregate knowledge and remain scientifically credible, all while avoiding crossing the "storm front" (see page 143) between scientific description and political prescription. The varied interpretations of and responses to the diagram highlight how this storm front is itself subject to interpretive flexibility; its positioning was very different in the mind of government reviewers from the USA and Germany, for example. The IPCC process must, by definition, somehow accommodate the international diversity of ways of reasoning about risk. Further work would be required to investigate whether something like a 'global civic epistemology' is emerging in these hybrid, transnational spaces of knowledge production and circulation[103]. The IPCC process incorporates actors with diverse civic-epistemological commitments, as I show in Chapter 6. It remains to be seen whether the fact of their interaction in a space outside the conventional settings of civic-epistemological drama (such as courtrooms, parliamentary committees and national media discourses) has or will lead to their transformation into a culture more cosmopolitan than national (Beck 2009; Beck et al. 2013). Following my reading of Jasanoff's civic epistemologies alongside Stanley Fish's interpretive communities, we

[103] The current emergence of IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services) offers a test case for how situated modes of reasoning may interact in a newly produced international space. Although modelled to some degree on the IPCC, IPBES has attempted to produce a scalar hierarchy of assessment practices which can attend more readily to local environmental conditions and political priorities. See Larigauderie & Mooney (2010), Turnhout et al. (2012), Beck et al. (submitted).

can see how the latter offers useful insights into how shared interpretive commitments change over time. The interpretive community is:

> an engine [rather than an object] of change because its assumptions are not a mechanism for shutting out the world but for organizing it, for seeing phenomena as already related to the interests and goals that make the community what it is. The community, in other words, is always engaged in doing work, the work of transforming the landscape into material for its own project; but that project is then itself transformed by the very work it does.
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> (Fish 1989, 150)

Fish suggests that the seeds of transformation, in the form of shared beliefs, are always-already in existence. Beliefs "are not all held at the same level or operative at the same time" (ibid, 144), and change is not something which arrives from an assumed outside and which "penetrates and alters the inside of a community or of a consciousness informed by community assumptions" (ibid, 148). Therefore, we should attend closely to how the kind of civic-epistemological norms described by Jasanoff are not absolutes but are themselves the product of contestation and settlement. They have an historical depth which brings to light their contingency and thus the potential for things to be otherwise. For example, the commitment in US political culture to numerical objectivity and a clear firewall between the scientific assessment and political management of risk can be attributed to a desire for impersonal validation of particular claims to knowledge and reason within a demographically diverse and sceptical polity (Porter 1995).

Such civic-epistemological norms have a remarkable persistence, but they are not constant or static features of political culture. The historical contingency of these ways of reasoning points to the possibility of change in the ongoing co-production of scientific knowledge and social order. For example, as polities change, as senses of solidarity and citizenship extend across borders, new modes of collective reasoning are likely to emerge. The IPCC is just such an experiment in new kinds of reasoning-together. If national styles of reasoning are themselves responses to particular, episodic requirements for compromise and settlement, then they contain within them the seeds of different ways of thinking and inquiring which might respond to what Beck (2009, 57) calls a 'cosmopolitan moment' – a grasping of the "*reality* of non-excludable plurality which is driving the dynamic of world risk society, regardless of whether this reality is ignored or demonized or embraced and transformed into active global policy" (emphasis in original). For Beck, the plurality of identities, risks and ways of reasoning will eventually force some kind of transformation in how collective interests are understood and acted upon. National interests will, of necessity, start to be articulated in terms which account for the new global connectivities brought into being by our knowledge of something like climate change. Although Beck's arguments veer uncomfortably between an epistemological constructivism and a political realism amid an almost teleological logic of cosmopolitan convergence, there is an important conversation to be had about the fate of national civic epistemologies in the 'world risk society'. This is a conceptual conversation to be had within the interpretive social sciences. It is also a practical question which institutions like the IPCC have been negotiating for some time.

In Chapter 8 I emphasised the role of non-governmental actors in contributing not just to epistemic constructions of climate change and the environment, but also to the politics of knowledge-making and the normative negotiation over the *kinds* of knowledge which should be deferred to in the face of pervasive environmental risks. I ventured a partial portrayal of an Indian civic epistemology characterised by poly-vocality and by the thoroughgoing entangling of the epistemic and the normative. These two characteristics are far from mutually exclusive: the existence of a range of prominent and influential non-governmental organisations engaged in climate change debates leads to the foregrounding of concerns for justice, sovereignty and development rights in analytic descriptions of the problem at hand. Commitments to how the world ought to be are never far from depictions of how the world is. Worldwide, NGOs have played a key role in the construction and negotiation of climate policy framings (Arts 1998; Newell 2006), leading to questions about whether the critical distance between such actors and governmental structures – in many ways their *raison d'être* – is compromised by their positioning at many high tables of political negotiation (Gough & Shackley 2001). In India, the negotiation of this distance has taken place in part through the politics of science. Challenging governmental knowledges has been a hallmark of the work of bodies like CSE, even though such critical distance sometimes collapses in the context of international negotiations. The elision of a clear distinction between climate science and politics evident in the discourses of both governmental and non-governmental actors in India contrasts sharply with the strident boundary work of the US government. In India, the more relevant boundaries were those of international geopolitics and of state sovereignty.

In Copenhagen, the Danish Prime Minister called a similar tune to the Indian environment minister in asking a particular group of scientists to offer new knowledges to aid and direct his pursuit of a politically desirable solution to climate change. However, as discussed above, the spatial rationalities underlying these two superficially similar demands were very different. In Chapter 7 I introduced the notion of 'boundary spaces' as a way of capturing the constitutive spaces of boundary work by transcending the organisational gaze of much contemporary STS scholarship on science-policy relations. I aimed to show that the negotiation over the boundaries of science and politics is not confined to the institutional walls of boundary organisations (Guston 2001) or bodies like the IPCC charged with the 'hybrid management' (Miller 2001a) of scientific credibility and political legitimacy. Boundary spaces are emergent and episodic, with confluences of objects, actors and discourses constituting unique local assemblages. Boundary spaces are defined of course by the coming-together of science and politics in some approximately formalised form, but the definitions of 'science' and 'politics' must be taken as empirical questions under the assumption that the two domains, and the boundary between them, will be defined by the relevant actors in ways contingent upon the particular context. Thus the negotiations over the level of prescriptiveness which could rightly be employed by the authors of the Congress *Synthesis Report* were inflected by the immediate political context of the document, while the politically consequential hermeneutic struggles over the 2°C temperature rise target offered new renderings of how scientists can most usefully respond to the inevitable flexibility of such boundary objects.

I also argued that boundary spaces overlap. This is largely self-evident, in that certain actors will always populate multiple boundary spaces, and objects like the 2°C target attain their discursive power through meaningful mobility between different boundary spaces[104]. I also argued that norms concerning the proper boundaries of science circulate through these spaces, but are subject to local reinterpretations. It was through such reinterpretation that the Congress organisers felt justified in using the burning embers diagram in a more politically explicit way than the diagram's creators had ever done. We might then begin to consider whether the diagrammatic space of the burning embers can too be considered a form of boundary space. It is a space where a variety of actors are both present and implicated, where science is hoped to speak to politics, and where the boundaries between the two have been subject to constant contestation. The diagram was a situated accomplishment which evolved as it travelled in space and time. It took an active role in new boundary spaces like those of Copenhagen in 2009, while folding other boundary spaces in on itself, for example in the contestations over the question of whether the inherent normativity of defining 'dangerous' climate change contravened the guiding principles of the IPCC more broadly. I read the case of the burning embers as a metaphor for broader struggles which have marked the institutional history of the IPCC. But the struggles over the diagram and over the politics of 'dangerous' are also directly constitutive of the evolving institutional identity and practices of the IPCC. Further conceptual refinement of the notion of boundary spaces might help address this questions of how we can think through the shared constitutive, epistemological and rational spatialities of the diverse spaces – from a two-dimensional diagram to a conference hall – where the boundaries of science and politics are contested, unsettled, and temporarily stabilised.

[104] For example, the Danish Prime Minister claimed that he drew his understanding of the veracity and authority of the 2°C target from the IPCC.

Politics

In Chapter 6 I suggested that the struggles over the proper boundaries of scientific assessment and expert judgment were rendered all the more acute – perhaps even rendered possible – by the politics of defining a deeply normative ontological threshold of danger. As acknowledged by various authors and commentators – including participants in the relevant IPCC chapters (e.g. Oppenheimer 2005) – the definition of such a threshold involves a complex combination of empirical analysis, probabilistic prediction and expert judgment, but ultimately can only be settled by an assessment and negotiation of deeply social values and preferences. In short, even faced with the same scientific evidence, the definition of danger will vary between different actors. The contingent politics of positioning the dividing line between these different modes of reasoning – what Oppenheimer (2005) calls the 'limits of science' – are clear to see in Chapter 6. To further the analysis, I want to begin by reflecting on the ontological politics of the climate *system*.

From Eratosthenes' descriptions of *klima* as a slope or piece of land inclined towards the sun (Heymann 2010a), through to Köppen's rendering of distinct climatic zones across the face of the globe (e.g. Köppen 1918), climate has been a resolutely spatial category, tied to particular places and to the local interactions of the human, the ecological and the atmospheric. With the development of statistical and then dynamic climatology in the late 19th and early 20th centuries, climate began to take on a temporal dimension as long-term average weather was compiled as 'the climate' of an area, while an ontology of flux and connectivity allowed the exploration of the temporal dynamics of the global atmosphere. The tensions between these different ways of knowing the climate are still evident in the definition given by the IPCC:

> Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often

> surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. In various parts of this report different averaging periods, such as a period of 20 years, are also used.
>
> (IPCC 2007a, 942)

The systemic definition of climate in the second half of the above extract represents the lineage of a dynamic climatology (e.g. Bergeron 1930). In the early twentieth century the description of atmospheric processes with differential equations allowed the atmospheric sciences to draw on the emerging powers of computation to simulate and, eventually, predict the sky-bound fluxes of matter and energy (e.g. Charney et al. 1950; Phillips 1956). This packing of the climate system into numerical functions was a key moment in the development of the general circulation models (GCMs) which would come to dominate the scientific foretelling both of the weather and of the climate (Edwards 2010).

Although climate still has currency as spatial delineation and as temporal average, the global climates of the computational modellers represent a profound break with previous forms of knowledge; an example of the kind of epistemological thresholds which, for Bachelard and Foucault, "suspend the continuous accumulation of knowledge, interrupt its slow development, and force it to enter a new time, cut it off from its empirical origin and its original motivations" (Foucault 2007a, 4). The climate was rendered as something akin to a machine – a series of interlocking systems and cycles with a stability and regularity belied by the vicissitudes of the weather (Lövbrand et al. 2009). This stability is now understood to be threatened by human actions. Anthropogenic interference in the chemistry and geology of the earth threaten a range of numerically-delineated "planetary boundaries" around the "safe operating space" which humanity currently enjoys (Rockström et al. 2009). It is this departure from the natural state of the climate and earth system that has led some to delineate a new geological epoch – the *Anthropocene* (Crutzen & Stoermer 2000; Steffen et al. 2007).

Yaron Ezrahi (1990) argues that machinic metaphors have been common features of Western liberal-democratic thought, in attempts to come to terms with and govern the complexity of human and nonhuman assemblages. Within such metaphors lie a tensile dualistic vision of the machine as the indifferent, inexorable regularity of nature, and as the embodiment of human mastery and invention – the means of transcending natural limits. “According to the first view, the machine, as a mirror of nature indifferent to humanity, represents the individual's tragic fate as a prisoner of implacable necessity. The latter view links the machine with humanity's power to break loose from the chains of natural necessity and fly to ultimate freedom” (ibid, 149). These twin poles also encompass, for Ezrahi, the spectrum of Western attitudes towards science and technology; “oscillating between the ideals of rational adaptation to given natural limits and the appropriation of ungiven freedoms” (ibid, 150). The history of liberal democratic politics can be read as a history of attempts to balance this constant tension between freedom and restraint, voluntarism and determinism, scepticism and meliorism. Scientific knowledge is often the fulcrum on which this balancing act is performed, tipping from technological idealism to warnings about “the hubris of the human violation of nature” (ibid, 153).

Ezrahi locates in European machinic metaphors an image of an ordered, structured system demanding esoteric knowledges among elite rulers. In US political culture by contrast, Ezrahi suggests that the machine has functioned as a metaphor for open, antagonistic politics. Scientific education was advanced by 20th century ideologues as a means of enabling rational, voluntary individual action in place of a “passive acquiescence to authority and fatalistic acceptance of natural limits” (ibid, 164). In post-independence India, the development of a “scientific temper” was inscribed in the Constitution of India as a fundamental duty of the Indian citizen[105]. For Jawaharlal Nehru, the scientific temper stood opposed to the irrationality of religious and humanistic thought. Contemporary scientists like Meghnad Saha “literally dreamt of a society based on the scientific method...India was a society as proud of its sample surveys and its science policy as it was of its flag” (Visvanathan 2005, 85). However, the rise of the People’s Science Movement (PSM, see Chapter 8) saw the hierarchies and boundaries of state-sanctioned science and technology come under challenge

[105] The state, meanwhile, is among a very few in the world which is constitutionally required “to protect and improve the environment and to safeguard the forests and wildlife of the country” (Constituent Assembly 1950).

from human rights activists, ecologists, feminists and others who campaigned against the violent conflation of scientific rationalism and technological utopianism which drove forward a developmental agenda insensitive – dismissive even – of the diverse cultures, values and needs of those captured within the "rituals of the laboratory state" (Visvanathan 1997, 17). The PSM sought to democratise science, and to allay the boundaries between scientism, humanism and religiosity. For Varma (2001, 4800), distinctions between scientific and political epistemologies are irrelevant to contemporary Indian debates about science and technology. In place of an insistence on social neutrality, "the link between science and society in India is viewed as organic" – as mutually reinforcing and subject to a humanistic ethics. Like in the US, science education was promoted initially as a path to rational, voluntary action. However, through the PSM, this morphed into a democratising push against the state's claims to be able to transcend natural limits and local ecological realities.

These comparative perspectives bear upon the climate change knowledge politics I have been discussing here. The different distinctions drawn between the role of epistemic and normative judgment in defining thresholds of danger and action are situated in part in these different attitudes towards the notion of *limit*, as expressed in machinic metaphors for scientific rationality. A US civic epistemology of numerical objectivity places checks on the ability of science to function "as a mirror of necessary natural constraints" (Ezrahi 1990, 165). The attempt to remove from the purview of the IPCC the definition of dangerous climate change represented a continuation of the struggle over a Janus-faced science which can at once identify "natural constraints" *and* expand "human freedom of action to its outer limits". Following Ezrahi's comparative line, the (broadly speaking) European championing of the 2°C target, and the expressed faith in science to delineate and justify such a limit, recapitulates a machinic conception of an ordered system demanding esoteric expert management. The embracing of such planetary boundaries and thresholds represents at once a continued commitment to speak for the globe, and a "scientific deference to external limits and regularities" (Ezrahi 1990, 151). In India, the popular transformation of the scientific temper into a scientific humanism indicates how this kind of epistemic deference only functions when rooted in a thoroughly normative engagement with the world. Abstract limits and thresholds have little hold on Indian climate politics. Such limits continue the project of detaching objective knowledge from subjective meaning and capturing the global as a supposedly post-political knowledge space (Swyngedouw 2010). In re-assimilating and embracing the politics of science, Indian climate change debates offer a quite different picture of how scientific knowledge and social order are being purposefully co-produced.

The politics of denial: 'science wars' and 'climate wars'

By now the reader may be wondering how a thesis on the geographies and politics of climate science has been able to dodge the question of climate change 'denial'. It is equally important to consider the question of how constructivist accounts of climate knowledges participate in the seemingly hyper-politicised landscape of truth and falsity in which much of our climate change debates play out.

Public calls for concerted political action to address climate change frequently feature a bemoaning of the negative influence of climate 'sceptics' or 'deniers' (Turnpenny 2012). Concerted efforts to marshal and communicate scepticism about the scientific veracity of climate change are often cited as impediments to political progress (Oreskes & Conway 2010; Jacques 2012). For those opposed to the expansion of industrial and environmental regulation, casting doubt either on the reality of recent temperature trends, their human causation or the severity of projected changes has been a key political strategy (McCright & Dunlap 2000). For example, a 2003 US Republican Party strategy document suggested that if "the public come to believe that the scientific issues are settled, their views about global warming will change accordingly" (Luntz 2003, 137). Therefore, Republican electoral candidates should "challenge the science" (ibid, 138) to swing the public debate against "Washington regulations" (ibid, 131).

David Demeritt (2006) notes that sceptical challenges to the science of climate change often contain elements of constructivist critique. 'Sceptics' point to how climatic knowledges are made by situated individuals and institutions with layered epistemic and normative commitments; to the fact that consensus formation is a social process rather than just the revelation of a pre-ordained natural reality; to the hybrid scientific and political role of the IPCC – all of which, as shown in this thesis, are topics of great interest to students of the co-production of scientific knowledge and social order. Concerns have therefore been expressed that constructivist critique contributes to a form of scepticism which is beholden to established and hegemonic industrial interests (Murphy 1995; Woodgate & Redclift 1998; Collins & Evans 2002). This politics of constructivism led Latour (2004b, 227) to ponder whether he was "wrong to participate in the invention of this field known as science studies".

It was similar anxieties about the subversion of objective rationality which animated the so-called 'science wars' of the mid-1990s. Alan Sokal (1996) bemoaned the flight of left-wing social scientists and humanists from a faith in the socially progressive, meliorist potential of scientific knowledge towards an "epistemic relativism" which offers no solid ground for belief or claims to truth. This intellectual trend simply reinforced obscurantism and irrationality. Sokal (1996, 64) argued that "[t]heorizing about the 'social construction of reality' won't help us find a cure for AIDS or devise strategies for preventing global warming" (see also Gross & Levitt 1997; Sokal & Bricmont 1999)[106]. Yet this critique wholly obscures the nuance and diversity of approaches labelled 'social constructivist' (e.g. Hacking 1999). The version of constructivism set-up and then attacked by Sokal "accepts the philosophical presumptions of scientific objectivity and seeks to falsify a particular scientific claim by showing how belief in its truth was mistakenly (and thus, by definition, socially) constructed" (Demeritt 2001, 310)[107]. It rests on an assumption that science is a pre-given entity with clear boundaries, and that 'social construction' only occurs through external influences when those boundaries erode (e.g. Schneider 2001, 339). But this is something of a straw man – for the vast majority of constructivists, 'social construction' is not the *explanans* or hallmark of scientific error, but a "signal that the facts of nature are not given as such but emerge artifactually as the heterogeneously constructed result of contingent social practices" (Demeritt 2001, 311).

[106] The 'science wars' reached a peak with Alan Sokal's successful publication of a spoof article in the journal *Social Text* which channelled and caricatured a number of key STS motifs. On the crushing irrelevancy of Sokal's intellectual prank to debates about the politics of science and technology in the 'life-world' of everyday lived experiences, see Visvanathan (2005).
[107] Hacking (1998) notes the similarities between these arguments and Karl Popper's notion of *falsification* as a means of determining the boundaries between good and bad science.

Therefore, rather than social constructivists employing similar deconstructive tactics to those of climate sceptics, it is *critics* of social constructivism which arguably have more in common with the assumptions and discursive strategies of those who deny the reality or seriousness of climate change. Dominant narratives of climate scepticism cling to a notion of 'sound science' free from the polluting forces of politics and interests. US Senator James Inhofe of Oklahoma – a prominent Republican critic of mainstream climate science – frequently appeals to sound science as the predicate of public policy, and bemoans how "emotions stoked by irresponsible rhetoric rather than facts based on objective science shape the contours of environmental policy" (Inhofe 2003, S10013). Such commitments to a straightforward correspondence theory of truth (Rorty 1979) are arguably shared by both proponents and opponents of strong climate change policy (cf. Montford 2010; Mann 2012), in tandem to commitments to linear model understandings of a deterministic relationship between scientific knowledge and political action (see Chapter 7). It is arguably as a result of these shared understandings – both of the possibility of a value-free science and its ideal role in democratic politics – that scientific knowledge has come to function as a key political battleground in the case of climate change. By insisting on the technical closure of matters of normative concern through appeal to matters of epistemic fact, advocates of strong climate policy simply invite further contestation over technical facticity (cf. Collins & Evans 2002; Latour 2004a), to the detriment of an open, deliberative, democratic debate over policy alternatives (Hulme 2009a; Latour 2012; Machin 2013).

Drawing on Mouffe (2005) and Rancière (2004), Goeminne (2012) argues that antagonism is a necessary and important part of the political[108], and that certain environmental policy orthodoxies serve to exclude or preclude an antagonistic politics of climate change. For thinkers like Mouffe and Rancière, the partial resurgence of far-right and far-left politics represents a frustrated response to economic crises and a stifling consensual environment of technocratic managerialism and political centrism. In line with Swyngedouw (2010), Goeminne suggests that a similar process of depoliticisation may be at work in climate change debates:

[108] For Mouffe (e.g. 2013), the dimension of antagonism is coextensive with 'the political'.

> Lost in the translation from science to policy, the concernful work of composition that goes into the construction of a matter of fact is obscured in consensual decision making, leaving policy nothing but externalities to be managed in a technocratic way.
>
> (Goeminne 2012, 6)

In a co-productionist argument that the 'composition' of matters of fact is inseparable from the composition of matters of concern (cf. Latour 2010), Goeminne suggests that science is always-already political, i.e. that scientific facts possess explanatory value in relation to the very matters of concern from which they arise. Such acts of composition participate in the ongoing composition of the common world (Latour 2004a; Latour 2012) and thus give rise to questions of inclusion and exclusion, whether concerning human or nonhuman actors, or alternative problem-framings:

> Understanding the task of raising and addressing matters of concern as a work of composition...is the true political heritage of constructivism, conceiving politics as a struggle for who and what is to be taken into account.
>
> (Goeminne 2012, 6)

Acts of depoliticisation – of exclusion and discursive foreclosure (cf. Stirling 2008) – lay the ground for an antagonistic 'return of the political' in the form of, for example, a denial of or scepticism about the central tenets of climate change science. The most effective way to express political dissent over the regulatory reach of national governments, the enactment of global multilateralism or the governance of the energy system therefore becomes the couching of such arguments in terms of scientific scepticism. Goeminne (2012, 7) thus concludes that "it is not surprising that a growing number of people are listening to those who proclaim that alternatives do exist, even if the latter carry a right-wing signature and are predicated upon a straight denial of sound scientific arguments".

Forsyth (2012) urges political analysts of the environmental sciences to attend to the geography of the exclusions described by Goeminne (2012). Both cite Agarwal & Narain's (1991) arguments about unjustly universal greenhouse gas metrics as an instance of repoliticisation of an otherwise hegemonic scientific/political framing of climate change (see Chapter 8). As I argue above, the knowledge spaces co-produced in climate policy debates always contain the potential for contestation. But rather than portraying the depoliticisation of climate change as a *fait accompli* (e.g. Swyngedouw 2010), we need to recognise the ongoing, contingent and mutual evolution of scientific and political norms and framings – depoliticisation, like repoliticisation, is in a constant process of agonistic becoming. Although Latour (2004b) translates his concern about the critical potential of constructivism into a call for a realist engagement with the composition of "good" or "bad" matters of concern, his project is akin to "agonism without antagonism", disempowering political effects in his eschewing of social difference and of the power relations which inhere in the construction and contestation of knowledge (Mouffe 2013, 79-82; see also Demeritt 2006)[109].

It is also therefore necessary to begin attending to the constitutive spaces of public deliberation, where different forms of rationality may co-exist in tension. Rather than appealing to a universal rationality to be delivered to scientifically illiterate citizens through uni-directional education programmes, we might recognise how the relationship of individuals to their peers might inform their attitudes towards climate change. As Kahan et al. (2012) argue, individuals may risk social alienation if, for example, they revealed to their Oklahoman oil refinery colleagues that they harbour concerns about climate change, or if they revealed to their Bostonian university colleagues that they believe climate change to be a hoax. In such situations, the 'rational' course of action may be defined by local, place-specific and relational circumstances rather than by an individual's 'scientific literacy' (McCaffrey & Rosenau

[109] Latour has recently appeared more comfortable in engaging with the politics of climate scepticism (see below). As Demeritt (2006) points out, Latour's disavowal of constructivism – rather like Sokal's – overlooks the complexity of such philosophical positions in his concerns about constructivism's political effects (in the form of "[a]rtificially maintained controversies" – Latour 2004, 227). Latour thus recapitulates a liberal, deliberative understanding of consensus as the ideal prerequisite of political action.

2012) or by the scientific rationality represented by the IPCC (see also Kahan et al. 2011). Thus the interest of geographers of science in the relationship between location and facticity (Livingstone 2000, 295) becomes also a question of the relationship between science and its various publics as knowledges circulate about the diverse spaces of public debate (cf. Bell et al. 2008; Withers 2010b).

My engagement with the epistemic geographies of climate change has brought to light some powerful co-productions of particular knowledge spaces, such as the abstract globality of the burning embers and the 2°C temperature rise target. I have argued that the latter has functioned as a powerful science-policy boundary object, to the ultimate detriment of effective, just and democratically realised climate change policy. Although I haven't dealt empirically with the perhaps equally powerful construction of ambiguity, ambivalence and ignorance[110] which has emanated from a grouping of influential think-tanks, corporate lobbyists and disaffected political commentators (Oreskes & Conway 2010), my effort to answer the question of how the spaces and boundaries of climate change knowledge have been recently contested points, like many constructivist arguments which have preceded it, to the possibility that things might be otherwise (e.g. Law & Singleton 2000; Rose 2007). In the journey from a global space of interchangeable equivalence which translates so easily into tradable commodities and carbon markets (Demeritt 2001; Oels 2005; Yusoff 2009; Lövbrand & Stripple 2011), to the Indian questioning of ontological equivalence and the construction of new, alternative knowledge spaces, we can see how attention to the epistemic geographies of climate change brings to light both the power and contingency of dominant political forms.

Following the scientific controversies and political failings of 2009, a political pragmatism has started to gain traction which decentres the unitary globalism of the climate regime in favour of sectoral and regional governance of, for example, energy systems, a preference for 'no regrets' mitigation and adaptation policies which offer benefits to human health and livelihoods as well to the climate, and a foregrounding of human dignity as a guiding normative concern (Prins et al. 2010). If such

[110] On ignorance as an outcome of political and cultural struggle rather than as a straightforward absence of knowledge, see Kleinman & Suryanarayanan (2012).

‘pragmatism’ is to take hold, it will inevitably be co-produced with new forms of climatic knowledges. These may be the kind of sub-global, territorial articulations of space and power which I described in Chapter 8. They may be new regional or sectoral forms of international scientific assessment (e.g. Nature Opinion 2010), which may be able to respond to the diverse forms of collective reasoning I analysed in Chapter 6. Or, more radically, they may be more open, pluralistic and resolutely agonistic deliberative fora where science and scientists aren’t forced to cower behind the “Maginot Line” of epistemology (Latour 2012)[111]. Here, our layered investments in how the world *is* and how the world *ought to be* can be brought into the open in the service of a democratic and accountable politics of an ontologically hybrid climate (cf. Latour 2004a; Hulme 2009a).

Towards epistemic geographies of the Anthropocene: conceptual and methodological reflections

In the foregoing discussion I have suggested that the notion of ‘epistemic geographies’ can capture at least some of the critique I have made of current approaches to the geography of science. In Chapter 2 I suggested that geographers of science are yet to engage fully with the conceptual challenges of co-production, in either its constitutive or interactional forms. Building on my own empirical findings, I have argued that studies of the constitutive spaces of science – the conventional subject matter of geographies of science – need to be supplemented by studies of how space functions as epistemological category and as political rationality in particular instances of knowledge production. In attending to these three spatial idioms, we may achieve a better grasp of the co-production of space, knowledge and power in the construction and practice of particular epistemic geographies.

Richard Powell (2007a, 309) suggests that efforts to develop geographical accounts of scientific practice “have been most successful in work by historical geographers and historians of geography” (see also Meusburger et al. 2010). Historical inquiry has

[111] The Maginot Line was a line of defences erected by France along its border with Germany after the First World War. In a cruel manifestation of the adage that ‘generals always fight the last war’, the German army simply circumnavigated the defences at the outset of World War II by attacking through Belgium.

focused on the constitutive spaces of past scientific activities – of the stabilised outcomes of the 'mangle of practice' (Pickering 1995) and their travels around a variety of cultural spaces (e.g. Turnbull 2002; Livingstone 2003; Naylor 2005a, 2005b). Although constructivist in orientation and focused on the constitutive significance of space in the *making* of science (Shapin 2003), such accounts possess the methodological advantage of being able to start with a subject matter consisting of 'finished science', before going back to into the archive (Withers 2002) to look at how it was *made*.

By contrast, STS analyses of the production of scientific knowledge have taken a largely sociological approach to 'science in the making', following in real-time the making, unmaking, authorisation and contestation of scientific knowledge through methodological techniques of ethnography and ethnomethodology (Latour & Woolgar 1979; Latour 1987; Knorr Cetina 1981; Merz & Cetina 1997). Such work has conventionally focused on sociological and anthropological themes of social relations and practices, hierarchy, community and negotiation (Franklin 1995), with a less explicit focus on space and place (Gieryn 2000). The 'socio-spatial' school of STS identified by Powell (2007a) is largely made up, by contrast, of historical works (e.g. Shapin & Schaffer 1985; Shapin 1988; Ophir & Shapin 1991; Secord 2004), which have often stood in tension with normative concerns within STS for the democratisation of science and technology, institutional transparency, and the recovery of lost or subjugated voices (cf. Jasanoff 2000; Daston 2009; Dear & Jasanoff 2010). How, then, might a renewed interest in contemporary geographies of science – or a new interest in epistemic geographies – fit into this disciplinary, conceptual and methodological landscape?

As Dear & Jasanoff (2010) argue, disciplinary chauvinism between history of science and STS carries few favours for anyone, except perhaps a measure of bureaucratic convenience. Knowledge-making, the subject matter of STS, even when it is unfolding before the very eyes of the ethnographer, is always historically situated. The sensibilities of the historian are required alongside those of the sociologist, the anthropologist and the political scientist. Although the 'contextual' drive to wholly historicise the making of scientific facts has not received universal acclaim in history of science (Daston 2009), any inquiry into the practices and politics of knowledge-making will make clear that science is a process which unfolds over and in time, just as it unfolds in and through space. This is not a prescriptive call for the institutionalisation of an “exceptional geography of science” (Powell 2007a, 322), nor for a form of interdisciplinarity which assumes disciplines themselves to be homogenous fields of shared theories, subjects and methods. Rather, “in the study of science and technology…all analytical and methodological techniques, and empirical resources, ought in principle to be available”. Diverse sources and resources “can always be purloined without apology or permission by scholars able to argue for their suitability. All ‘disciplines’ are in this sense ‘interdisciplinary,’ unless they have frozen into dogmatic bodies of faith” (Dear & Jasanoff 2010, 772).

In this thesis I have suggested that geography of science has become just such a productive interdisciplinary space where conceptual resources have been ‘purloined’ from adjacent fields to develop novel and innovative accounts of the constitutive spaces of scientific practice. However, I have also contended that the time is right for geographers of science to look to STS for new theoretical and methodological resources to inform an approach to inquiry into the contemporary geographies of science. The ‘place’ of science in present day societies is very different to that of the early-modern, Enlightenment or Victorian societies which have most interested geographers of science so far. Scientific knowledge is no longer just an object of esoteric, gentlemanly concern, an engine of industrial development or of imperial expansion (Shapin 1988; Livingstone 1993; Withers 2010a). Scientific and technological knowledges are active forces in the ongoing remaking of our collective life-worlds. Most significantly, such knowledges lie at the root of the current proliferation of social and environmental risks, while also being at the forefront of societal efforts to understand and manage such risks (Beck 1992). “In risk societies, the consequences and successes of modernization become an issue with the speed and radicality of processes of modernization… [Risk society] epitomizes an era of modern society that no longer merely casts off traditional ways of life but rather wrestles with the side effects of successful modernization” (Beck 2009, 6-8). Scientific knowledge thus becomes the fulcrum of Beck’s epochal shift as quantitative calculation becomes the chief means by which societies grapple with risks and anticipate catastrophe[112].

The geographies of science have thus undergone a radical shift. While there may have been “a time when science took place in the laboratory as a spatially and temporally limited empirical science”, that time, for Beck (2009, 36), “is past. The world has in the meantime become a laboratory”[113]. Through their spatial indeterminacy and unboundedness, global risks “unexpectedly liberate a world-historical *cosmopolitan moment*” (ibid, 20, emphasis in original), as discussed above. The global laboratory is thus not only a space where unknown consequences of industrial modernisation unfold, but also a space where, “given the indeterminateness of risk, existential experimentalism is unavoidable” (ibid, 5; see also Davies 2010). This is a normative call to a mode of collective governance which is able to comprehend, assimilate and live with the inevitable uncertainties of pervasive risks and the collapse of ontological security (e.g. Gross 2010), as opposed to what Beck (2009, 14) sees as a Western “civilizational faith in controllability”.

The participation of scientific knowledge in such existential transformations accords to some extent with the co-productionist interest in the mutual constitution of science and social order. Although Beck arguably overemphasises the level of ‘social order’ in existence before the advent of the risk society while apparently clinging to a faith that the relations between science, politics and society can be productively and homogeneously re-ordered at a global level[114], his arguments provide a provocative context to a consideration of what a geography of science equipped to tackle the contemporary knowledge politics of the Anthropocene might look like. The rise of regulatory science as a prominent feature of the democratic landscape (Jasanoff 1990) has drawn STS analysts out of the laboratory and into political spaces whose “analysts must also be students of politics” (Dear & Jasanoff 2010, 773). In the regulation of the

[112] On the potential for spatio-temporal reductionism in such ‘epochal thinking’, see Larner (2011).
[113] See also Szerszynski (2005). I have written on the geographies of the global laboratory in relation to the crossing of the 400ppm mark in atmospheric CO_2 concentrations (Mahony 2013). See Appendix 7.
[114] To return to Goeminne’s (2012) readings of Mouffe and Rancière, Beck arguably shares Rancière’s view that a new form of political order can and will be established after moments of epistemic or democratic eruption. By contrast, Laclau & Mouffe's (2001) conception of a radical, agonistic politics is arguably better suited to the indeterminacy and disorder of the ‘risk society’. See Purcell (2013, 57-74).

air and the water, of biodiversity and the climate, scientific knowledge is co-produced with new governmental rationalities and democratic imaginations.

I have suggested that contemporary approaches to the geographies of science are under-equipped to make sense of these new epistemic geographies. Attending to the constitutive spaces of scientific practice and mobility remain central challenges. But in treating spatial contexts simply as an *explanans* of epistemic variation, there is a risk of losing sight of the participation of geographic and scientific knowledges in the ongoing re-ordering of the world and its political, economic and cultural geographies. This is the reason why, in Chapter 8, I brought together STS literature on co-production with analyses of the participation of spatial knowledges in the ongoing production of national territory. Work on the history of cartography has largely proceeded in parallel to work on the geographies of science. It is my contention that in linking studies of the constitutive spaces of science to work on spatial epistemologies and rationalities, we may better grasp not only the significance of location in scientific practice but also the re-working of space and spatial organisation through scientific practices themselves.

This emphasis on the co-production of space perhaps brings us full-circle, re-connecting geography of science with its discursive origins in the history of geography and geographical thought (e.g. Livingstone 1993). It means turning a geographical eye on geographical practices – on the representational construction of space, on theories of distribution and difference, and on accounts of temporal change. It is from such spatial knowledges that concerns about the crossing of "planetary boundaries" (Rockström et al. 2009) or "tipping points" (Lenton 2011) emerge. In its substantive and analytical engagement with such debates, geography thus has the potential to further become a reflexive discipline able to reflect critically on its own assumptions and practices. Emerging ethnographies of field sciences point to this potential for cultural geographers to engage more readily with their physical geography colleagues (Wainwright 2012; Forsyth 2013; see also Gregory 1995; Tadaki et al. 2012) in the interest of dialogue and understanding rather than "an endlessly touted environmental synthesis" (Crang 1998, 1973; Demeritt 2009). Likewise, Livingstone (2002, 79) remarks that "[c]ultural geographers find themselves side-by-side, in the same department, with physical geographers working in the natural science tradition. And a golden opportunity is thus provided for them to examine what could be called the cultural geographies of the bench-scientist and the field-worker." However, this interest in the laboratory bench and the field site as the constitutive spaces of geographic inquiry recapitulates dominant narratives about the identity of geography as a discipline concerned with embodied experience and nonhuman encounter; with collecting, recording and narrating (Driver 2004; Withers 2011; Forsyth 2013, 529). Geographies of science also need to engage with what we might call the deliberative and computational 'turns' in the geographic sciences – with the spaces of transnational knowledge production like the IPCC, and with the geographies of nonhuman encounter through the mediation of the algorithm and the computer screen (e.g. Heymann 2010b; Hastrup & Skrydstrup 2012).

The computational, representational and performative (Knuuttila 2006) spaces of global climate models are perhaps the last places where a notionally 'pure' climate still exists, if only in theoretical and experimental form, as researchers seek to delineate 'anthropogenic' from 'natural' causes of simulated change (e.g. Hegerl & Zwiers 2011). As I argued in Chapter 3 and Chapter 8, simulation is a key site where the epistemic and ontological politics of climate change are played-out. We need more ethnographic studies of the representational and cartographic practices of simulation (e.g. Shackley 2001; Sundberg 2010; Guillemot 2010; Landström et al. 2013), with a renewed attention to the epistemic geographies of the virtual worlds of computer models and their participation in the broader spatial politics and public deliberation of environmental change (e.g. Kasemir et al. 2003; Whatmore & Landström 2011). As Merz & Knorr Cetina (1997, 75) show, the protocols of conventional laboratory ethnography may be stretched by the study of scientific practices which engage less in the direct material manipulation of the world, and more with "the building and understanding of disembodied objects such as models and equations". The "interactional expertise" (Collins & Evans 2002) of the ethnographer in relation to her subject group may be a crucial determinant of comprehensibility and observability of the 'methodical' cognitive work of 'struggling' with equations, models and computer code (see also Gale & Pinnick 1997; Knorr Cetina & Merz 1997).

But the epistemic practices of the modern sciences of global risks do not just reside in the interactions of researcher, computer screen, algorithm and simulated environment. They also reside in the deliberative spaces of organisations like the IPCC which, as I discussed in Chapter 4, present their own challenges of access and observability. In the international networks of climate science, the 'shop-talk' of laboratory ethnographies may be largely replaced by email correspondence (cf. Merz 1998) – conventionally a private medium, an assumption which led to the candid conversations of the 'climategate' emails and the subsequent criticism of the scientists following their release. However, STS scholars shouldn't rely on stolen or leaked correspondence for empirical data. Rather, relations of trust and mutual understanding are required to enable access to otherwise secretive spaces of scientific work (Taber 2010; Reeves 2010). This in part demands that geographers of science are able to negotiate the epistemic and normative tensions between constructivist and realist accounts of the world – particularly of environmental change (cf. Demeritt 2001; Schneider 2001) – in the often prosaic processes of negotiating access and consent. This means recognising the relationality of our methods and our own normative positionality in debates about environmental change. Geographers of science need to "remember that their expertise provides resources for arbitrating over what scientific practice *ought* to be in contexts of environmental, social and cultural contestation" (Powell 2007a, 322).

With institutions like the IPCC and emerging platforms like Future Earth[115] engaged in constant struggles for credibility, accountability and authority, my sense is that there is an increasing willingness to engage with scholars of scientific practice (O'Reilly et al. 2012; Barnes et al. 2013) – to enact an ethnographic 'complicity' (Marcus 1998, 105) – in order to reflect on the social processes of knowledge production and authorisation within this landscape of contestation. Geographers of science are well-placed to contribute to this project. By adding the laboratory, the simulation model, the conference venue, spaces of correspondence and online environments (Dwyer &

[115] http://www.icsu.org/future-earth

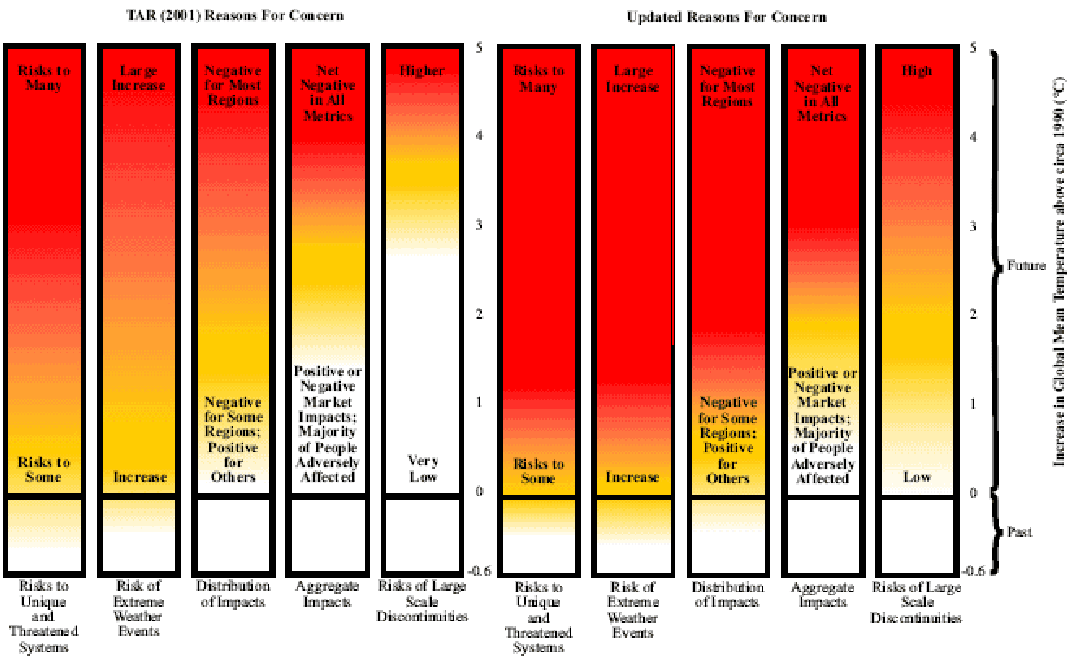
Davies 2009) to the repertoire of textual and physical spaces explored in the service of geographical inquiry, geographers of science can make essential contributions to our understanding of the knowledge politics of the Anthropocene – because, in the end, science must be understood as a geographical phenomenon.

Appendix 1

Sample topic sheet provided to respondents prior to interview

Interview topics **Friday 13th May 3pm**

- The IPCC's 'Reasons for Concern' (i.e. 'Burning Embers') diagram:
    - The history of the diagram's production for the IPCC's Third Assessment Report;
    - The subsequent circulation of the diagram;
    - The exclusion of the diagram from AR4.



From Smith et al (2009) 'Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC) "reasons for concern".' PNAS

- Experiences of providing scientific advice to European policymakers, concerning the avoidance of 'dangerous' climate change.
- Practices of climate change assessment at the science-policy interface:
    - The *Copenhagen Diagnosis* and the *Climate Congress* hosted by the University of Copenhagen, both 2009;
    - How these assessments came about;
    - The success of these projects and their reception by policy makers;
    - The future of the IPCC, particularly in light of recent controversies and the InterAcademy Council review of IPCC procedures.

Appendix 2

Consent form presented to interview respondents

The spatial ordering of climate change knowledge and the IPCC

CONSENT FORM

	Please delete as applicable
I confirm that I have read the information sheet provided to me by the researcher and understood the purpose of the study and the manner in which my personal data will be used.	Yes/No
I agree to participate in an interview.	Yes/No
I agree for the interview to be recorded and for notes and transcriptions to be made from the recording to be used in the research.	Yes/No
I understand that any information which I provide will be treated confidentially, but that extracts from the interview may be presented anonymously in subsequent documents and publications.	Yes/No

Signed: ____ Date:

Appendix 3

Sample interview schedule used by me

Burning embers

- You were a Coordinating Lead Author of WGII's Chapter 19 on Key Vulnerabilities, in which appeared the first 'burning embers' diagram. How did that diagram come about?
  - Who? When
- How was the diagram viewed by other members of the chapter writing team, the reviewers, and others within the IPCC, including government representatives?
- What impact do you think the diagram had on discussions of climate change impacts and ideas about what might constitute 'dangerous' climate change?
- You have been quite engaged in debates in science and policy circles about how we might think about what constitutes dangerous climate change. How has your thought on that matter evolved over the years?
  - What kinds of knowledge are driving that change?
- You weren't directly involved with the AR4 manifestation of Chapter 19, but did you get a sense of why the burning embers did not appear in AR4?
- The diagram has been criticised for being too 'subjective'. How would you respond to that allegation?
- Do you have any sense of whether the diagram may be making a comeback in AR5? Would that be a good thing?

Copenhagen

- In 2009 Copenhagen between a site of quite fervent political and scientific activity. You were involved in writing both the *Copenhagen Diagnosis* and the synthesis report of the Climate Change Congress hosted by the University of Copenhagen. What was it about Copenhagen which inspired so much scientific activity?
- The Congress delivered six key messages based on the contributions of thousands of researchers. How were these arrived at?
- Did the congress address the direct concerns of policymakers more effectively than the IPCC has been able to do?
- How did the Congress compare with the Diagnosis? (Diagnosis focused more on 2 degrees target and dangerous CC)
- These two assessments certainly seemed to fill a gap left by the IPCC in the run-up to COP15. Do you think they provide a model for how the IPCC might adapt itself to the current climate of environmental politics?
- What do you think is the future of the IPCC?
  - Regional assessments, more responsive, tailored information
- How would you like to see the IPCC respond to the IAC recommendations, concerning issues such as transparency, a more careful treatment of uncertainty, its approach to regional climate issues, and so on?
- I wondered if you have any thoughts on how the climate science community has responded to the controversies of 2009 and 2010, and the effects these controversies have had on popular and political discussions of climate change.

Appendix 4

Sample extract from interview transcription

[‘MM’ = Martin Mahony, ‘IR’ = interview respondent]

(…)

MM: I wonder if you could comment on, or perhaps characterise what you sense being the relationship between IPCC and the Indian government and the Indian scientific community. I mean you’ve already mentioned these questions about participation and its sort of political agenda that it seems to fulfil. If we focus on India, how would you characterise that relationship?

IR: I don’t know. I mean I don’t know how, in any case, when it comes to the regional impacts of climate change, IPCC’s a very, the models are used at a very high level of, I mean at a very low level of resolution right? So it’s not that IPCC can directly tell me what’s going to happen to a particular part of my country in terms of...it’s pitched at a more general level. And I don’t think that beyond a very general, broad sense the IPCC documents are so useful for the negotiations. You know, the negotiations, the whole UNFCCC and the COP process, right? And all of the things that come out of the UNFCCC – the Kyoto Protocol. I mean in a broad sense it tells us what to do. So I would always argue that, to me the real core and the value of the IPCC is in WGI. Less in WGII are very less in WGIII. WGIII, I mean in my view we could even do without WGIII.

MM: right!

IR: I mean in a sense it’s very normative. And actually if you go back and see that, if you look at the four assessments and go back to particularly WGIII recommendations and all the market-based instruments. None of that has really made, it’s almost like we’re working in two different boxes. So when it comes to the negotiations and so, and even at the global level, when you look at the UNFCCC process and you see how much has, say, WGIII has said something. You know, say the 4th assessment said there should be, carbon should be priced. Has that in any meaningful way been translated into the negotiations? Not really, but I mean the EU, you know, the Kyoto Protocol and a little bit of the EU ETS [Emissions Trading Scheme] and so on, but that’s all you know? So in that sense, you can take large chunk of WGIII work in the 4th assessment – and I’m sure in the earlier assessments, I haven’t read all the assessments – there’s not pretty much, I mean, because as an economist I can tell you even now that if you want action from the economic perspective they should have a price for carbon, whether it’s through taxes or permits or whatever. Now here’s that simple thing – how is that being discussed in the negotiations? I don’t see much of it happening anywhere. So in that sense it’s almost erm, you know, so I’m very sort of sceptical about what IPCC is contributing, as far as Working Group III’s concerned. And as I said, the process is very political. So you have a northern and a southern CLA [co-ordinating lead author] and then they try to also have some representativeness across LAs [lead authors]. And the other key thing is that each Working Group is serviced by a technical support unit [TSU] which is funded by the national government. So the UK for example in the 3rd assessment was supporting I think one of the Working Groups. So it's essentially, to put it very crudely, he who has the money calls the shots. So if, in my working group now, the TSU is housed in Germany and is effectively being run by the German co-Chair. So there's not much of a role for the other co-Chairs you know? In the sense that who is part of this process, who are the lead authors, and you know, is all being driven by them, by the TSU in a sense, right? So, so, so, then, I mean I would very strongly argue, and I've argued privately – I haven't written about it but I'm happy to write and be quoted on this – that at least the, the emerging big countries of the south like the BRICS [Brazil, Russia, India, China and South Africa], have enough money and have enough amount of I think scientific depth to host a TSU. And to the best of my knowledge none of the TSUs of any of the Working Groups of any of the assessments – so we've had what – four assessments? We have the fifth one going on. Each has three working groups – we've had 15 TSUs. I don't know, you would know. Has any TSU been housed in a southern country?

MM: I don't think so, no. I think you're right. I think it's sort of stayed in...

IR: It's ludicrous. I mean, there is no reason why the government of India couldn't put whatever money it takes – 10, 20, 30 million, 40 million. It's nothing, you know? Or China or Brazil. And has enough scientists, there's enough organizations to host a TSU, you know? It doesn't happen, you know? So I think [inaudible] it's a huge problem, I think, India [inaudible]

MM: So what kind of power does the TSU exercise, in your experience, over the assessment process?

IR: Well the co-Chair of the TSU, I mean the co-Chair of the country...so basically if I am say from the United States or from UK and I'm the co-Chair and I have a TSU supporting me. Then my relationship with my other co-Chair is a relationship of unequals, right? It's a totally unequal relationship.

(…)

Appendix 5

List of interviewees

Interview number	Description & country of residence	Date	Medium
1	Earth system scientist (Germany)	13/05/2011	In person
2	Environmental economist (USA)	28/06/2011	In person
3	Environmental economist (UK)	08/08/2011	In person
4	Environmental economist (Rep. Of Ireland)	28/09/2011	Telephone
5	Climate impacts scientist (Denmark)	29/09/2011	Telephone
6	Climate & ocean scientist (UK)	03/10/2011	In person
7	Environmental scientist (Netherlands)	04/10/2011	Telephone
8	Climatologist (Belgium)	04/10/2011	Telephone
9	Climate impacts scientist (USA)	10/10/2011	Telephone
10	Oceanographer (Denmark)	04/11/2011	Telephone
11	Oceanographer (Australia)	08/11/2011	Telephone
12	Environmental geographer (UK)	25/11/2011	In person
13	Earth system scientist (Australia)	29/11/2011	Telephone
14	Climate policy analyst (USA)	01/12/2011	Telephone
15	Environmental scientist (USA)	05/12/2011	Telephone
16	Oceanographer (Australia)	20/12/2011	In person
17	Climate policy analyst (India)	10/02/2012	In person
18	Environmental NGO researcher (India)	16/02/2012	In person
19	Environmental economist (India)	17/02/2012	In person
20	Environmental NGO researcher (India)	17/02/2012	In person
21	Environmental NGO researcher (India)	18/02/2012	In person
22	Government scientist (India)	24/02/2012	In person
23	NGO researcher (India)	01/03/2012	In person
24	Climate change policymaker (India)	02/03/2012	In person
25	Climate and ocean scientist (India)	02/03/2012	In person
26	Science journalist (India)	06/03/2012	In person
27	Epidemiologist (India)	07/03/2012	In person
28	Climate & policy researcher (India)	07/03/2012	In person
29	Climate & policy researcher (India)	07/03/2012	In person
30	Climate & policy researcher (India)	07/03/2012	In person
31	Climate & policy researcher (India)	07/03/2012	In person
32	Climate & policy researcher (India)	07/03/2012	In person
33	Atmospheric scientist (India)	09/03/2012	In person
34	Government scientist (India)	09/03/2012	In person
35	Environmental economist (India)	12/03/2012	In person
36	Climatologist (India)	13/03/2012	In person
37	Science & technology NGO director (India)	14/03/2012	In person
38	Development NGO researcher (India)	14/03/2012	In person
39	Development NGO researcher (India)	14/03/2012	In person
40	Development NGO researcher (India)	14/03/2012	In person
41	Development NGO researcher (India)	14/03/2012	In person

42	Government analyst (India)	17/05/2012	Telephone
43	Environmental NGO researcher (India)	28/08/2012	In person

Appendix 6

List of analysed documents

Documents related to chapters 5 & 6

Number	Title	Author(s)	Publisher	Date	Type
1	Targets and Indicators of Climate Change: Report of Working Group II of the Advisory Group on Greenhouse Gases	F. Rijbersman & R. Swart	Stockhom Environment Institute	1990	Scientific publication
2	The greenhouse marathon: proposal for a global strategy	P. Vellinga & R. Swart	*Climate Change: Science, Impacts and Policy* - Cambridge University Press	1991	Scientific publication
3	Framework Convention on Climate Change	United Nations	United Nations	09/05/1992	Policy document
4	Climate Change in the European Union	European Environment Agency	Europian Union	1997	Report
5	WGII plenary meeting report	IPCC	IPCC TAR archives, Environmental Science and Public Policy Archives, Harvard University	03/10/1998	Institutional document
6	Lead author nominations, evaluations and selections	IPCC	IPCC TAR archives, Environmental Science and Public Policy Archives, Harvard University	1998	Institutional documents
7	Author selection - email from H.J. Schellnhuber to J. McCarthy	Hans Joachim Schellnhuber	IPCC TAR archives, Environmental Science and Public Policy Archives, Harvard University	03/08/1998	Email
8	Invitations to WGII Ch 19 drafting meeting, 1-3 July, Potsdam	WGII chairs	IPCC TAR archives, Environmental Science and Public Policy Archives, Harvard University	21/06/1905	Correspondence
9	WG II Ch 19. Vulnerability to Climate Change and Reasons for Concern: A Synthesis. First Order Draft	Joel B. Smith et al.	IPCC	1999	Scientific publication
10	WG II Ch 19. Expert review	Various	IPCC	Oct-99	Institutional document
11	WG II Ch 19. Vulnerability to Climate Change and Reasons for Concern: A Synthesis	Joel B. Smith et al.	IPCC	2001	Scientific publication

12	WG II Ch 19. Vulnerability to Climate Change and Reasons for Concern: A Synthesis. Final draft for Government review	Joel B. Smith et al.	IPCC	2001	Scientific publication
13	WG II: Impacts, Adaptation and Vulnerability. Summary for Policymakers	IPCC	IPCC	2001	Scientific publication
14	WG II Ch 19. Government review	Various	IPCC	May-01	Institutional document
15	Speech by Dr Rajendra K. Pachauri, Chairman of the IPCC, at the Twenty First Session of the IPCC	Rajendra K. Pachauri	IPCC	07/11/2003	Speech transcript
16	Probabilistic integrated assessment of "dangerous" climate change	Mike Mastrandrea & Stephen Schneider	Science	23/04/2004	Scientific publication
17	IPCC Expert Meeting on the science to address UNFCCC Article 2 including key vulnerabilities	IPCC Secretariat	IPCC	May-04	Meeting report
18	WG II Ch 19. Assessing key vulnerabilities and the risk from climate change. First Order Draft	Stephen Schneider et al.	IPCC	2005	Scientific publication
19	Probabilistic assessment of "dangerous" climate change and emissions pathways	Stephen Schneider & Mike Mastrandrea	Proceedings of the National Academy of Sciences	01/11/2005	Scientific publication
20	WG II Ch 19. Expert review of first order draft	Various	IPCC	05/12/2005	Institutional document
21	WG II Ch 19. Assessing key vulnerabilities and the risk from climate change. Second Order Draft	Stephen Schneider et al.	IPCC	2006	Scientific publication
22	WG II: Impacts, Adaptation and Vulnerability. Summary for Policymakers. Second Order Draft	IPCC	IPCC	2006	Scientific publication
23	Framing the Economics of Climate Change: an international perspective. Submission to the Stern Review on the Economics of Climate Change	Michael Grubb et al.	IPCC	2006	Scientific publication
24	Hearing of the Senate Foreign Relations Committee: The Hidden Cost of Oil	Sen. Richard G. Lugar (chair)	Federal News Service	30/03/2006	Hearing transcript
25	WG II Ch 19. Expert review of second order draft	Various	IPCC	Aug-06	
26	WG II Ch 19. Government review of second order draft	Various	IPCC	Aug-06	Institutional document
27	WG II: Impacts, Adaptation and Vulnerability. Summary for Policymakers. Second Order Draft. Government review	Various	IPCC	Dec-06	Institutional document
28	WG II: Impacts, Adaptation and Vulnerability. Summary for Policymakers. Second Order Draft. Expert review	Various	IPCC	Dec-06	Institutional document
29	WG II: Impacts, Adaptation and Vulnerability. Summary for Policymakers	IPCC	IPCC	2007	Scientific publication
30	Climate Change 2007: Synthesis Report	IPCC	IPCC	2007	Scientific publication
31	WG II Ch 19. Assessing key vulnerabilities and the risk from climate change. Working Group II contribution to IPCC AR4	Stephen Schneider et al.	IPCC	06/04/2007	Scientific publication
32	Eight session of Working Group II of the Intergovernmental Panel on Climate Change, 2-6 April 2007	IISD	Earth Negotiations Bulletin	08/04/2007	Meeting report
33	Climate change report to warn of potentially 'irreversible' impacts	Marlowe Hood	Agence France Press	16/11/2007	Online news article
34	New York Times: What didn't make it into the final IPCC report	Yves Smith	Naked Capitalism	17/11/2007	Online news article

35	Intergovernmental Panel on Climate Change - Fourth Assessment Synthesis Report	Mike Townsley	Targeted News Service	17/11/2007	Online news article
36	UN chief seeks more leadership on climate change	Elisabeth Rosenthal	New York Times	18/11/2007	Newspaper article
37	Washington holds firm on emissions	Tony Walker	Australian Financial Review	19/11/2007	Newspaper article
38	Act now to stop global warming, says panel	Jamie Smyth	The Irish Times	19/11/2007	Newspaper article
39	UNEP and WMO panel puts final full stop behind risks and rewards of combating climate change	States News Service	States News Service	19/11/2007	Online news article
40	Tipping the scales	Tim Lenton & Hans Joachim Schellnhuber	Nature Reports Climate Change	22/11/2007	Opinion piece
41	Frequently asked questions about the science of climate change	Environment Canada	Government of Canada	2008	Online resource
42	Procedures for the preparation, review, acceptance, adoption, approval and publication of IPCC reports	IPCC Secretariat	IPCC	04/09/2008	Institutional document
43	Only a small price to tackle emissions	Rajendra K. Pachauri	The Australian	08/09/2008	Opinion piece
44	IPCC "reasons for concern"		Center for Climate and Energy Solutions	2009	Online resource
45	Risks of global warming have been underestimated	Potsdam Institute for Climate Impacts Research	PIK	23/02/2009	Press release
46	Climate 'embers' burning brighter	Andrew C. Revkin	Dot Earth Blog	23/02/2009	Blog post
47	Why 2007 IPCC report lacked 'embers'	Andrew C. Revkin	Dot Earth Blog	26/02/2009	Blog post
48	Risks of global warming have been underestimated	Digital Journal	Digital Journal	27/02/2009	Online news article
49	Rekindling the climate embers	Ben Pile	Climate Resistance	28/02/2009	Blog post
50	Earth may be entering climate change danger zone	Catherina Brahic	New Scientist	10/03/2009	Magazine article
51	Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC) "reasons for concern"	Joel B. Smith et al.	Proceedings of the National Academy of Sciences	17/03/2009	Scientific publication
52	Defining dangerous anthropogenic interference	Michael E. Mann	Proceedings of the National Academy of Sciences	17/03/2009	Scientific publication
53	Wilkins about to go pfft	Lou Grinzo	The Cost of Energy	05/04/2009	Opinion piece
54	Wesleyan University's Gary Yohe: On carbon costs, media, and not 'looking silly'	Christine Woodside	Yale Forum on Climate Change and the Media	25/06/2009	Online news article
55	Climate as art: What's your review?	Andrew C. Revkin	Dot Earth Blog	14/09/2009	Blog post
56	Treading on burning embers	Julien Vincent	Greenpeace Australia	29/09/2009	Blog post
57	Climate Change Science Compendium		United Nations Environment Programme	21/10/2009	Scientific publication

58	Science as a Contact Sport: Inside the Battle to save Earth's Climate	Stephen Schneider	National Geographic Books	03/11/2009	Autobiography
59	Amid worrisome signs of warming, 'climate fatigue' sets in	Richard A. Kerr	Science	13/11/2009	Magazine article
60	"Reasons for concern" (about climate change) in the United States	Gary Yohe	Climatic Change	01/03/2010	Scientific publication
61	IPCC got it tragically wrong	Lou Grinzo	The Cost of Energy	20/03/2010	Opinion piece
62	Global emissions targets will lead to 4C temperature rise, say studies	Juliette Jowit & Christine Ottery	The Guardian (UK)	05/07/2010	Newspaper article
63	Present targets for CO2 emission cuts will not prevent a 4C global temperature rise		West Coast Climate Equity	11/07/2010	Blog post
64	Climate Change Assessments: Review of the Processes and Procedures of the IPCC	Harold Shapiro et al	InterAcademy Council	30/08/2010	Report
65	Decisions taken with respect to the review of IPCC processes and procedures	IPCC Secretariat	IPCC	13/05/2011	Report
66	Volvo Environment Prize awarded to climate researcher		Business Wire	08/09/2011	Online news article
67	Decision taken by the Panel at its 32nd Session: With regards to the Recommendations resulting from the Review of the IPCC Processes and Procedures by the InterAcademy Council	IPCC Secretariat	IPCC	14/10/2011	Report
68	The brutal logic of climate change	David Roberts	Grist.org	06/12/2011	Opinion piece
69	Climate Change and Food Security: Science		Climate Energy Institute	27/07/2012	Online resource
70	Realistically what might the future climate look like?	Skeptical Science	Skeptical Science	31/08/2012	Online resource
71	IPCC reasons for concern		Climate Change Emergency Medical Response	n.d.	Online resource

Documents related to chapter 7

Number	Title	Author(s)	Publisher	Date	Type
72	Climate Change: Global risks, challenges and decisions. Synthesis Report	Katherine Richardson et al.	IARU	Mar-09	Scientific publication
73	ClimateCongress.ku.dk	University of Copenhagen	University of Copenhagen	Mar-09	Website
74	Climate's 11th hour	Adam Morton & Tom Arup	The Age (Australia)	09/03/2009	Feature article
75	Global warming may trigger carbon 'time bomb', scientist warns		The Guardian (UK)	10/03/2009	Newspaper article
76	Greenland ice tipping point 'further off than thought'		The Guardian (UK)	10/03/2009	Newspaper article
77	Scientists look at new evidence that climate change is accelerating		United Nations Environment Programme	10/03/2009	Press release
78	Politics and Gaia: Surviving Collision	John Ashton	United Kingdom Foreign and Commonwealth Office	10/03/2009	Speech transcript
79	Chaos at the climate conference	Oliver Tickell	The Guardian (UK)	10/03/2009	Feature article
80	Climate change transforming rainforests into major carbon emitters, warn scientists		The Guardian (UK)	11/03/2009	Newspaper article

81	Permafrost: Carbon rise as heat turns frozen soil to compost		The Guardian (UK)	11/03/2009	Newspaper article
82	The Weekly Carboholic: IPCC 2007 conclusions were too conservative	Brian Angliss	Scholars and Roagues	11/03/2009	Online news article
83	Heatwaves set to kill many more people in Scots cities	Jenny Haworth	The Scotsman	11/03/2009	Newspaper article
84	Health hazards demand stronger climate change measures argues UN agency	United Nations	United Nations	11/03/2009	Press release
85	Health impact of climate change needs attention	World Health Organization	World Health Organization	11/03/2009	Press release
86	£50bn of European investment needed to kick-start Saharan solar plan		The Guardian (UK)	11/03/2009	Newspaper article
87	California could flood this century		Digital Journal	12/03/2009	Newspaper article
88	7°C rise will render half of the world's areas unliveable, expert warns		The Guardian (UK)	12/03/2009	Newspaper article
89	Green shoots before the recovery	Oliver Tickell	The Guardian (UK)	12/03/2009	Feature article
90	Letters and emails: Obama can lead us to a green economy	John Nissen	The Guardian (UK)	12/03/2009	Newspaper correspondence
91	Fast-Action' measures are needed in addition to cuts in CO2 emissions	Alexandra Viets	Institute for Governance & Sustainable Development	12/03/2009	Press release
92	Global warming killing 150,00 more people in poor countries: WHO		Hindustan Times (India)	12/03/2009	Newspaper article
93	Watch out climate-change impact: WHO		RTT News (US)	12/03/2009	Online news article
94	A kick-start in Copenhagen: The picture scientists laid out at our climate summit is bleak, but the research paves the way for action	Katherine Richardson	The Guardian (UK)	13/03/2009	Opinion piece
95	Key messages from international scientific congress on climate change	Australian National University	Australian National University	13/03/2009	Press release
96	How we win	Juliana Williams	It's Getting Hot in Here: Dispatches from the Youth Climate Movement	15/03/2009	Online news article
97	Let's get cleaning	Francis Wilson	The Sunday Times (UK)	15/03/2009	Opinion piece
98	Clean energy can meet 40% of global demand by 2050		See News Renewables	16/03/2009	Online news article
99	Biofuel growth needs bigger energy crop yields		See News Renewables	16/03/2009	Online news article
100	What message, and whose, from Copenhagen?	Mike Hulme	BBC News Online	16/03/2009	Opinion piece
101	New renewables to power 40 per cent of global electricity demand by 2050		Space Daily	17/03/2009	Online news article
102	In the Arctic, a time-lapse view of climate change	Terry Gross	National Public Radio	18/03/2009	Radio show transcript
103	Global green new deal needed to save planet	Frank McDonald	The Irish Times	18/03/2009	Opinion piece
104	Kiwis solve global warming riddle		New Zealand Herald	20/03/2009	Newspaper article
105	Dialog on science and policy to address the climate crisis to conclude the International Association of Research Universities Climate Congress, Copenhagen, Denmark	Paul Baer & Daniel M. Kammen	Environmental Research Letters	Apr-09	Editorial

106	Fighting global warming offers growth and development opportunities		Space Daily	01/04/2009	Online news article
107	Will a wind turbine work for you?	UK Met Office	UK Met Office	03/04/2009	Press release
108	Early action vital	UK Met Office	UK Met Office	07/04/2009	Press release
109	First wave of 'climate refugees' on the seas	James Norman	The Age (Australia)	09/04/2009	Newspaper article
110	Deep emissions cuts could lessen climate change, study finds		Climate Wire	15/04/2009	Online news article
111	Rising sea levels in Pacific create wave of migrants	Kristina Stefanova	Washington Times (US)	19/04/2009	Newspaper article
112	This Earth Day, educate one another	Mike Honda	Politico.com	22/04/2009	Online news article
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342	Orissa Climate Change Action Plan, 2010-2015.	Government of Orissa	Government of Orissa	04/06/2010	Policy document
343	Himalayan glaciers won't shrink by 2035		Hindustan Times	11/06/2010	Newspaper article
344	Kerry warns of escalation in Indo-Pak tension due to climatic changes		Hindustan Times	17/06/2010	Newspaper article
345	National Mission on Strategic Knowledge for Climate Change	Department of Science and Technology	Government of India	01/07/2010	Policy document
346	Effect of global warming on glaciers - question 432	Dr. K. Malaisamy	Rajya Sabha	Aug-10	Parliamentary question
347	Study on impact of climate change and global warming - question 955	N.R. Govindarajar	Rajya Sabha	Aug-10	Parliamentary question
348	United States: Report on Green House Gas Emissions		TendersInfo	10/08/2010	Online news article
349	Pachauri likely to get away with mild rap	Yashwant Raj	Hindustan Times	29/08/2010	Newspaper article
350	Review panel suggest leadership reforms in IPCC		Indian Express	31/08/2010	Newspaper article
351	Himalayan glaciers - question 1863	Shreegopal Vyas	Rajya Sabha	Sep-10	Parliamentary question
352	Impact of global warming on glaciers - question 1086	Prof. Alka Balram Kshatriya	Rajya Sabha	Sep-10	Parliamentary question
353	Read the signals	Darryl D'Monte	Hindustan Times	13/09/2010	Opinion piece
354	Pressure mounting on Pachauri to resign as IPCC head		Hindustan Times	23/09/2010	Newspaper article
355	CSE comes down hard on proposal to allow international scrutiny of domestic targets	Centre for Science & Environment	Centre for Science & Environment	03/10/2010	Press release
356	Dutch review supports key warnings of IPCC report		Hindustan Times	06/10/2010	Newspaper article
357	Pachauri calls Indian govt. report on melting Himalayan glaciers as "voodoo science"		Hindustan Times	09/10/2010	Newspaper article
358	Put on notice, IPCC's Pachauri tasked with carrying out IPCC reform		Hindustan Times	20/10/2010	Newspaper article
359	Climate Change and India: A 4x4 Assessment	INCCA	Ministry of Environment & Forests	Nov-10	Scientific document
360	India should focus on domestic climate change: Ramesh		India News	12/11/2010	Online news article
361	Jairam Ramesh criticises NAPCC, says people should be involved		PTI News	12/11/2010	Online news article
362	Jairam Ramesh's speech at National Policy Dialogue for Climate Change Action	Jairam Ramesh	YouTube	12/11/2010	Speech transcript

363	A question of timing	M Rajshekar	Hindustan Times	13/11/2010	Newspaper article
364	Ahead of Cancun, India to release climate change data		The Pioneer	14/11/2010	Newspaper article
365	India releases major new study on climate change science	INCCA	Ministry of Environment & Forests	16/11/2010	Press release
366	Climate change to have mixed impact on India: report		Indian Express	17/11/2010	Newspaper article
367	India may be two degrees warmer by 2030: report		MINT	17/11/2010	Online news article
368	Climate change to hit four sectors hard		The Pioneer	17/11/2010	Newspaper article
369	Catch more fish but don't celebrate warmth		The Telegraph (India)	17/11/2010	Newspaper article
370	India faces major climate changes by 2030	Katy Daigle	Live Mint	17/11/2010	Online news article
371	Temperatures to be up 1.7-2.2 by 2030		Times of India	17/11/2010	Newspaper article
372	Hasnain leads in race for JNU top job	Anubhuti Vishnoi	Indian Express	17/11/2010	Newspaper article
373	Climate change report vindicates IPCC	Manu Sharma	Climate Revolution	17/11/2010	Press release
374	An apple a day could soon vanish		Mail Today	18/11/2010	Newspaper article
375	RTI reveals Govt failure to protect public interest in climate talks	Manu Sharma	Climate Revolution	22/11/2010	Press release
376	Melting of glaciers - question 3584	Shyamal Chakraborty	Rajya Sabha	Jan-11	Parliamentary question
377	State Action Plan on Climate Change (2010-2015): Mizoram	Government of Mizoram	Government of Mizoram	07/01/2011	Policy document
378	State Action Plan on Climate Change: Meghalaya (Draft copy)	Government of Meghalaya	Government of Meghalaya	08/01/2011	Policy document
379	Assam State Action Plan on Climate Change, 2012-2017	TERI	Government of Assam	10/01/2011	Policy document
380	Sikkim Action Plan on Climate Change (2012-2030)	Government of Sikkim	Government of Sikkim	Mar-11	Policy document
381	Isro: 75% of Himalayan glaciers retreating	Jayashree Nandi	Times of India	16/05/2011	Newspaper article
382	Climate science mired in politics: Ramesh		Indian Express	09/06/2011	Newspaper article
383	Dry Gujurat, rich in wetlands		Times of India	09/06/2011	Newspaper article
384	Jairam Ramesh's allegation - climate scientists have political agenda - absurd, dangerous	Manu Sharma	Climate Revolution	10/06/2011	Press release
385	Arunachal Pradesh State Action Plan on Climate Change	Government of Arunachal Pradesh	Government of Arunachal Pradesh	13/07/2011	Policy document
386	State Action Plan on Climate Change for Andhra Pradesh	Environment Protection Training and Research Institute	Government of Andhra Pradesh	16/07/2011	Policy document
387	Climate change research initiative: Indian Network for Climate Change Assessment	Subodh Sharma & Rita Chauan	Current Science	Aug-11	Scientific document
388	India: Impact of climate change on agriculture		TendersInfo	06/09/2011	Online news article
389	India launches network to assess climate change		Zee News	15/10/2011	Online news article

390	Second National Research Conference on Climate Change: Report		IIT-Delhi, IIT-Madras & Centre for Science and Environment	Nov-11	Conference report
391	India most vulnerable to climate change: Omkar Singh		Garhwal Post	14/11/2011	Newspaper article
392	The Twelfth Five-Year Plan of the Government of India	Planning Commission	Government of India	09/12/2011	Policy document
393	Rajasthan State Action Plan on Climate Change	TERI	Government of Rajasthan	15/12/2011	Policy document
394	Madhya Pradesh State Action Plan on Climate Change	EPCO	Government of Madhya Pradesh	Feb-12	Policy document
395	India's path to knowledge	Kamaljit S. Bawa	Science	30/03/2012	Letter to journal
396	India: Second national communication to the United Nations Framework Convention on Climate Change	Ministry of Environment and Forests	Government of India	04/05/2012	Policy document
397	Rs 300-crore scheme to strengthen research for climate change cleared	Chetan Chauhan	Hindustan Times	08/07/2013	Newspaper article

Appendix 7

Published at societyandspace.com on 26 July 2013 as part of a collection of pieces entitled *400ppm: Exit Holocene, Enter Anthropocene.*

400ppm: Geographies of a global experiment

The wavering, saw-toothed plot of atmospheric carbon dioxide levels pushed determinedly over the threshold of 400ppm, tracing a line from the global space of the atmosphere to the hermetic spaces of geoscientist Charles Keeling's early CO2 observations. As one of millions of virtual witnesses to this traversal, I was reminded that Keeling's deployment of his 5-litre flasks was not the first time that a glass orb had changed science and, with it, the world.

Charles Keeling began his work of estimating sky-bound CO2 by sampling the air with spherical glass flasks fitted with a tap to control the flow of atmospheric matter, and to transform the interminable flux of the troposphere into an abeyant, isolated segment of a much larger whole. The 17th century chemist Robert Boyle also dealt with questions "of how to put the air into abeyance, suspending its operations in order to see it, as it were from the outside, as an outside that was paradoxically enclosed conveniently in visible and manipulable interiors" (Connor 2010, 26). Boyle resolved these challenges with his mechanical air pump, with which he inquired into the nature of a vacuum and the variability of air pressure. Blown glass enabled the enactment of a new experimental space where the effects of air on other types of matter could be observed, witnessed, and granted the status of positive knowledge.

Like the observational spaces of Keeling's spheres, Boyle's experimental forms evolved in a complex relationship with the broader cultural milieu. Experimental knowledge-making, with its 'invisible college' of trustworthy witnesses and its lucid linguistic strategies which recapitulated the transparency of the air pump itself, was promoted as a model of calm, respectful collective reasoning which offered an alternative to the vehemence and antagonism of the concurrent restoration of the English monarchy. The epistemic and communicative strategies of the new experimentalists perhaps helped establish the primacy of the visual in Western political culture (Ezrahi 1990), while capturing perfectly the notion that solutions to the problem of knowledge are found in solutions to the problem of social order (Shapin and Schaffer 1985).

Like Boyle's efforts to put both the air and political hostility into abeyance, Keeling's measurements of the air's gaseous composition ushered in a new cosmopolitics. It was a cosmopolitics which changed our relationship with the sky. No longer the domain of the gods or the vicissitudes of an indifferent Nature, the sky was rendered social. In drawing associations between human actions the global atmosphere, Keeling and his contemporaries and followers did 'politics', "in the sense of altering the associations – and thus directly the 'social' – that all beings establish with all other beings." (Latour 2012, 72). This new cosmopolitical space has been called experimental – not in the epistemological sense of control and repetition, but in the more unnerving sense of inadvertent drivers and indeterminate outcomes. While participation in Boyle's experimental community was tightly regulated and symptomatic of a deeply stratified polity, this new planetary experiment renders us all both object and subject; both knower and known.

The site of this new cosmopolitics – its principle 'centre of calculation' – is the Mauna Loa observatory in Hawaii. Strategically located above the layer of particulate industrial pollution, the observatory reaches into the 'well-mixed' portion of the troposphere, where representative samples of the global can be captured, sealed and processed. This site thus speaks for the globe, and its geography renders it the perfect fulcrum from which to narrate the shifting cosmology of the sky: from ethereal purity to experimental hybridity.

Most of the words we use to describe this experimental situation trade upon a lack of something, rendered by a negative prefix: think of 'indeterminacy' or 'uncertainty'. Perhaps that is why numbers like 400ppm or 2°C have such potency. They offer a temporal and phenomenological anchor amid the ongoing unfolding of our collective futures; a restoration of epistemic and political order like that promised by the air pump. Just as Robert Boyle offered a new epistemology for his turbulent times, climate science has offered numbers that become the currency of political deliberation.

While the readings of 400ppm are unnerving, these observational figures provide a peculiar comfort amid the epistemological ambiguity of climate change. Unlike model projections of future changes and measurements of the atmosphere's thermal energy, CO2 numbers have not been subject to public tussles over their scientific veracity. There is something reassuringly empirical and controlled about sealing a flask, taking it to a laboratory, and teasing-out the tiny molecules of CO2. The subsequent visual inscriptions, particularly the iconic 'Keeling Curve', have been powerful allies to those who read from these upward-trends a compelling argument for social and political change.

While numbers like 400ppm are useful pointers and descriptors, they unfortunately help us little with the task of responding to climate change equitably, democratically, and justly. We should see Keeling's flasks, with their hermetic fastenings, not as a metaphor for rational control but as an instrument of atmospheric cosmopolitics. They should remind us that the climate is a space of emergent associations; of a political complexity that we are only starting to ascertain in our own cosmologies; to capture in our own flasks.

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