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Uncertainty management in the IPCC: agreeing to disagree

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Looking back over three and a half Assessment Reports, we see that the Intergovernmental Panel on Climate Change (IPCC) has given increasing attention to the management and reporting of uncertainties, but coordination across working groups (WGs) has remained an issue. We argue that there are good reasons for working groups to use different methods to assess uncertainty, thus it is better that working groups agree to disagree rather than seek to bring everybody on one party line.

In the IPCC First and Second Assessment Reports, uncertainty was not addressed systematically across WGs. Uncertainty statements were not centrally coordinated, but left at the authors' discretion. In 1990, the WG I executive summary started with what the authors were certain of and what they were confident about, thus taking a subjective perspective. They used strong words like "predict", a term which would nowadays rightly be avoided. For WG II (Impacts) and WG III (Response Strategies), the review procedures were not very rigorous yet and uncertainties were not a major topic of debate. The formulation of key findings did take uncertainties into account, albeit not in any consistent manner. Two pages were devoted to scenarios – as a description of uncertainty about the future – used in the WG III report. The Summary for Policymakers contains a few sentences stressing several uncertainties, e.g. those related to the difficulty of making regional estimates of climate-change impacts.

In the Second Assessment Report (1996), WG I dropped the usage of uncertainty terms in its main policy messages, but added a special section on uncertainties. Efforts were made to reach consensus on appropriate formulations for uncertainty-laden statements. The key formulation "The balance of evidence suggests..." was coined during the Plenary meeting jointly by IPCC delegates and lead authors. "Predicting" was replaced by "projecting" climatic changes on the basis of a set of scenarios. In its concluding chapter "Advancing the understanding", WG I mentions the need for a more formal and consistent approach to uncertainties in the future. WG II, which covered scientific-technical analyses of impacts, adaptations and mitigation of climate change, assigned low, medium or high levels of confidence to the major findings of the chapters in the executive summaries, following again the subjective approach. Explicit reporting of uncertainties was not a key focus in the WG III assessment on the economic and social dimensions of climate change. They were captured through reporting of ranges from the literature and scenario-based what-if analyses of costs of response action.

In preparation for the TAR (2001), a strong demand for a more systematic approach to uncertainties was identified - as recommended by WG I in the Second Assessment Report. The subsequent discussion led to the cross-cutting "Guidance Paper" by Moss and Schneider (2000). The paper summarized the relevant literature and build upon the Second Assessment Report's lessons. It was tempting to organize guidelines on uncertainty around a general scale going from totally true and certain (i.e. known) to totally unknowable. This indeed may be an attractive idea from the perspective of a perceived need for simplicity, and it has been discussed by the team which prepared the Guidance Notes. But this would have been oversimplification, so a two-dimensional qualitative way to qualify key findings based on the amount of evidence (number of sources of information) and the degree of agreement (do they point out in the same direction) was proposed. It was left up to author teams to calibrate the 'amount of evidence' and 'degree of agreement' scales. The relationship between evidence and belief varies a lot between disciplines. Presumably, a single available case study would score low on the first dimension, while more than six independent controlled experiments make a high score, on both dimensions if their results would be similar. Thus, the guidance paper proposed 1/ an analysis methodology (recommended steps for assessing uncertainty); 2/ a common vocabulary to express quantitative levels of confidence and 3/ terms describing qualitative levels of understanding, based on both the available amount of evidence and the degree of consensus among experts.

In the Guidance Paper, no difference was made between disciplines or WGs, implicitly suggesting a common approach for all WGs, issues and disciplines. During the writing process, discussions in author teams focused on the choice of the most appropriate terminology for the summaries rather than on a consistent application of the full uncertainty assessment methodology. WG II largely adopted the proposed levels of confidence. WG I authors amended the guidelines by adding a "virtually certain" category and developing a different terminology for describing quantified levels of likelihood. Their definition of likelihoods refers to judgmental estimates of confidence. WG III authors were encouraged to use the Guidance Paper, but – with a few exceptions – ignored it, feeling that the proposed approach did not address their perspectives on uncertainty. This led to fairly consistent treatment of uncertainties within but not across WGs in the TAR. WG I focused on uncertainties in climatic processes and probabilities, WG II on risks and confidence levels, and WG III (primarily economists and other social scientists) continued to address uncertainties less systematically and in a different fashion.

This outcome can be understood because the issues met with by social scientists have a different nature from those met with by natural scientists, adding uncertainties due to human choice to the lack of scientific understanding of the systems which determine climatic changes and associated impacts. More than a century of philosophical discussion on uncertainty has shown that there are divisions that must be respected:

- The division between the objective and subjective views of probability is the oldest. Objective views of probability include the classical approach (probability is the proportion of favorable cases over total cases), the frequentist approach (probability is the limit of frequency in the long run (von Mises, 1957)), and the propensity approach (probability is a physical tendency (Popper, 1959)). These views are objective in that probability is seen as an intrinsic property of the system. These approaches are opposed to the subjective point of view (called Bayesian by some authors, although there are objective Bayesians), in which probability refer to degrees of belief (de Finetti, 1937; Savage, 1954).
- The distinction between risk and uncertainty is also very old (Knight, 1921). It describes the difference between situations where information can legitimately be represented using precise probabilities (risk), and situations where information is too imprecise to meaningfully use a probability distribution (uncertainty). In addition to risk and uncertainty, Wynne (1992) distinguishes ignorance (where we 'don't know what we don't know', i.e. there is no list of mutually exclusive and collectively exhaustive list of outcomes) and – spanning uncertainty and ignorance – indeterminacy (where causal chains or networks are open). The later two aspects are either implicitly or explicitly (e.g. when describing surprises) included in IPCC assessments.
- The third dimension is the difference between uncertainty in natural systems and uncertainty in human and social systems. The former are causal: the past determines the future. However, human systems are intentional, so the arrow of time can be reversed: long term goals can determine the present. Intentionality also implies that Laplace's principle of indifference (all outcomes are equally probable) should be replaced with a principle of optimization: to assume that agents in the system will choose what they think is best rather than act randomly. Thus, game theory is more relevant than probability theory for analyzing these systems.

The objective/subjective difference is philosophically irreducible, since truth and belief are fundamentally different concepts (and knowledge is another, requiring true belief). But the distinction between theories of precise risk and imprecise uncertainty is not irreducible, since precise probabilities can be seen as the limit case of imprecise probabilities, when the imprecision is zero. While probabilistic reasoning is by far the best understood method in agreement with the dominant precise approach in science, it is only an ideal model. Situations where precise probabilities are not well defined cannot be avoided when assessing the long-term future of a real global system. Mathematical procedures dealing with imprecision are being developed in a growing body of empirical and theoretical literature, some directly related to the climate change issue (see Kriegler et al., 2005).

As for the role of human choice captured by the causal/intentionality dimension above, it is fundamental from a policy point of view to distinguish between the uncertainties related to a lack of knowledge about the way bio-geochemical and socio-economic systems function and those related to the understanding of the role of human choice. Allen et al. (2004) recommend that WG I distinguish between scenario uncertainty (different emissions paths), natural variability, and response uncertainty (incomplete knowledge of timescales and feedback processes). In an overview of inputs into a US hearing on scientific uncertainties communication, Briscoe (2004) noted that the science of climate change is affected by two main types of uncertainty: uncertainty about how the climate system works and uncertainty about how human actions will impact climate change.

Critically for an interdisciplinary panel, there is a deep cultural divide between traditional experimental sciences methods and social sciences methods. Experimental sciences seek to determine precise objective frequencies based on a large body of observations, assuming that experiments are reproducible. Social sciences have rarely replicated controlled experiments or even complete observations, and often the most adequate available description of knowledge is narrative. This leads to imprecise theories, which are also subjective in that they are based on the actions of humans as observed by other humans. Some debates on uncertainty within IPCC circles (for example on the question of the likelihood of future emission levels and resulting climate change, which depends critically on the socio-economic scenario) can be viewed as discussions between the imprecise-subjective and the precise-objective positions. These cultural habits lead to a natural inclination to play on the difference between natural system uncertainty and human choice and to divide the various WGs according to the dominant epistemic philosophical position and corresponding level of precision. In AR4 also, each WG tends to define its preferred approach regarding communication of uncertainties.

While these differences across WGs may be confusing to readers, they are in fact both legitimate and appropriate. A one-size-fits-all approach would obscure important differences in the type of uncertainties and in the methods. The questions which are addressed by the three WGs differ, and hence also the approach towards uncertainty should differ. An important reason why WG III resists collapsing all uncertainties into a single metric is that doing misleadingly oversimplify the decision-making issue. When likelihood estimates are available, expected net benefit maximisation unambiguously defines an optimal policy, downplaying the critical issues of precaution and controversies.

But agreeing to disagree on the preferred approach does not mean that the approaches are exclusive. Importantly, both objective and subjective sources of information can be precise or imprecise. Imprecision occurs in the objective frequentist setting when the sample size is small, and in the subjective setting when experts are deeply uncertain and cannot give precise probabilities, and hence cannot quantify risk. The distinction between experimental sciences and social sciences methods has never been a hard rule. In economics, a social science, there is a large experimental branch. And experimental results can also be very imprecise when there are missing data or a small number of observations. Even in the natural science of climate, which is largely an observational science, imprecision reign, since some critical data are scarce and experimentation with the climate system is impossible. On the other hand, there are social objects such as financial markets, which lend themselves well to an objective (frequentist) approach.

From third to fourth assessment report, changes to the Guidance Notes were made to better address the epistemic challenges of interdisciplinarity. In the TAR guidelines (Moss and Schneider, 2000), the simple typology of uncertainty listed basic 'sources' of uncertainty in the way one would list the possible causes of failure of a modeling process. The implicit mental model was that there is a Truth to be discovered, and uncertainty is the objective product of defective or limited means of knowledge. The corresponding typology in AR4 guidelines demonstrates a broader view on the issue of uncertainty, as it relates also to subjective types of uncertainty, the human dimensions of uncertainty getting a bigger role as a cause for unpredictability. Guidance Notes for AR4 offer both a vocabulary for levels of confidence (based on expert judgement) and degrees of likelihood (based on quantitative or expert views), as well as an expanded two dimensional table to qualitatively define levels of understanding using the "amount of evidence" and "level of agreement" dimensions.

Since the guidelines' primary goal is to encourage very diverse authors to describe uncertainties, they can not prescribe one single approach, as a normative vocabulary that has meaning only for one philosophical position will not be used by everybody. The diverse, multi-dimensional approach to uncertainty communication used by IPCC authors teams is not only legitimate, but enhances the quality of the assessment by providing information about the nature of the uncertainties. In the future, authors should be encouraged to use the technically correct vocabulary to represent the evidence assessed in the literature. It is indeed desirable that WG III authors use the terminology for frequency-based likelihoods when data are available, even if the WG III as a group uses qualitative uncertainty statements. We would also promote emphasis on the distinction between findings based on observations, those based on models (such as the attribution of observed changes in ecosystem to climate change) and those based on future scenarios including human choice. Qualitative terminology is more adequate rather than a quantitative likelihood scale for issues that involve complex modeling and/or human choice, such as scenarios or the costs and potentials of response options.

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