10

CLIMATE INFORMATION FOR PUBLIC HEALTH ACTION

Challenges and opportunities

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> Water, water everywhere,
> Nor any drop to drink
> 'The Rime of the Ancient Mariner' *by Samuel Taylor Coleridge*

10.1 Introduction

Throughout history, weather has played a major role in all aspects of human endeavour including the outcome of wars and battles. A Japanese word that has been adopted into English is even derived from such instances – 'kamikaze'. In 1274 and 1281 Kublai Khan led two invasions of Japan, but both were thwarted by what seemed like miraculously timed typhoons (§ 4.2.8). The typhoons were then denoted 'divine winds' (or 'kamikaze'). War has also played a major role in the development of weather forecasting. For example, the modern numerical approach to weather forecasting (§ 7.4) was initiated by an experiment conducted in World War I. Further major improvements in technology and observation were made during World War II. It should therefore come as no surprise that many meteorological agencies were initially established by the military. The UK Met Office, for example, was within the Ministry of Defence until 2011 when it was reorganized as part of the Department for Business, Innovation and Skills.

While weather and seasonal climate conditions may impact military capability and operational effectiveness, climate change is identified as a national security issue[1] and as a threat to global security.[2] Health security (see § 1.3.8) requires a cross–sectoral approach, and brings together a wide range of government agencies including national security, health, agriculture, environment wildlife, communication, etc. to tackle imminent health threats.[3] The capacity of the National Meteorological and Hydrological Services (NMHS) to contribute to health security is being

strengthened through new investments in hydro–meteorological services.[4] The threat that both climate variability and change pose to the achievement of development targets has resulted in an increasing concern for climate-sensitive development sectors, including health. Collaborative platforms have emerged involving government, academia, civil society and the private sector to better understand, mitigate and manage climate-related risks to health.[5] While these new efforts are welcome it is clear that health lags behind other sectors in responding to climate risks and the potential use of climate information to help reduce those risks.[6]

Throughout this book, we have sought to identify how, when and where climate information, based on historical data, monitoring products and predictions of future weather and climate can be used to inform health policy and practice. We have prioritized operational information over research opportunities to ensure a focus on practical outcomes. In this chapter, we provide a short review of climate information currently available, as described in detail in Chapters 4–9. We then explore how developments in technologies, institutional arrangements and the education of health professionals are providing new opportunities for translating climate information into a new resource for health-sector decision-making.

10.2 Climate services for health

There are numerous opportunities for creating climate information that can serve to improve health decision-making (Table 10.1).

These include creating information and services from detailed historical analyses as the basis for risk assessment. For example, a review of prior years can help identify at what time of year heat waves are most likely to occur and health services should be on high alert, or how consistent the onset of the malaria transmission season is and when control programmes should initiate indoor residual spray campaigns. With sufficient historical data (80 years) it is possible to distinguish year-to-year and decadal variations as well as long-term trends in the climate. These analyses can help identify for example, whether or not a health event is triggered by El Niño or other global climate predictors.

Monitoring products, using a selection of satellite, model and ground observations (Chapter 6), provide users with near real-time climate information that may be predictive of some health events months in advance. Historical and monitoring information are available for all regions of the world and in all seasons whether or not weather and climate forecasts are available. However, the value of the information products depends on the quality of the data relative to the spatial and temporal scale of the problem being addressed and whether or not they are available to the user in near real-time. All climate information is compromised if its construction relies on sparse and poor quality historical data, as is common in many developing countries. There are significant opportunities for improving national climate information in developing countries if the best globally available products (e.g., satellite or reanalysis) are combined with quality-assessed local ground observations from the national climate archives and monitoring services.[7] Initiatives to rescue

TABLE 10.1 Summary of climate information of relevance to health sector decision-making

Weather- and climate-informed intervention	Climate information	Data requirements	Where practical	When practical	Chapters
Risk assessment for better targeting of interventions					
Assessment of underlying drivers of climate risk to health	Timescale decomposition of variability in historical climate data into interannual, decadal and long-term change	80 years monthly data	Wherever data quality permits	All year, but best to analyse by season	2,3,5
Routine spatial targeting of at-risk population	Indication of geographic region where climate suitability favours particular health risk	Historical climatological data for specific risk indicator – with sufficient years of data, estimates of uncertainty can be included		Whenever data quality permits	2,3,6
Routine seasonal targeting of interventions	Indication of time of year where climate suitability favours health risk	30 years daily data permits detailed characterization of seasonality of extremes, onset, offset and peak season, monthly data for shorter time series can be used for simpler analyses	Wherever data quality permits	All year	2,3,6
Early warning of emergent health risks					
Assessment of interannual variations in health risk associated with ENSO (or other predictors) and therefore potentially predictable using a seasonal climate forecast	ENSO (or other predictor) impact assessment	30 years of monthly or seasonal climate data along with SST data (e.g., ONI)	Wherever data quality permits and there is a defined ENSO (or other predictor) effect	During seasons where there is a defined ENSO (or other) effect	2,3,5,8

(Continued)

Early warning of adverse health events based on current and cumulative climate observations	Near real-time monitoring of climate variables and model that links climate variables to health outcome	Daily, decadal or monthly climate products	Wherever there are reliable near real-time monitoring products (plenty for rainfall but not for temperature)	All year	2,3,6
Early warning of onset or offset in climate suitability for seasonal disease transmission	Weather forecasting up to ten days	Daily averaged weather forecasts	Most skilful in the extra-tropics	Before the onset, offset	2,3,7
Early warning of hot or cold spells	Weather forecasting up to ten days	Daily averaged weather forecasts	Most skilful in the extra-tropics	Most skilful in the winter	2,3,7
Early warning of future winter storms and tropical cyclones with immediate health threats	Weather extremes – e.g., tropical storm forecasts up to ten days	Hourly to daily averaged weather forecasts	In the extra-tropics or in tropical storm-affected regions	During winter storm or tropical cyclone seasons	2,3,4,7
Early warning of health risks one week to one month in advance	Sub-seasonal forecasting	Averaged weather forecasts (not yet operational)	Still experimental	Most skilful in the winter season but limited testing	2,3,7
Early warning of seasonal changes in health risks	Forecasting of seasonally-averaged climate – integrated with climate monitoring system	Seasonal forecasts as seasonally-averaged probabilities	In the tropics	Most skilful during seasons where there is a defined ENSO (or other) effect	2,3,8
Early warning of interannual changes in health risks	Forecasting interannual climate within the next few years	Interannual forecasts as annually or multi-annually averaged probabilities	Still experimental	Most skilful in years two and three and with temperature	2, 3, 9

(*Continued*)

TABLE 10.1 (Continued)

Weather- and climate-informed intervention	Climate information	Data requirements	Where practical	When practical	Chapters
Long term planning and preparedness – for adaptation					
Interventions based on decadal and multi-decadal forecasting	Decadal and multi-decadal forecasting	Decadal prediction – next two to nine years	Low skill everywhere	Not yet viable	2,3,9
Early warning of shifts in climate averaged over 30 years for adaptation planning	Multi-decadal/climate change	10.2.2 Multi-decadal temperature and rainfall averaged over 30 years; best where decadal variations are weak or absent	Globally for temperature; rainfall limited to specific regions	All year, but best analysed by season	2,3,9
Use of climate in assessment of the impact of interventions					
Assessment of impact of climate-sensitive health interventions (removing the climate component to reveal the intervention component)	Analysis of historical climate data to assess difference between base line and intervention years	Data consistent with spatial and temporal characteristics of health data	Wherever data quality permits	All year	2,3,6

Abbreviations: ENSO, El Niño – Southern Oscillation; ONI, Oceanic Niño Index; SST, Sea Surface Temperature.

observational data and to work with NMHS to integrate all relevant station data with global products (see Box 6.2) are essential to improve the quality and coverage of climate data needed for decisions. Sometimes the lack of availability of national observations is the result of a data gap; sometimes it may be the result of NMHS policy that provides forecast information products freely to end-users but withholds access to high-resolution historical data. Data policies vary by country, but whatever the underlying reason for the policy, lack of ready access to quality historical data limits user engagement in climate services.

The emergence of climate services over the last decade has included a strong focus on forecasts and projections of weather and climate.[8,9] In Chapters 7, 8 and 9 we describe the basis of these predictions and when and where they are likely skilful. All forecasts vary in their skill depending on the lead-time, timescale, spatial scale, geographic region, season and over years and decades. What works in in one region or season may not work well in another. The use of climate and weather forecasts has to take into account this complexity, and so their relevance for specific health issues must be tested locally with the help of relevant experts. Standard operating procedures (SOPS) for the development of an international response to El Niño – Southern Oscillation (ENSO) forecasts have recently been developed.[10] These SOPS will need to be elaborated carefully at the national and subnational level to enable an effective response.

The weather and climate forecasting community are pushing the boundaries of predictability at all timescales. Having demonstrated predictability and utility at weather, seasonal and climate-change timescales they are increasingly paying attention to the in-between timescales – sub-seasonal and decadal – in the search for predictability (see Box 7.4 and § 9.3.2). Indications are that sub-seasonal predictions may have a role to play in health early warning systems in the coming years.[11]

Enabling the development and uptake of climate services are: i) major advances in technology that can connect data on the one hand and people on the other; ii) changes in institutional arrangements that support multi-sectoral collaborations; and iii) a growth of educational and professional training initiatives that support the health communities' understanding and use of climate knowledge and information. These areas are elaborated further below.

10.3 Advances in technology

The evolution of our capacity to monitor and predict the climate has been enabled through advances in information and communication technologies (ICT). Advances in recent decades have had a profound impact on societies, transforming many to knowledge-based economies where the ability to integrate disparate information is central to making more effective decisions. These technological advances have increased the connectedness between data and people. This increase in connectedness is substantially due to massive increases in computer power and data storage as well as the global penetration of ICT technologies. A summary of

BOX 10.1 TECHNOLOGY CHANGES PRE, DURING AND POST THE MDG ERA

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The pre-MDG era (1970–2000)

In the pre-MDG period, professionals from both climate and health communities were working on desktop PCs and mainframes. Information was shared via FTP, email, bulletin boards, floppy disks and large magnetic tapes. The emergence of the internet as a research tool in the 1980s and the arrival of the World Wide Web (WWW) as a publicly available communication service in 1989 created a phenomenal new capacity to connect data and information on the one hand and people on the other (see Figure 10.1).

This early stage of development of the WWW is often referred to as Web 1.0.[12] Research and governmental institutions began creating their own websites for the online dissemination of knowledge and data.

The rapidly developing internet was quickly exploited by initiatives, such as the Program for Monitoring Emerging Diseases (ProMED), designed to enable prompt reporting of disease outbreaks.[13] Thus, by the beginning of the new millennium, an extraordinary set of new capacities was available to the health community to understand, predict and manage environmentally-determined health risks. However, many of these opportunities were limited to technically savvy individuals in government research laboratories in the developed world. In1995 it was estimated that only 0.4% of the global population had access to the internet.

MDG era (2000–2015)

Prior to the turn of the millennium the majority of research articles were published in hard copy by scholarly societies for their members (for a fee) and accessed by students and researchers via university libraries; a service severely limited in many developing countries. The arrival of the WWW revolutionized the way research literature could be found, accessed and consumed. With increasing penetration of the internet, students and scholars around the world could download the material they needed from online sources and Open Access (OA) journals, such as the *Malaria Journal* (where papers are available online and free of charge to the user).[14] The Social Web (referred to as Web 2.0) arrived in the late 1990s and early 2000s enabling social networks, blogging and wikis. Now, a new generation of information gatherers, providers and collaborators could contribute to the global knowledge-base.

More astoundingly, mobile broadband technology grew from 738 million mobile cellular subscriptions in 2000 to more than seven billion by the end of the MDG era.[15] The technology provided developing countries with the opportunity to leapfrog cumbersome fixed telephone and broadband technologies, and mobile phones emerged as the communication method of choice for disaster alerts.[16]

With the advent of *big data* analytics it became possible to mine millions of data streams (including electronic health patient records, social media, internet, mobile phones and remote sensing) in an instance.[17] This capability was exploited by Google who monitored online behaviour to provide predictions of flu trends based on an algorithm that captured search behaviour that was initially highly correlated with patients presenting with flu symptoms. The preliminary results from the Google Flu Trends (GFT) tool looked promising. Not only did the GFT predict flu outbreaks ten days before they were observed by the Center for Disease Control, but they were considered to be potentially more accurate.[18] However, after GFT predicted flu trends poorly for a number of years, it became clear that this analytical approach cannot supplant more traditional methods of data collection and analysis.[17] GFT algorithms are not open to public scrutiny, which raises broader concerns of the role of private companies in providing public predictions of epidemics.

ICT may also play a critical role in educating the global public health community about the risks of climate variability and change to health outcomes and the opportunities for improved health created through climate information. The development and provision of Massively Open Online Courses (MOOCs) has expanded rapidly in the past ten years, and their use in climate and health education and profession training is increasing (see Table 10.2).

Sustainable Development Goals era (2015–2030)

The latest evolution of the Web is Web 3.0, or the Semantic Web. This phase emerged towards the end of the MDG period through the realization of 'linked data' on the web. Online knowledge and data can now be classified in ontologies (a set of concepts and categories in a subject area or domain that shows their properties and the relations between them) with inference rules. Sophisticated semantic queries can be applied to this information to extract related content from large databases. These queries can lead to the discovery of relationships between pieces of information that had not been thought of or identified before. Intelligent 'guided' searches can be applied to online data that have semantic metadata. This new capacity is a significant opportunity for data integration in the time of the Sustainable Development Goals (SDGs).

TABLE 10.2 Resources in the climate change–climate and health arena

- Climate Literacy – http://flexible.learning.ubc.ca/news-events/climate-literacy-mooc-launches/
- Climate Services – www.kiusdesign.com.ar/worldBank/index.html
- Climate Change and Health – https://iversity.org/en/courses/climate-change-and-health
- Climate Change Policy and Public Health – https://moocs.wisc.edu/mooc/climate-change-policy-and-public-health/
- Climate Change and Health US-Gov – https://health2016.globalchange.gov/
- Climate Change and Health – www.unitar.org/new-climate-change-learning-modules-health-and-cities-now-available-online
- Climate Curriculum, Climate Information for Public Health Short Course – https://academiccommons.columbia.edu/catalog/ac:130711
- Global Consortium on Climate and Health Education – https://www.mailman.columbia.edu/research/global-consortium-climate-and-health-education

The SDGs call for an integrated approach to development at the country level, and a set of ambitious targets that will be achieved by 2030 (see Chapter 1). The goals include an end to extreme poverty and hunger, while improving access to health care and education, protecting the environment, and building peaceful, inclusive societies. Many of the technological trajectories that emerged during the MDG period are likely to continue during the SDGs. Increasing access to information technologies and massive increases in access to data at higher and higher spatial and temporal resolutions and increasingly in near real-time will certainly continue. According to the 2017 International Telecommunications (ITU) report,[i] 80% of global youth now have access to the internet in 104 countries. Not surprisingly, data and ICT have been prioritized as a core resource to deliver the SDGs (including SDG 13 'to take urgent action on climate change and its impacts'), and to measure progress to their achievement.[19]

the evolution of ICT, from before the Millennium Development Goals (MDG) era to the present day, illustrates the speed of change and is provided in Box 10.1.

While technologies have, and continue to, transform our lives at a phenomenal rate, health decision-makers and the public have struggled to keep up with the sheer volume of data, approaches and tools becoming available. In part, this is because of a proliferation of information services that are not specifically tailored to health user needs. Web platforms designed to support specific health decision-makers are often created by researchers without the capacity (resourcing or interest) to deliver routine dynamic information for specific decision-making needs in a sustainable manner. For example, of 11 web-based platforms designed to service malaria decision-makers only two (the IRI Malaria Maproom and Health
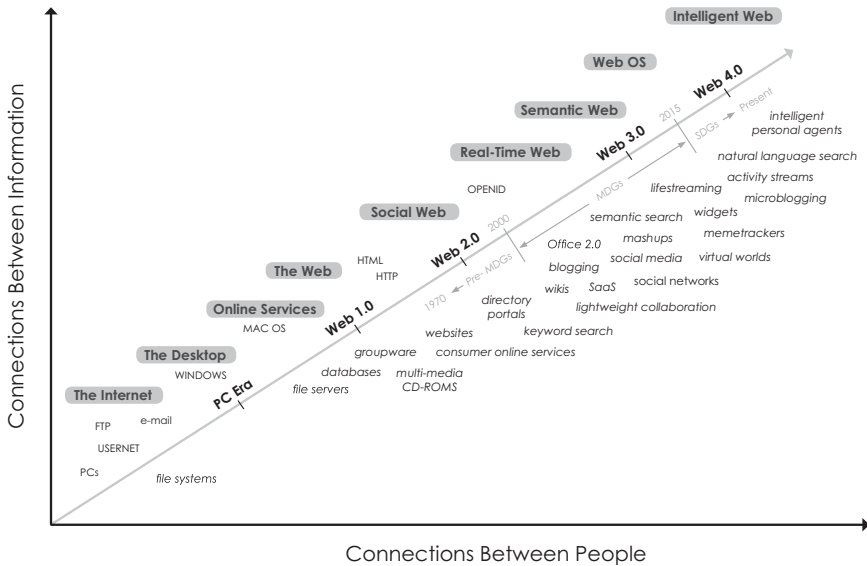
FIGURE 10.1 Connecting information and people. Image adapted with permission from "the intelligence is in the connections" created by Nova Spivack www.novaspivack.com

Map) were automatically updated in near real-time.[20] For national-level planning and surveillance, the District Health Information System II (DHIS2) software has emerged as a global leader in the development of digital tools for the health sector in developing countries[21] and efforts are underway to integrate climate information into the DHIS2.

Technological advances in supercomputing and data storage are also helping to refine details in climate models and providing increasingly accurate early warnings of weather and climate risks at multiple timescales (Chapters 6, 7, 8 and 9). At all forecasting timescales beyond a few hours or days, uncertainty is substantial. Reducing model uncertainties is a priority for the weather and climate community. Investments in a new generation of climate models, capable of resolving finer details, including cloud systems and ocean eddies, is justified given the opportunity to improve forecasts of extreme events and reduce uncertainty in climate-change projections used for adaptation purposes.[22] Technology also plays a major role in enhancing the dissemination and uptake of climate information by decision-makers and the public. However, while technologies bring enormous opportunities they do not serve all equally and they may also bring new and unprecedented risks to society.[23]

10.4 Institutional arrangements

The landscape of actors involved in climate and health activities is broad. It includes United Nations (UN) and multi-lateral agencies, many key institutions representing civil society, health policy and practitioner organizations, government and partners

from other sectors, private industry, non-governmental organizations, academics, philanthropists and development banks. Some of the key drivers of international health policy are described in Chapter 1. Increasing alignment of policy processes around the SDGs provides new opportunities for integrating climate into health policy-making.

The basic building blocks of climate and health interactions revolve around four levels of public health authority: international, national, sub-national and local. International collaboration in infectious disease is particularly important since diseases do not respect national boundaries, and pandemics pose health security threats to far beyond their country of origin. The national level is where policies, developed at home or internationally, are implemented through further elaboration and legislation. Regional authorities often play important roles in translating national policies to local realities. Finally, public health actions, both in developed and undeveloped countries, substantially happen at the local level where regional and local health authorities, private concerns and civil society organizations have sufficient direct access to the population. Decentralization of decision-making to regional bodies provides new opportunities for local meteorological services to engage with local stakeholders. For example, in Kenya significant devolution of government authority to the county (regional level) has occurred in the last five years. Directors of 47 county meteorological services are now empowered to work directly with county-level health directorates providing new opportunities for local innovation.

Health care financing may influence the type and effectiveness of health-related climate-change adaptation and mitigation policies at the national level. During the MDG era, development assistance to lower-income developing countries has prioritized commodities (drugs and medical supplies) for targeted diseases rather than the delivery of health care services and the monitoring of the effectiveness of disease programmes. Without a strong health system with an effective supply-chain management, it is hard to see how climate information can be used to improve the delivery and targeting of health services. The countries most at risk of climate-related health challenges are in Africa and South East Asia where health systems are especially weak. In 2014, only a small proportion (2.84%) of official health development assistance to the 20 countries most vulnerable to climate change focused on the health effects of climate change.[24] Development assistance for strengthening health systems could be reinforced if climate change adaptation funding (e.g., from the Green Climate Fund) were also used to strengthen health care delivery through reductions in climate-related health risks.

In the last few years, the climate and health communities have been coming together in an unprecedented way to ensure the development of weather and climate services that can truly meet the needs of the health community. However, lack of evidence of climate risks to health and the value of climate information to health decision-making in specific contexts is a significant barrier to greater investment in climate and health research. To date, the extensive resources in weather and climate data have been little used in practical decision-making. When investments are made, converting scientific knowledge to information suitable for uptake by

policy-makers is critical if results are to be translated into practical outcomes.[25] Decisions occur at the interface of a number of perspectives including those provided by policy and stakeholder communities. Decisions are also constrained by organizational perspectives (such as the timing when decisions are routinely made or when budgets are released), and build on practitioner experience and capacities (Figure 10.2). Thus, mapping institutional mandates, national and subnational policies and practices along with local capacities (and local champions) and resource flows is a necessary starting point for the development of climate services for the community.

10.5 Education and training

One way to increase uptake of research evidence in policy and practice is to ensure that climate-change issues are taught in schools of medicine, public health, nursing, etc. This will ensure that health workers are familiar with the knowledge, data, methodologies and tools necessary to incorporate climate into health decisions.
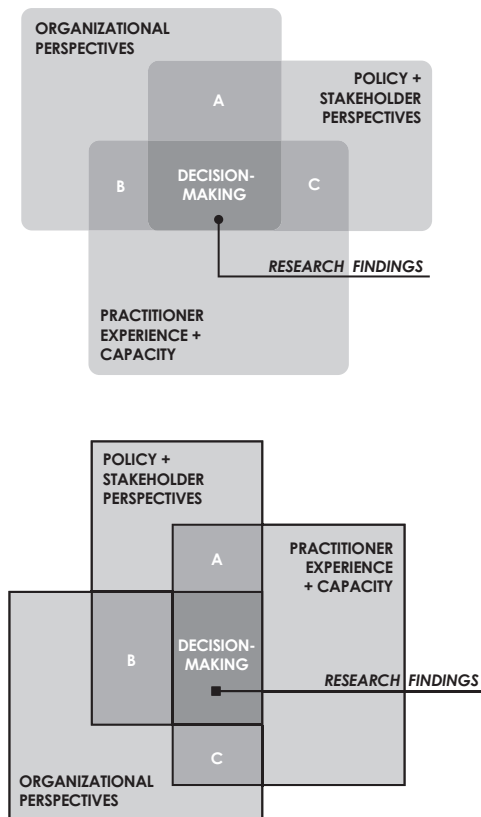

FIGURE 10.2   Research findings can better inform decision-making if they take into account the different perspectives that influence decision-making

Over 2400 years ago the Greek physician, Hippocrates, *Father of Modern Medicine*, encouraged his medical students to understand the local environmental character–istics and to consider seasonal and unusual climatic factors when diagnosing disease in their patients.[26] This perspective has been maintained over the millennia through various schools of medicine, and remains relevant today.[27] The emergence of health professionals as a trusted voice in alerting the public to climate–change risks as well as the health co–benefits of climate–change mitigation has reinforced the need for a climate-literate health community,[28] and the introduction of climate–change education into global public health.[29,30] Some medical institutions are starting to include limited modules on climate change in the core curricula of undergraduate and graduate programmes, but much more needs to be done (Case Study 10.1).

CASE STUDY 10.1 CLIMATE AND HEALTH EDUCATION IN COLOMBIA

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The Pontificia Universidad Javeriana undertook a survey in October 2017 to evaluate the current state of climate-change and health education in univer-sities across Colombia. The ultimate objective was to better understand how education can be improved to help build the next generation of doctors that are cognizant of climate-change issues and to create a healthier and more secure future.

The survey comprised of 28 questions presented in three parts: part one, titled 'Identification', with demographic questions; part two, titled 'Climate Change and Health Courses', with questions including types of courses of-fered, number of students enrolled, professor profile, types of resources uti-lized and barriers to implementing courses; and part three, titled 'Projects and Research on Climate Change and Health', with questions pertaining to financ-ing and objectives of such research. The survey was then distributed by e-mail to all universities in Colombia with an accredited Department of Medicine.

Fifty-nine universities in Colombia were identified with Departments of Medicine. Out of these universities, a total of 47 (80%) responded, across 17 states. The survey revealed that 25 universities offer the topic of climate change and health as part of their undergraduate programme, with only Pontificia Universidad Javeriana in Bogotá offering the topic at both the un-dergraduate and graduate level. Twenty-one of these universities included a course on climate change within a mandatory course of public health or epi-demiology in their curriculum.

Climate-change and health sessions have been taught in one or more universities for the last eight years. Across all institutions, an average of

60 students are currently taught per semester. The most common resource used to teach climate-change and health sessions is scientific literature, followed by documentaries and movies, internet and web pages, and newspapers and print articles.

Out of 22 (47%) universities that reported that they did not have climate-change and health education, 15 have not attempted to implement any course into their curriculum, with the biggest barriers including a lack of personnel to develop the curriculum and a lack of available hours to include the course within the curriculum. As of 2017, only four universities in Colombia have initiated research projects on climate change and health, suggesting that the priority of climate-change and health education is low among the medical community.

Although universities in Colombia have included the topic of climate change and health as a session in a regular course of public health for undergraduate students for an average of eight years, it is clear that there is still more that needs to be done in emphasizing the importance of the topic for future generations of students. To meet this need, medical schools in Colombia must continue to focus their broader curricula around the intersection of climate change and social determinants of health. They must continue to develop research and training to increase the health community's capacity to understand, use and demand appropriate climate information, which is of primary importance to understand how to manage climate-related diseases and how to aid not only the communities they serve, but also the planet.

New initiatives are underway, such as the Global Consortium on Climate and Health Education (GCCHE), which aims to unite medical schools, nursing schools and schools of public health in sharing best practices to build curricula and core training.[31]

The risks to humanity of exceeding planetary boundaries are increasingly clear.[32] Health professionals are now looking to connect large-scale biophysical and societal processes to what is happening to populations within their area of concern. Once near-term climate-related risks to health have been identified it is possible to seek local solutions. Thus, when considering how we might adapt to a changing climate, we are forced once more to reconnect with the Hippocratic perspective and focus our attention on understanding the local climate, its drivers, seasonality, variability (including extremes) and longer-term trends.[33] The reader is directed to 'Climate Services for Health – Improving Public Health Decision-making in a New Climate'. This guide seeks to promote the development of climate services for the health sector.[34] It advocates the creation of tailored climate services by building an enabling environment through: guaranteeing sufficient human and technical capacity; compiling and conducting necessary research; and undertaking purpose-driven

product and service development. Climate services are poised to offer a critical contribution to society's capacity to protect health from emerging climate-related risks. As evidence of the increasing interest from the health community, the Lancet Countdown[33] will report annually on a set of indicators that reflect progress on health and climate change, including the development of climate services for health decision-making.

10.6 Conclusions

This book is based on the premise that health professionals, researchers and policy-makers need increasingly to take climate into account when promoting policy, implementing programmes and treating patients. To work with climate information effectively they need to become climate-literate, i.e., to have enough basic knowledge on the climate system, how it is measured and modelled, to be able to make the correct inference from climate information (historical, current and future), and to respond accordingly. They should not travel this road alone; this book seeks to be a valued companion and is designed to stimulate further dialogue and collaboration between health specialists and climate information providers.

Note

i   See ITU report. Available at: https://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2017.pdf.

References

1 Morales Jr., E. Global climate change as a threat to U.S. national security. *Journal of Strategic Security* **8**, 133–148 (2015).
2 WEC. *The Global Risks Report 2016* (World Economic Forum, Geneva, 2016).
3 Kandel, N. *et al.* Joint external evaluation process: bringing multiple sectors together for global health security. *The Lancet Global Health* **5**, e857–e858, doi:https://doi.org/10.1016/S2214-109X(17)30264-4 (2017).
4 Rogers, D. P. & Tsirkunov, V. V. *Weather and Climate Resilience Effective Preparedness through National Meteorological and Hydrological Services* (Development/The World Bank, Washington, DC, 2013).
5 Vaughan, C. & Dessai, S. Climate services for society: origins, institutional arrangements, and design elements for an evaluation framework. *Wiley Interdisciplinary Reviews. Climate Change* **5**, 587–603, doi:10.1002/wcc.290 (2014).
6 Jancloes, M. *et al.* Climate Services to improve public health. *International Journal of Environment and Public Health* **11**, 4555–4559 (2014).
7 Dinku, T. *et al. THE ENACTS APPROACH: Transforming Climate Services in Africa One Country at a Time* (World Policy Institute, New York, 2016).
8 Hewitt, C., Mason, S. & Walland, D. The global framework for climate services. *Nature Climate Change* **2**, 831–832 (2012).
9 Brasseur, G. P. & Gallardo, L. Climate services: lessons learned and future prospects. *Earth's Future* **4**, 79–89, doi:002/2015EF000338 (2016).
10 IASC. *Inter-Agency SOPs for Early Action to El Niño/La Niña Episodes.* 35pp (Inter-Agency Standing Committee for the UN, Geneva, 2018).

11 Tompkins, A. M. *et al.* Predicting climate impact on health at sub-seasonal and seasonal timescales, in *Sub-seasonal to Seasonal Prediction*: *The Gap Between Weather and Climate Forecasting* (eds. A. Robertson & F. Vitart) (Elsevier, forthcoming 2018).

12 Choudhury, N. World Wide Web and its journey from Web 1.0 to Web 4.0. *International Journal of Computer Science and Information Technologies* **5**, 8096–8100 (2014).

13 Yu, V. L. & Madoff, L. C. ProMED-mail: an early warning system for emerging diseases. *Clinical Infectious Diseases* **39**, 227–232, doi:10.1086/422003 (2004).

14 Smith, E., Haustein, S., Mongeon, P., Shu, F. & Ridde, V. Knowledge sharing in global health research – the impact, uptake and cost of open access to scholarly literature. *Health Research Policy and Systems* **15**, 73, doi:10.1186/s12961-017-0235-3 (2017).

15 UN. *The Millennium Development Goals Report*. 72 (United Nations, New York, 2015).

16 Chan Mow, I., Sasa, H., Shields, C. & Fitu, L. Towards a people centered early warning and disaster response system in Somoa: the use of ICT by Somoans during disaster. *The Electronic Journal of Information Systems in Developing Countries* **81**, 1–18 (2017).

17 Bansal, S., Chowell, G., Simonsen, L., Vespignani, A. & Viboud, C. Big data for infectious disease surveillance and modeling. *The Journal of Infectious Diseases* **214**, S375–S379, doi:https://doi.org/10.1093/infdis/jiw400 (2016).

18 Ginsberg, J. *et al.* Detecting influenza epidemics using search engine query data. *Nature* **457**, 1012–1014, doi:10.1038/nature07634 (2009).

19 Earth Institute and Ericsson. *How Information and Communications Technology can Achieve the Sustainable Development Goals: ICT and SDGs* (2016). Available at: http://unsdsn.org/wp-content/uploads/2015/09/ICTSDG_InterimReport_Web.pdf.

20 Briand, D., Roux, E., Desconnets, J. C., Gervet, C. & Barcellos, C. From global action against malaria to local issues: state of the art and perspectives of web platforms dealing with malaria information. *Malaria Journal 17*, 122 (2018).

21 Kiberu, V. M. *et al.* Strengthening district-based health reporting through the district health management information software system: the Ugandan experience. *Medical Informatics and Decision Making* **14**, 40, doi:10.1186/1472-6947-14-40 (2014).

22 Palmer, T. Climate forecasting: build high-resolution global climate models. *Nature* **515**, 338–339, doi:10.1038/515338a (2014).

23 WEC. *The Global Risks Report 2017* (World Economic Forum, Geneva, 2017).

24 Gupta, V., Mason-Sharma, A., Caty, S. N. & Kerry, V. Adapting global health aid in the face of climate change. *The Lancet Global Health* **5**, 133–134 (2017).

25 Ramirez, B. & TDR–IDRC Research Initiative on Vector Borne Diseases and Climate Change. Support for research towards understanding the population health vulnerabilities to vector-borne diseases: increasing resilience under climate change conditions in Africa. *Infectious Diseases of Poverty* **6**, 164, doi:10.1186/s40249-017-0378-z (2017).

26 Clifton, F. *USC School of Medicine Digital Collections* (London, 1734).

27 Valencius, C. B. Histories of medical geography. *Medical History Supplement*. **20**, 3–28 (2000).

28 Rudolph, L. & Harrison, C. A. *Physician's Guide to Climate Change, Health and Equity* (Public Health Institute, Oakland, CA, 2016).

29 Maxwell, J. & Blashki, G. Teaching about climate change in medical education: an opportunity. *Journal of Public Health Research* **5**, 673, doi:10.4081/jphr.2016.673 (2016).

30 Friedrich, M. J. Medical community gathers steam to tackle climate's health effects. *Journal of the American Medical Association* **317**, 1511–1513 (2017).

31 Shaman, J. & Knowlton, K. The need for climate and health education. *American Journal of Public Health* **108**, S66–S67, doi:10.2105/AJPH.2017.304045 (2017).

32 Steffen, W. *et al.* Planetary boundaries: guiding human development on a changing planet. *Science* **347**, 1259855 (2015).

33 Watts, N. *et al.* The Lancet Countdown: tracking progress on health and climate change. *The Lancet* **389**, 1151–1164 (2017).

34 Shumake-Guillemot, J. & Fernandez-Montoya, L. *Climate Services for Health: Improving Public Health Decision-making in a New Climate* (WMO/WHO, Geneva, 2016).