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Health and Climate – Needs

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Abstract

This paper describes the needs for climate risk management and information services for the health sector to serve research, educational and operational needs of ministries of health and their partners, those agencies that support broader public health service provision as well as respond to epidemics and emergencies. While climate information is considered highly relevant to helping guide improvements in public health provision, to date this information is largely underutilized. We explore some of the gaps in satisfying these needs, and we make recommendations to help fill the identified gaps.

Keywords: Information and education; climate services for health; health monitoring and surveillance

1. Introduction

Climate influences human health through a number of direct and indirect mechanisms. Direct mechanisms include episodes of heat or cold stress, which aggravate existing health conditions such as pulmonary and respiratory disease, and extreme events such as hurricanes, which cause accidental injury and/or the breakdown in public services and sanitation, which may also directly impact health. Indirect mechanisms include the impact of climate anomalies on risk of infectious diseases such as malaria, dengue, meningitis and cholera. Though a relationship between health and climate has long been recognized, it was somewhat downplayed during the development of modern medicine. In recent years, concern about climate change has rekindled interest in the relationship between health and climate. Meeting the climate-related challenges to public health will require a significant and concerted effort on the part of the climate, health and development communities.

2. Health and climate: outlining the need for climate risk management in health

Climate-related health impacts are most pronounced among poor populations in developing countries, particularly the Least Developed Countries (LDCs), where vulnerable people lack the basic infrastructure to cope with climate variability and change. In these countries, the livelihoods of millions of people are heavily dependent on rainfed agriculture and seasonal water resources. Such people also suffer the most from infectious (including waterbourne and vector-borne) diseases and have the least access to health services and public health regulation. Public health is "the science and art of preventing disease, prolonging life, and promoting health through the organized efforts and informed choices of society, organizations, public and private, communities and individuals" [1]. As a result, the health consequences of climate change and climate variability are inextricably linked to global development choices, including issues of equity [2].

This situation is exacerbated by the fact that many developing countries lack the human, institutional and financial resources necessary for health-related research and implementation. In 1990, the Commission on Health Research for Development noted that only a small percentage of the world's resources for medical research were being applied to health problems arising in developing countries, despite the fact that more than 90 per cent of the global burden of preventable mortality was suffered by developing nations [3]. This disparity has come to be known as the 10/90 gap. Given this resource allocation gap, it is clear that greater attention must be paid to the health needs of poorer populations when combating the health challenges imposed by climate change. In cases where health investments are increasing – as, for example, through the Global Fund for AIDS, Tuberculosis and Malaria – the risks posed by a varying climate must be taken into account for investments to be effective and sustainable.

While the effects of climate change will be worst in developing countries, Hurricane Katrina and the 2003 heatwaves in Europe proved that vulnerable populations – particularly the poor and elderly – in the developed world may also be severely affected. Protecting human health from the vagaries of climate variability and change will demand a wide variety of strategies and must occur on every continent.

In recognition of this, the international community has begun to explore and advocate for strategies to "climate-proof" health as a means to protect and further hard-won development gains. Examples of this kind of effort include the 2008 World Health Day

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"Protecting Health from Climate Change", and a special resolution on climate and health passed at the sixty-first meeting of the World Health Assembly in 2008 [4]. This resolution built on previous efforts, including the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) and a growing collection of documentation commissioned by the World Health Organization (WHO), the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP), and the Food and Agriculture Organization of the United Nations (FAO) [5][6][7][8].

More recent reports include a study commissioned by *The Lancet* and carried out by University College London [9], and another from the World Health Organization [10]. The report from *The Lancet* study reviewed the implications of climate change on health through the broader perspective of socio-economic development sectors, demographics, environmental change and pressure on ecosystem services, all of which will impact on changing disease patterns, food security and malnutrition, water entitlement and sanitation, and considerations of shelter and settlements in the context of more frequent extreme events. The authors call for a broad coalition of socio-economic development agencies ready to take forward the agenda of a new public health movement appropriate to the scale of the problem [9].

The WHO report, *Protecting Health from Climate Change: Global Research Priorities*, is organized around six key themes. According to the report, health effects of climate change must be placed more firmly within the overall context of improving global health and health equity, rather than being considered as an independent issue. Likewise, the assessment of the costs and benefits of mitigation and adaption mechanisms is crucial, as is improved policy-relevant risk assessment to build a stronger bridge between evaluation of health risks from current climate variability and the effects of gradual climate change. Risk assessments need to incorporate the context of other epidemiological transition drivers such as socio-economic development and urbanization and provide a comprehensive evaluation of the effectiveness and cost-effectiveness of protective measures. Applied interdisciplinary research is needed to help maximize the public health benefits of decisions taken outside the health sector. Improved research on surveillance and other decision-support tools is needed to enhance operational effectiveness of disease surveillance systems [10].

There are a number of examples in which climate information has been used to improve health surveillance, including the development of integrated disease and weather–climate surveillance systems such as Euro-HEAT and the Malaria Early Warning Systems, which should be seen as a resource to the health surveillance community [11][12]. Though these efforts have varied in scope and scale, they indicate that strategies to protect health from climate need to be based on practical policies developed from firm evidence. This evidence must be informed by available climate and environmental data (from ground and satellite observing systems). Furthermore, in the case of malaria control, the goal posts have shifted in a number of regions where recent control interventions have reinvigorated the ultimate desire to rid the world of this disease. Countries in the Amazon Basin, the Mekong Delta and the Southern Africa Development Community (SADC) have expressed policy commitments towards the elimination of malaria from these regions within the next decade. Successful and sustained control of malaria, especially in Southern Africa where malaria reaches the margins of the climate envelope for transmission in Africa, could benefit greatly from the development of climate-informed control policy and more broadly informed surveillance systems.

Recent improvements in understanding the global climate system – including the ability to monitor and model it – have furthered interest in using climate forecasts to predict and mitigate health impacts. While welcome, these efforts are far from sufficient in meeting the risk management challenges associated with climate change. A great deal of information is still needed. Moreover, data requirements are not the only impediment to efforts to mitigate the effects of climate on health. Tackling the political, financial, institutional and intellectual challenges associated with the intersection of climate and health will require the collective, concerted effort of the health, climate and development communities. It will also require these communities to establish priorities and make good strategic choices about the best use of resources.

Bringing these disparate communities together will not be easy. As the Organisation for Economic Co-operation and Development (OECD) report on climate and development, *Bridge over Troubled Waters*, suggests, "The climate change and development communities are not monolithic blocks that can be linked by a simple handshake. Rather, mainstreaming (climate change into development) may require a meshing at multiple levels between the diverse range of actors and institutions connected with the two fields" [13]. However, willingness to share information would be a good starting point for a cooperation to last as long as climate-related public health and development challenges exist.

Developing multiple entry points is a challenging prospect. The process of developing climate-based early warning systems, for instance, requires that partnerships develop between those who supply information, those who use it and those who understand the societal consequences of both negative and positive impacts [14][15][16]. To date these connections have been hard both to build and to maintain. There is also a need for more rigorous validation of some climate information used for disease risk mapping and surveillance by correlating it with the ground-based environmental information and case-based surveillance data. Climate prediction models should endeavour to include disease control information in their forecast exercises whenever it is possible.

Building such connections will require engaging the climate community as part of the public health community. Public health is an effort organized by society to protect, promote and restore the people's health. It is the combination of sciences, skills and beliefs directed to the maintenance and improvement of health through collective or social actions. In this context, climate researchers should be considered a part of the public health community. Establishing new mechanisms to help the climate community to protect, promote and restore the health status of societies will be an essential part of combating the challenges of climate-related health impacts.

It will be important to facilitate the sharing of data, information and services, and it may be necessary to revisit the adequacy of Resolution 40 [17] in contributing to these needs. There is at present a global challenge in accessing and managing relevant climate data, environmental information [18] and epidemiological data in a way that is useful to the operational research and decision-making communities focused on improving public health outcomes [19]. For example, local meteorological datasets can be prohibitively expensive due to cost recovery policies, and many remote-sensing and climatology datasets are distributed without sufficient quality and quantity assurance [20][21]. Furthermore, the current data management systems for geographical information

systems (GIS) require laborious processing in order to match projections used for data from different global, regional, national and local sources. Considerable skill is needed to use them and the cost of the software is unaffordable for many research groups attached to disease control programs in developing countries [22].

The sharing of data, information and capacity will aid in the development of health monitoring and surveillance systems, which the IPCC Fourth Assessment Report termed the most elementary public health adaptation [23]. At present, Least Developed Countries have poorly developed surveillance systems. Many developing country governments lack the resources and expertise for collecting appropriate data for health care prioritization or effective monitoring of the impacts of climate change. Data sharing and capacity strengthening for local data collection and development of integrated early warning and response systems are very important.

At the same time, a strong public health infrastructure and active local community involvement is necessary to achieve effective responses to information provided by the surveillance of infectious diseases. New global rules on health surveillance from the WHO-supported International Health Regulations (IHR) should provide new energy to improving health surveillance (local, national and international) at a time when the challenges of climate change require better knowledge of what is happening around the world. Through IHR, member states were required to complete an assessment of their surveillance and response capacities by June 2009. Many international public health concerns, including life-threatening emerging and re-emerging pathogens, are climate-sensitive in their transmission and spatial distribution. The development and implementation of plans of action aim to ensure that these core health surveillance capacities are functioning by 2012; this process is already underway [24].

The need for new regulations on health surveillance and data sharing highlights another requirement for the effort to mitigate the health impacts of climate. Specifically, strong South–South, South–North networks are needed to facilitate the sharing of data, knowledge and lessons learned. Such networks will also encourage research and implementation of climate risk management for public health. For example, while vector-borne diseases, heat stress, respiratory disease and enhanced allergies have been highlighted as health challenges associated with a changing climate [25][26][27][28][29], the effects of climate change on water resources, food security and economic development are likely to have the greater impact on health outcomes for the majority of the world's population. In some cases, climate change adaptation policies may themselves be harmful to health if not adequately considered.

National, regional and international networking is of vital importance for strengthening research capacity. Unfortunately, in many parts of the world – particularly where the health challenges are greatest – researchers are severely constrained in this regard. Constraints include few other researchers, the absence of accessible data and/or information-sharing structures and mechanisms, and an absence of appropriate policies, resources or training. There are also technological constraints as knowledge sharing is essential to the establishment of research and operational networks around climate and health agendas [30]. Creating international networks of researchers, public health professionals and communities of practice that share best practices and lessons learned is a means of overcoming such limitations. Through such networks, developing countries' personnel can learn directly from each other by sharing local knowledge, the latest methodologies and recent successes and failures in research translation [30]. This implies a dynamic flow of knowledge, which will allow professionals in developing countries to "scan globally and reinvent locally" while at the same time allowing development institutions in the North to become more responsive to demand and knowledge flows in the South [31].

The World Health Organization has demonstrated leadership in highlighting the relationships between climate and health over the recent past – advocating for greater understanding of the health risks of climate change, the potential co-benefits of climate change mitigation strategies as well as the development of climate-informed early warning systems for epidemic diseases. As the directing and coordinating authority for health within the United Nations system, WHO is responsible for providing leadership on global health matters, shaping the health research agenda, setting norms and standards, articulating evidence-based policy options, providing technical support to countries and monitoring and assessing health trends. We therefore suggest:

Recommendation 1

The health community, through WHO, should be fully engaged in any follow-up to the World Climate Conference-3 to establish an appropriate structure within the international community to deliver climate services for the health sector. This should include:

(a) Reinforcing, revising and changing existing policies in order to make data, information and services freely available to the research and operational health community and to related humanitarian actors that impact health outcomes;

(b) Establishing strong South–South, South–North networks for research and implementation of climate risk management for public health.

3. Information and education: availability, access and interpretation

Increasing the health community's capacity to understand, use and demand the appropriate climate information is of primary importance to efforts to mitigate the health impacts of climate change. However, good information is not enough. The health community must also be able to distinguish among different kinds of data to determine what is relevant, and at what timescale, to their population. Consider, for instance, the many ways that temperature affects human health. Rising average temperatures are predicted to increase the incidence of heatwaves which are known to be a major hazard to particular segments of the population including those with heart problems, asthma, the elderly, the very young and the homeless. Rising temperatures may also increase the incidence of infectious diseases and contribute to air quality problems. Determining which of these issues are most pressing will require health professionals to interpret various kinds of information.

While there is a need to produce strong researchers, influential research and effective decision- making and implementation, an additional requirement is education and training relevant to problem identification and solution. Unfortunately, at present there are

very few courses on climate and health, no academic texts, and – perhaps most important – no valued professional qualification in this interdisciplinary field. The International Research Institute for Climate and Society (IRI) offers courses such as "Climate Information for Public Health" at its Summer Institute. Though courses like this one are useful in elucidating training needs and in testing curricula development, medical and/or climate researchers who concentrate their efforts on the intersection between climate and health are still taking a risk with their careers – going out on a limb, as it were. There needs to be better professional recognition of this education and training gap for health professionals. To remedy this situation, we must develop research and professional training in the use of climate information for public health decision-making that can be launched in centres of learning (for example, schools of public health for graduate and non-graduate health professionals) throughout the world.

Meanwhile, though climate change is expected to increase temperature, climate variability poses a different set of challenges to creating effective health sector responses. This is illustrated by the graph in Figure 1, which depicts the Global January Land–Ocean Temperature Index between 1880 and 2008 – one indicator of global warming. While the measured increase in global temperature trend over this period (red dashed line) is +0.74ºC, there is considerable variation around this trend. There is, for instance, a period of approximately three decades – between 1944 and 1974 (blue dotted line) – when January temperatures largely declined. There is also high variability on a year-to-year basis: the difference between January 2007 (the warmest in the record) and January 2008 is -0.75 ºC, a value greater than the trend over the whole period. Long-, medium- and short-term trends will have differing implications for health. Those working in the sector need to be aware of this and be able to discern the potential risks for their field of specialism.

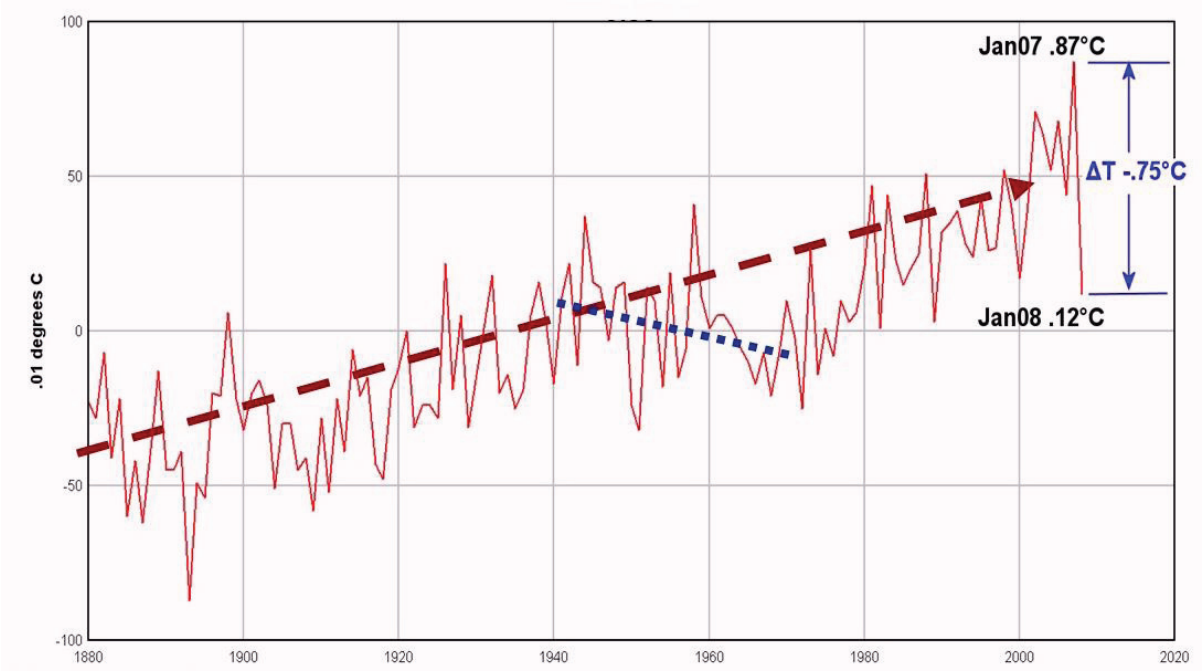

Figure 1. Global land–ocean temperature index in 0.01°C: base period 1951 – month of January (Source: Goddard Institute for Space Studies http://data.giss.nasa.gov/gistemp/)

Rainfall also plays both a direct and indirect role in human health, and similar challenges exist in relating short-term events to annual and decadal variability within longer time period trends. For instance, while flood risk poses immediate health dangers, seasonal variations in rainfall contribute to fluctuations in crop production and food security. With respect to vector-borne disease, seasonal variations also influence vector, parasite and host dynamics. Consider the graph in Figure 2.

Figure 2 represents rainfall over the Sahel region from the last century to the near present. The long-term trend is declining (black line) with marked inter-decadal variability (blue line) and highly variable interannual variability (red line). The variance in the dataset for these trends is 18 per cent, 27 per cent and 55 per cent, respectively. The long-term drought from the mid-1960s to near present was associated with widespread hunger and declining livelihoods (particularly so the devastating deep drought troughs in 1972 and again in 1984). In addition, malaria declined dramatically in parts of the Sahel during the period 1963 to 1995 largely without concerted control efforts [32].

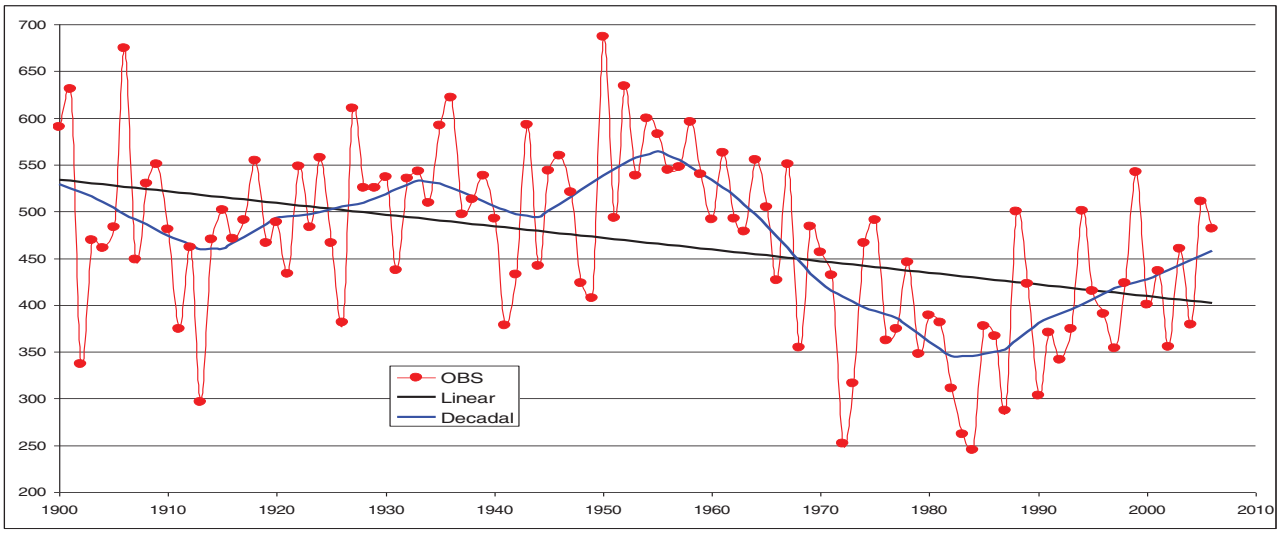

Figure 2. Sahelian rainfall (Source: http//iri.columbia.edu/data/library)
Red dots (OBS) represent observations. The decadal trend is shown in blue; the long-term trend is shown in black.

In this situation, health professionals will have to determine to what extent the changing climate is aiding or impeding efforts to control a particular climate-sensitive disease in a particular region. Should policymakers in the region be prepared for drought and dry condition diseases such as meningitis in the next 10 years or will seasonal flooding and associated diseases be more of a problem? There is little confidence in the predictability of long-term trends in rainfall, in part due to the confounding effect of decadal processes. Those working in the health sector should be aware of this. Who can and should inform them? Health professionals must begin to answer these questions in order to improve assessments of the impact of climate-sensitive interventions.

Though climate information can be used to help mitigate health impacts, from the decision-makers' perspective there is often a lack of clear evidence showing the importance of climate (relative to other factors) as a driver for specific health outcomes. There may also be a lack of evidence regarding the value of climate information in reducing negative (or enhancing positive) health outcomes. Much greater understanding of climate–health interactions, at various scales and within varying contexts, is needed across the range of communicable and non-communicable diseases through empirical analyses and careful elucidation of the mechanisms involved. There is a dearth of academic texts or practitioner methodologies and tools that can be used to build an appropriate evidence base. Furthermore, there are very few boundary institutions able to offer appropriate training opportunities for health researchers or practitioners to learn how to understand and use climate and environmental data in health research activities [33]. For this reason, we recommend the establishment of the equivalent of an independent expert process for assessing the evidence of health–climate linkages for policy development and decision-making. This process could follow the example of the Cochrane review process, which explores the evidence for and against the effectiveness and appropriateness of treatments in specific circumstances [34].

In addition, new tools are needed for the analysis of climate and health data. In dynamic systems, such as epidemic malaria, it is impossible to understand the system without an understanding of its spatial and temporal context. Storing, managing and analyzing data that describes the environmental, climatic and social factors that support infectious disease transmission require temporal as well as geospatial referencing of data. Commercial geographical information systems have traditionally focused on geospatial and not temporal referencing of data, limiting the usefulness of GIS for robust spatio-temporal analysis and the visualizing of dynamic health events. Predictive models are often misleading due to poor representation of uncertainty in model outputs and so a probabilistic approach is essential [35][36]. Appropriate tools to train health researchers in this area are long overdue [37]. As a result, we recommend integrating climate and weather research in order to create a seamless, probabilistic prediction system, working with researchers from other disciplines to create tools relevant to health decisions.

Finally, though a primary focus must be on the health community's comprehension and ability to use current climate information, the improvement of current data is always a goal. Specifically, we recommend developing verification and quality assurance of climate products relevant to health outcomes. Climate information providers will also have to ensure that the information they produce is credible and its uncertainties are adequately conveyed. Users value weather and climate information of good quality – authoritative, accurate, informative and specifically tailored through stakeholder engagement to their own needs. Unfortunately, historical monitoring and forecast products currently in the public domain vary enormously in terms of quality and relevance for particular user needs and without a more "climate-smart" health community there is considerable room for error.

In summary, we suggest:

Recommendation 2

Assessment, research and training opportunities should be developed through collaboration across all relevant disciplines. This should include:

(a) Improving assessments of the impact of climate-sensitive interventions;

(b) Developing research and professional training in the use of climate information for public health decision-making to be launched in centres of learning (for example, schools of public health training for graduate and non-graduate health professionals) throughout the world;

(c) Establishing the equivalent of an independent expert process for assessing the evidence of health–climate linkages for policy development and decision-making using the example of the Cochrane and Campbell reviews processes;

(d) Integrating weather and climate research to continue to create a seamless prediction system, and creating tools relevant to health decisions;

(e) Developing verification and quality assurance of climate products relevant to health outcomes.

4. Facilitating the provision of climate services

Even with appropriate policies and a trained community of health practitioners, the climate and health effort requires good climate information services. The nature of climate services, while intimately connected to weather services, differs in the level of user engagement required to be of value to society. The user must understand the probabilistic nature of climate service outputs, and the value of the service can only be assessed over time with an intimate knowledge of the specific decisions that are being influenced and the associated outcomes.

Climate services for health, by definition, are mission-oriented and driven by public health needs to enhance livelihoods, maintain and improve environmental quality, and decrease negative health outcomes while promoting positive ones. Although climate services are integral to the climate and health effort, they are in themselves a new service. Very few countries have established climate services that extend beyond current weather services in a comprehensive way. Climate science and service typically remains a small component of the national weather service activities in most countries of the world.

However, it must be understood that for a health user the distinction between weather and climate may seem academic – what is sought by the health community is perhaps a “one-stop shop” of relevant weather, climate and environmental information products that are of known quality and are accessible, as required, in an appropriate format. A public service platform within WMO Member institutions could help provide this kind of information and encourage cross-sectoral interaction. Such a platform would include cooperation on the establishment of observing networks, the development of decision-support tools and systems, and the development of advisory services for the health sector.

The public service platform must focus on vulnerable populations. As mentioned earlier, poor people and people in developing countries are the worst hit by the impacts of climate change and climate variability. In most cases, these people also have the least access to climate services. WMO member institutions should provide services and direct focus to this important group. In addition, member institutions should work to protect climate-sensitive investments in research and operations that improve the health outcomes of the most vulnerable.

One particular challenge in establishing a public service platform is the perceived value users place on access to raw ground-based weather station observations (a data source that is highly restricted in its distribution and, for many regions, in decline). As Figure 3 illustrates, many of the ground-based weather stations in Africa and Latin America do not report fully into the globally available climate datasets. Data deficiencies are most pronounced in areas of the world where the need is greatest, especially in Africa, where the functioning observation network is less than an eighth of that recommended by WMO [38]. This obviously has implications for the value of using globally available data to try to meet regional or national climate information needs.

Percentages indicate the extent to which stations report into globally available datasets, while the parenthetical numbers indicate the number of stations reporting at this level.

There are other challenges associated with the development of a public service platform. For instance, arguments have been made for significant investment in data rehabilitation and new observations and information systems to provide useful sector-specific climate data and information [18]. This challenge was taken up by the African Union through the creation of Climate for Development in Africa (ClimDev Africa), sponsored jointly by the African Development Bank, African Union Commission and the United Nations Economic Commission for Africa [39].

There are also policy-related data challenges that need to be resolved for public service platforms to be effective. In most cases, these challenges stem from changes in atmospheric data exchange policy that took place in the 1990s. For nearly 150 years prior to this year, nations of the world had cooperated with respect to the free and unrestricted international exchange of atmospheric data and service, particularly information observed or derived in support of daily operational weather warnings and forecasts. In the late 1980s, budget cuts in many of the world’s national meteorological services prompted these agencies to restrict and sell their data as a way to acquire new sources of funding. (See: Landis Policy Case Study at http://www.ametsoc.org/atmospolicy/documents/PartIDataExchange.pdf.)

The need to improve data-sharing policies and practices is now a recurring theme in most discussions on the development of a climate–health knowledge base [40][41] and comparisons between the American and European models for data dissemination tend to favour the former [42]. Since data are the cornerstones of good research, good policy and good practice, making data freely available will be an important step in meeting the health-related challenges of climate. It will also be important to consolidate data in a one-stop shop where users can access data to meet all their needs. This is especially true for the health sector, which is not generally engaged in the collection of climate data and so currently relies on partnerships to access information. It will also be useful in cases

in which climate and environmental data are needed for decision-support systems. An example of this kind of consolidated data distribution system is the IRI's Data Library. National climate service providers might also take on this role [43].

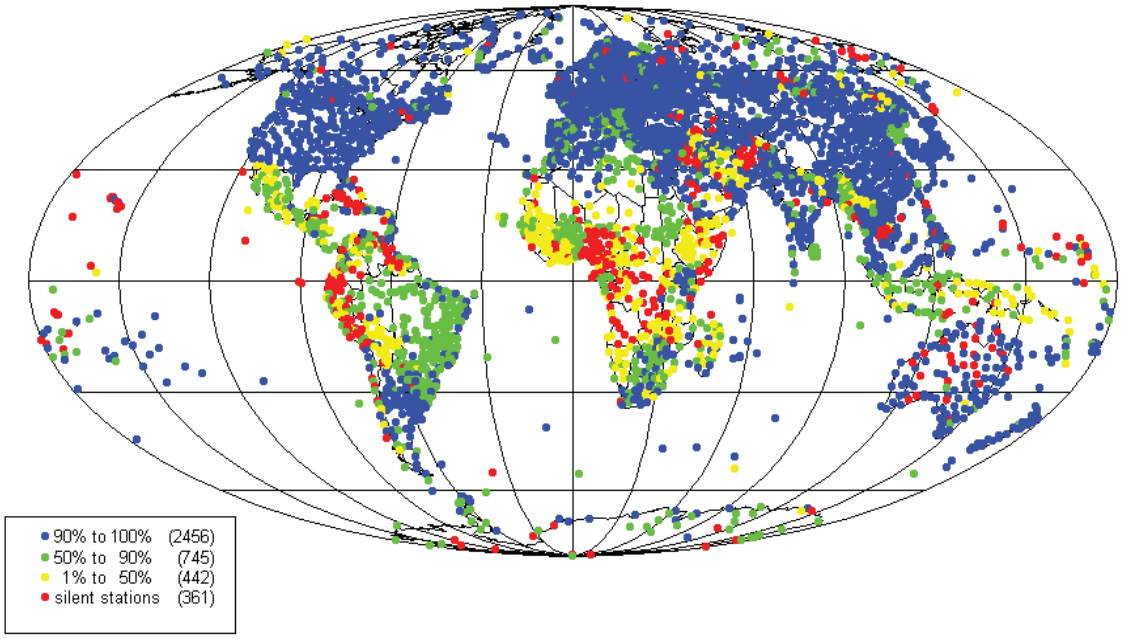

Figure 3. The distribution of ground-based weather stations in the Global Telecommunication System (Source: Washington, Harrison and Conway [38])

Despite these challenges, recognition of the global need for meteorological observations for increasing the resilience of nations to climate change was noted at the G8 meeting in Gleneagles in 2005. The G8 Gleneagles Plan of Action states that, "All countries need further access to information and to develop the scientific capacity that will allow their governments to integrate climate, environmental, health, economic and social factors into development planning and resilience strategies. We note that Africa's data deficiencies are greatest and warrant immediate attention" [44]. Unfortunately, the weaknesses of the ground-based (and upper air) observing systems contribute to these deficiencies (described in detail in Washington et al. [38]). They must be improved in order to support this work.

The public service platform should also help users to focus on relevant time frames for decision-making with an emphasis on days to decades, including seasonal and interannual variability, but also including long-term adaptation to climate change. Given the effects of variations on different timescales, it is clear that information is needed on all levels. Climate variability and trends over multiple timescales pose a major challenge to the use of climate change scenarios for near-term climate change (for example, over 10–30 year time horizons). As has been shown above, longer-term trends may be countered by shorter-term experience both on year-to-year and decadal timescales. As they stand today, climate change models are only able to capture the overall variability within the trend; they are incapable of indicating when in the future decadal or year-to-year changes and extremes may occur.

In addition to developing information relevant to timescales on which people operate, researchers must also develop data to guide us on what sort of climate impacts to expect on relevant spatial scales. As information about future climate change has mounted, there have been numerous attempts to develop modelling frameworks for climate change impact analysis that are relevant at the local level. The modelling methodologies have largely been drawn from those designed to convince policymakers of the need to mitigate climate change through the control of greenhouse gas emissions.

Climate change scenarios and seasonal climate forecasts are modelled at the global–regional scale at best. A variety of tools and approaches exist for the downscaling of global climate products for use at regional and local scales. Furthermore, downscaling from global to regional models has similar constraints in terms of predicting the spatial scale [45] Several regional climate models (and forecast systems) have been developed and applied in developing country settings. However, few developing country institutions have both human and infrastructure capacity to utilize these models routinely in seasonal forecasting or in longer-term climate assessments.

By comparison, there are more approaches and active efforts in developing and employing statistical downscaling schemes, both in time and in space. At this stage, a respectable array of methodologies exists internationally, but so far there is limited attention to comparative evaluations among these [46][47]. This kind of comparative work will be an important requirement for health users to ascertain which approach is best suited to their specific needs. While we are aware that decadal prediction in operational terms is still a long way off, the development of tools that inform questions at relevant spatial and timescales will allow users to strengthen health surveillance and response systems in accordance with needs identified in the IPCC Fourth Assessment Report.

With regard to the provision of climate services, we recommend:

Recommendation 3

A public service platform within WMO Member institutions should be created to encourage cross-sectoral interaction including the cooperation on the establishment of observing networks, the development of decision-support tools and systems, and the development of advisory services for the health sector. This should be structured to include:

(a) Focusing on the needs of vulnerable populations;

(b) Protecting climate-sensitive investments in research and operations that improve the health outcomes of the most vulnerable;

(c) Focusing on relevant time frames for decision-making with an emphasis on days to decades, including seasonal and interannual variability, but also including long-term adaptation to climate change;

(d) Strengthening the ground-based observing systems in support of improving health outcomes – especially for climate services where deficiencies are greatest, such as in Africa;

(e) Strengthening health surveillance and response systems in accordance with needs identified in the IPCC Fourth Assessment Report.

5. Conclusions

Meeting the climate-related challenges to public health will require a significant and concerted effort on the part of the climate, health and development communities. It will require the participation of national government agencies and international organizations. We will have to meet needs in the realm of policy, practice, data and services. Here we have aimed to elucidate the key needs at the intersection of climate and health. They include: a) the development of effective public health policies to protect vulnerable populations from the health-related impacts of climate variability and change; b) the uptake and use of climate information in practice – this will require significant investment in research as well as education and training; c) the development of demand-led climate services; and d) investment in necessary climate research, as well as rehabilitation and acquisition of observational data from which relevant climate services can be developed. We make our recommendations in order to help meet these needs. The recommendations included in this paper also point to the need to create a climate-smart community of practice able to cope with the challenges at the intersection of climate and health.

References

[1] C-E. A. Winslow, The untilled fields of public health. Science. 51 (1920) 23.

[2] Global Ministerial Forum on Research for Health (GMFRH), The Bamako call to action for research on health: Strengthening research for health, development, and equity, in: Report from Bamako: Strengthening Research for Health, Development and Equity (B. Peterson Stearns, ed.). Geneva, Global Ministerial Forum for Research on Health, 2008.

[3] Global Forum for Health Research (GFHR), The 10/90 Report on Health Research 2003–2004, Global Forum for Health Research, Geneva, 2004.

[4] World Health Organization (WHO), Climate Change and Health, Report by the Secretariat. WHO, Geneva, 2008.

[5] World Health Organization (WHO), Our Planet, Our Health: Report of the WHO Commission on Health and Environment, WHO, Geneva, 1992.

[6] World Health Organization (WHO), Ecosystems and human well-being: Health synthesis (C. Corvalan, S. Hales and A. McMichael), WHO, Geneva, 2005.

[7] B. Menne and K. Ebi (eds), Climate Change Adaptation Strategies for Human Health, Heidelberg, Springer, 2006.

[8] Intergovernmental Panel on Climate Change (IPCC), Climate Change 2007: Synthesis Report, IPCC, Geneva, 2007.

[9] A. Costello, M. Abbas, A. Allen, S. Ball, S. Bell, R. Bellamy, S. Friel, N. Groce, A. Johnson, M. Kett, M. Lee, C. Levy, M. Maslin, D. McCoy, B. McGuire, H. Montgomery, D. Napier, C. Pagel, J. Patel, J.A. Puppim de Oliveira, N. Redclift, H. Rees, D. Rogger, J. Scott, J. Stephenson, J. Twigg, J. Wolff and C. Patterson, Managing the health effects of climate change, The Lancet. 373 (2009) 1693.

[10] World Health Organization (WHO), Protecting Health from Climate Change: Global Research Priorities, WHO, Geneva, 2009.

[11] World Health Organization (WHO), Web-based tool for early warning of malaria epidemics in Africa: Monitoring current rainfall anomalies in zones at epidemic risk, Weekly Epidemiological Record, 77 (2002) 276.

[12] World Health Organization-Europe, Improving public health responses to extreme weather/heat waves – EuroHEAT (B. Menne and F. Mathies, eds) Copenhagen, WHO Regional Office for Europe, 2009.
http://www.euro.who.int/__data/assets/pdf_file/0010/95914/E92474.pdf.

[13] S. Agrawala, (ed.), Bridge Over Troubled Waters: Linking Climate Change and Development, Organization for Economic Cooperation and Development, Paris, 2005.

[14] D. Conway, L. Schipper, M. Yesuf, M. Kassie, A. Persechino and B. Kebede, Reducing vulnerability in Ethiopia: Addressing the implications of climate change: Integration of results from Phase I. UK, University of East Anglia, Overseas Development Group, 2007.

[15] J. Linnerooth-Bayer and R. Mechler, Insurance against losses from natural disasters in developing countries, Background paper to the United Nations World Economic and Social Survey, IIASA, New York, 2007.

[16] M. Pelling, and B. Wisner (eds), Disaster Risk Reduction: Cases from Urban Africa. London, Earthscan, 2008.

[17] World Meteorological Organization, Resolution 40 (Cg-XII): WMO Policy And Practice For The Exchange Of Meteorological And Related Data And Products Including Guidelines On Relationships In Commercial Meteorological Activities, WMO, Geneva, 1995.

[18] J.W. Hansen, M. Hellmuth, M. Thomson and J. Williams (eds), A gap analysis for the implementation of the Global Climate Observing System Programme in Africa. IRI Technical Report Number IRI-TR/06/01. International Research Institute for Climate and Society, Palisades, 2006. http://iri.columbia.edu/outreach/publication/report/06-01/report06-01.pdf

[19] S.B Macfarlane, M.C. Thomson and C.L. AbouZahr, Millennium: Invest in country statistical systems, Nature. 446 (2007) 974.

[20] T. Dinku, , S.J. Connor, P. Ceccato and C.F. Ropelewski, Comparison of global gridded precipitation products over a mountainous region of Africa, International Journal of Climatology. 28 (2008) 1627.

[21] T. Dinku, S. Chidzambwa, P. Ceccato, S.J. Connor and C.F. Ropelewski, Validation of high-resolution satellite rainfall products over complex terrain, International Journal of Remote Sensing. 29 (2008) 4097.

[22] P. Ceccato, S.J. Connor, I. Jeanne and M.C. Thomson, Application of geographical information systems and remote sensing technologies for assessing and monitoring malaria risk, Parassitologia. 47 (2005) 81.

[23] Intergovernmental Panel on Climate Change (IPCC), Climate Change 2007: Synthesis Report: Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (The Core Writing Team, R.K. Pachauri and A. Reisinger, eds), IPCC, Geneva, 2007.

[24] World Health Organization (WHO), International Health Regulations (2005). Second Edition. WHO, Geneva, 2005.

[25] D. Yoganathan and W.N. Rom, Medical aspects of global warming, American Journal of Industrial Medicine. 40 (2001) 199.

[26] A. McMichael, R.E. Woodruff and S. Hales, Climate change and human health: Present and future risks. The Lancet. 368 (2006) 842.

[27] L. Kelly-Hope and M.C. Thomson, Climate and infectious disease, in: Seasonal Forecasts, Climatic Change and Human Health (Advances in Global Change Research) (M.C. Thomson, R.G. Herrera and M. Beniston, eds). Dordrecht, Springer, 2008.

[28] J.A. Patz, S.H. Olson, C.K. Uejio and H.K. Gibbs, Disease emergence from global climate change and land use change, Medical Clinics of North America. 92 (2008) 1473.

[29] K.D Lafferty, The ecology of climate change and infectious disease, Ecology. 90 (, 2009) 888.

[30] T.A. Ghebreyesus, Z. Tadese, D. Jima, E. Bekele, A. Mihretie, Y.Y. Yihdego, T. Dinku, S.J. Connor and D.P. Rogers, Public health services and public weather services: Increasing the usefulness of climate information in the health sector, WMO Bulletin. 57 (2008) 256.

[31] J. Luijendijk and D. Mejia-Velez, Knowledge networks for capacity building: A tool for achieving the MDGs?. in: Workshop proceedings on design and implementation of capacity development strategies, Final Report, 56th IEC Meeting and nineteenth Congress of the International Commission on Irrigation and Drainage (ICID). FAO, Rome, 2005.

[32] J. Mouchet, S. Mangiun, J. Sircoulon, S. Laventure, O. Faye, A. Onapa, P. Carnevale, J. Julvez, and D. Fonenille, Evolution of malaria in Africa for the past 40 years: Impact of climatic and human factors, Journal of the American Mosquito Control Association. 14 (1998) 121. http://www.ncbi.nlm.nih.gov/pubmed/9673911.

[33] P.L., Kinney, R. Garcia-Herrera and S.J. Connor, Recent developments and next steps in climate change and health. In: Seasonal Forecasts, Climatic Change and Human Health (Advances in Global Change Research) (M.C. Thomson, R.G. Herrera and M. Beniston, eds). Dordrecht, Springer, 2008.

[34] M. Pai, Systematic reviews of non-experimental (observational) studies, (PowerPoint Presentation) 2009.

[35] P. Diggle and S. Lophaven, Bayesian geostatistical design, Scandinavian Journal of Statistics. 33 (2006) 53.

[36] P.J. Diggle, M.C. Thomson, O.F. Christensen, B. Rowlingson, V. Obsomer, J. Gardon, S. Wanji, I. Takougang, P. Enyong, J. Kamgno, J.H. Remme, M. Boussinesq and D.H. Molyneux, Spatial modelling and prediction of Loa loa risk: Decision making under uncertainty, Annals of Tropical Medicine and Parasitology. 101 (2007) 499.

[37] G.E. Glass, Update: Spatial aspects of epidemiology: The interface with medical geography. Epidemiologic Reviews. 22 (2000) 136.

[38] R. Washington, M. Harrison and D. Conway, African climate report: A report commissioned by the UK government to review African climate science, policy and options for action, 2004. http://www.g7.utoronto.ca/environment/africa-climate.pdf

[39] African Partnership Forum (APF), Climate Change and Africa. Paper presented to the 8th Meeting of the Africa Partnership Forum, Berlin, 2007.

[40] P. Arzberger, P. Schroeder, A. Beaulieu, G. Bowker, K. Casey, L. Laaksonen, D. Moorman, P. Uhlir and P. Wouters, An international framework to promote access to data. Science. 303 (2004) 1777.

[41] L.J. Smith and C. Doldirina, Remote sensing: A case for moving space data towards the public good, Space Policy 24 (2008) 22.

[42] P. Arzberger, P. Schroeder, A. Beaulieu, G. Bowker, K. Casey, L. Laaksonen, D. Moorman, P. Uhlir and P. Wouters, Promoting access to public research data for scientific, economic, and social development, Data Science Journal. 3 (2004) 135–152.

[43] D.P. Rogers and M.S. Boulahya, National climate and environmental services for development. In: Proceedings of International Symposium on PWS: A Key to Service Delivery. 3-5 December 2007, WMO, Geneva. http://www.wmo.int/pages/prog/amp/pwsp/.

[44] G8, Gleneagles Plan of Action: Climate Change, Clean Energy and Sustainable Development, G8, Gleneagles, Scotland, 2005.

[45] International Research Institute for Climate and Society (IRI), Position statement on climate change, International Research Institute for Climate and Society, Palisades, 2006.

[46] S.J. Mason and S. Chidzambwa, Verification of RCOF Forecasts, World Meteorological Organization RCOF Review 2008, Arusha, United Republic of Tanzania. IRI Technical Report 09-02, 2008.

[47] S.J. Mason, Recommended Procedures for the Verification of Operational Seasonal Climate Forecasts, World Meteorological Organization, Commission for Climatology XIV Expert Team on CLIPS Operations, Verification, and Application Service. IRI Technical Report 09-03, 2009.