



JOINT OFFICE FOR CLIMATE AND HEALTH

# CLIMATE SERVICES FOR HEALTH

Improving public health decision-making in a new climate

CASE STUDIES







WHO Library Cataloguing-in-Publication Data

WHO/WMO. (2016) Climate Services for Health: Improving public health decision-making in a new climate. Eds. J. Shumake-Guillemot and L. Fernandez-Montoya. Geneva.

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ISBN pending

Subject headings are available from WHO institutional repository.

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## ACKNOWLEDGEMENTS

The WMO–WHO Joint Climate and Health Office would like to thank first and foremost all of the contributing authors and institutions for sharing their experiences in building climate services for health. Appreciation is also directed to the WHO, the Government of Norway and the US NOAA for financial contribution to the publication, to Inis Communication for technical editing support, and to Artiflex Creative Webnet (ACW) for design and layout services.

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## FOREWORD

Climate and health are inextricably linked and the relationship is growing closer and more complex as a consequence of climate change. More frequent and intense extreme climate events such as heat waves, extreme precipitation, flooding and droughts have a fundamental impact on human health and well-being.

Nevertheless, advances in climate science mean we have an ever-increasing array of tools to anticipate and meet climate-related challenges. The World Meteorological Organization (WMO) is increasingly encouraging its members to reach out to varied sectors of society, to help them strengthen their access to information and understanding about the weather and climate, as it affects specific communities and sectors.

The Global Framework for Climate Services (GFCS), an international initiative spearheaded by WMO, improves the provision and use of these tools and fosters new partnerships and alliances. Health is one of the top priorities of the GFCS, which is enhancing the provision of weather and climate services, such as severe weather forecasts, hazard maps, heat-health warnings and long-term climate projections that are tailored to the needs of the public health sector.

WMO and the World Health Organization have strategically joined forces to accelerate the essential partnerships, research and applications, and help improve health sector and general public preparedness for climate and weather extremes. The case studies presented here demonstrate the vast potential and the benefits of improving public health decision-making in such a new climate.

# ABOUT THIS PROJECT

Climate services for health are an emerging technical field for both the health and climate sectors. The current 'Climate Services for Health Case Study' project profiles over 40 country-based programmatic examples that help readers better understand what, how and why health-tailored climate services can support the optimal design of health solutions – and ultimately health systems – that are responsive and resilient to climate risks. It shows the vast range of knowledge and tools being co-developed to improve the management of health risks related to climate variability and change.

## OBJECTIVES

The WHO–WMO Joint Climate and Health Office is showcasing these case studies to illustrate the importance of developing and using appropriate climate services for health, with the aim of highlighting common needs, good practices and the potential for future expansion of climate services for health. The case studies highlight:

- the range of exemplary work being done by a large community of practice around the world;
- the value and impacts that climate services can have for health research, policy and practice;
- Common practices for working across sectors in order to develop useful climate knowledge for the health community.

## METHODS

Author teams were requested to respond to an open call and describe: (1) The health problem being solved, including timescale and types of decision needs requiring climate or weather information (2). The type of climate services developed, including a description of the process used to develop and apply the services (3). The benefits of the approach to the health community (4), key lessons learned, including failures and limitations or good practices.

Case studies were selected based on criteria of relevance to public health decision-making, and of innovative use of climate information, and further analysed to identify common processes and success elements. Preliminary findings informed a further survey of author teams to generate a more complete perspective of the climate service development and application experience. Survey results informed a common framework for developing climate services for health.

The resulting collection summarizes the state of current science, identifies a broad range of common needs and challenges, and provides guidance to health and climate partners for collaboration on solution-driven projects. It should also help raise awareness of professionals working in public health, meteorology, climate science and related fields of development, regarding the vast range of opportunities for climate service applications to enhance understanding and decision-making related to health conditions that are sensitive to climate and weather. The current publication is only the beginning of a living project, and over time new project information and results to demonstrate and expand discovery of new advances and applications in this field will be included in the project website.





## EXECUTIVE SUMMARY

A new generation of pioneering health and climate scientists and practitioners are charting the way for the health sector to keep people safe and healthy in a rapidly changing global climate. The route is not an easy one. Roadblocks are posed by not only the immense range of variation in human health vulnerability and complex routes of disease transmission; but also by innumerable scientific and institutional challenges along the way. Nonetheless, the collection of case studies in this publication shows that the necessary ingenuity and solutions exist and that they can improve public health decision-making in a new climate.

**“ CLIMATE SERVICES ARE A NEW TYPE OF HEALTH SERVICE THAT CAN IMPROVE THE EFFECTIVENESS OF OUR CORE BUSINESS –DETECTING DISEASE, MONITORING HEALTH RISKS, ANTICIPATING PROBLEMS, AND TAKING ACTION TO SAVE LIVES. ”**

- Margaret Chan, WHO Director General  
Statement to the Intergovernmental Board on Climate Services, November 2014.

### *RISK*

Health risks are on the rise due to climate change. More frequent and intense extreme events such as heat waves, extreme precipitation, coastal flooding and prolonged droughts bring dramatic and immediate, as well as more complex and long-term, impacts on human health. Many of the climate events we are experiencing today, such as high-magnitude heat waves, are unprecedented, but likely to become more commonplace in a warming world.

Risk factors for health are multiple and often difficult to distinguish from one another. The case studies in the current publication demonstrate that the range of health risks related to climate variability and change are heavily interwoven with prevailing ecological conditions, human development and habitation patterns, and social and individual choices. For example, the vulnerability of populations in coastal cities and small islands increases when unplanned urbanization, lack of access to water and sanitation and health care services interact with sea-level rise and more extreme weather events. Addressing these risks therefore requires action by a range of sectors, such as urban planning, water, food security and safety, and health systems, which are each affected by climate shocks and pressures in unique ways.



# POTENTIAL

As daunting it may seem to tackle the current and potential future health consequences of climate change, vulnerability and risk can indeed be reduced. Better understanding of climate risks to health can help call the public health community to action. From national leaders to individual citizens, decision-makers can take appropriate action to keep people safe and healthy, that is if given access to the best possible information on the health risks of extreme weather, climate variability, and climate change.

Currently, and despite wide recognition of the connections between climate and health, climate information and services to inform health decisions are not used to their full potential (Rogers et al. 2010). The case studies in this book, demonstrate that the demand for dialogue and co-production of health-tailored information products and service solutions (e.g. early warnings of outbreaks, or real-time risk monitoring of hazardous air quality) is rapidly expanding, along with global experience and partnerships in this field. Given that a warmer, more volatile future climate is now inevitable, future research and decision-making in public health needs to embrace the transdisciplinary applied science that can unleash the potential of climate services.

The time is right for new partnerships and alliances to tackle these challenges in integrated ways. Growing recognition and concern among health professionals about the impacts of climate change has increased demand to understand, access and apply meteorological and hydrological knowledge of climate. In response to this burgeoning need for climate information, the meteorological community is also moving to enhance the traditional functions of its agencies so as to supply more customer-oriented capacities and services. These 'climate and weather services' can help analyse data and generate fit-for-purpose information products, such as severe weather forecasts, hazard maps, and long-term climate projections. Such services can significantly benefit societies by also informing practical decisions in other climate-sensitive sectors.



## JOURNEY

A new era of applied climate science for health has begun. However, its potential will only be realized through informed investments of time and effort. Climate and weather science is a probabilistic science that is generated, processed and analysed in entirely different ways to health information and epidemiology. Use of this knowledge by other fields calls not only for translation, but also understanding of specialized vocabulary and methods, as well as a substantive dialogue to allow synthesis and transfer of the knowledge of one field into another.

Lessons from the multidisciplinary teams around the world show there is often a common journey taken to identify, envision, develop and apply climate services. Each phase is important to unlocking insights and unpacking the potential of applied climate knowledge. This common pathway is set out as a six-part framework, illustrated with examples of steps to:

- I. Establish an enabling environment for partnership;
- II. Build necessary capacities;
- III. Identify needs and conduct research;
- IV. Co-develop and deliver products and services;
- V. Apply the services to health policy and practice;
- VI. Iteratively evaluate the product and service delivery process.

The collection of case studies also highlights five common actions that have helped the necessary partnerships flourish: Spend time to define the problem and the knowledge needs; plan so as to create not only a reliable climate product, but also a support system, which can sustain the product or service until it becomes a mainstreamed health application; pursue co-development to help create relevant and reliable products that are fit-for-purpose and have the greatest utility and impact; build adequate financial and human resources to sustain the services; include informed communication planning to ensure the information is actionable.





## *INSIGHT*

By their very nature, climate services bring diverse disciplines together to solve common problems. By combining a diversity of skills, data and perspectives, the approaches captured in this publication for creating applied climate services for health breed innovation and creative thinking. The case studies presented here show that demand from the health sector is spurring innovations in climate and weather science, which are evolving to provide forecasts of extreme weather events farther in advance, to blend satellite imagery and air quality monitoring data to model and predict where and when air quality may become a public health hazard, and to identify where and when environmental conditions such as water quality may be compromised or provide perfect conditions for disease vector breeding. Advances in data visualization and processing also help explain complex health risk dynamics better than ever; and thanks to improving interoperable data management systems, this information is increasingly accessible to health analysts. Social and behavioural sciences often play a critical role in identifying how communities and individuals perceive environmental risks, understand change and use information to make decisions about protecting their health.

## *IMPACT*

The practical benefits of harnessing climate knowledge for health are increasingly clear. Climate services can help health professionals to better understand the influence of climate and weather conditions on health; to anticipate when, where and who may be at greatest risk of negative impacts. This enables targeting of interventions, resulting in more lives saved, more cases treated, reduced disease burdens, and cost savings made in health service delivery. Climate-services for health are a new type of health service to help the health sector become smarter and more agile in an uncertain and increasingly extreme climate. The case studies demonstrate that, for example, in Uganda, hundreds of additional patients were able to receive medical care for plague as a result of climate-informed spatial-risk modelling that helped focus interventions in the highest risk villages. In India, a city level extreme heat warning and response system has measurably reduced heat-related mortality during heat waves. In Hungary, a climate-based analysis of pollen season informs allergists of when pollen season will start, end and how severe it is likely to be for their patients and serves to trigger environmental remediation and health service planning. And in Canada, a risk modelling framework provides projections of climate change impacts on food and water safety, and allows decision-makers to visualize diverse potential outcomes and select the most appropriate risk management strategies. Climate services provide health professionals with dynamic risk assessment and management options that are more aligned with the daily lives and vulnerabilities communities face today.

TRAINING IN DEVELOPING COUNTRIES

3.A

### Enabling Environment

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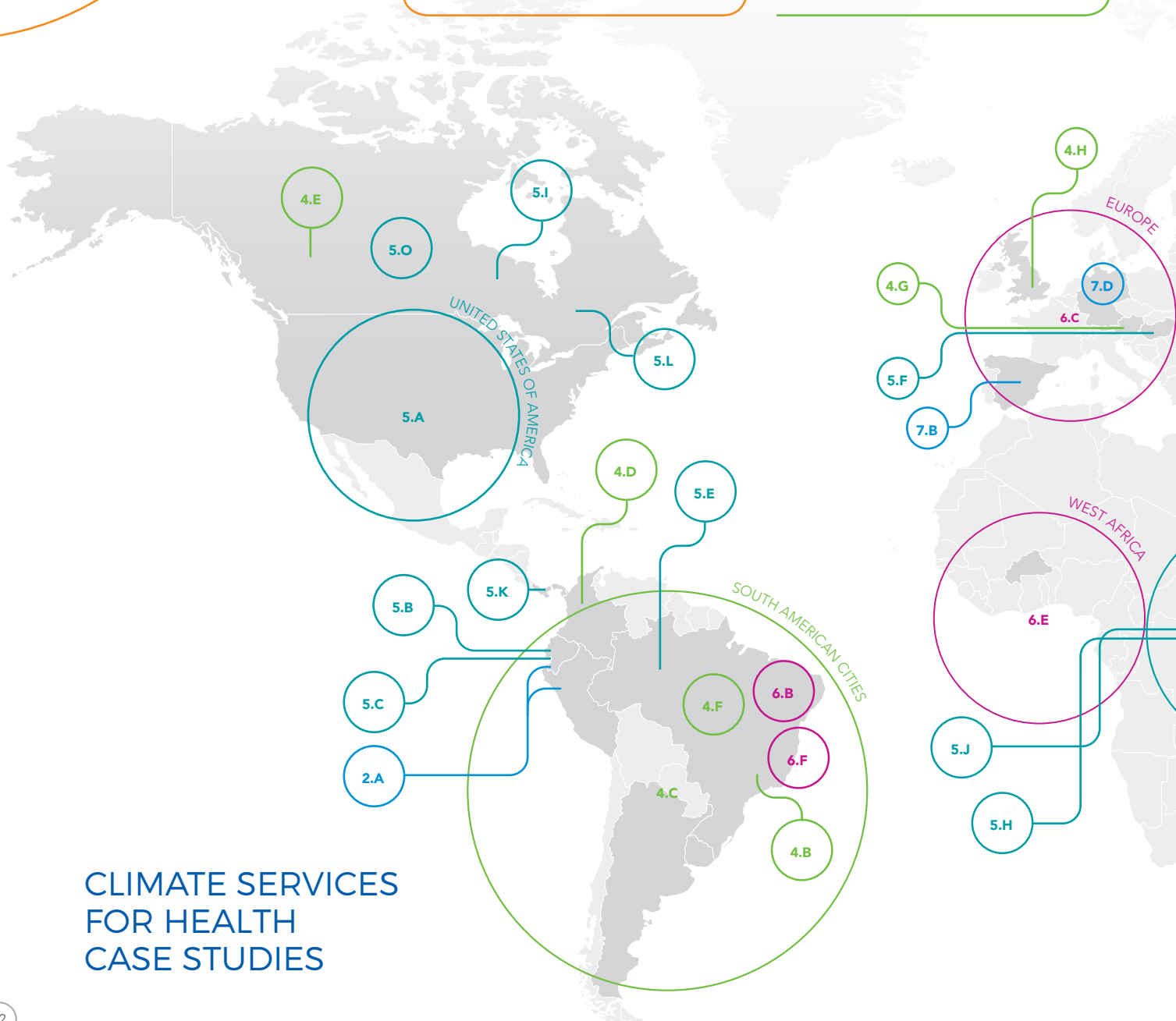
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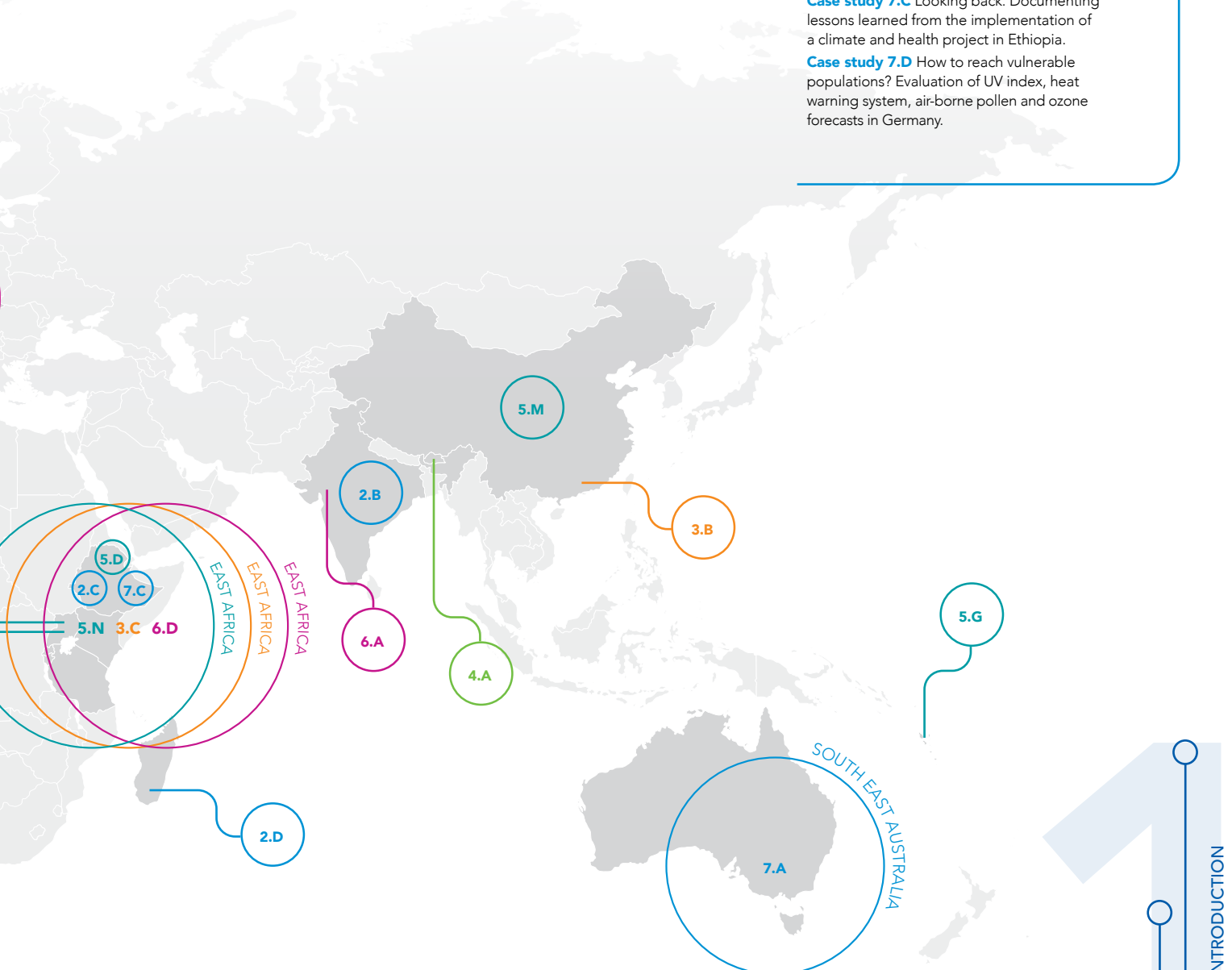
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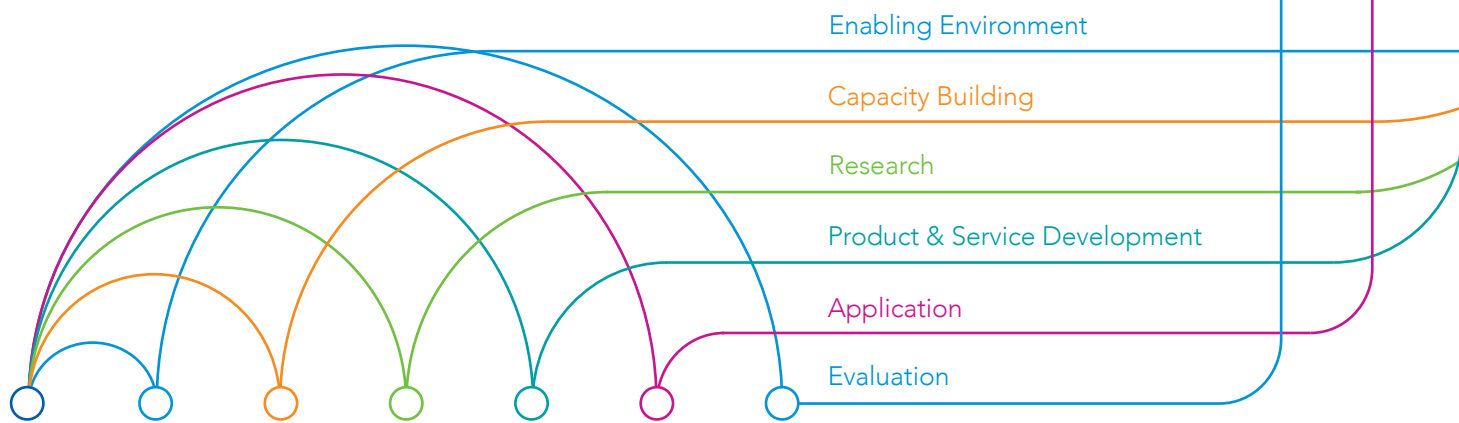
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## SECTION 1

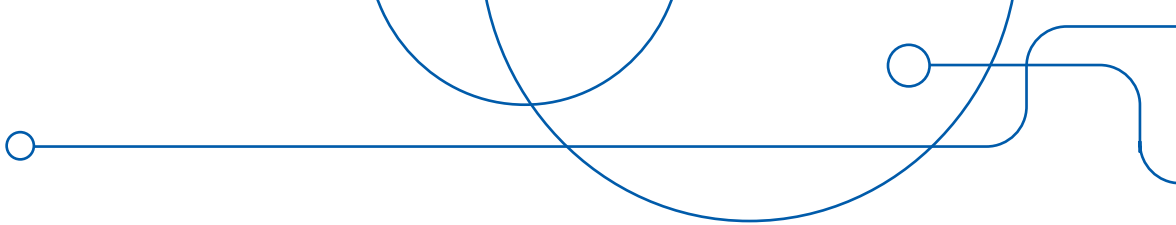
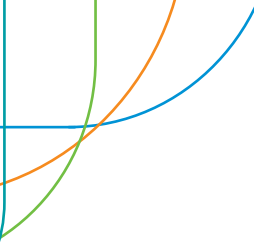


# INTRODUCTION: HEALTH-TAILORED CLIMATE SERVICES

### 1.1 WHY DOES THE HEALTH COMMUNITY NEED CLIMATE SERVICES?

Health professionals are increasingly concerned about how changing patterns of climate variability and long-term climate change are mediating health risks and affecting their ability to protect the health of citizens. The direct and indirect influences of meteorological and climatic conditions can result in acute health impacts, as well as slow onset changes in health risk determinants. At one end of a spectrum, extreme weather events can seriously affect people's mental and physical health and can compromise their access to health care, food, clean water and physical safety, resulting in vulnerability, illness, injury or death. And at the opposite end, even small or gradual changes in weather and climatic conditions – such as local temperature, humidity or wind direction – can result in significant shifts in people's exposure to harmful or beneficial conditions, from disease transmission to changing water quality. The growing understanding that climate conditions can influence many global health priorities has recently unlocked a clear demand for improved climate and health evidence and decision-tools that can harness this knowledge for action.

Public health policy and practice is founded upon evidence-based decision-making. Professional and ethical standards call upon the field to use rigorous approaches to collect and use the best available information for public health decision-making. In the context of climate change, information from the health domain alone is insufficient. It has thus become imperative for public health professionals to take a transdisciplinary approach to problem solving, which includes building partnerships that generate appropriate, integrated and actionable scientific knowledge about the health impacts of climate and weather exposure.



Climate services are mission-oriented processes driven by societal needs, which result in the production and delivery of relevant, authoritative, timely and usable information about climate change, climate variability, trends, and impacts to improve decision-making in climate sensitive sectors. Climate services can take many forms, but have common characteristics and the common goal to produce integrated and actionable climate knowledge, stemming from a well-grounded holistic perspective of past, present or future states of climate-related risks to society. This is accomplished by blending scientifically informed understandings about the climate and weather with relevant social, cultural, environmental or other information, particularly about population vulnerabilities and exposures, in order to create tailored products that inform and communicate risk information. Thus by definition, the processes of tailoring climate services require strong partnerships between producers and users of climate information.

Strengthening the climate resilience of the health sector will increasingly call for reliable and robust climate services. Robust and tailored climate products and services can become a powerful part of the public health toolkit that enhance the evidence and information available to detect, monitor, predict, and manage climate related health risks. The benefits of understanding associations, anticipating health risks, and assessing intervention effectiveness using climate information are many. Climate services for health (and health-affecting sectors) can facilitate access to multidisciplinary risk knowledge and increase capacity, fostering the development of customized tools to identify and target the most vulnerable areas or populations; provide analytical diagnostics to improve available evidence about how, when and where climate can affect human exposure to hazardous or beneficial conditions, who is likely to be affected, and what the magnitude, pattern and duration of the exposure and vulnerability are likely to be; explore future climate scenarios and hypothesize about how service delivery may perform under diverse climatic conditions; and help evaluate which health interventions are most likely to be effective at different times of the year. Robust and tailored climate services for health can therefore critically extend the lead time for decision-making, save lives and promote the efficient use of limited resources.

## 1.2 HOW CAN CLIMATE INFORMATION HELP THE HEALTH COMMUNITY?

'Climate-informed' health decisions use techniques to understand and apply knowledge about how climate in the past, present, or future influences health outcomes, health risks, and health service delivery. A range of techniques can be used to integrate spatial and time-scaled weather and climate information in combination with clinical, epidemiological and other health data (for example, ecological suitability for vector proliferation in the case of vector-borne disease) in order to understand for example, climate exposure - health outcome associations, or how health risk dynamics are influenced by climatic conditions. At a broad level, health decisions that can benefit from being informed by weather and climate information include:

- risk and vulnerability identification;
- disease control strategies;
- health policy and regulations;
- disease monitoring and surveillance;
- financial and human resource allocation;
- pharmaceutical, health supply, pesticide and vaccine supply flow;
- health infrastructure siting and maintenance;
- emergency preparedness;
- community education and public health information dissemination, for example through public service announcements and alerts to raise awareness of risks;
- targeted public advisories, medicines or supplies for vulnerable populations;
- training of the health workforce for potential outbreaks or signs of illness (even including side-effects of medicines in extreme temperatures);
- impact assessment of climate sensitive interventions.

Measurable benefits of climate informed decisions can include lives saved and reduced case burden thanks to early warnings and preparedness measures; optimization of financial, human, and other resources; and improved planning resulting in reduced stress and strain on health delivery systems due to increased awareness and preparedness of extreme weather or climate related influences.

### 1.3 WHAT KIND OF CLIMATE AND WEATHER INFORMATION IS USEFUL TO HEALTH PARTNERS?

The type of weather and climate information that can be useful to health decisions varies greatly according to four factors: the health problem being addressed, the timescale of climate-related risk, the geographic scope of the problem, and availability and quality of data.

The principle determining factor of what climate information may be decision-relevant depends on the health problem, decision, or policy-relevant research question to be addressed -- starting with what is known about the environmental and climate sensitivity of the health outcome of interest. To determine sensitivity and identify if a reliable climate signal or measurable influence on health exists, quantitative and qualitative approaches to integrate historical climate data observations and epidemiological information are used based on our understanding of the particular disease transmission mechanisms and/or exposure-response relationships. If appropriate diagnostics reveal statistically significant associations between key variables, and a climate signal is understood, then climate information may be helpful to estimate population risk, monitor the effectiveness of health planning and interventions, and detect, monitor and anticipate climate-sensitive health hazards (e.g. flooding, pathogen transmission, extreme temperatures), up to days, months, years or even decades in advance.

Critically, climate is only one of many factors that influence health outcomes and health service delivery. However, climate and weather conditions can have complex direct and indirect effects on health risk management. For climate-smart public health, (i.e. climate appropriate investment in and deployment of public health and health care, policy and services), information on the degree of direct influence that climate and weather bear on health risks and outcomes should complement well-founded understandings of short- and long-term climate influences on proximal determinants of health, such as drinking water, food security, disaster management, and urban planning.

The second determining factor of what climate information may be decision-relevant is the timeframe of when identified risks may occur (today, next year, or 20 years from now) and when decisions need to be made. For example, information to trigger emergency response actions will turn to daily or weekly forecasts of extreme weather risks. However, for planning a vaccination campaign, disease transmission and outbreak risks need to be evaluated months in advance to allow enough time for vaccine procurement and mobilization of local immunization campaigns, and planners may turn to seasonal scale climate information. Table 1.1 shows weather and climate information products and services according to timescale (e.g. the historic record of climate observations, current weather information, short- to long term future climate information). The availability, reliability and precision of these products can vary greatly from country to country and operational products may not exist at the national level in many cases. Techniques to use alternative downscaled regional or global information products, such as remotely sensed data, can in these situations be used with certain trade-offs.

**Table 1.1** General status of climate and weather information relevant for health decision-making.

Timescale	Example climate information products – which may be available and relevant in some regions and seasons	Example health-decision applications	Status: Experimental <sup>a</sup> , Operational <sup>b</sup> , Research <sup>c</sup>
HISTORIC RECORD OF CLIMATE OBSERVATIONS	Historic time series data, summary statistics and other information products	Epidemiological trend and regression analysis to understand associations of climate and health; develop disease forecasting from current and recent observation data, particularly for infectious diseases with time lags between observed ambient conditions and diseases onset	OPERATIONAL
WEATHER INFORMATION (HOURLY, DAILY, WEEKLY, 30 DAYS)	Real-time monitoring of daily weather: temperature, precipitation, humidity, etc. 8-14 probabilistic outlooks Extended range forecasts from 10-40 days Tercile forecasts (above normal, normal, below normal) probabilistic prediction of rainfall and temperature Extreme weather probability prediction	Short-term operational decisions such as public weather advisories, and thresholds that trigger action plans for staff deployment, delivery of supplies, and public protection	OPERATIONAL EXPERIMENTAL
SHORT-TERM CLIMATE INFORMATION (1 – 12 MONTHS)	Risk indexes of cyclones, floods, dust storms, wind storms, extreme temperature, fire  Long-range forecasts of average, maximum and minimum temperature and precipitation conditions 1 - 9 months ahead (e.g. seasonal forecasts and trends)  Tercile forecasts (above normal, normal, below normal) probabilistic prediction of rainfall and temperature.	Short-term operational investment in preparedness, outbreak prevention, resource needs	EXPERIMENTAL OPERATIONAL
MID-TERM CLIMATE INFORMATION (ANNUAL TO MULTI-YEAR)	Annual to interannual forecasts (several years ahead) describing large scale state of the climate  Status of El Niño Southern Oscillation (ENSO) Conditions  Dynamic and statistical climate models	1-5 year policy decisions for disease control, research, health systems planning	LIMITED APPLICATION OF INFORMATION BEYOND ENSO
LONG-RANGE CLIMATE INFORMATION (DECADES)	10-30 year decadal forecasts of surface temperature, precipitation, sea surface temperatures, etc.  Climate change scenarios, dynamic climate models, global circulation models	Long-term health infrastructure investments, research, demographic and population models, health system planning  Increase understanding of disease trends, epidemic behaviour on a regional scale	RESEARCH EXPERIMENTAL

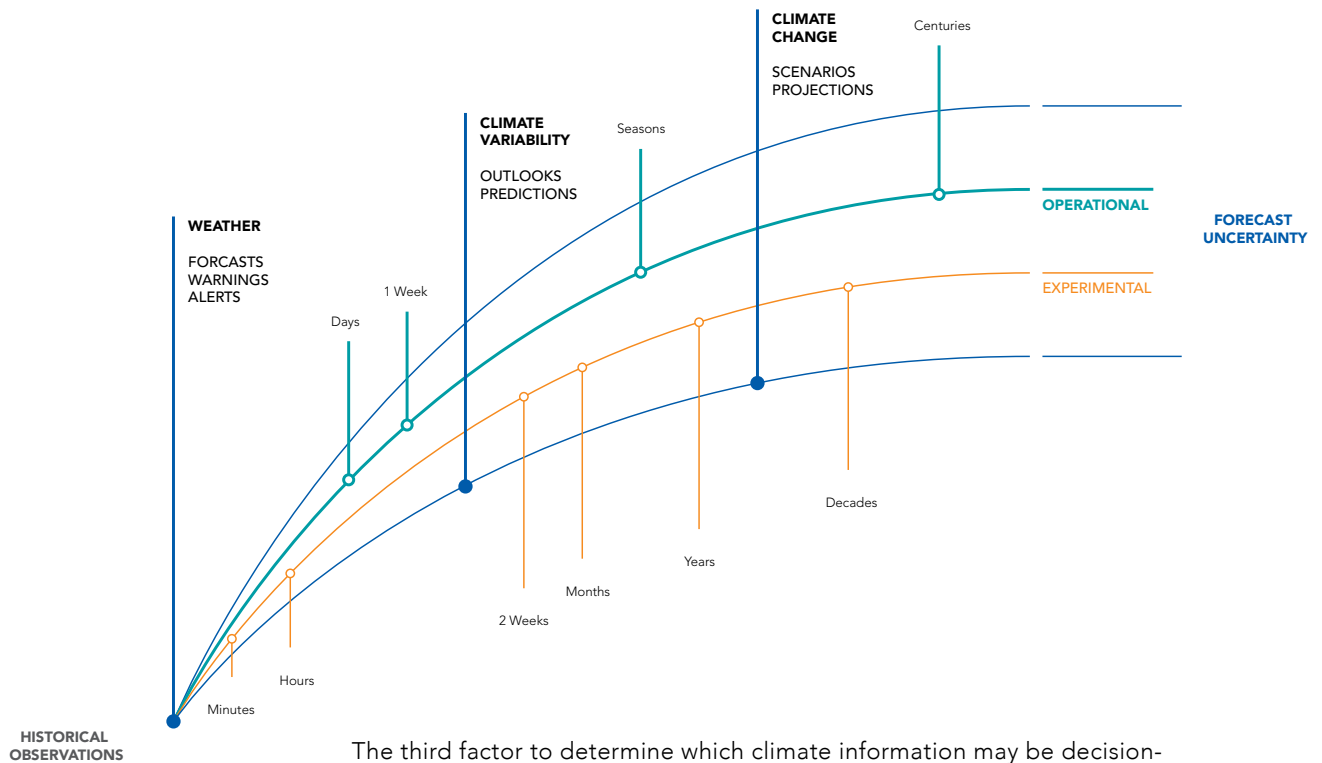
<sup>a</sup> Experimental product defined here as, general knowledge available, but products need to be assessed by climate scientists for local decision-making relevance.

<sup>b</sup> Operational product defined here as routinely available and provided by climate practitioners.

<sup>c</sup> Research product is defined here as under scientific development to improve reliability and skill of products for future use.



**Figure 1.1** Availability of climate information products



The third factor to determine which climate information may be decision-relevant is the spatial scale of problem and information. Health data is presented at a specific spatial resolution (e.g. at the facility level, the district level, the provincial level etc.). Climate information must be available at the appropriate spatial scale to match the health data. Many climate products are simply too crude to match with point or district based health information, and techniques for aggregating comparative scales such as district, province, or national level are often needed.

Understanding and selecting the appropriate spatial scale of information, along with considerations of the quality of this information to inform the health decision is important. For example, global scale dynamical climate models will not provide the needed level of detail to create future projections of climate change impacts at the national and/or sub-national levels.

Fourthly, the quality and timeliness of information will determine its adequacy and relevance for use in the public health context. The professional and ethical standards of public health practice demand that the information used for making decisions about people's lives and well-being are held to robust standards and methods. Health professionals must scrutinize available information with the recognition that data quality may be poor, measurement biases may exist, the skill of forecasts are regionally and seasonally specific, and that conditions of uncertainty must be clearly documented for users and decision makers. Health professionals may deem climate information unusable if products are not validated, unreliable, or other conditions cannot be met. Furthermore, if information cannot be provided in a timely manner, it may not be usable. For example, if observed or forecasted climate information is available, but not updated routinely in a timely manner, it cannot be used for early warning systems.

For national or subnational health decision-making, discussion with the National Meteorological and Hydrological Services (NHMS) who are most often responsible to collect and produce climate and weather information, and understanding of local data sharing policies, is a first step to identifying the relevant, available, and accessible weather and climate information.

#### 1.4 WHAT ARE HEALTH-TAILORED CLIMATE SERVICES?

Climate services provide actionable information and products about the past, present and future climate and weather conditions. Climate services take many forms. They are not only about information products, but represent partnerships and comprise the entire process of bringing relevant stakeholders together to develop tailored evidence, tools, and information services that help solve problems for different sectors.

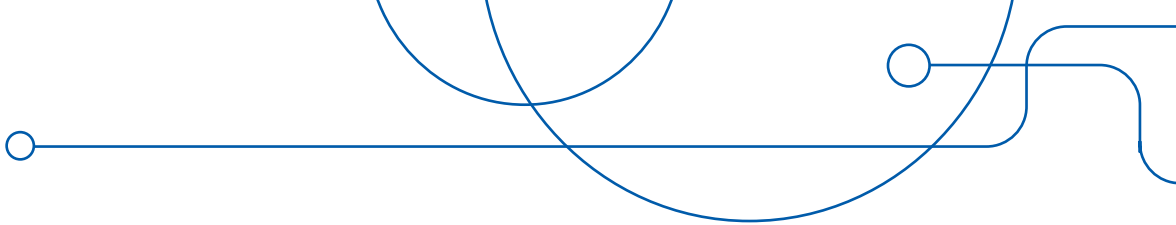
Climate services for health are defined here as “the entire iterative process of joint collaboration between relevant multidisciplinary partners to identify, generate and build capacity to access, develop, deliver, and use relevant and reliable climate knowledge to enhance health decisions.”

Sometimes a climate service can be as simple as having an enabling data sharing policy and good relations that allow for regular or periodic information exchange between health authorities and NHMS; and other times a climate service may reflect years of joint research and capacity building to co-develop, regularly produce, and use specific products such as public advisories. For example, climate services can be developed to monitor how and where smoke plumes move during forest fires to anticipate when and where populations may be in harm’s way; to identify climate influences on disease dynamics; to map disease transmission risks at high spatial resolution to indicate when and where populations may be at risk for seasonal disease exposure and better target vector control interventions; to provide customized information for high-risk populations during heat waves; or to understand drought risks and reduce vulnerabilities to rapid and slow onset impacts of droughts. Regardless of the form, the expected outputs of a climate service are customized, relevant, and reliable information products that help health professionals understand the influence of climate on health, or take appropriate action.

#### 1.5 WHY IS CO-PRODUCTION IMPORTANT?

Climate services represent activities that cannot be accomplished by one sector alone. In the case of climate and health, health professionals depend on strong partnerships with the National Meteorological Services and other partners to access relevant data and capacity to solve health challenges and questions related to weather and climate.

Where good quality data, capacity, and knowledge sharing capabilities exist, the health community may rapidly expand their use of climate information without additional cumbersome administrative burdens often associated with multi-sectoral arrangements. For example, the analyses of climate and health relationships that strictly use historic observations of quality controlled meteorological data, may call for less joint collaboration, but require data sharing policies that will allow health partners to build the evidence-base for identifying climate service needs.



However, when the public health problem or decision-need is seeking to use probabilistic weather or climate forecasts, projections or scenario information, close collaboration and co-production of products becomes particularly important.

Co-production not only expands the available expertise and knowledge that can be harnessed for problem solving; but helps to make informed judgments about the uncertainty and the probabilistic nature of future weather and climate conditions, which are inherently uncertain. Joint accountability for the generation and use of probabilistic information is fundamental.

Developing tailored climate products and services that can be fully mainstreamed into public health decision-making, policy and operations is a multifaceted process. It calls for first clearly identifying the problem and information needs; having the capacity to interpret the information provided by climate products; having mechanisms to incorporate this information into decision-making; building communication channels with partners and communities involved in risk management or response; and monitoring mechanisms to evaluate the performance of the products.

The development process for creating usable climate products and services for robust public health decision-making may take months to years, and commonly requires iterative rounds of trial and error, capacity-building, and refinements through active partner engagement and collaboration. Furthermore, the development process should focus not only on the technical specifications of the climate product, but also on the soft-processes that are necessary for building capacity and incorporating user needs.

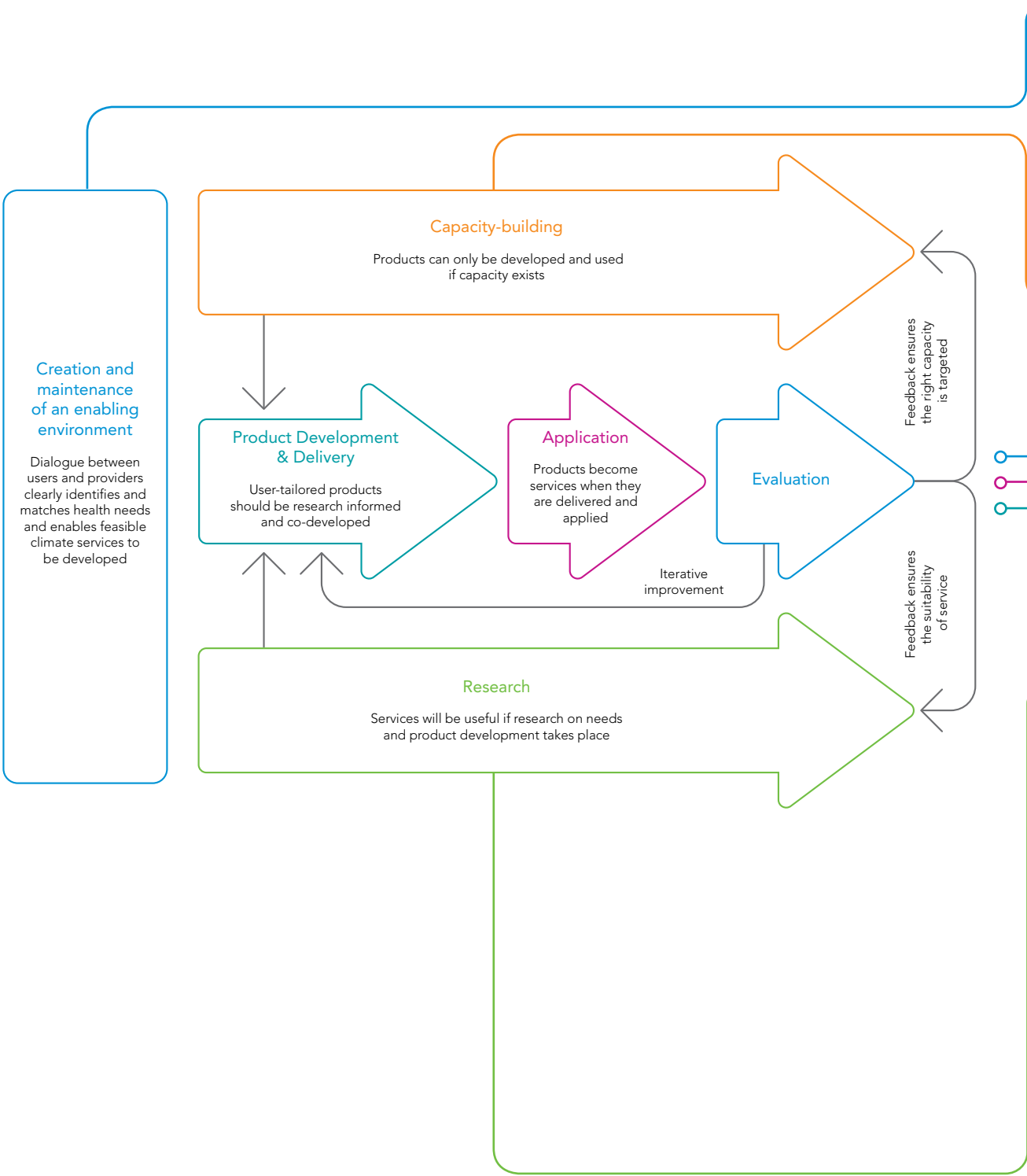
#### 1.6 DEVELOPING CLIMATE SERVICES FOR HEALTH: A HOLISTIC PROCESS

By definition, climate services are an end-to-end multifaceted process through which a partnership creates a fit-for-purpose information solution. The process of developing a climate service starts with an active discussion between climate information producers and users about specific problems: such as the context, ultimate application, and user specifications. It starts with the question “what is the climate-sensitive health problem, decision, or policy relevant research question that needs to be addressed, and what is its spatial and temporal dimension?”

Following careful problem definition, six common components frequently comprise the approaches taken to develop and deliver climate products and services for health. These include activities to create an enabling environment, build capacity, conduct research, develop and deliver products and services, apply the knowledge, and evaluate the products and user-experience. Each component serves a specific goal in the overall process, as shown in Figure 1.2. These components are not necessarily sequential, but very often must occur simultaneously to design, develop, and apply useful weather and climate services.

Table 1.3 presents the goals of each component. Global experiences have shown that although the product development process can be difficult, ensuring that the resulting tools and information are effectively applied and maintained are even greater challenges.

**Figure 1.2** Process of tailoring climate services for health.



**Table 1.3** Goals of individual process components.

### ENABLING ENVIRONMENT

The goal of creating an enabling environment is to promote the close, coordinated and sustained collaboration and exchange of information between relevant stakeholders, thereby building the technical, institutional, legal and normative foundations that allow smooth, timely and successful collaboration for activities within each of the process components.

### CAPACITY BUILDING

The goal of capacity building is to ensure that adequate human and other resources, institutional and community skills and know-how are available to allow for appropriate development, optimal use and sustainability of climate services.

### RESEARCH

The goal of Climate service research is to generate evidence on the needs for climate services for health, and to produce the necessary know-how for the development and application of such services.

### PRODUCT AND SERVICE DEVELOPMENT AND DELIVERY

The goal of product and service development and delivery is to collaboratively design and create tailored information products that are integrated and interoperable to user specifications, and that provide decision-makers and communities with timely and relevant information to manage health risks specific to climate and weather.

### APPLICATION

The goal of applying climate services is to bring benefits to individuals and communities.

### EVALUATION

The goal of evaluation is to provide evidence on the performance, effectiveness and cost-effectiveness of climate services to save lives and reduce climate-related health risks and its cost-effectiveness vis-a vis other interventions.

**Table 1.2** Key terms and examples.

### Weather information products

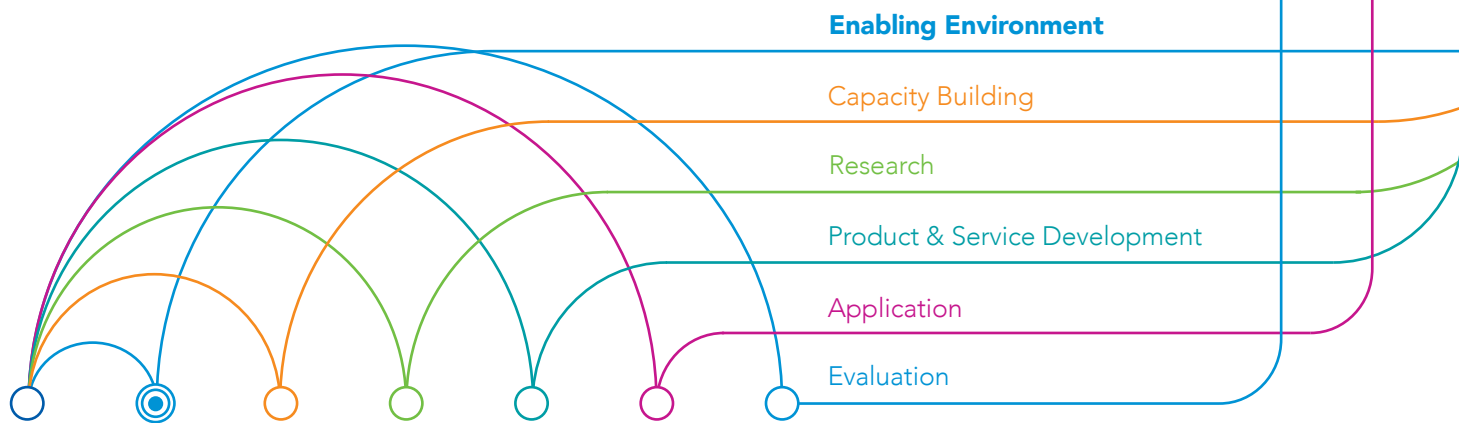
measure the state of the atmosphere at a specific time and place, particularly temperature, precipitation, cloudiness, etc. (Real-time monitoring, historical time series, summary statistics temperature, precipitation, humidity, etc.)

### Climate information products

are the result of processing and presenting climate data or climate information, alone or in combination with other types of data or information, in such a way that allows for their application to a specific practical purpose. It covers a range of spatial scales and can include derived variables related to impacts, such as crop water satisfaction indices, epidemic disease hazards or streamflow. (Summary statistics, historical time series records, near real-time monitoring, predictive information from daily weather to seasonal to interannual timescales, and climate change scenarios.)

**Climate services** are mission-oriented processes driven by societal needs, which result in the production and delivery of relevant, authoritative, timely and usable information about climate change, climate variability, trends, and impacts to improve decision-making in climate sensitive sectors. (Early warning systems, Integrated monitoring systems. Provision of data, Risk forecasting systems.)





## CHAPTER 2

# 2 CREATING AN ENABLING ENVIRONMENT

**GOAL** to promote the close, coordinated and sustained collaboration and exchange of information between the climate and health sectors and other relevant stakeholders, thereby building the technical, institutional, legal and normative foundations that allow for smooth, timely and successful collaboration for activities within each of the process components.

An enabling environment is the structured context that brings together the principal actors whose technical and practical expertise and decision-making are needed to inform, develop, and apply the climate service. Simple organizational and institutional steps can markedly improve partnerships and the outcomes of joint activities by helping to delineate clear and joint expectations, procedures, and processes that can assist partnerships to mature and be successful throughout their intended duration. For example, the frequent and structured exchange of information, such as through regular meetings, or communications, provides the opportunity to actively participate in discussion and decision-making at each step. Participation and ownership is key for the creation of trust and mutual understanding between partners, which will help climate and weather products be confidently endorsed and applied by users to improve health decision-making.

Strong evidence of local climate and health linkages, and demonstrating the results of applied climate information is also a fundamental part of enabling, sustaining, and justifying the value of investments in climate service partnerships.

## IMPORTANCE OF AN ENABLING ENVIRONMENT TO EFFECTIVE CLIMATE SERVICES

An enabling environment should be maintained throughout the whole climate service production process. In the initial stages of the climate service development process, intentional activities should be undertaken to:

- clearly define the problem being solved and its space and time dimensions;
- facilitate dialogue between partners to encourage understanding of each other's needs and interests;
- conduct an assessment of each partner's capabilities and limitations, including data sharing and resource exchange policies;
- envision and scope the type of climate products and service to be developed;
- evaluate feasibility of the end-to-end process, including capacity, research and application requirements, and explore implementation options;
- define and monitor step-wise progress and setbacks of activities to be conducted throughout the entire climate service development process;
- establish rules and procedures for engagement (for example meeting schedules, memorandums of understanding, timetables, data sharing arrangements);
- create a plan for evaluating, providing feedback, and making needed adjustments;
- identify data, financial and technical resources required.

In the later stages of product development and application, activities may be needed to:

- maintain communication channels for partners to exchange data and information;
- discuss and solve problems;
- evaluate and provide and receive constant mutual feedback;
- address sustainability of services;
- identify new needs and/or expand the applications and partnerships.

## COMMON APPROACHES

Enabling environments are created in different ways, depending on the context, national institutional environment, and familiarity of partners with the subject and with each other. Activities that help create and structure an enabling environment include:

- mapping national partners' interests and strengths;
- collaboration with international stakeholders or partner countries to fill gaps in available knowledge or resources;
- clearly defining roles and responsibilities of partners;
- formalizing a memorandum of understanding or clear terms of reference outlining how the collaboration will work;
- adopting common standards and schedules;
- formulating data-sharing policies;
- creating a multidisciplinary team;
- scheduling regular meetings, trainings, and workshops with all stakeholders;
- involving high-level decision-makers to increase their understanding, appreciation and trust to use the information and services in order to make critical and often life-saving decisions;
- engaging academia as a neutral partner to mediate between national health and climate authorities.

## WHO'S OFTEN INVOLVED?

**Health professionals** frequently include health authorities and programmatic decision-makers, planners, researchers, statisticians, epidemiologists, public health practitioners, clinical staff and community health workers, who may be working for the private sector, government or non-governmental health system.

**Climate professionals** often include meteorologists, climatologists, and researchers from the National Meteorological Services, academia, or applied institutes.

**Professionals from health-determining sectors** such as water management, agriculture and food security, urban planning, and disaster risk management are also key actors in developing tailored information products related to or adapted from knowledge and decision tools used in these domains.

**Knowledge brokers and professionals from complementary disciplines** often include information and communication technologists, project managers, policy-makers, legal experts, statisticians and community representatives.

**Community members**, including individuals expected to use the climate information, and the media who may be transmitting information to the public, are also important stakeholders.

## ENABLING ENVIRONMENT CASE STUDIES

The following four case studies illustrate different approaches to fostering an enabling environment.

A

**2A:** A Ecuador–Peru cooperation to use climate and health information for dengue surveillance: establishing a multinational and multidisciplinary team

Case study 2A, shows how a collaboration between experts in Ecuador and Peru was established to address a shared problem of endemic dengue transmissions in the border areas of the two countries. A transnational and multidisciplinary team of specialists in public health, epidemiology, tropical medicine, climatology and statistics came together following participation in two 2-week “Andean Course on the Use of Climate Information for Public Health”, which provided the team adequate and consistent understanding of the topic to collectively tackle the problem.

B

**2B:** Integrating air quality, health and meteorological expertise to address the impact of poor air quality on health in Indias

In India, case study 2B describes a partnership formed between one climatological and two health-related specialized agencies in India, in order to identify and bring together information from diverse sources required to generate evidence and monitor the health impacts of air pollution. Steps taken to map the knowledge assets of each institution and address data collection requirements, proved essential to building trust, enhancing product quality, and creating a strong basis for the future development of future forecasting of hazardous air quality that can be used for making public advisories.

C

**2C:** Long-term climate and health collaboration in Ethiopia to improve forecasting of malaria outbreaks

In Ethiopia, case study 2C narrates the long-term collaboration between the Ministry of Health and the National Meteorological Agency in Ethiopia, to inform malaria prevention and control. In this case, research justified the value of using climate information for epidemic forecasting and early case detection. Using this evidence, the Ministry of Health was able to support the National Meteorological Agency to improve meteorological observation infrastructure and data management systems, which helped ultimately improve available products. Enabling activities such as a multidisciplinary Climate and Health Working Group, regular bulletins, and trainings helped develop and advance the use of climate information for malaria control.

D

**2D:** Madagascar Climate and Health Working Group

In Madagascar, case study 2D describes how a Climate and Health Working Group has been maintained since 2008, thanks to strong institutional arrangements, information sharing policies, clear needs identification, and joint trainings. The research and advisory products the team produces have also helped to demonstrate results, create a strong local evidence base, and gain legitimacy as an inter-ministerial expert group able to support the Ministry of Health and family planning with information and evidence related to climate variability and change.

# ECUADOR–PERU COOPERATION FOR CLIMATE INFORMED DENGUE SURVEILLANCE: CREATING A INTERDISCIPLINARY MULTINATIONAL TEAM

Authors : E. Quichi (Ministry of Health, Peru), R. Mejia (Instituto Nacional de Meteorología e Hidrología, Ecuador), W. Torres (Servicio Nacional de Control de Enfermedades Transmitidas por Vectores Artrópodos, Ecuador), Y. Escadillo (El Servicio Nacional de Meteorología e Hidrología del Perú), M. Mena (Universidad Central del Ecuador), A. von Hildebrand (World Health Organization).

## CONTEXT

Converting weather and climate data into a decision-making tool for health authorities to use in order to reduce the burden of climate-sensitive diseases is a potentially powerful initiative, but remains a challenge in most developing countries.

Strategies for climate change adaptation can reduce morbidity and mortality (1), yet there is very little information exchange between the health and meteorological sectors, causing uncertainty in risk-management decisions to better cope with health threats from climate change.

The epidemiology of dengue transmission over the past 20 years has shown epidemic cycles of three to five years. To date, the only method of preventing and controlling the transmission of the dengue virus is vector control, an integrative and multidisciplinary task (1, 2). WHO recommends that new strategic approaches to address dengue should focus on partners, such as WMO, and management of climate information (3, 4).

Dengue transmission in the common border areas of Ecuador and Peru remains endemic throughout the year and epidemic cycles coincide with rainy seasons. The persistence of dengue transmission is associated with social, economic, environmental and cultural determinants that prevail in approximately 70% of the border areas (5, 6).

Between January and November 2012, a total of 3227 dengue cases were reported in these border areas (5–7). High human mobility from intense commercial activity and tourism, fragmentation of information systems and morbidity underreporting are factors that characterize the need for interdisciplinary approaches.



In 1998, a *Binational Development Plan* was established along the Ecuador–Peru border. It aims to facilitate access to services such as roads, water and sanitation, watershed management, and basic infrastructure for health and education (8).

In 2011, with the support of the Ecuador and Peru WHO country offices and funds from WMO, staff from the ministries of health and the meteorological services from both countries launched a joint initiative to establish a binational dengue surveillance network using climate and health information along the Ecuador–Peru border. The aim is to team up the health and meteorological services and other operational staff to reduce the dengue disease burden.

#### NEW APPROACHES

**Establishment of a team.** The project team comprises multinational and multidisciplinary specialists in public health, epidemiology, tropical medicine, climatology and statistics, all participants in a two-week, WHO/WMO-sponsored ‘Andean course on the use of climate information for public health’ that was held in 2012, attended by a total of 18 experts from nine countries (9).

**Workplan.** The following workplan, with funds allocated, institutional support and written reporting mechanisms agreed, was set up by the team:

**Objective 1:** Identify the technical, human, legal and procedural resources of the institutions in charge of human health and of weather and climate information related to vector-borne diseases in the border area.

Activities:

- 1.1 Identify and map the stakeholders to participate in the binational dengue surveillance network.
- 1.2 Prepare a workplan.
- 1.3 Prepare a standardized survey form to collect information on the institutional knowledge and capacities to provide weather information related to dengue epidemiology in the border areas.
- 1.4 Review and analyse the results.

**Objective 2:** Promote the use of selected weather information, adjusted to the needs of the health sector, to monitor and control dengue, within the framework of the *Binational Development Plan*.

Activities:

- 2.1 Organize a binational planning workshop.
- 2.2 Create a dengue surveillance network web site.
- 2.3 Obtain official government approval and support for the establishment of the dengue surveillance network.

## CASE STUDY 2.A



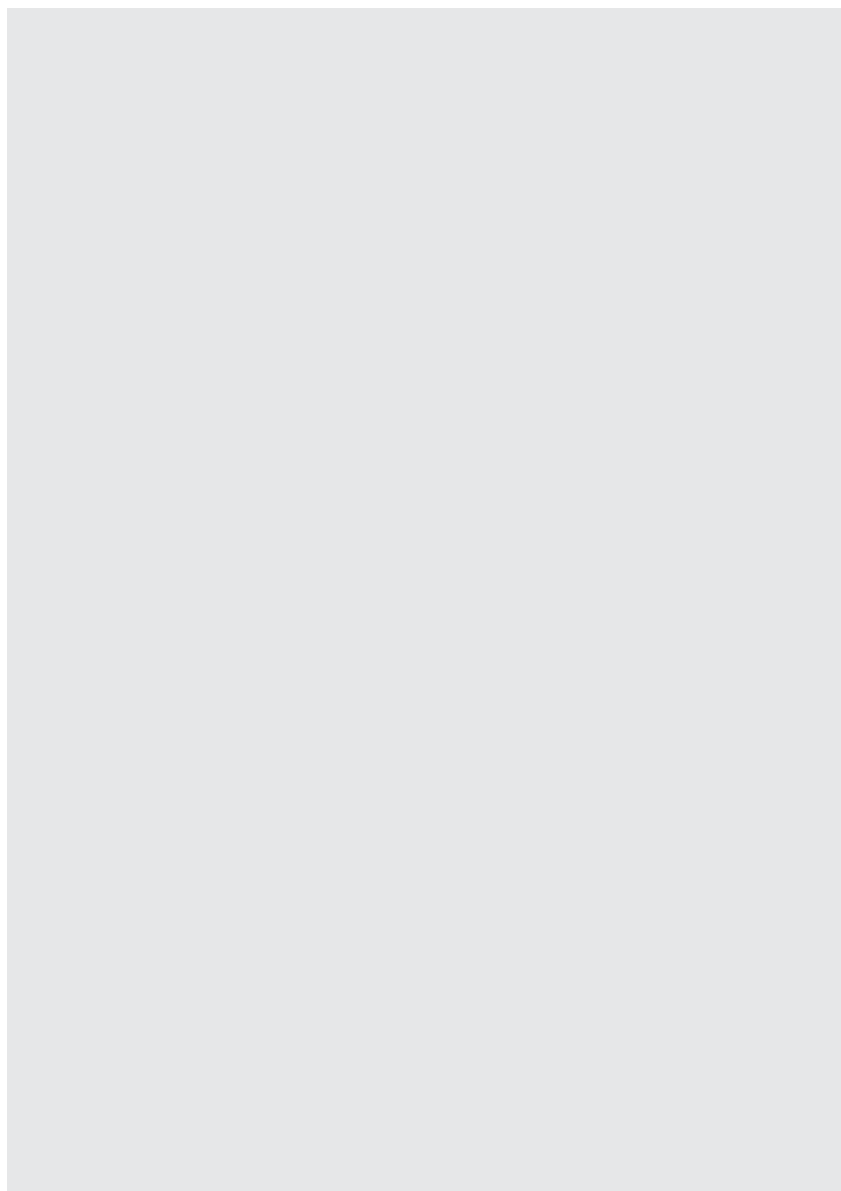
Enabling  
Environment

Research

Evaluation

**Establishment of a baseline of the installed institutional capacities.** Since 2010, the Ecuador Ministry of Health has addressed health concerns linked to climate change through an integrated approach to manage the social and environmental determinants of health. Likewise, in Peru, the Environmental Health General Directorate of the Ministry of Health implements strategies addressing climate change impacts on human health as a disease prevention approach. The *Binational Development Plan* is aimed at strengthening health actions in both countries' border areas (8).

The National Service for Meteorology and Hydrology (El Servicio Nacional de Meteorología e Hidrología del Perú, SENAMHI) in Peru leads the meteorological, hydrological and environmental, and agrometeorological activities in the country. SENAMHI monitors and generates atmospheric information useful for the improvement of public health. In Ecuador, the National Institute for Meteorology and Hydrology (Instituto Nacional de Meteorología e Hidrología, INAMHI) has led major research processes using climatological information for predictability models for vector-borne diseases (10).



Placeholder for image

**Climate–health capacities and knowledge of local and national institutional actors.** The dengue surveillance network standardized form was completed by health and climate authorities in both countries, leading to the following observations:

- All health survey participants knew about an information system on dengue cases; only half knew about information transfer systems; 88% said there was no quick and fast way to exchange information on dengue cases and indexes.
- Of survey participants, 76% were not aware there was a monthly climate–health information reporting system.
- None were aware of climate information maps.
- All said no correlation of climatic variables and dengue cases was performed.
- All climate survey participants mentioned that weather information was extremely valuable to health, but it was not available in a language assimilated by Ministry of Health staff.
- Information on dengue cases was centralized in the Ministries of Health and was not publicly available, and there were no formal avenues for information flow to allow joint action.
- The high turnover of staff undermined the ability of the two countries to work together.
- Local communities were unaware of climatological information and possible climate–health relationships.
- The Ecuador–Peru Binational Development Plan had a funded framework to improve the health of people living in border areas, but was not socialized among local actors.

#### BENEFITS AND LESSONS

Despite restricted funds, the binational monitoring network for dengue control using climate and health information in the border regions of Ecuador and Peru was established, along with a workplan. This promising initiative needs further support. Recommendations for next steps including seeking official recognition of the dengue surveillance network for it to implement its workplan as part of the Binational Development Plan; and for the dengue surveillance network to become an official part of the regional and local community development plans.

#### ACKNOWLEDGEMENTS

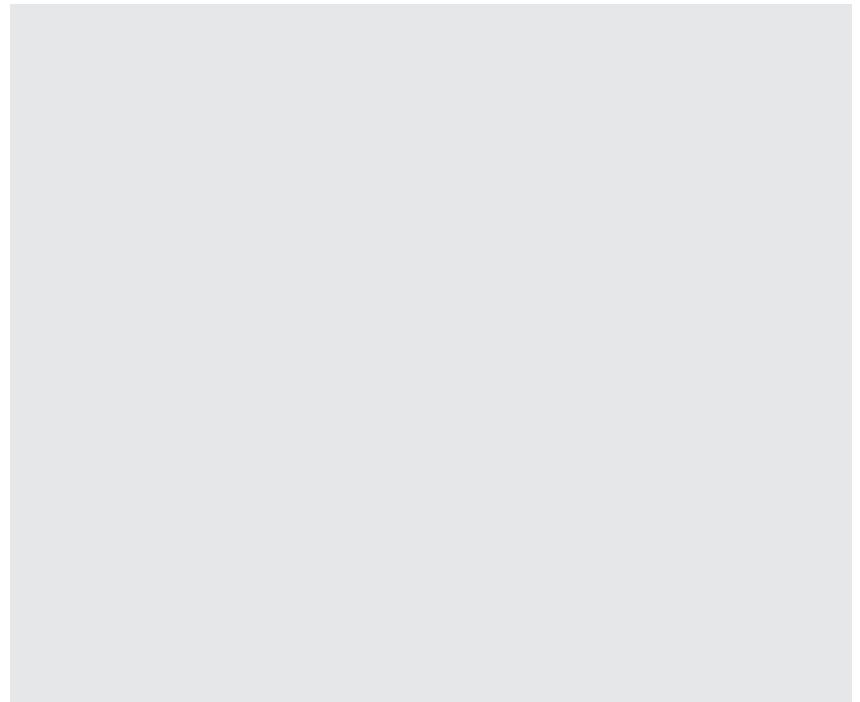


# ADDRESSING IMPACTS OF POOR AIR QUALITY ON HEALTH IN INDIA: INTEGRATING AIR QUALITY, HEALTH AND METEOROLOGICAL EXPERTISE

Authors: G. Beig and D.M. Chate (Indian Institute of Tropical Meteorology), S. Salvi (Chest Research Foundation), S. Juvekar (KEM Hospital Research Centre Pune and INDEPTH Network, Accra, Ghana).

## CONTEXT

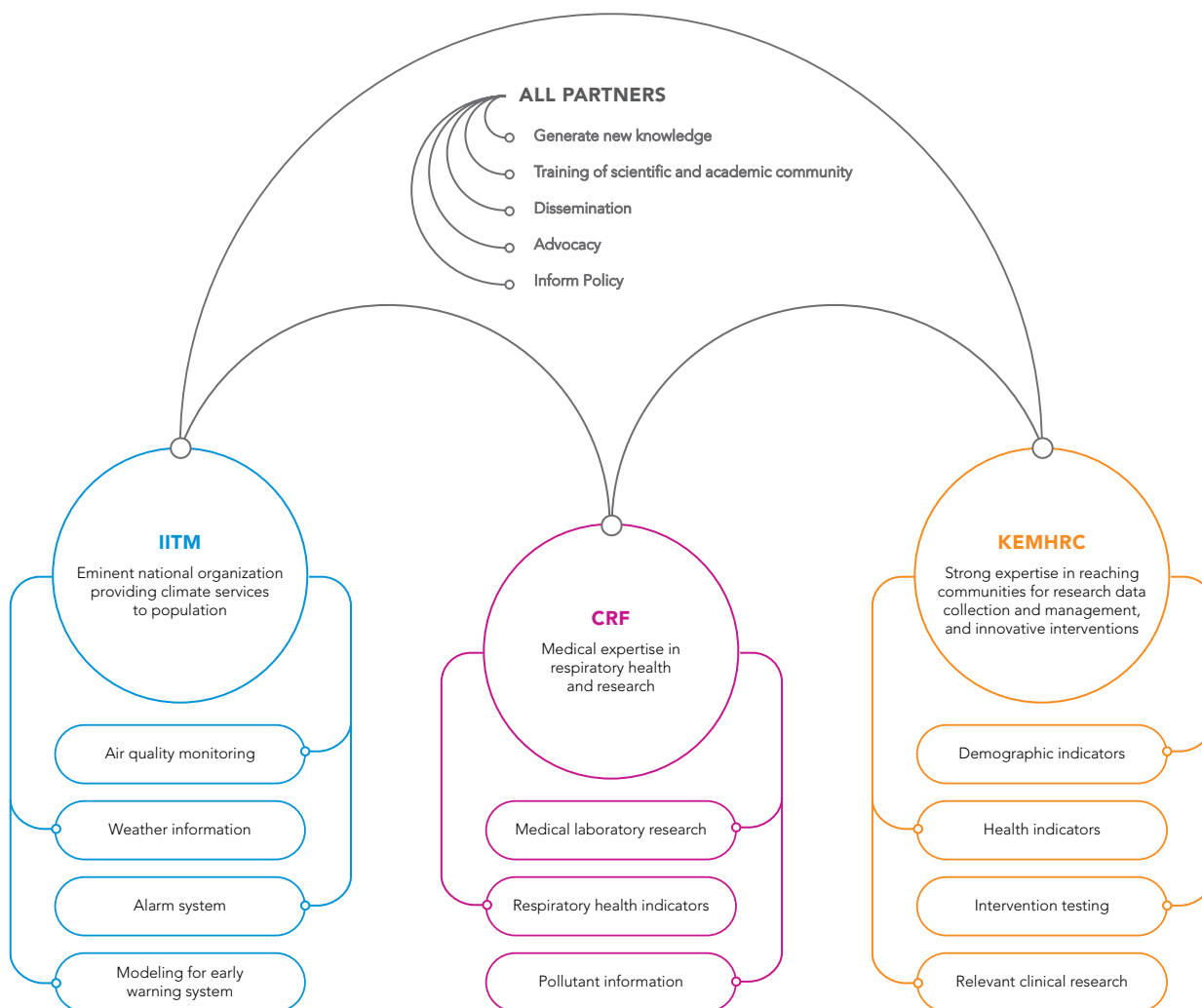
Climate change is poised to worsen air quality globally. In developing India, one of the fastest-growing global economies, air quality is deteriorating at a rapid pace.



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This poses a serious challenge to health and food security. However, a wide communication gap has traditionally existed between data gatherers and forecasters of weather, climate and air quality, and the health professionals who are responsible for preventive care and policy decisions on human health. Therefore, a framework for air quality and health was established whereby air quality domain experts involved in the System of Air Quality and Weather Forecasting and Research (SAFAR) of the Indian Institute of Tropical Meteorology (IITM) worked together with health experts from the Chest Research Foundation (CRF) and the KEM Hospital Research Centre (KEMHRC) towards better understanding of the link between air pollution and health. Figure 2.1 presents a schematic diagram of the framework.

**Figure 2.1** Framework for uniting air quality, climate change and health research in India.



### NEW APPROACHES

SAFAR (11), under the Indian Ministry of Earth Science, was conceived, developed and commissioned by IITM and adopted as a pilot project by WMO. It integrates a meso-network of air quality and weather stations, utilizing emission inventories and an air quality forecasting model. SAFAR facilitates current and forecasted information 24 to 72 hours in advance for ozone, nitrogen oxide, carbon monoxide, PM<sub>2.5</sub> and PM<sub>10</sub>,<sup>d</sup> volatile organic compounds, ultraviolet (UV) index and weather parameters. SAFAR products are disseminated through various media to inform actions designed to keep the population healthy. CRF (12) has state-of-the-art pulmonary function laboratories to measure obstruction in airways, total lung capacity, oxidative stress, oxygen flow, airway hyper-responsiveness, and nasal pressure and flow parameters for detecting air quality-mediated health problems. KEMHRC (13) is a health research organization that conducts surveillance for tracking births, deaths, cause of death and migration through its Vadu Health and Demographic Surveillance System, specifically focusing on rural India. It carries out health intervention studies that address previously unanswered questions on maternal, child and adult health with respect to both communicable and non-communicable diseases (NCDs).

<sup>d</sup> Particulate matter less than 2.5 and 10 micrometres in diameter, respectively.

## CASE STUDY 2.B

Enabling Environment

Research

Evaluation

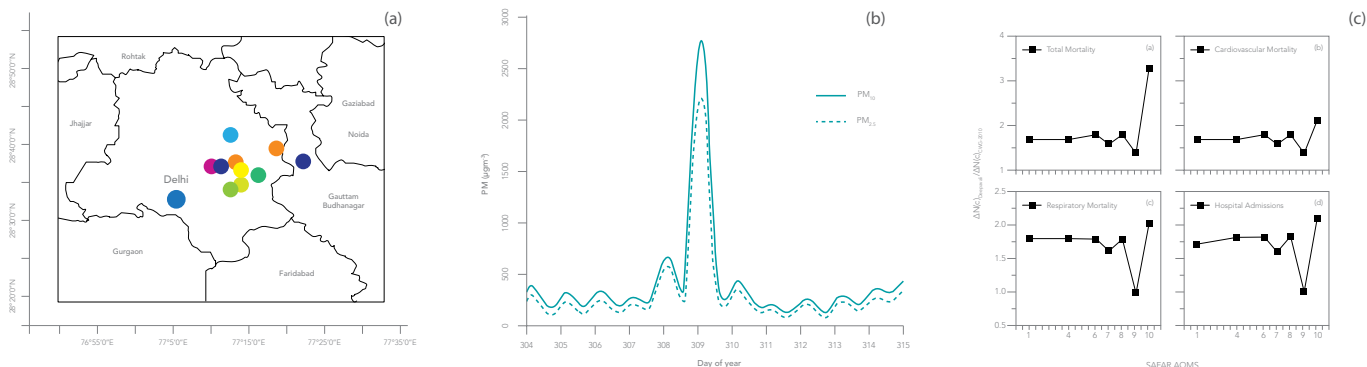
CRF has a registry of patients attending its clinics and the tests carried out for each patient. KEMHRC maintains population demographic data (e.g. birth date, sex, occupation, education, home address, death date, cause of deaths) as well as data on hospital admissions and laboratory testing. Using CRF and KEMHRC health data and real-time SAFAR data, air quality and UV index functions will be developed by IITM, and information on the relative risks associated with extreme weather and poor air quality will be co-developed by respective partner institutes. IITM, KEMHRC and CRF already collaborate closely, and their information-sharing agreements will be further developed and nurtured to facilitate interdisciplinary research and effective implementation of the system.

### Various research projects have already taken place in India under the framework:

- One of the most striking findings of a research study by CRF established that lung function values of Indians are 30% lower than matched Caucasians, based on a lung function study conducted with 10 000 persons across five urban centres in India (14). The finding has been attributed to deteriorating air quality.
- Studies focused in rural Pune by KEMHRC showed clear association between climate change and mortality due to wide variations in maximum and minimum temperatures (15). This study demonstrated that the biggest impact was observed among children aged 0–4 years, where relative risk of mortality was found to increase by 66% if the temperatures went above 35°C or less than 25°C, and this effect lasted up to six days.
- Recently it has been demonstrated by KEMHRC and CRF that the prevalence of chronic obstructive pulmonary disease (COPD) is high in rural Pune and is mainly associated with household air pollution. This study was conducted among 3500 randomly selected adults from 22 villages using post-bronchodilator spirometry.
- Studies by IITM under SAFAR established that in Asia's second-largest megacity, New Delhi, the pyrotechnic displays (widespread prolonged fireworks) and temperature inversion in winter may lead to peak PM<sub>2.5</sub> levels up to 500µg per cubic metre (24-hour average) with hourly peaks reaching 2000µg per cubic metre. This resulted in a twofold increase (from the reference point) of cases of total, cardiovascular and respiratory mortality and hospital admissions for COPD cases (Figure 2.2) (16).



**Figure 2.2** Extreme pollution episode during Deepavali, 2010: (a) AQMS-AWS SAFAR stations, (b) PM<sub>2.5</sub> and PM<sub>10</sub> 5 November 2010, (c) daily mortality PM<sub>2.5</sub>.



## BENEFITS AND LESSONS

The Indian framework for air quality and health envisions the following:

- (a) increase understanding of the relationship between air pollution, climate change and disease;
- (b) establish an operational forecast model (or module/tool) to issue health advisories; and
- (c) provide climate–health predictions to the public and provide guidelines on preventive measures.

During this initial cooperation it was realized it is very important that overlapping of periods of data collection on various parameters by different partners should be resolved at the micro level, as differences in the periods could result in a significant increase in statistical uncertainty. Hence the format of the data needs to be modified. Collaboration between the institutions was found to be robust and conducive to the development of final products. Such levels of collaboration, leading to the generation of strong scientific evidence, have increased political willingness to develop health advisory services. Sufficient human capacity, financial resources and institutional willingness to develop and maintain the partnership between institutions are necessary to enhance understanding of the relationships between air pollution, climate and diseases.

## ACKNOWLEDGEMENTS





# LONG-TERM CLIMATE AND HEALTH COLLABORATION TO FORECAST MALARIA OUTBREAKS IN ETHIOPIA

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## CONTEXT

Malaria is a major health problem in Ethiopia, with almost 60% of the total population (around 52 million) at risk of infection (17). Altitude and climate are major determinants of malaria epidemiology (18), and those variables are used for stratification to support the design of malaria interventions (Figure 2.3). Moreover, malaria transmission is seasonal and unstable, resulting in occurrence of epidemics overlapping with abnormal weather conditions (19–21). This implies that monitoring of climate information is helpful in predicting malaria ahead of time and to guide early preparedness.

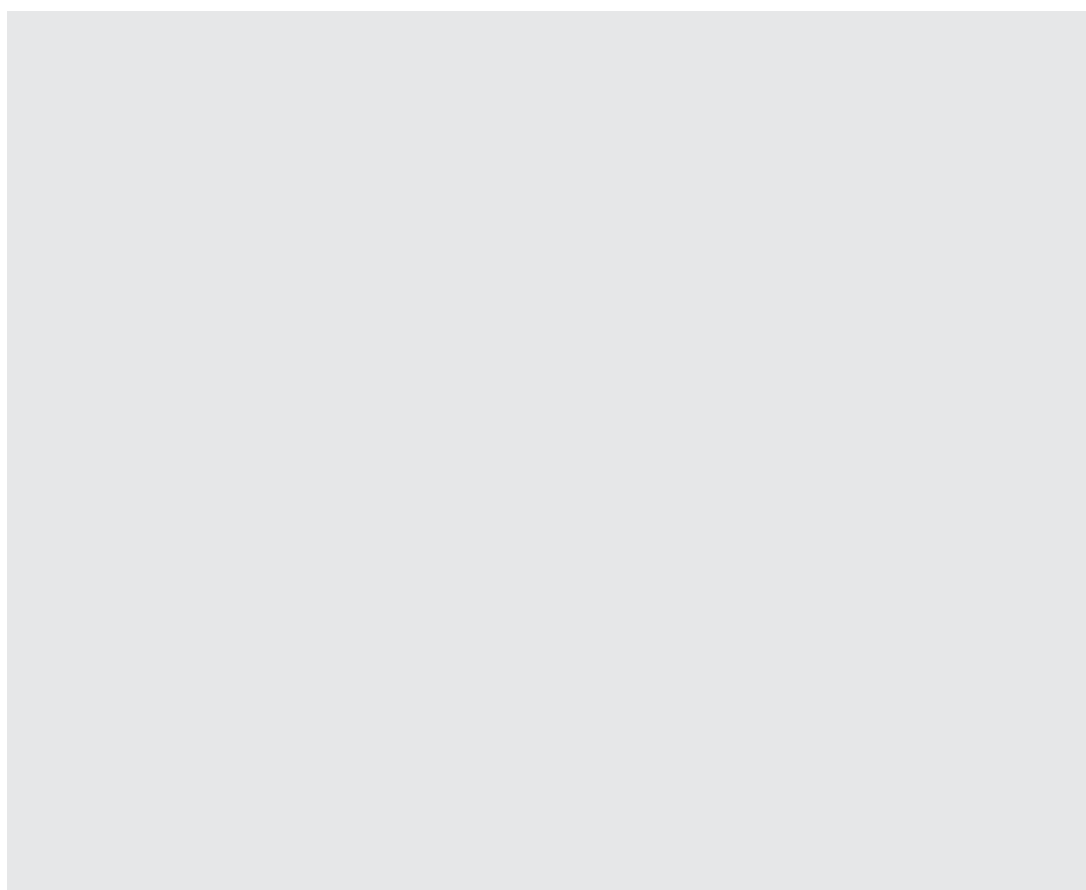
Enabling Environment

Capacity Building

Product & Service Development

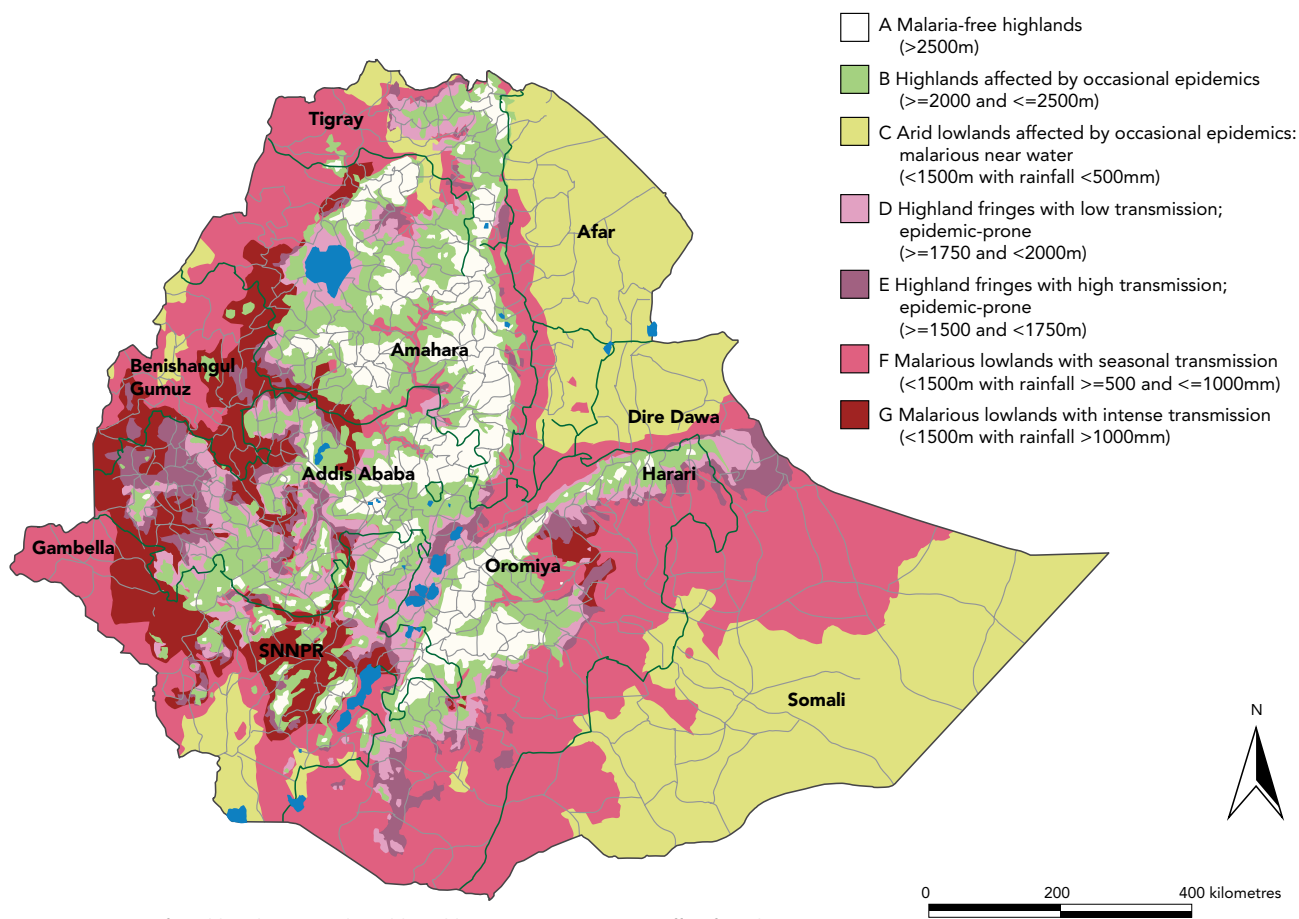
Application

Evaluation



Placeholder for image

**Figure 2.3** Altitude and rainfall-based stratification of malaria in Ethiopia, 2007.



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*Note: Figure developed by Ministry of Health of Ethiopia and WHO Ethiopia Country Office as part of a Global Fund proposal. Altitude and rainfall estimations are used to define strata A to G. Most of the areas (B, C, D and E) were known to be epidemic prone, with repeated experiences of malaria epidemics of various magnitudes. As most of the Ethiopian population resides in the highlands, a large proportion of the population is at risk of malaria exposure during outbreaks.*

## CASE STUDY 2.C



Enabling Environment

Capacity Building

Product & Service Development

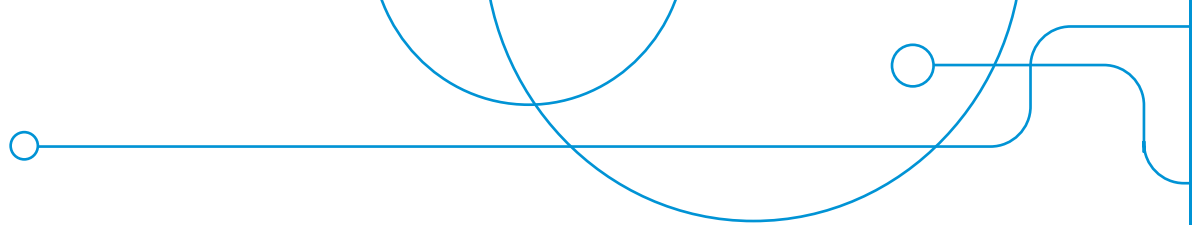
Application

Evaluation

### NEW APPROACHES

Ethiopia has been committed to malaria control for more than five decades, including through a renewal of efforts under the Roll Back Malaria (RBM) Partnership from 1998 (22). During 2000, the first Five-Year Strategic Plan for Malaria Prevention and Control (2001–2005) was designed as part of the RBM initiative (23), which aimed to reduce the malaria burden by 50% by 2010 compared to the 2000 baseline. Epidemic prevention and control was the main component of the strategic plan. The use of climate information was found to be vital in epidemic forecasting and early detection. Accordingly, climate and health experts started collaborating in data sharing, technical support and other activities in the early 2000s, and several studies clearly showed the relationship between climate and malaria in various areas and assessed tools for epidemic forecasting (20, 24, 25). Later, the Ministry of Health of Ethiopia allocated significant financial resources to improve the infrastructure of meteorological sites and the data management system at the National Meteorology Agency using a grant from the Global Fund to Fight AIDS, Tuberculosis and Malaria, which has helped in ensuring an improvement in the quality of climate information.

In addition, trainings were organized for professionals engaged in malaria control programmes at various levels. The National Meteorology Agency tailored its service towards supporting decision-making in forecasting malaria transmission using already proven tools (26). The use of such tools enabled an association to be made between rainfall and temperature on the one hand, and the biology of malaria parasites and mosquitoes on the other hand, in order to forecast the possibility of a malaria outbreak. The Ministry of Health of Ethiopia is well informed about malaria risks and shares relevant information with regional states for action at grassroots level or in health facilities and communities.



## BENEFITS AND LESSONS

The collaboration between the climate and health communities has not only supported informed decision-making in the health sector but has also improved the quality of climate data and its accessibility to users. Health planners at various levels have come to appreciate the importance of climate information in their decision-making processes. The National Malaria Control Programme as a result, shares a monthly bulletin with regional health bureaus for planning and decision-making. In addition, a number of malaria epidemiological studies have focused on climatic variables and the development of malaria prediction models (27). Similarly, the National Meteorology Agency has given attention to improving the quality of climate information and generating quality data (28). Moreover, the climate and health community established a Climate and Health Working Group, which was forged from various institutions during 2008. Between 2008 and 2010, this group helped strengthen human resource capacity-building to improve the use of climate information at national and local levels in Ethiopia.

In the past two decades, the climate and health sectors have come together to create opportunities for knowledge translation and technology transfer in Ethiopia. This collaboration has also stimulated the use of climate information in Ethiopia and attracted research. Online data accessibility via the National Meteorology Agency website and related technical support have resulted in improvement of climate services. Despite these successes, certain limitations remain, including lack of adequate financial resources to sustain capacity-building for climate information users in the health sector. In addition, the national network for climate and health, including the Climate and Health Working Group, has not been sustained, partly due to the lack of clear institutional arrangements. Also, the capacity-building scheme emphasized the involvement of participants from regional health bureaus, but high turnover of staff, and transfer of staff between departments, have made it difficult to create a body of experts able to use climate data on an ongoing basis for public health decision-making. The curricula used also did not adequately address the needs of the climate–health interface. Finally, there are limited resources for disseminating malaria forecasting tools, and appropriately downscaling information for decision making at the resolution of the district level.

## ACKNOWLEDGEMENTS



# MADAGASCAR CLIMATE AND HEALTH WORKING GROUP

*Authors: Climate and Health Working Group, H. Kootval and J. Guillemot (World Meteorological Organization).*

## CONTEXT

Madagascar has a tropical climate with two distinct seasons: the winter dry season from May to October and the summer rainy season from November to April. During the tropical cyclone season from November to April, tropical disturbances can cause severe damage. Rainfall and temperatures vary widely across the island due to variations in altitude.

Climate-sensitive diseases, such as zoonoses and waterborne and vector-borne diseases, are responsible for almost 40% of illness registered at health centres in Madagascar and contribute to 57% of the alerts received by the Directorate of Public Health and Epidemiological Surveillance (Direction de la Veille Sanitaire et de la Surveillance Epidémiologique). This does not include alerts that go directly to individual health programmes fighting diseases such as malaria and plague, which present high mortality rates in the island.

## NEW APPROACHES

In 2003, the Ministry of Health took the initiative to meet the National Meteorological and Hydrological Service following a malaria outbreak. The aim was to establish a close collaboration between the unit and the Applied Research Service of the National Meteorological and Hydrological Service for malaria monitoring, prevention and response. This collaboration was strengthened by participation of malaria unit staff in the International Research Institute for Climate and Society summer institute and of Applied Research Service staff in the Southern African Development Community Climate Expert Meeting and the Southern African Regional Outlook Forum in 2005. The Directorate of Public Health and Epidemiological Surveillance, the Pasteur Institute of Madagascar and international organizations working in the health sector – such as the United Nations Children's Fund (UNICEF) and the President's Malaria Initiative (led by the United States Agency for International Development) – also became involved.

In 2008, as a result of these initial steps, WMO selected Madagascar as the first country for the implementation of a pilot project focusing on the use of climate information to support the health sector. A launch workshop in 2008 resulted in the signing of an interministerial memorandum of understanding for partnership in climate and health, establishing the Madagascar Climate and Health Working Group and defining terms of reference and initial priorities. The 15 original members of the group were formally appointed, including eight health experts (one each for malaria, plague, Rift Valley fever and health and environmental issues, and five for epidemiological surveillance, including animal health), five climate experts (climatology, weather forecasting, climate forecasting, research and hydrology), and a researcher from the Pasteur Institute of Madagascar.

Enabling  
Environment



The working group aimed to identify the climate and weather information and service needs of the health sector, including gaps in current data, information and service delivery, and to help the Madagascar Meteorological Service meet the specific needs of the health sector. It also aimed to help the health sector use climate data and information efficiently for the prevention of epidemics and for guiding response activities for malaria, plague and Rift Valley fever, three priority climate-sensitive diseases in the country. The working group was also a catalyst for resource mobilization to ensure the sustainability of the project. The strategies adopted included institutional data sharing, access to climate and weather tools, and targeting of research, education and training needs across the sectors.

The group organized two workshop training sessions with local and international facilitators. The training improved knowledge of climate data and information at national and international levels, as well as methods for accessing and manipulating existing databases to analyse and interpret epidemiological and climate data.

As one of the main outcomes of these joint training workshops was the identification of the health sector needs in climate data and information. Following the health sector request, WMO provided six manual climate stations for six health sentinel sites, accompanied by the establishment of a memorandum of understanding between the Ministry of Health and the National Meteorological and Hydrological Service defining the roles of each sector in the management of the climate observation sites. This included the training of local health workers and climate experts on measurement of climate variables, data transmission and interpretation, the use of climate information for local epidemiological monitoring and surveillance, and the transformation of data into information for decision-makers.



Climate monitoring station at the health sentinel site in Ambositra



## CASE STUDY 2.D

Enabling  
Environment

These efforts have resulted in the development of a seasonal and intraseasonal climate outlook, which gives information to the health sector on climatic conditions in forthcoming rainy seasons and is used by the Ministry of Health to produce its climate and health monthly bulletin, and to provide free-of-charge data for research or post-disease outbreak analysis by the National Meteorological and Hydrological Service.

Under the financial support of the WMO/PWS program, since 2008 the group regularly organizes follow up on field missions on the climate and health sentinel site and national climate and health workshops, gathering all climate and health stakeholders from the 22 regions of Madagascar. The workshop is aimed to share the use and benefits of climate stations on the health sentinel site, to assess the gaps and needs and to define the future workplan in climate and health.



Participants at Climate and Health Workshop, September 2015, Antananarivo

### CLIMATE AND HEALTH WORKING GROUP MEMBERS:

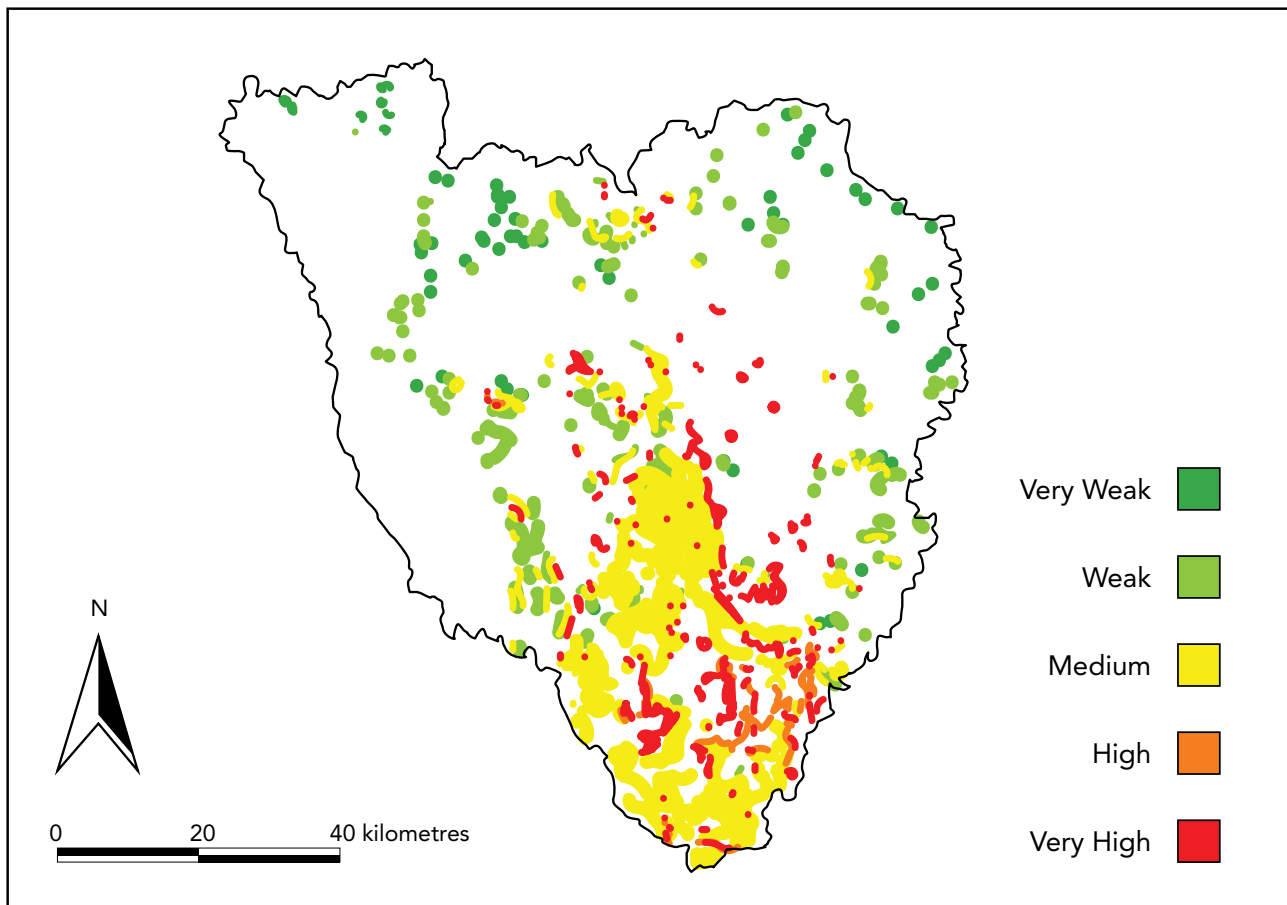
#### Climate Experts:

*Dr Nirivololona RAHOLIJAO*  
*Ms Sahondra RANIVOARISOA*  
*Ms Vaohanginirina RAMIANDRISOA*  
*Mr Andrianjafinirina*  
*SOLOMONENJANAHARY*

#### Health Experts:

*Dr Yolande RAOELINA*  
*Dr Alain RAKOTOARISOA*  
*Dr Marie Clémence RAKOTOARIVONY*  
*Dr Fanjasoa RAKOTOMANANA*  
*Dr Madeleine RAZAFINDRAMAVO*  
*Dr Manuela Christopher VOLOLONIAINA*  
*Dr Huguette RAMIAKAJATO*  
*Dr SABAS*  
*Dr Norohasina RAKOTOARISON*

**Figure 2.4** Risk gradient for Ankazobe district of Madagascar.



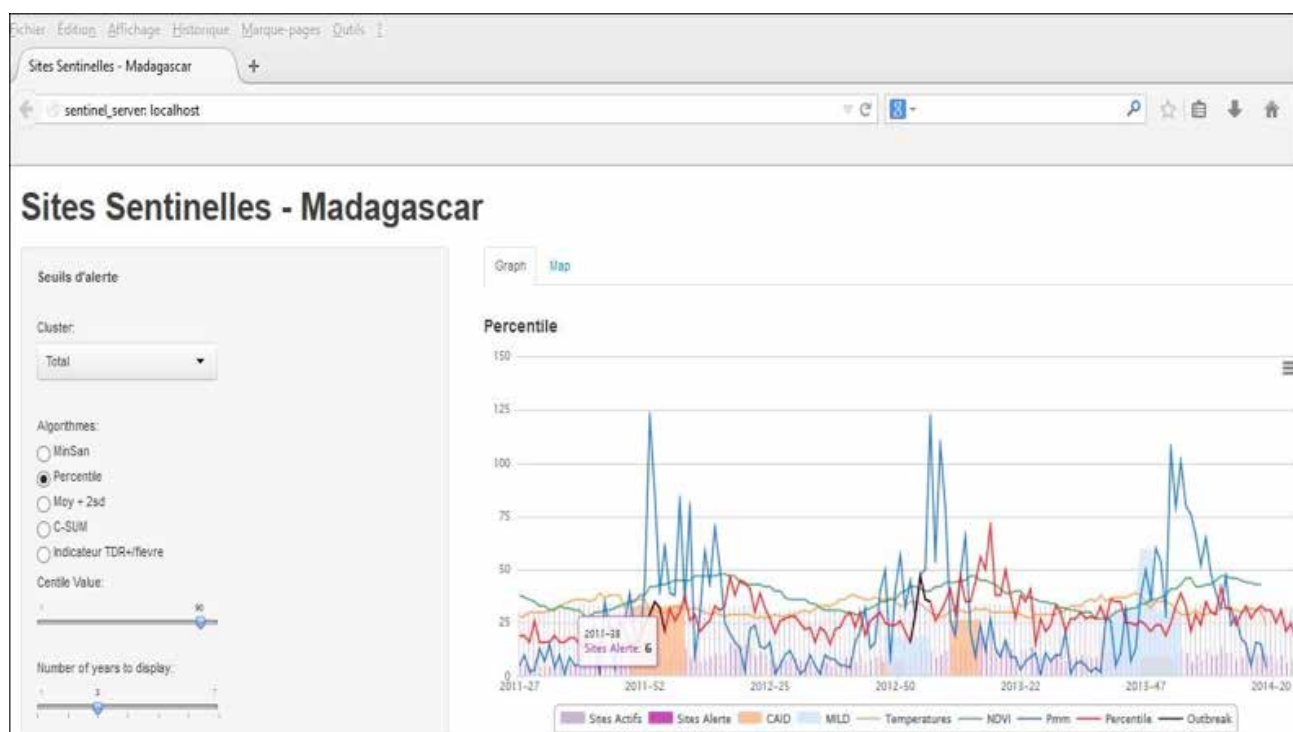
Research is also one of the CHWG activity. The Geographical Information System (GIS) Team of the Madagascar Pasteur Institute, led by Dr Fanjasoa RAKOTOMANANA, a member of the group, has conducted a GIS and vector control project to identify priority areas for indoor residual spraying (IRS) with insecticides. This project covers all the highlands of Madagascar and helped improve understanding of the importance of climate for epidemic preparedness and response. The aim is to provide a tool for decision-makers and health actors. Climatic factors and environmental data are taken into account as decisive criteria to assess epidemiological risk and to help decision-making. GIS and weighted linear combination techniques are used to identify priority areas for IRS. Figure 2.4 shows mapping of the risk gradient for Ankazobe district in Madagascar, from very low risk to very high risk. A buffer zone was drawn around localities to identify priority areas.

## CASE STUDY 2.D

Enabling  
Environment

Since 2007, a fever sentinel system has been implemented in 34 health facility centres across the country. The main objective is to have an early warning system to detect febrile syndromes. The GIS Team of the Madagascar Pasteur Institute configured an application to automatically download environmental and climate data from the server of the International Research Institute for Climate and Society. These data are processed and stored in the PostgreSQL virtual server. The data are used to implement a dynamic predictive model of epidemiological risk to trigger health actors. The model includes data such as temperature, rainfall and normalized difference vegetation index, as well as malaria control approaches (long-lasting insecticidal nets, IRS) (Figure 2.5).

**Figure 2.5** Alert detection using climate and environmental data, based on sentinel sites real-time data.



## BENEFITS AND LESSONS

As a result of the project, meteorological data can be analysed together with epidemiological data (historical, real-time and forecast) and transformed into information to facilitate early detection of fresh disease outbreaks or probable epidemics, and to select the strategies for prevention and response.

The main challenges facing all the stakeholders are sustainability of the activities and maintenance of the current dynamism and enthusiasm. Four key factors are crucial to the long-term success of the health and climate working groups: interest in working together; health professionals' awareness of the need for climate information and services; presence of an external agent (such as WMO) acting as a catalyst to bring the groups together; and availability of seed-funding mechanisms for pilot projects.



People waiting for a physician outside a sentinel site

## ACKNOWLEDGEMENTS

WMO for financial support to initiate and maintain the working group. The United States Agency for International Development: financial support of the Surveillance and Data Management Project, including the GIS sub-project conducted by the GIS Team of the Madagascar Pasteur Institute.



PRESIDENT'S MALARIA INITIATIVE



"Avy amin'ny vahoaka amerikanina"



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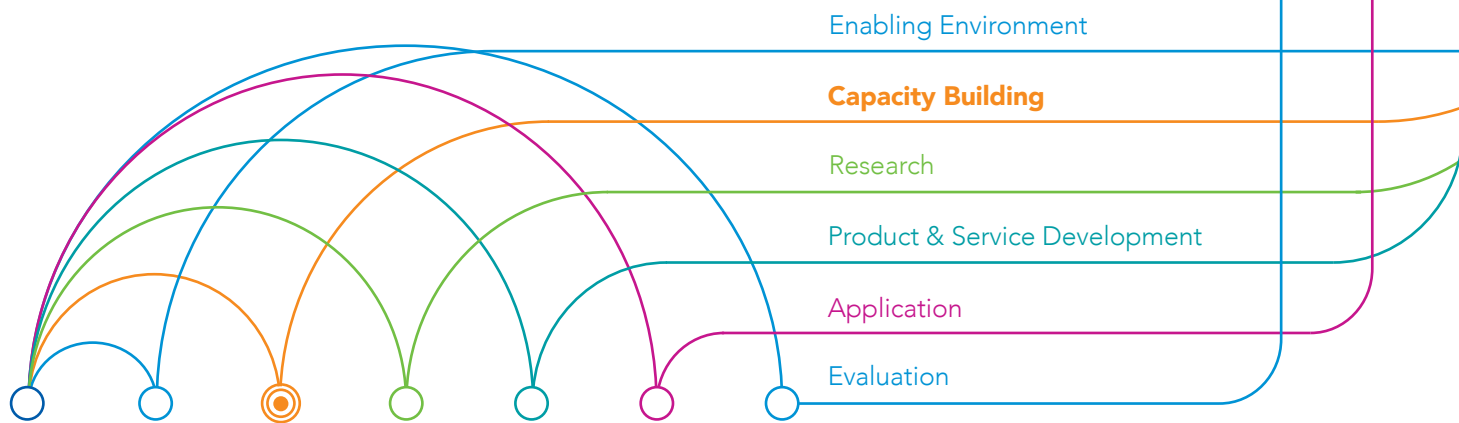
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### CHAPTER 3

# CAPACITY-BUILDING FOR CLIMATE SERVICE DELIVERY AND USE

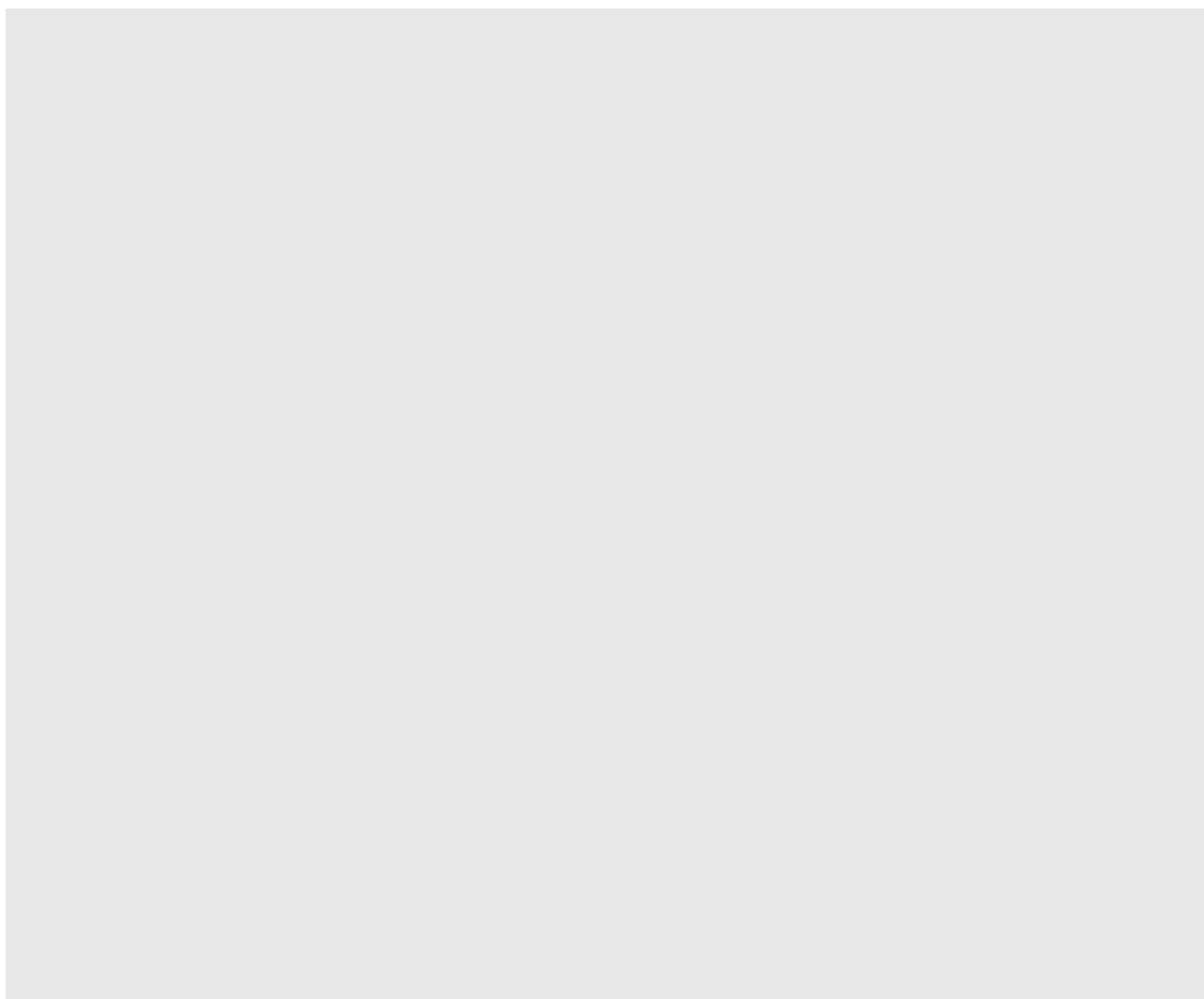
**GOAL** to ensure that adequate human and other resources, institutional and community skills and know-how are available to allow for appropriate development, optimal use and sustainability of climate services.

Capacity-building refers to the broad range of activities undertaken to enhance available resources such as human resource knowledge and technical skills, institutional abilities, and infrastructural capacities in order to facilitate the process of developing to applying climate knowledge to health decision-making.

Fundamentally, the underlying functional capacities of National Hydrological and Meteorological Services (NHMS) to provide end-to-end climate services will determine the starting point for many collaborations toward health tailored climate services. The infrastructural and institutional capacity of NHMS includes their ability to: observe the local climate, along with data collection and exchange procedures; the practices for climate data management and quality control, including data rescue and digitization; the status of for product development such as operational climate monitoring, assessment and prediction, climate change projections and downscaling; and finally the ability to engage with various sectors in order appropriately package and communicate to co-produce tailored products. This is often paralleled by the ability of health partners or health authorities to conduct health surveillance, data management procedures, epidemiological analysis, and the familiarity and confidence to use probabilistic risk information for intervention monitoring and planning.

Different kinds of stakeholders will require diverse types of capacity-building, based on the roles they play to produce and use climate information. Focusing on the human and institutional resources particularly needed to co-produce and apply climate information, the principle actors can be grouped into four broad categories: meteorological and climate professionals, health professionals, health-relevant partners, and citizens. (See Table 3.1)





Placeholder for image

The meteorological community needs technical and infrastructural capacities to produce and deliver usable and reliable climate products, and human resource skills to understand the health problems being addressed, to clearly communicate climate science, and to listen and understand user needs to be able to engage in meaningful dialogue;

Activities targeting health professionals often focus on enhancing managerial capacities to lead the development and implementation process; capacity to engage in multidisciplinary dialogue; to understand and generate evidence on the linkages between climate and health; and to value and use the climate services developed to protect the health of the population.

Multi-disciplinary health-relevant partners are critical to develop effective climate services for health risks that originate and are managed outside the health sector. Capacity building should help build bridges that share information and diagnostics, strengthen collaboration, and improve multi-sectoral risk management.

Community-targeted capacity-building often includes efforts to raise awareness of the health risks of extreme weather and climate; which populations are most vulnerable; how to interpret public service messages; and the actions that should be taken at the community and individual levels to protect health.

**Table 3.1** Example capacity-building needs of diverse partners.

	<b>Meteorological professionals need capacity to:</b>	<b>Health professionals need capacity to:</b>	<b>Multi-disciplinary health relevant partners need capacity to:</b>	<b>Citizens need capacity to:</b>
<b>ENGAGEMENT</b>	Listen and understand user and community needs Communicate climate science	Define, inform, and prioritize information and knowledge needs	Identify and translate risk or impact relevant information and stakeholders	Access information and value the benefits of climate services
<b>RESEARCH</b>	Conduct product research and development Access and understand global and regional products	Conduct research using climate information	Participate in climate and health research	Collect and provide community sourced information
<b>PRODUCTION</b>	Ensure quality observational data is available and related products and services are quality controlled and transparently produced. Develop and test products Deliver services	Identify and provide data and analytical inputs Develop and test products	Identify and support linkages Contribute relevant data and analytical inputs	Inform preferences for climate service outputs, i.e. language, format, frequency
<b>APPLICATION</b>	Communicate uncertainties and strengths/limitations of the services developed	Understand and internalize new information Institutionalize climate services as decision tools	Share information and build bridges to integrate knowledge into multi-sectoral risk management	Understand messaging Know how to respond appropriately to information and warnings
<b>EVALUATION</b>	Resources and methods to measure reliability and validity of products, as well as user-uptake and satisfaction	Resources and methods to measure and evaluate impacts	Resources and methods to measure and evaluate cross-sectoral impacts	Opportunities to provide feedback on user-experience and impact

### Box 3.1 Types of Capacity Development for Climate Services.

**Human resource capacity** – equipping individuals with the knowledge, skills and training to enable them to generate, communicate and use decision-relevant climate information;

**Infrastructural capacity** – enabling access to the resources that are needed to implement infrastructure to generate, archive, quality control, communicate, exchange and use climate data and decision-relevant information and products, including on the supply side instruments for observing networks, data management systems, computer hardware and software, internet access, communication tools, manuals and scientific literature, with similar things on the demand side but potentially much more diverse;

**Institutional capacity** – on the climate side includes elaborating management structures such as defining the position and terms of reference of NHMSs for climate services, processes, policies and procedures that enable effective climate services, not only within organizations but also in managing relationships between the different organizations and sectors (i.e. public, private and community, including international collaboration).

On the health side often includes mandates of government agencies to prioritize and address climate change as a health risk, as well as the organizational arrangements for disease control, nutrition, environmental management, and emergency preparedness and response; policies and procedures that facilitate intra- and inter-sectoral environmental, disaster, and climate risk management; data management and exchange policies; working relationships with other health sector partners (i.e. NGOs, research institutions, universities, etc.) and the availability of personnel.

#### IMPORTANCE OF CAPACITY-BUILDING IN EFFECTIVE CLIMATE SERVICES

Capacity should be built simultaneously at individual, institutional, and community levels. Even with adequate levels of technical expertise for climate services development, they will not become useful tools for health decision-making unless health decision-makers are able to effectively understand, value, trust and use these services. This requires decision-makers to have the capacity to institutionalize climate services as decision tools; interpret climate service outputs; integrate and use these outputs in the global context of health risk evaluation; and include information provided by climate services in identifying and selecting the most cost-effective solutions. This capacity can be improved by communication and dialogue with other experts and partners. Likewise, if the technical expertise and capacity among health decision-makers is present but communities are not capable of understanding or taking action based upon public advisories, the advantage derived from those services will be severely limited. Communicating research findings to communities in a clear and understandable language will help them understand the need for climate services. The engagement of communities in climate service development, application and evaluation will help to build their capacity to benefit from the climate services developed. This implies that climate knowledge and information need to be integrated into public health training at all levels – including schools of public health and professional courses such as those for field epidemiology.

### COMMON APPROACHES

Capacity-building needs will vary depending on the goals of the climate service being developed. However, some useful common approaches include:

- mapping and assessing existing institutional, infrastructural, human resource, and community capacities through surveys or other instruments;
- training community leaders, volunteers and health workers on the health risks exacerbated by climate and weather conditions and appropriate responses that can be taken;
- involving communities in health and climate data collection and interpretation;
- training health professionals from local and regional health bureaus on health and climate linkages, disaster management, and analytical methods, such as environmental epidemiology and spatial biostatistics;
- conducting workshops to build capacity at appropriate levels (local, regional and national) to use the climate products and services developed;
- embedding climate and health courses in the course curricula of higher education institutions and engage them in technology and knowledge transfers to the public health community;
- developing tailored training and outreach materials especially targeted to high-risk groups;
- organizing multidisciplinary discussion groups to increase communication capacities across professionals from different fields;
- organizing regular knowledge refresher courses on climate-sensitive disease detection and diagnosis;
- Fostering expert and staff exchanges between national and regional partners, such as Regional Climate Centers.

## CAPACITY-BUILDING CASE STUDIES

The following case studies exemplify approaches to building human resource and community capacity to co-produce and use tailored climate services.

A

**3A:** Training a new generation of professionals to use climate information in public health decision-making

The first case study (3A) describes a training program specifically developed to enhance the capacity of health professionals to use climate information, focusing on building core competencies and based on five modules. In addition to training, participants are able to remain connected via a Climate Information for Public Health Action Network, with more than 240 alumni from around the globe, that aims to act as a knowledge sharing catalyser and multiplier.

B

**3B:** Protecting the elderly from heat and cold stress in Hong Kong: Using climate information and client-friendly communication technology

The second and third case studies focus on building community and citizen capacity to uptake climate information. In Hong Kong, case study 3B is an example of innovative program to develop a service and mobile phone application that can be used by the families of senior citizens, in order to locate and contact them during high risks periods for heat stress. To make sure the product is appropriately tailored to the needs of senior citizens, a forum was created for them to provide ideas and suggestions for how best to provide weather information and advisories to them.

C

**3C:** Working with communities in East Africa to manage diarrheal disease and dengue risk in a changing climate

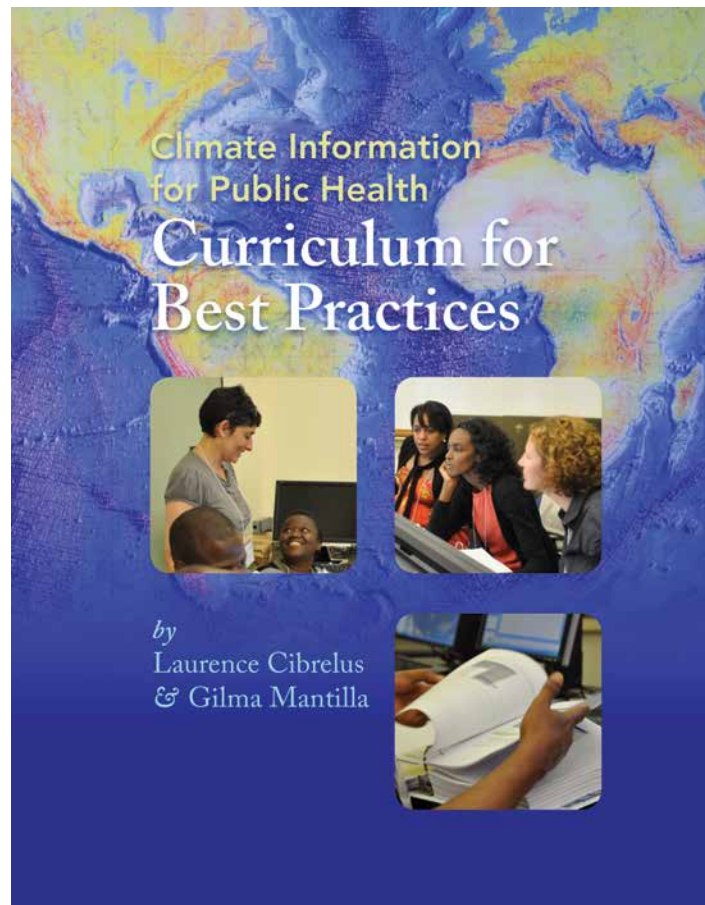
In East Africa, case study 3C adopted a broad series of activities to improve community-scale early warning early action. Grounded in the exploration of community perceptions of climate risks, educational materials were developed, Red Cross volunteers were trained, and climate informed contingency plans. Locally appropriate interventions were rolled out, focusing on water management and vector control to demonstrate how seasonal forecasts can be used to inform the appropriate timing of risk reduction activities and build community resilience.

# TRAINING A NEW GENERATION OF PROFESSIONALS TO USE CLIMATE INFORMATION IN PUBLIC HEALTH DECISION-MAKING

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## CONTEXT

A key component of climate variability and climate change adaptation is the training of a new generation of leaders to understand the role that climate plays in driving disease burden and impacting economic growth (1). Such capacity-building helps to strengthen and improve decisions made in the public health sector to minimize the impacts of environmental change. To this end, several initiatives have been developed to train young climate and health researchers and practitioners to understand, access, explore, model and translate climate information to inform public health decision-making.



Climate information for public health: A curriculum for best practices  
[http://iri.columbia.edu/docs/publications/2010-12%20RPT-SI2010\\_Curriculum.pdf](http://iri.columbia.edu/docs/publications/2010-12%20RPT-SI2010_Curriculum.pdf)

## NEW APPROACHES

Following on from the International Research Institute for Climate and Society (IRI) Climate information for public health: A curriculum for best practices (2), several international and regional climate and public health schools and side-events have emerged, taking place in Brazil, Colombia, Ecuador, Ethiopia, Italy (International Centre for Theoretical Physics, ICTP), Jamaica (Third International Conference on Climate Services, ICCS3) and Uruguay. Financial support was provided by several donors including ICTP, the World Meteorological Organization (WMO), IRI, MERCOSUR's Intergovernmental Commission for Environmental Health and Labour, Inter-American Institute for Global Change Research (IAI), Pan American Health Organization (PAHO) and Oswaldo Cruz Foundation (FIOCRUZ), among others. Hosting at locations such as ICTP permits pan-global participation and the efficiencies afforded by the dedicated training facilities and infrastructure on offer. Alternatively, organizing regional activities brings together a wider spectrum of participant expertise and occupations, allowing regional networks and partnerships to be formed that amplify the legacy of such events. Training activities are usually run over a two-week period and are broadly structured as follows:

1. Fundamentals of climate and public health interactions.
2. Tools to analyse climate, environmental and public health data.
3. Environmental epidemiology.
4. Statistical and dynamical disease modelling.
5. Development of participant projects.

The objective of the first module is to understand the value of applied public health surveillance and to identify opportunities where climate data can enhance surveillance quality. A practical introduction to climate observations and model output databases is given, exposing participants to the many accessible online data repositories (e.g. IRI Data Library, KNMI Climate Explorer). The second module introduces the concepts of remote sensing and provides information on how to retrieve data on environmental factors using remotely-sensed products, available through the IRI Data Library. The operational use of these products by UN agencies, ministries of health in Africa, Asia and Latin America is also demonstrated (3). The third module introduces the concepts of disease risk related to environmental aspects, presents statistical techniques to explore potentially harmful thresholds, time lags and other associations between environmental factors and disease incidence over time, and explores spatial patterns of disease and environmental risk factors, using the statistical software 'R'. The fourth module focuses on predictive models for vector-borne diseases, such as malaria and dengue, based on a spatio-temporal statistical modelling approach and dynamic, process-based mathematical disease models.



## CASE STUDY 3.A

**Table 3.2** Description of the domains addressed in a CIPH Training and their associated competency statements.

DOMAIN	COMPETENCY STATEMENT
1. Basic Concepts in Public Health and Climate	Understand the basic frameworks for public health analyses, the factors that drive the climate system and the range of methods used to capture public health and climate information
2. Methods and Tools for Analyzing Climate and Public Health Data	Analyze in space and time the relationship between climate and public health data using appropriate statistics, methods and tools
3. Use of Climate Information in Decision-Making for Climate-Sensitive Diseases	Apply climate information to enhance public health surveillance, early warning, prevention and control of climate-sensitive public health issues
4. Computer and Information Technology	Use computers and relevant software for applications in climate information for public health
5. Communication in Public Health and Climate	Develop effective communication means and tools for public health and climate information
6. Collaborating, Mentoring and Training on Climate Information for Public Health	Advise, train and collaborate with public health and climate and weather professionals using relevant platforms, mechanisms and partnerships



**Photo Credit** Brian Kahn.

## BENEFITS AND LESSONS

One of the main objectives is to train young PhD students, climate scientists and public health practitioners from developing countries to work in data-scarce environments. Participants are exposed to the many freely available online data repositories and are invited to integrate disease datasets relevant to their own country. They are shown how to use and develop state-of-the-art modelling tools for handling climate and disease data at different temporal and spatial scales. Participants are also provided with climate and environmental datasets that could be used to develop in-country predictive models as part of early warning systems for disease risk. Feedback received during the course helps ensure the quality of future climate and public health schools.

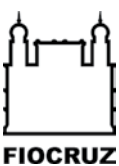
These training schools play a vital role in building capacity to incorporate climate information into public health decision-making. The ultimate goal is to create experts who can be a link between providers and users of climate information, in order to effectively translate and communicate climate information for public health action.

Several research projects and publications have emerged from these training activities, using data made available or organized during the courses, or applying techniques learned (4). Alumni stay connected through a web-based platform. They have also created various mechanisms to transfer their climate and public health knowledge at global and local levels. By involving alumni in the design and dissemination of course materials and by creating online resources, it is hoped that a wider audience can be reached (5).



Photo Credit Brian Kahn.

## ACKNOWLEDGEMENTS



# PROTECTING THE ELDERLY FROM HEAT AND COLD STRESS IN HONG KONG: USING CLIMATE INFORMATION AND CLIENT-FRIENDLY COMMUNICATION TECHNOLOGY

Authors: Tsz-cheung Lee (Hong Kong Observatory), I. Leung (Senior Citizen Home Safety Association)

## CONTEXT

Previous studies suggest that thermal stress under cold and hot weather conditions is strongly linked with higher mortality and hospitalization rates in Hong Kong, particularly among the elderly (6–8). In Asia, Hong Kong is second only to Japan in terms of population ageing. Moreover, in the past few decades, increasing numbers of senior citizens now live on their own after their children have grown up and moved out to start their own families. There is a significant need, therefore, to provide more care for the elderly in the city. In September 1996, the Senior Citizen Home Safety Association (SCHSA) was founded as a self-financing, not-for-profit organization providing a 24-hour personal emergency support and caring service to elderly citizens in Hong Kong.<sup>e</sup>

## NEW APPROACHES

In the past couple of years, using the climate data of HKO, the SCHSA and HKO jointly studied the effect of weather on the health of elderly people and their help-seeking behaviour, as reflected by the number of users activating SCHSA's personal emergency and caring service who subsequently required hospitalization. The results showed that the number of hospitalized users increased when the minimum temperature dropped below 22°C and when the maximum temperature was higher than 30°C. It was also found that dry weather (relative humidity at 70% or below) had greater impact on the elderly in the cool season (9). Furthermore, elderly women, older elderly and users who do not live alone were more sensitive to extremely hot and cold weather conditions (10). These findings helped SCHSA to formulate appropriate response actions under cold and hot weather conditions based on the 9-day weather forecast and the experimental monthly climate forecast provided by HKO. For example, SCHSA would remind the elderly to prepare for impending wintry weather through its Call and Care Centre, so as to minimize the health impact of weather changes on them. SCHSA also worked with the media to remind the public to take the initiative of providing care and assistance to elderly people living alone or in need. Strengthening of the manpower of the Call and Care Centre was also planned in anticipation of such weather conditions.

Recently, HKO and SCHSA also joined hands to: (a) develop a new version

<sup>e</sup> Whenever in need, subscribing users simply press a 'safety button' on a custom-made, home-based or mobile device. A call will be triggered to SCHSA 24-hour Call and Care Centre that offers immediate assistance by calling ambulances, reporting to the police, and informing family members in emergency cases.

of HKO's Weather Information for Senior Citizens web page (<http://elderly.weather.gov.hk/socare.htm>) with ideas and suggestions from the elderly volunteers of SCHSA incorporated; (b) enhance the SCHSA e-See Find service<sup>f</sup> with the provision of real-time weather information (temperature and humidity) in different parts of Hong Kong, weather warnings (e.g. tropical cyclone, rainstorm, very hot/cold) and special weather tips on significant weather changes and impending severe weather; and (c) host press conferences to promote public awareness on the impacts of weather on the elderly when a major cold surge is expected. The new version of the *Weather Information for Senior Citizens* web page was well received with over 3 million page views each year in 2013 and 2014, about 100 times more than the previous version. With enhanced awareness on the caring of the elderly, incoming calls increased by 15% during colder/hotter days in comparison to average days. Also, as outdoor assistance and support are essential for senior citizens taking part in outdoor activities, the number of outdoor safety service users has increased over recent years.

### BENEFITS AND LESSONS

The close collaboration between SCHSA and HKO highlighted the importance of partnership and stakeholder engagement in improving the delivery and communication of useful weather and climate information to the health sector and promoting public awareness on the care of elderly people.



Dr Cheng Cho-ming, Assistant Director of HKO (far right), and Ms Irene Leung, Chief Executive Officer of SCHSA (far left), jointly hosted a press conference on 13 December 2013 to remind the public to be prepared for an impending cold spell.



HKO's Weather Information for Senior Citizens web site with ideas and suggestions from the elderly volunteers of SCHSA incorporated.

### ACKNOWLEDGEMENTS



<sup>f</sup> 'e-See Find' is a service for family members/care-givers to locate the whereabouts of elderly users.



## CASE STUDY 3.C

# WORKING WITH COMMUNITIES IN EAST AFRICA TO MANAGE DIARRHEAL DISEASE AND DENGUE RISK IN A CHANGING CLIMATE

Authors: A. Wynter, E. Coughlan de Perez, L. Nerlander, F. Monasso, M. van Aalst, G. Mantilla, E. Muli, T. Nguyen, G. Rose, and C. Rumbatis Del Rio. Red Cross/Red Crescent Climate Centre, International Research Institute for Climate and Society, Kenya Red Cross, Tanzania Red Cross, International Federation of Red Cross and Red Crescent Societies, Rockefeller Foundation

### CONTEXT

A Red Cross/Red Crescent pilot project implemented in Indonesia, Kenya, Tanzania and Viet Nam incorporated climate information and considerations in health operations. Funded by the Rockefeller Foundation, the project was the first of its kind in the Red Cross/Red Crescent movement (11).

In 2010 in East Africa, diarrhoeal diseases are estimated to have caused nearly 9% of all deaths of children under five years of age, or some 90 000 in total, according to the US Institute for Health Metrics and Evaluation (IHME). Climate change is predicted to increase the risk of diarrhoeal diseases by 23% in Equatorial Africa by the end of the century, based on model projections for temperature and precipitation (12). The project selected two diseases with contrasting climate–health interactions: diarrhoeal disease in Kenya and Tanzania and dengue fever in Indonesia and Viet Nam. It aimed to integrate climate information in traditional health interventions to improve the response to each disease.

In East Africa, once-consistent rainfall patterns are shifting, and this could have significant implications for disease, creating more larval habitats for mosquitoes, washing pathogens into water sources and disrupting sanitation.

In Kenya the project sites were located in Nyando province, near Lake Victoria – an alluvial plain vulnerable to endemic malaria, devastating floods and diarrhoeal disease. In Tanzania, projects were undertaken in coastal Tanga province – one of the country’s most densely populated regions where diarrhoeal disease and malaria are common.

### NEW APPROACHES

The project sought to introduce ‘early warning, early action’ systems, allowing community-level interventions for malaria and diarrhoeal disease and reducing human vulnerability through the use of climate information.

Technical support from the Red Cross/Red Crescent Climate Centre in The Hague was provided to the International Federation of Red Cross and Red Crescent Societies (IFRC) and the Red Cross National Societies that were directly involved. All four incorporated a baseline study of community perceptions of climate risks and disease, as well as educational material, training for Red Cross volunteers, contingency plans, and a final survey matching to the baseline survey.

Capacity Building

Research

Product & Service Development

Application

Working with the National Meteorological Services, project implementers used seasonal and short-term climate information to design the educational materials and health contingency plans that informed when and where disease prevention activities should be concentrated. This climate-based disease anticipation was based on the increase in disease incidences seen in different seasons and following short-term heavy rainfall events. See Table 3.3 for further information.

**Table 3.3** Activities and structures of climate-based disease anticipation approaches.

	SETTING	
	KENYA	TANZANIA
ONGOING ACTIVITIES	Awareness creation on hygiene; hazard review	Monitor forecasted season start date
PRE-PEAK-SEASON ACTIVITIES	Strengthen flood gates, clean water channels, de-silt rivers, stockpile water purifiers, treat drinking water, clean mosquito breeding grounds, dispose of waste, fortify latrines and homes, hand-washing campaigns	Volunteer meeting about rainfall forecasts prior to advent of rainy season, clean local environment, distribute treated bed nets and water purifiers, sanitation campaigns
PEAK SEASON ACTIVITIES	Open water channels and ponds, review disaster response activities	Check that treated bed-nets are hung, people with symptoms are going to clinic, water/sanitation education
PARTNERS	Provincial Government, Local Committee, Meteorological Department	Meteorological Service, Health Department
UNIQUE COMPONENTS	Incorporate traditional early warning signs when mobilizing community	Seasonal calendar for non-food-item distribution



In Kenya, the picture shows Silas Liech, a KRCS volunteer, and 8 month-old Daren Onunga.

#### ACKNOWLEDGEMENTS



#### LESSONS AND BENEFITS

Subsequently to the approach taken in this project, community-level risk reduction behaviour significantly increased in project locations. This included hygiene activities as well as participation in the construction of latrines in Kenya, for example. Lessons learned focused on three areas: First, beneficiaries' views on the relationship between climate and health. In all countries, more than half of those surveyed were familiar with the concept of climate change before the projects began. Secondly, the importance of data availability to show the relationship of disease and climate indicators both at the seasonal and short-term timescale. Thirdly, scale up of accepted health interventions is feasible if climate information gives an indication of heightened disease risk; this should be accompanied by disease monitoring and sharing of related information.

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3

Enabling Environment

Capacity Building

Research

Product & Service Development

Application

Evaluation

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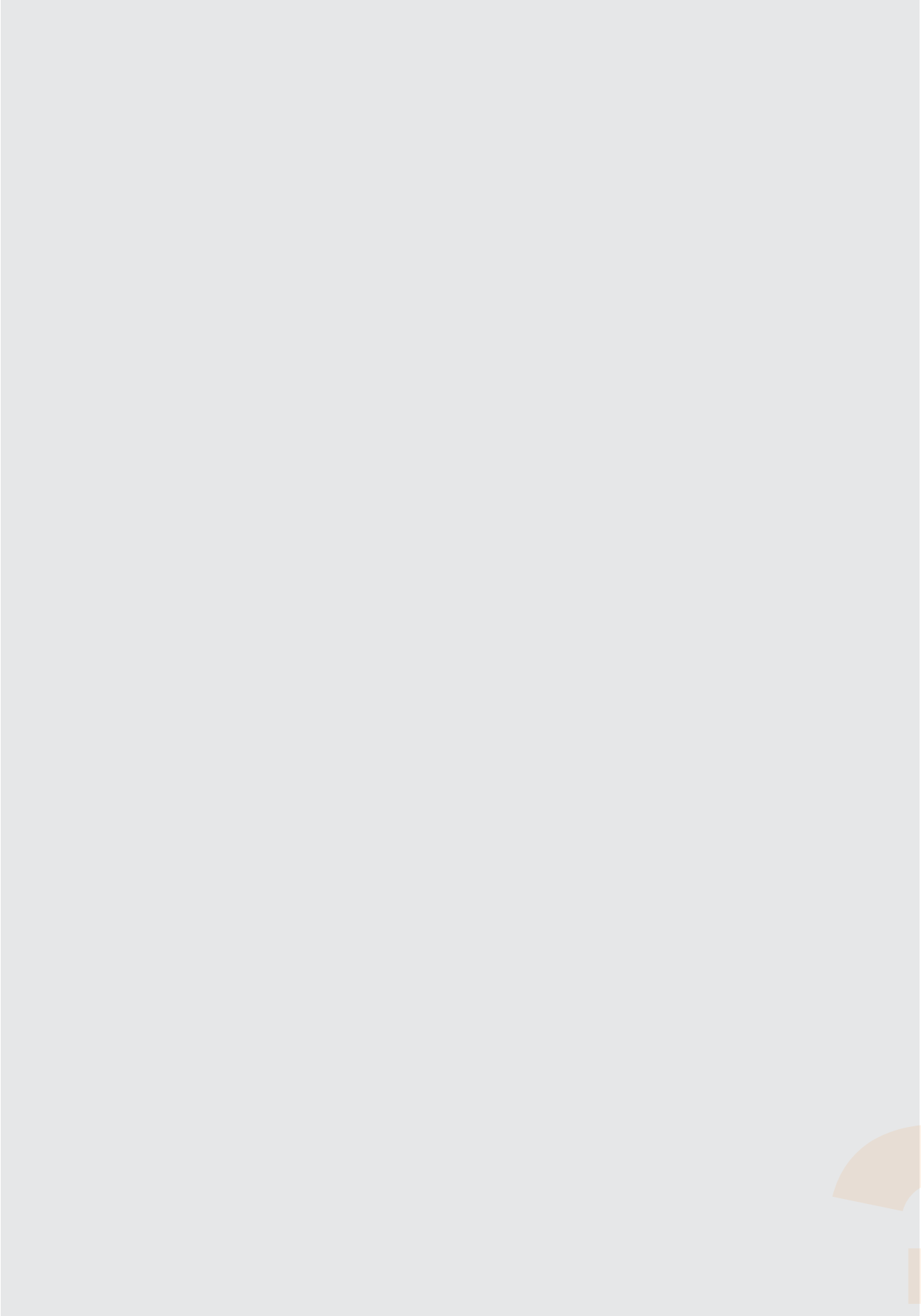
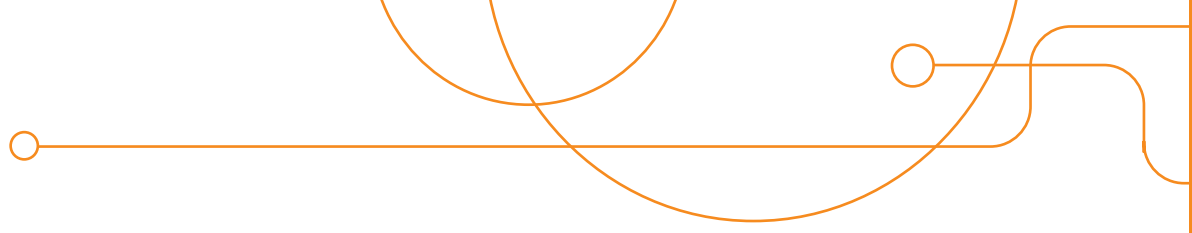
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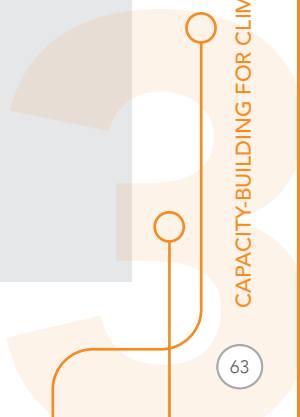
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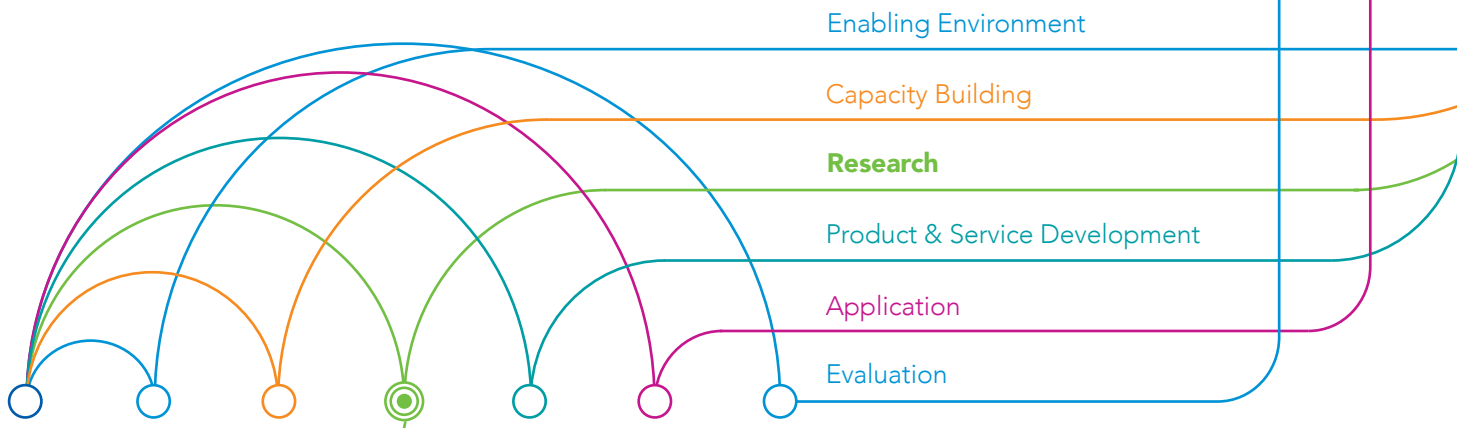
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**CHAPTER 4**

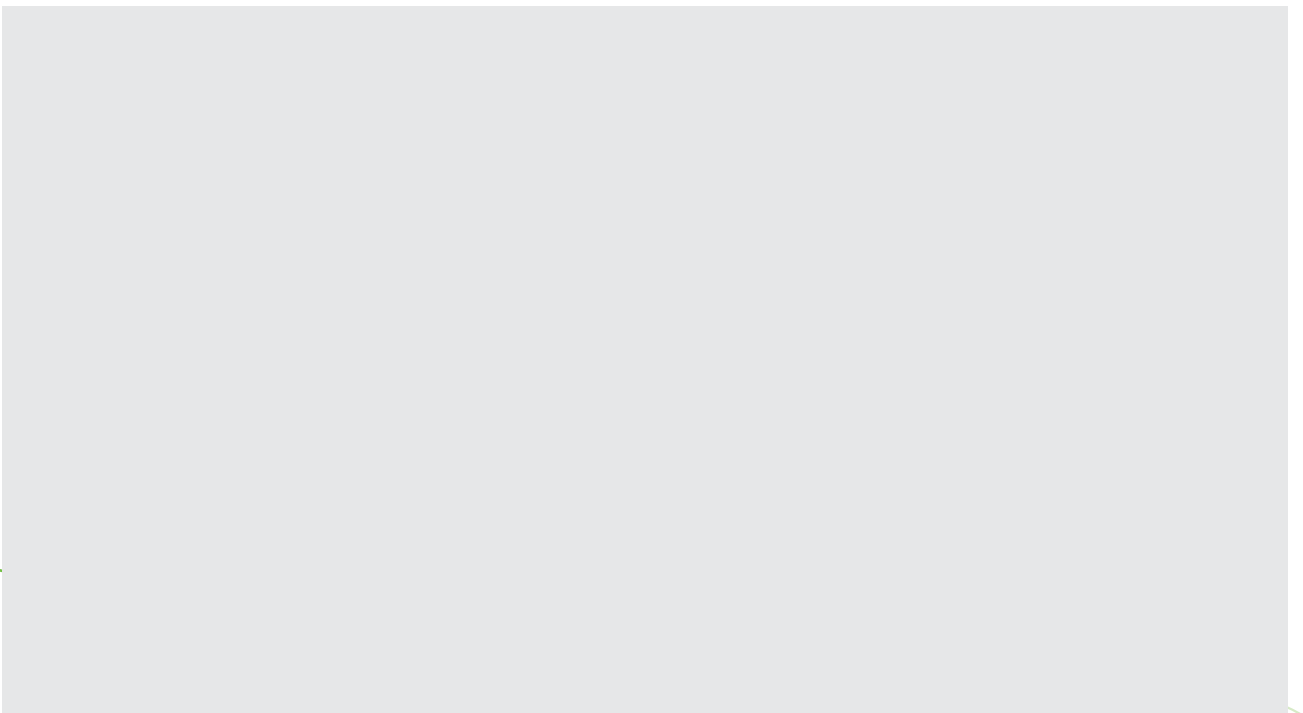
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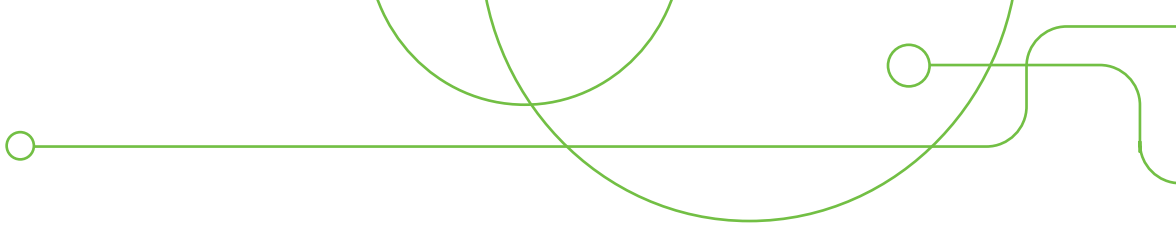
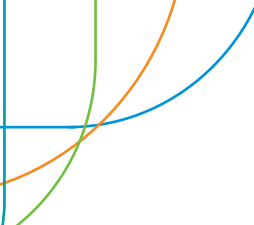
**RESEARCH TO INFORM CLIMATE SERVICES**

**GOAL** to generate evidence on the needs for climate services for health, and produces the necessary know-how for the development and application of such services.

Climate services for health begin with research or are based on research that establish the associations of climate and weather conditions with health outcomes, risk factors, or health service delivery performance. Understanding the "climate signals" which may play a role in disease outcomes are required for any application of climate information to decision making.

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However, research for climate services may come in many forms, since a broad range of technical and context-specific information is needed to develop products and design effective services. Research activities often fall into three categories:

1. **Applied research** includes investigations undertaken to acquire knowledge about a specific practical aim or objective, such as understanding the linkages between climate conditions and health outcomes; the relative need for and value of climate information; data validation and development; and specific analytical methodologies to assess model validity and uncertainty.
2. **Product research and development** can include purpose-based activities for the generation of sufficient know-how to develop tailored climate information products and services. Some examples include: exploration of context-appropriate data collection, data digitalization and data transferring systems, analysis and refinement of the sensibility of the service to detect certain levels of climate-related risks, comparative evaluation of different risk indicators or exploration of information visualization and communication tools.
3. **Operations research** draws upon management and organizational sciences, using qualitative or quantitative techniques to explore and generate practical knowledge and know-how on climate services application. Operations research is applicable to the entire climate services development process, and can include analyses on: the demand for and readiness of communities or organizations to use a climate service; the optimal internal administrative and human resources structures needed for the successful application and sustainability of the service; the legal institutionalization of the service; the best stakeholders coordination and information-sharing mechanisms; as well as cost-efficiency assessments.

#### IMPORTANCE OF RESEARCH AND THE END-TO-END PROCESS

Applied research helps define priorities for health care delivery using an evidence-based approach, and provides new information on the potential uses and limitations of climate services. This type of research is also important for exploring the potential benefits from developing decision tools relative to other public health interventions; and can help identify needs and justify investments in climate services for health, as well as identify data related shortcomings or issues.

Product research and development is crucial to the development of functional and reliable climate services that meet user-needs. User-centered approaches in which users are involved in the product development should be prioritized, to receive timely feedback on progress and user-specifications, and test prototypes before the service is rolled out on a larger scale. It helps ensure that climate services are valid, quality controlled, and reliable; use appropriate technology for target users; and provide relevant information which is accessible, interpretable and usable.

Operations research generates evidence on how to best support climate services with suitable administrative, organizational and legal structures that enhance application and sustainability. It helps optimize the use of resources during climate service implementation, such as by building on existing climate products. Operations research is crucial for ensuring that implemented climate services achieve the greatest benefits, with the lowest resource burden possible.

### COMMON RESEARCH TOPICS AND TOOLS

Iterative research and information collection for feedback is essential prior to development of climate products or services. It informs product specifications, user needs and requirements, and identifies optimal communication and application. Research methodologies range from quantitative analyses, to focus groups and surveys for exploring community perceptions and human resource capacities.

The following types of research are commonly used:

- Statistical analysis of health sensitivity to climatic conditions.
- Mathematical or statistical modelling of climate risk indicators and thresholds.
- Spatial or temporal risk modelling and mapping.
- Feasibility and readiness assessments of data or information systems.
- Qualitative study of population risk perceptions, behaviours, priorities, and practices.
- Operational or process research on health service delivery.
- Institutional and human resource capacity assessments.
- Assessment of adaptation options, including identification of climate information needs.
- Identification and development of appropriate communication strategies.

## RESEARCH CASE STUDIES

The following eight case studies illustrate the range of research often undertaken to inform climate services, from identifying knowledge needs to optimal ways to ensure the delivery and uptake of climate knowledge.

A/B/C

**4A:** Vulnerability and adaptation assessment: Identifying climate information and decision needs in Bhutan

**4B:** Understanding the sensitivity of dengue to climate and urban risk factors in Minas Gerais State, Brazil

**4C:** Analysis of the health impacts of climate variability in four major South American cities

The first three case studies (4.A, 4.B, 4.C) focus on applied research activities which explore the connections of climate and health, and assess the strength of climate as a driver of local disease incidence. The first case study from Bhutan (4.A) is an example of a climate and health vulnerability and adaptation assessment conducted to identify the climate sensitivity of key health priorities, describe national vulnerabilities, and map out climate knowledge needs, upon which future decision-tools and adaptation measures can be developed. The second case study from Brazil (4.B) assessed the relationship between dengue incidence and certain climatic and non-climatic variables to identify high risk intra-urban micro-climates. The research experience also identified barriers to future climate services, since available data were insufficient for routine use in integrated surveillance and monitoring. The third case study (4.C), found that despite a significant association between several diseases and climate conditions in multiple South American cities, the incompatibility of temporal and spatial scales of health and climate data limited robust analyses and the research highlighted a range of opportunities for improved data collection and management.

D/E/F

**4D:** Malaria sensitivity to climate in Colombia: the importance of data availability, quality and format

**4E:** Iterative development and testing of a heat warning and information system in Alberta, Canada

**4F:** Predicting the impacts of climate on dengue in Brazil: Integrated risk modelling and mapping

Case studies 4.D, 4.E., and 4.F are examples of research which inform product development, on the possibilities to use climate as a predictor to establish operational forecasts and early warnings. In Colombia (4D) teams aimed to create a numerical statistical model to assess the probability of malaria, and explored how to overcome incompatible data, the range of available software and models that may be applicable to solve this challenge in Colombia. In Alberta Canada (4E), teams underwent 24 months of iterative exploration on the requirements to establish a heat warning and information system. In Brazil, case study 4F conducted a range of quantitative analyses to identify the relevant variables which drive dengue transmission to generate an operable dengue risk model, that could be available for future application.

G/H

**4G:** CcTALK! Communicating effectively with high-risk populations in Austria: a five-step methodology

**4H:** Knowing when cold winters and warm summers can reduce ambulatory care performance in London

Case studies, 4.G. and 4.H are examples of operations research undertaken to make sure climate services make an impact, and are appropriately tailored and communicated to reach the intended audiences. Case study of CcTalk (4G), tested a methodology for evaluating the best ways to communicate climate knowledge in Austria, and the final case study (4.H) provided evidence of the usefulness of climate information to inform ambulance emergency service planning in London.



## CASE STUDY 4.A

# A VULNERABILITY AND ADAPTATION ASSESSMENT: IDENTIFYING CLIMATE INFORMATION AND DECISION NEEDS IN BHUTAN

Authors: G. Sithey and K. Thinley (Centre for Research Initiatives), Joy Shumake-Guillemot (World Health Organization), R. Dukpa (Ministry of Health, Bhutan).

### CONTEXT

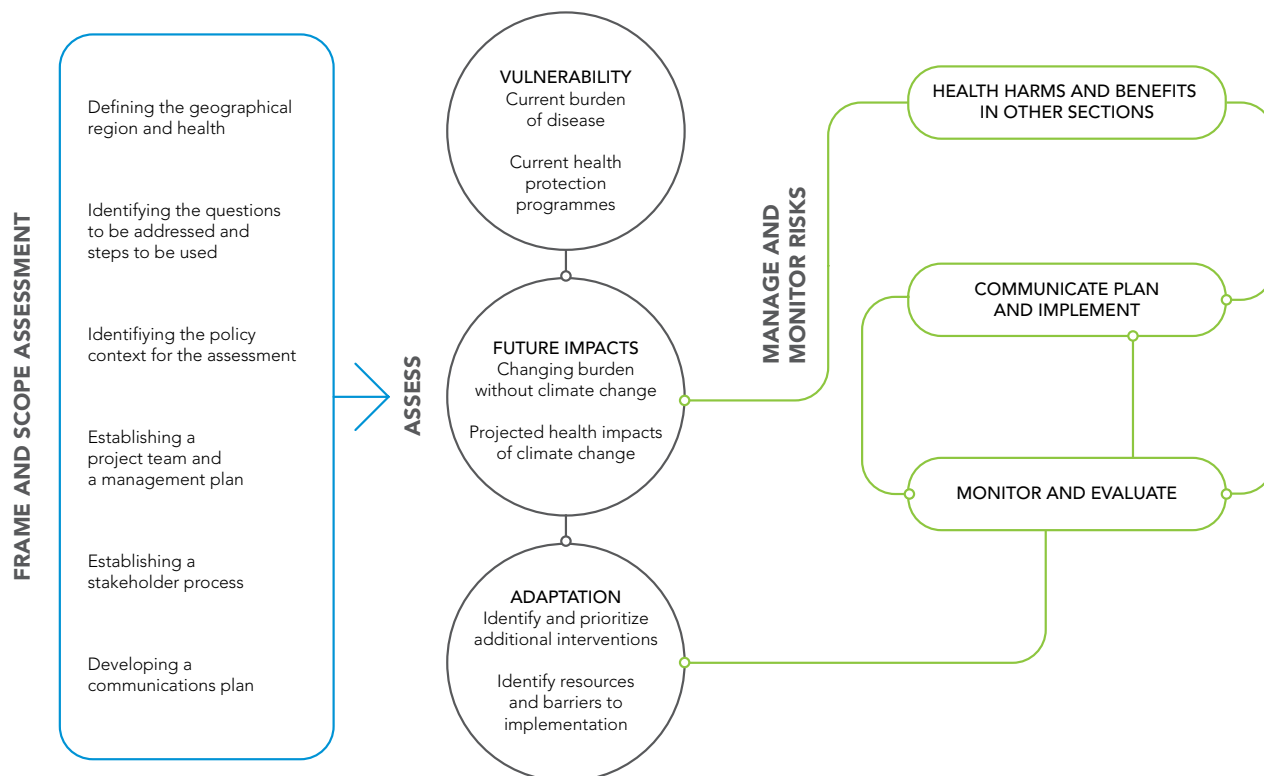
In Bhutan, climate change is expected to lead to an average temperature increase of ~ 0.8°C - 1.0°C by 2010-2039, and ~ 2.0°C - 2.4°C by 2040 - 2069, as well as a progressive and steady increase in precipitation, which has been on the rise since 1980. Higher precipitation increases are expected during the monsoon season compared to the winter season. These changes will exert pressure on five fundamental environmental health determinants in Bhutan: forests and biodiversity; air quality; food and water security; mountain snowpack; and disasters. However, due to its geographical location and its diverse topographical conditions, climatic changes are expected to differ across the wide range of Bhutan's microclimates. Understanding how such heterogeneous environmental changes could influence future local health conditions required further research.

In 2012, a systematic climate and health vulnerability and adaptation (V&A) assessment was conducted in Bhutan using the WHO methodology (1) (Figure 4.1), in order to provide national level evidence of climate and health connections, improve understanding of local and specific health vulnerabilities, identify knowledge and information gaps and needs, provide the opportunity for capacity-building in applied research, and to monitor how health risks may be influenced by a changing climate over time. The assessment informed efforts of the Ministry of Health to further develop adaptation programming, including defining needs for climate-informed decision tools such as integrated surveillance and early warning systems.

### NEW APPROACHES

The study was led by the Department of Public Health, Ministry of Health, and supported by national and international consultants. It particularly examined the influence of climate on current and future diarrheal and vector-borne diseases, and the vulnerability of health and the health system to extreme weather and glacial lake outburst floods. The importance of other climate-sensitive health conditions such as nutrition, food security and safety, mental health, respiratory disease, cardiovascular disease and cancer were also considered.

**Figure 4.1** WHO Climate and Health Vulnerability and Adaptation Assessment Framework.



In Bhutan, diarrhoea is one of the top ten causes of morbidity and is highly climate sensitive. Analysing diarrhoeal disease vulnerability highlighted the importance of using multiple perspectives across time, space, and information sources to understand current and future risks. Temporal considerations included understanding seasonal disease incidence trends during 2003-2011 and extrapolating disease trends for the periods of 2010-2039 and 2040-2069, using two diverse sets of future climate projections. Geographic considerations clustered disease data by health facilities and districts in three diverse climatic zones 1) the Northern Alpine regions 2) Central inner valleys and 3) Southern low lands, which due to their specific microclimates will each experience diverse range of climate change impacts. Furthermore, multiple sources of information were used such as national and district scale statistics, as well as first hand observations of risk factors, and interviews with health workers and communities, to complement official statistics.

The assessment explored the climate influence on risk factors for diarrhoea, such as levels of access to improved water and sanitation infrastructure. Since 1997, the coverage of water and sanitation has been over 70%, reaching 96% in 2011, with 55% of households having access to improved latrines. However, this high level of access to safe drinking-water and sanitation has been insufficient to reduce diarrhoeal disease incidence in parts of Bhutan. Furthermore, seasonal analysis reveals a strong seasonal pattern of diarrheal cases (Fig. 4.2), with 53% of total cases being reported between April and August. Understanding the temporal disease pattern highlighted the opportunity to particularly focus control measures before and during the high risk period.

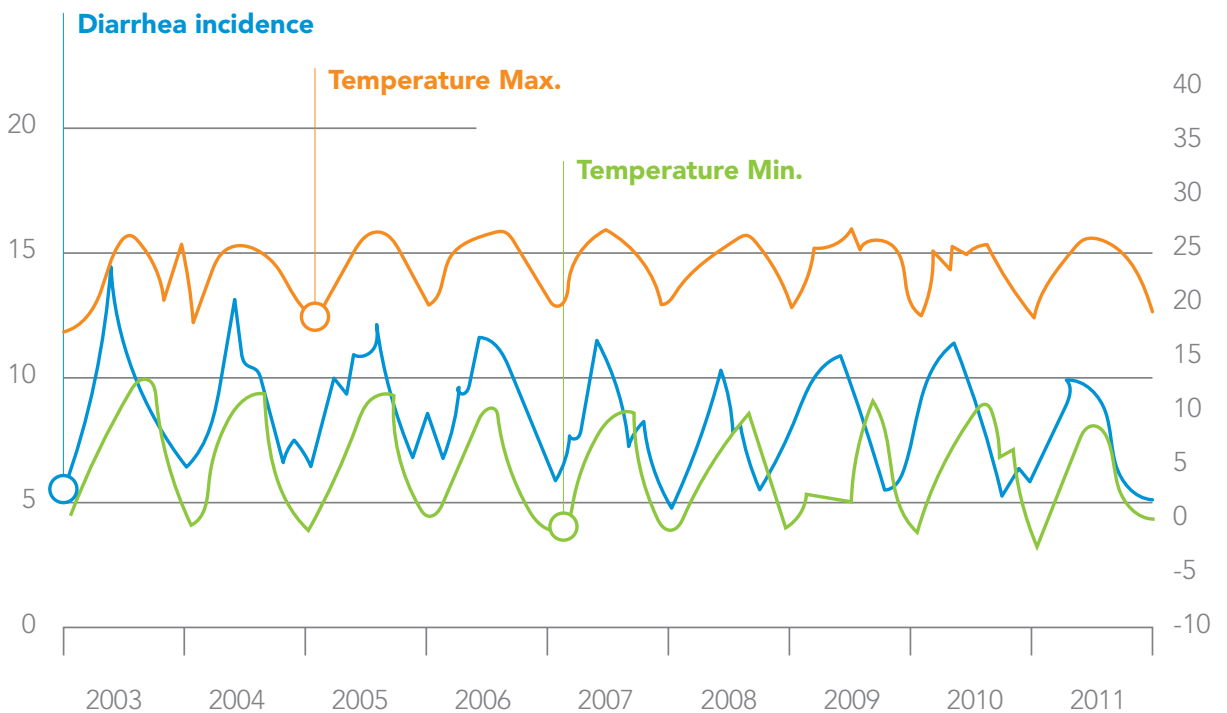


## CASE STUDY 4.A

The outcomes from community-based surveys showed that in some areas, the true vulnerability conditions differ significantly from the analyses derived only from official estimates. For example, in Lingzhi (a village block in Thimphu District) despite official statistics citing 74% of the population having access to improved piped water, the field survey revealed a reality of only 6%, as many water points exist but are not functional (Figure 4.3). Furthermore, although 80% of houses have a latrine, the majority were not usable, some had never been used and most of the villagers still used open defecation. In the context of climate change, poor reporting leads to inaccurate risk identification. These situations when reality and reporting do not align, can contribute to increased vulnerability of both, communities and the health system, by overlooking existing needs and resulting in a range of deteriorating conditions that can lead to disease outbreaks.

Research

Figure 4.2 Trends of total diarrheal incidence and temperature (degree C) 2003 to 2011.



**Figure 4.3** Available but inoperable community water point.



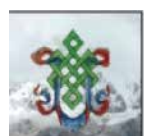
#### BENEFITS AND LESSONS

The assessment provided improved evidence about the sensitivity of underlying health determinants to climate conditions, across the varied microclimates of the country. This evidence served to inform recommendations and actions for the health sector to protect populations from climate-related risks. The assessment also highlighted the need for integrating climate information with disease surveillance to develop disease early warning systems that can inform multisectoral disease control and preparedness activities. It showed the importance of complementing national statistics with qualitative studies at the community level in order to identify local realities and propose realistic disease prevention and control strategies.

The study recommended that public health and health care delivery systems be strengthened in specific ways, such as the need for enhanced preparedness for emergencies and extreme weather events. Public advisories and warnings were identified as needed to announce the start of the monsoon season, when transmission risk of diarrheal diseases increases as a result of warmer temperatures and water sources becoming contaminated with surface run off and sediments. Vector-borne disease control strategies should be extended to incorporate changing population dynamics such as the rapid rural-to-urban migration, and influx of migrant workers from malaria-endemic areas that accompany the mushrooming industrial and power projects across the country. Minimum standards for health, hygiene and sanitation conditions should be developed and promoted for particularly vulnerable migrant labour settlements, such as those established around hydro-electric project sites, industrial areas, private construction companies, and low-income and informal settlements in urban areas. The assessment also calls on for additional actions to reduce transmission of waterborne diseases in identified water stressed areas by exploring alternate water sources. In Bhutan, vector prevention and control measures are focused mostly in the seven southern endemic districts of the country. Therefore, strengthening vector surveillance, diagnostic and treatment capacity of the health professionals from the non-endemic areas were considered a priority. Finally, disease surveillance systems should be strengthened (including on-going data collection, validation, databases, analysis and reporting).

#### ACKNOWLEDGEMENTS

*This work was made possible by funding from WHO-UNDP-GEF Piloting Adaptation to Climate Change Project.*





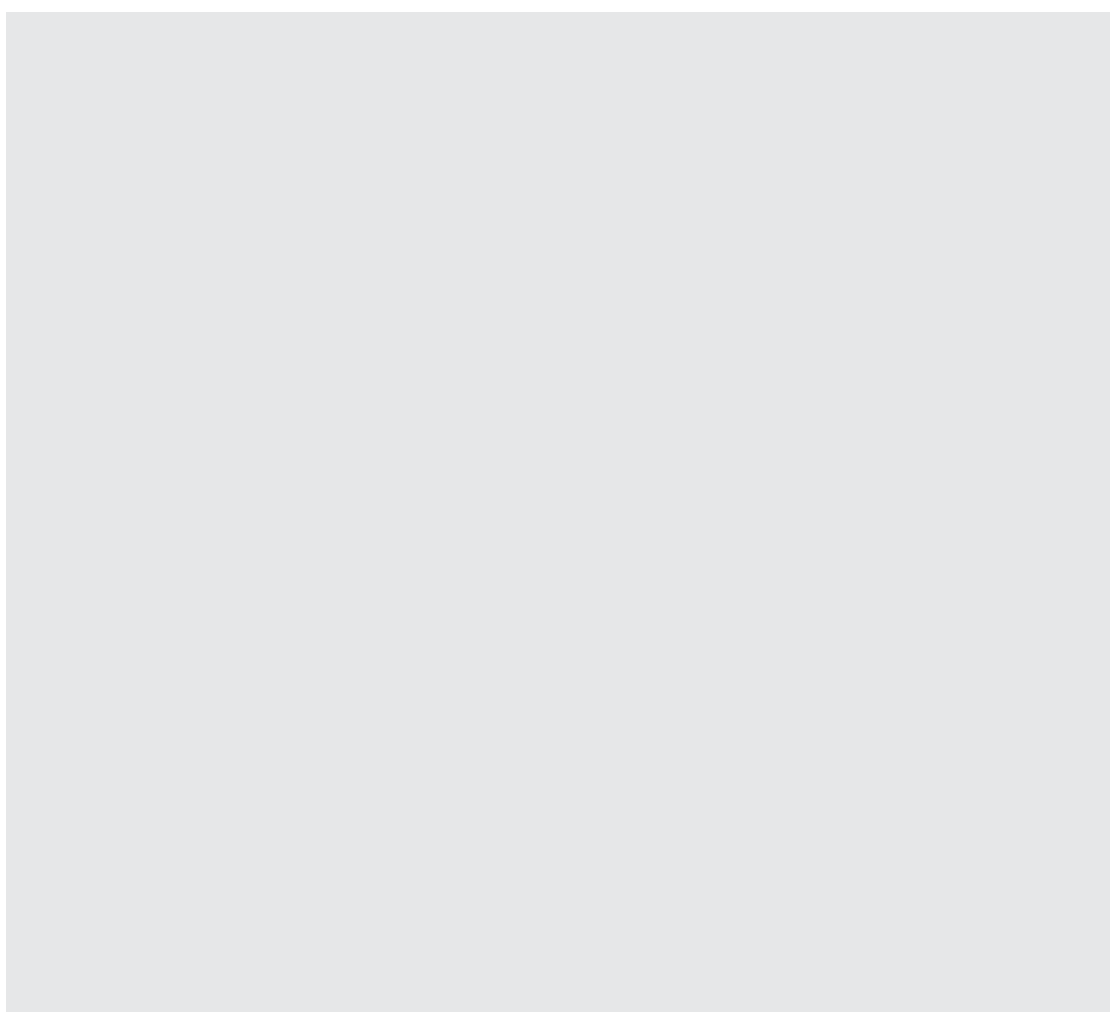
# UNDERSTANDING THE SENSITIVITY OF DENGUE TO CLIMATE AND URBAN RISK FACTORS IN MINAS GERAIS STATE, BRAZIL

Authors: M. da Consolação Magalhães Cunha, J. Marques Pessanha, W. Teixeira Caiaffa (Observatoire pour la Santé Urbaine, Belo Horizonte, École de médecine de l'Université Fédérale de Minas Gerais, Brésil)

## CONTEXT

This study was motivated by the complex dengue epidemic that has occurred the Brazillian state of Minas Gerais since the 1990s and the related difficulties faced by the public health sector to promote effective vector control activities and reduce transmission of the virus in vulnerable populations (2,3). It is part of an ongoing study of dengue and climate variables by the WHO/Kobe Center for Health Development's Observatory for Urban Health, which is implemented in partnership with local-, regional- and country-level health authorities.

Research



Placeholder for image

### NEW APPROACHES

The aim of the study was to assess dengue vulnerability to climate, geographical and demographic factors in order to support the public health service to address climate change-related risk using a vector-borne disease model. To do so, the occurrence of dengue was investigated in relationship to climate variability in an urban environment.

The study first investigated the historical time–space relationship between dengue epidemics and climate, geographic and demographic variables in Minas Gerais State, in south east Brazil, from 2001 to 2014. Based on a proposed theoretical model (4), reported cases of dengue were geocoded by county and macro region of the Minas Gerais State. Data on rainfall, altitude and temperature were obtained from the National Meteorological Institute, a government agency managing the complete information about the weather and the climate throughout Brazil. Urban population density data are publicly available from the Brazilian Institute of Geography and Statistics (5).

The dengue epidemic occurrence was defined as the cumulative incidence rate greater than 300 cases per 100 000 inhabitants per annual cycle from July to June (5) in all 853 state counties, during the 13 years of observation. Independent variables for each municipality were the following: a. Weather: comprising rainfall (in mm) and temperature (in degrees Celsius) (6); b. Geographic: by altitude (in metres); and, c. Demographic: by urban population density (inhabitants/urban area).

Initial analysis involved graphical inspection of the correlation of all variables ( $r=0.71$ ). Multiple linear regression analyses showed significant associations ( $p<0.01$ ) of average temperatures ( $\beta=0.35$ ), rainfall ( $\beta=0.02$ ), altitude ( $\beta=-0.003$ ) and urban population density ( $\beta=15.41$ ).

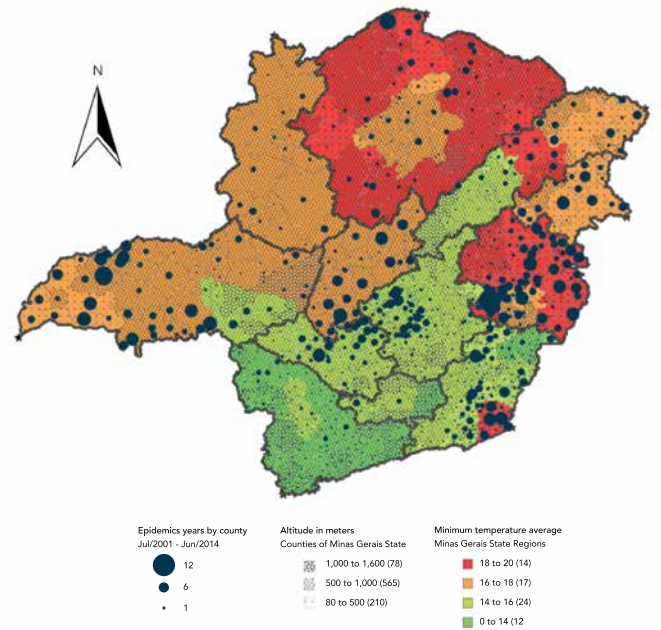
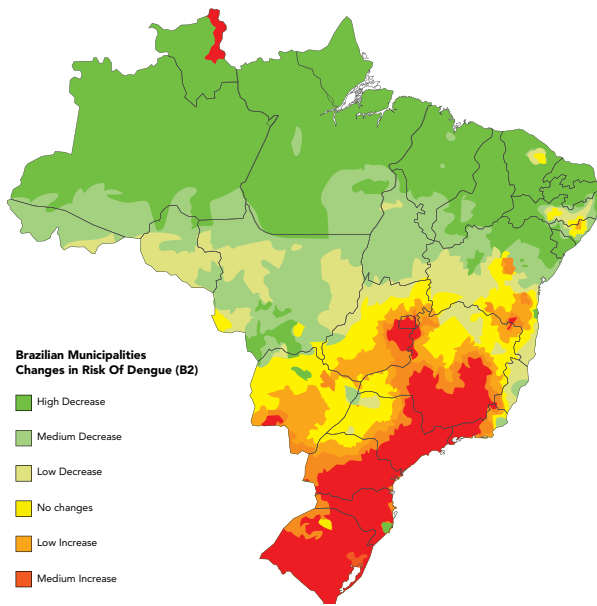
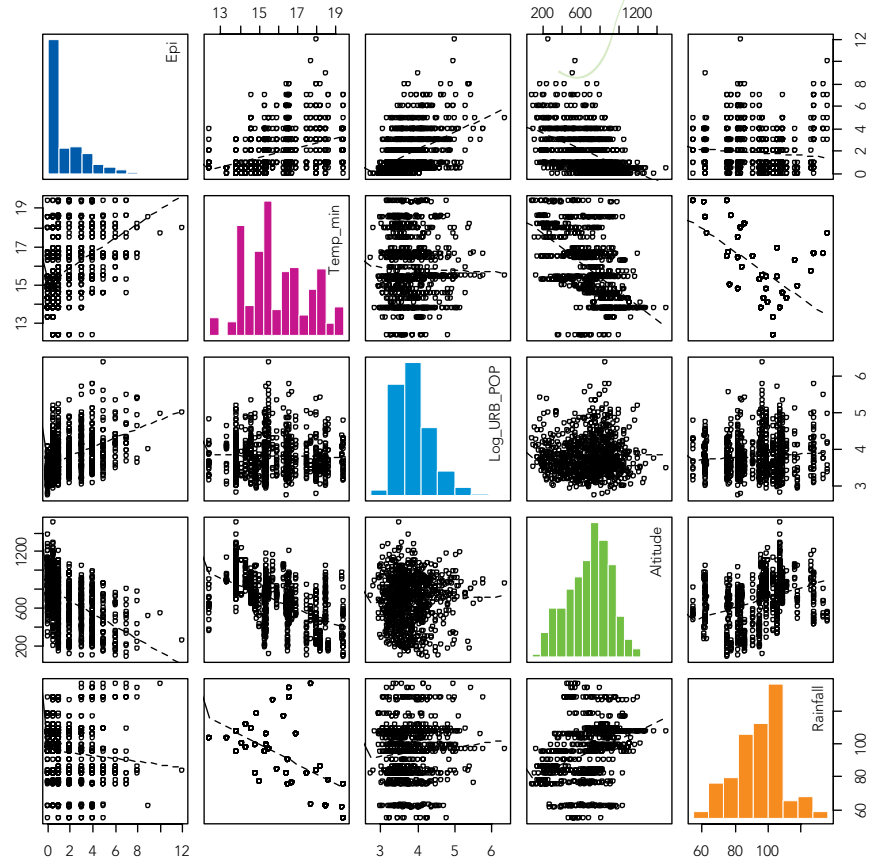
In the second phase of the study, geographic information systems (GISs) were used to compare climate averages to dengue incidence rates in macro-regions and municipalities in Minas Gerais State (5). The results show an overlapping of high incidence rates of dengue with hot and densely populated regions (Figure 4.4).

# CASE STUDY 4.B



Research

**Figure 4.4** Scatter matrix (top); Thematic map, rainfall versus epidemics (bottom left); Thematic map, altitude and minimum temperature versus epidemics (bottom right).



## BENEFITS AND LESSONS

The results of this study have been communicated in scientific forums to public health authorities and other research groups. They have been presented by means of maps and charts for discussion among specialists from various fields. This approach has proven to be effective in enhancing the understanding of the etiology of this climate-sensitive vector-borne disease and created a favourable environment for the debate on how to further investigate dengue in relation to climate and environmental factors (5). For effective participation in such discussions, public officials needed to be instructed in a wide range of disciplines – such as health, geography, demography and statistics – in order to achieve efficient dengue control protocols and actions, and capture the complexity and diversity of factors affecting the transmission of the disease.

Considering the ubiquitous distribution of the dengue vector, its correlation with geographic and climatic factors (7), and the special climatic conditions and changes in urban areas (i.e. increases in the minimum annual temperature in cities over recent years and the well-documented urban 'heat-island' effect), it is necessary to create means for systematic integrated monitoring to further investigate the combined effects of these variables on dengue, mainly in urban settings with a high, non-uniformly distributed population density. Therefore, initiatives aiming to assess smaller geographical units within a city, comprising intra-urban microclimates (8) have high potential to contribute to the mitigation of risk of dengue transmission associated with climate change (4). The lack of intersectoral coordination, climate data and tools to perform appropriate analyses, are obstacles to conducting adequate integrated surveillance and monitoring.

Intersectoral approaches can facilitate discussion and the creation and support of a network for exchange of information, experience, scientific production and structuring of health services. Fundraising is an essential prerequisite for multidisciplinary projects aiming at expanding monitoring and enhancing knowledge on dengue vector control and factors influencing dengue transmission.

## ACKNOWLEDGEMENTS





# ANALYSIS OF THE HEALTH IMPACTS OF CLIMATE VARIABILITY IN FOUR MAJOR SOUTH AMERICAN CITIES

Authors: Barboza, G. (Ministerio de Salud Pública, Uruguay); Martínez, M. (Ministerio de Salud Pública, Uruguay); Frasco, L. (Universidad de Buenos Aires); Fontán, S. (Ministerio de Salud de la Ciudad de Buenos Aires, Argentina); Chesini, F. (Ministerio de Salud de la Nación, Argentina); González, E.C. (Servicio Meteorológico Nacional, Argentina); Saravia, C. (Centro Universitario Región Noroeste sede Salto, Universidad de la República, Uruguay) y Xavier, D.R. (Fundação Oswaldo Cruz, Brasil)

Enabling Environment

Research

## CONTEXT

This case study is the result of the 'Climate variability and its potential impacts on health' project, elaborated and approved by the regional "Training Institute on Climate and Health"<sup>9</sup> in Piriápolis (Uruguay) organized by the Interamerican Institute for Global Change Research (IAI), the International Research Institute for Climate and Society (IRI) and the Ministry of Public Health of Uruguay (MSP). This research was financed by the Training Institute Seed Grant (TISG) of IAI.

## NEW APPROACHES

Extreme meteorological events (i.e. heat and cold waves, rain floods and droughts) were analysed from 1981 to 2010 and, particularly, their relationship with impacts on public health were analysed from 2005 to 2010. The categorization of cold and heat waves was conducted by calculating percentiles 10 and 90 for maximum and minimum temperatures. The events were classified as mild, moderate and severe. The average daily temperatures and relative humidity were used to calculate the bio-meteorological index of temperature and humidity (ITH), in order to characterize the thermic environment.

For determination of extreme rainfall events, the 90 and 10 monthly percentiles were calculated and accumulated on a weekly basis.

The climate-associated health events were grouped into communicable and noncommunicable diseases (NCDs). The communicable diseases studied were: diarrhea, viral hepatitis A, leptospirosis, dengue, acute upper respiratory tract infections, influenza, acute lower respiratory tract infections.

The following NCDs were studied: hypertensive disorders, ischemic heart conditions, cerebrovascular diseases and chronic lower respiratory tract diseases.

In Uruguay, the data sources used for the study were from the Division of Epidemiology of the Ministry of Public Health (Montevideo) and the Medical and Surgical Society (Salto, Mutualista). Buenos Aires data were provided by the Direction of Statistics and Information in Health and by the Direction of Epidemiology, both part of the Argentina National Ministry of Health. For Manaus, data were extracted from the hospitals information system (HIS).

Data processing involved the application of a quantitative methodology to establish association between climate and health. This included the application of exploratory data analysis techniques to assess frequencies, measures of central tendency and dispersion. Furthermore, bivariate correlation was applied to assess statistical dependence and independence (9).



Heatwaves were identified along the entire study period (1981–2010). The highest frequency of events was observed in summer in Salto, Aeroparque (Buenos Aires) and Carrasco (Montevideo). For the summer season, every city registered at least one heat wave event during the 30 years analysed. Cold events were registered in every city throughout the year, with maximum frequency in winter. The highest frequency of severe cold waves was registered in winter in Buenos Aires, Montevideo and Salto, while in Manaus the minimum temperature varied only slightly. Rainfall patterns were similar in Aeroparque and Carrasco.

### BENEFITS AND LESSONS

Communicable pathologies such as diarrhoea, hepatitis A and dengue are sensitive to the influence of climate variables such as temperature and rainfall. Common diarrhea was studied in Buenos Aires, Salto and Manaus. The relation of diarrhea with extreme temperature was analysed in Buenos Aires, with both extreme temperature and rainfall in Salto, and with extreme rainfall events in Manaus. Only in Manaus it was observed an increase of diarrhea cases in lower rainfall months.

Hepatitis A was studied in Buenos Aires, Manaus and Montevideo. In Manaus it was observed a similar behaviour as with diarrhea. In Montevideo, Hepatitis A was studied in relation to heat waves and it was found out an increase in the number of cases when heatwaves were severe. In Buenos Aires it was not observed an association between Hepatitis A and heat waves.

Bronchiolitis (in under 2 year-olds) and pneumonias were studied in Buenos Aires and Salto, and influenza conditions were studied only in Buenos Aires. Acute respiratory infections were assessed in Salto. These pathologies were correlated with cold waves. In Salto, an increase in the number of cases coincided with increase cold wave severity. In Buenos Aires, the peak of bronchiolitis cases in under 2 year-old and in influenza-like disease in the general population coincided with a cold wave in 2007.

Dengue and leptospirosis were studied in Manaus, while in Buenos Aires it was only studied leptospirosis. The number of cases of dengue raised in all age groups, especially in children under 14 year-old, as the rainfall increased in Manaus. Leptospirosis was analysed in relation with rainfall. Like dengue, the number of cases of leptospirosis raised in the highest rainfall months in Manaus, in which economically active population showed the greatest number of cases. In Buenos Aires it was not observed an association between leptospirosis and extreme rainfall events.

Weaknesses in health information systems were identified, particularly in relation to the availability and consistency of appropriate spatio-temporal data scales, required to generate robust time series comparable with climate data. Although climate time series are available, this information is not always accessible for health users for disease prevention and health adaptation purposes. Nevertheless, this problem could be solved by strengthening the collaboration between national meteorological services and the ministries of health of each country.

This work contributes to the strengthening of health systems preparedness and response capacities by means of the collection, systematization, processing and analysis of information.

It was possible to build a solid 50-year database of meteorological information for various cities. It was difficult to homogenize health data due their different spatial (city, district, country) and temporal (weeks, month) scales. This fact hampered the establishment of the correlation with climate data. In addition, health data time series are very short in comparison to climate time series.

### ACKNOWLEDGEMENTS



**Buenos Aires Ciudad**



Ministério da Saúde  
**FIOCRUZ**  
Fundação Oswaldo Cruz



**Ministerio de Salud**  
Presidencia de la Nación





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# MALARIA SENSITIVITY TO CLIMATE IN COLOMBIA: THE IMPORTANCE OF DATA AVAILABILITY, QUALITY AND FORMAT

Authors : L. López Álvarez (Instituto de Hidrología, Meteorología y Estudios Ambientales - IDEAM, Bogotá, D.C. Colombia)

## CONTEXT

This study is part of the global Integrated National Adaptation Project (INAP) and focuses on numerical-statistical modelling, with the aim of obtaining a methodology that assesses the probability of malaria occurrence in Colombia. The ultimate goal is to develop an early warning system, based on average temperature and rainfall and their correlation with the number of malaria cases, particularly in five locations with evidence of endemic malaria (Puerto Libertador, Montelíbano, San José del Guaviare, Tumaco y Buenaventura).

Weather and climate data and malaria data, were provided by the Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM) and the Instituto Nacional de Salud (INS) respectively, and processed with the aim of updating the existing data base.

## NEW APPROACHES

The first difficulty encountered was asynchronous climatological and epidemiological years. Information had to be divided and aligned as a series of weeks.

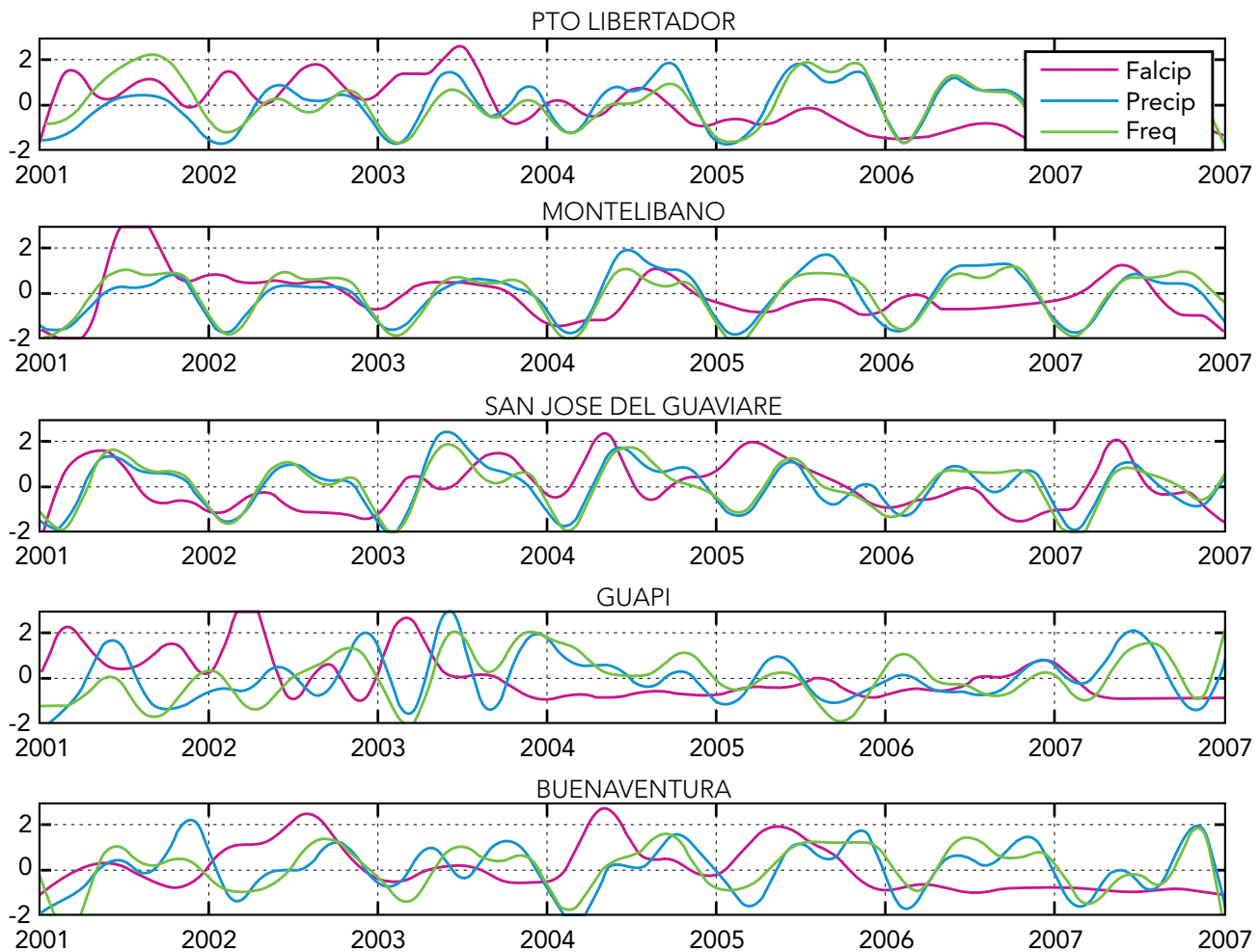
Interdisciplinary meetings between climatologists and medical doctors were held to unify criteria regarding the type of information required, and to estimate the dynamics of disease transmission (e.g. parasite and vector lifespans). This allowed identification of the seasons (rain or dry) that have a direct impact on the number of vectors and therefore help to define a seasonally-based malaria prevention system.

Various groups were convened to review work completed and determine progress in the first phase of the model development. Exploratory research was also undertaken to understand the status of technological and scientific tools in the field of malaria globally (e.g. databases, specialized software, existing models etc.) to complement the work that was being conducted.

Results were reviewed by the INS. It was observed that climate has varied impacts on vector multiplication rates and on the general health of population in the different regions. Given the range of variables and effects, it was concluded that development of a climate–health model, specific for each population was essential. (10)

The variable effects can be seen in Figure 4.5, depicting rainfall and the number of malaria cases in each local population. While the number of cases increases with rainfall in San José de Guaviare, the opposite is observed in Buenaventura.

**Figure 4.5** Comparison between the series of Plasmodium falciparum and standardized rainfall (2001 to 2008)



**BENEFITS AND LESSONS**

Available health time series data in Colombia are very short and have not undergone robust statistical analysis. As a result, it is very difficult to determine the seasonality, epidemic behaviour or correlation with climate data series.

Similarly, it has been concluded that the format of climate information is not the most appropriate for such analysis. In some cases it is in text format, while in others in numerical format, which makes cleaning and processing the data more difficult. The health information on malaria cases is also often incomplete or inadequate for optimal analysis.

Even though an extensive and complete exploratory analysis of the variables was conducted, which is a fundamental first step in the development of an adequate model, the project lacked continuity because it was connected to a broader project that ended midway through the current study. This led to staff turnover and project interruption. The initial climate and malaria/dengue model was not implemented due to lack of institutional capacity. (11)

**ACKNOWLEDGEMENTS**

The authors acknowledge the support of staff at the IDEAM and International Research Institute for Climate and Society at Columbia University for the implementation of this project.



# ITERATIVE DEVELOPMENT AND TESTING OF A HEAT WARNING AND INFORMATION SYSTEM IN ALBERTA, CANADA

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Institutions: 1. Office of the Chief Medical Officer of Health, Alberta Health; 2. Alberta Health Services; 3. Agrometeorology Applications and Modelling Section, Alberta Agriculture and Forestry; 4. Health and Air Quality Forecast Services, Meteorological Service of Canada, Environment and Climate Change Canada; 5. Prediction Services Directorate, Meteorological Service of Canada, Environment and Climate Change Canada; 6. Climate Change and Innovation Bureau, Health Canada.

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## CONTEXT

Climate change is anticipated to increase the frequency and intensity of extreme heat events in northern latitudes, including in Canada (12–14). Such heat events can lead to increases in hospital admissions, morbidity and premature mortality, particularly among the most vulnerable groups (15, 16). The western Canadian province of Alberta has relatively little experience with severe heat waves of long duration. In 2012, consistent with Alberta’s Climate Change Adaption Framework (17), Alberta Health, the Provincial Government Department of Health, initiated a high-level vulnerability assessment that led to the development of a Heat Warning and Information System (HWIS) involving collaboration between several agencies with expertise outside of public health.

## NEW APPROACHES

Starting in 2012, Alberta Health initiated a process to develop a HWIS based on two core principles:

1. Leveraging existing partnerships and networks: Alberta Health partnered with the Meteorological Service of Canada (MSC) and Health Canada (two Federal Departments), the Provincial Department of Agriculture and Forestry (AF), and Alberta Health Services (local community level). Through these strategic partnerships, Alberta Health was able to access advice (e.g. epidemiological analyses) and infrastructure (e.g. climate forecasting systems) to design the roll-out of the HWIS.
2. Building on existing best practices and lessons learned: Alberta Health completed a survey, with the assistance of Health Canada and the MSC, of best practices and lessons learned relevant to the provincial context. The results of this survey fed directly into the development of both the structure of the HWIS (e.g. the thresholds), as well as the corresponding communication plan.

After approximately 24 months of development, Alberta Health initiated a pilot of its provincial HWIS during the summers of 2014/15. The goals of the pilot were threefold: First, to test the effectiveness of the proposed thresholds and associated responses (see Table 4.1). The thresholds were determined by evaluating historical summertime meteorological conditions alongside emergency room department visits and mortality statistics. During the pilot season, the final decision on initiating a response action was the responsibility of the local Medical Officer of Health (MOH). Second, promote awareness among key decision-makers and the general public through a targeted communication initiative. Third, test the web-based infrastructure that AF developed in collaboration with Alberta Health. Using an existing information systems platform, the AgroClimatic Information Service of AF developed a web-based mapping application that monitored communities and their corresponding threshold level, as well as an information content feed for local MOHs so that they could be notified when thresholds were exceeded (see Figure 4.6).

There were three heat events during the summers of 2014 and 2015 with several for which public health actions were taken. The events were short duration (i.e., 2 to 3 days), and involved several communities. The pilot will be evaluated to further develop the system for future years.

**Table 4.1** Comparison between the series of *Plasmodium falciparum* and standardized rainfall (2001 to 2008)

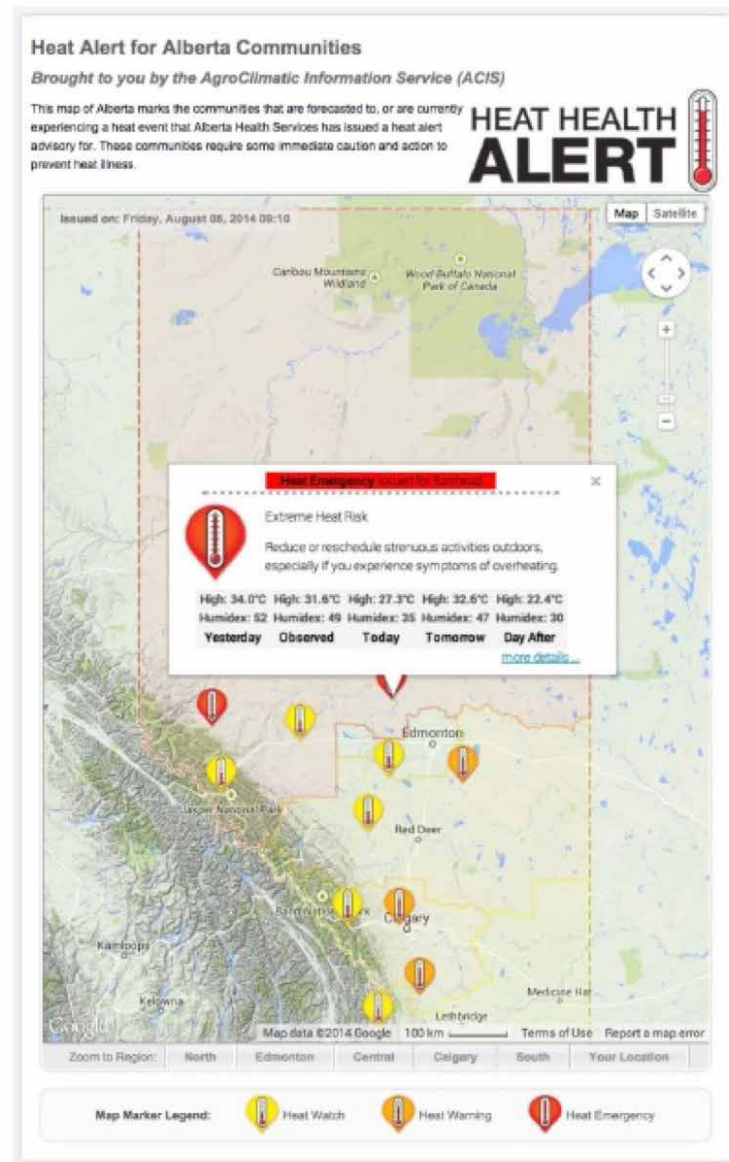
DESCRIPTION	CRITERIA
<p><b>Heat Warning</b></p> <p>MSC provides early notification to MOHs that a heat event is building, and provides guidance on duration, severity and geography of the event.</p> <p>MSC issues a heat warning to the public.</p> <p>The local MOH monitors the local situation and adjusts public health response.</p>	<p>When Forecast of two or more consecutive days above the 95th percentile of maximum and minimum temperatures.</p>
<p><b>Extended Heat Warning</b></p> <p>MSC maintains the heat warning, notifies MOHs and provides guidance on severity, duration and geography of the event.</p> <p>The local MOH may contact municipalities, vulnerable population organizations to implement response measures.</p> <p>The local MOH may notify Emergency Management Services and hospitals to be prepared for surge during and after the event.</p>	<p>Observed maximum and minimum temperatures are above the 95th percentile for 3 consecutive days and are Forecast to continue.</p>

## CASE STUDY 4.E

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Research

Figure 4.6 Screen view of the Alberta HWIS real-time weather monitoring webpage.



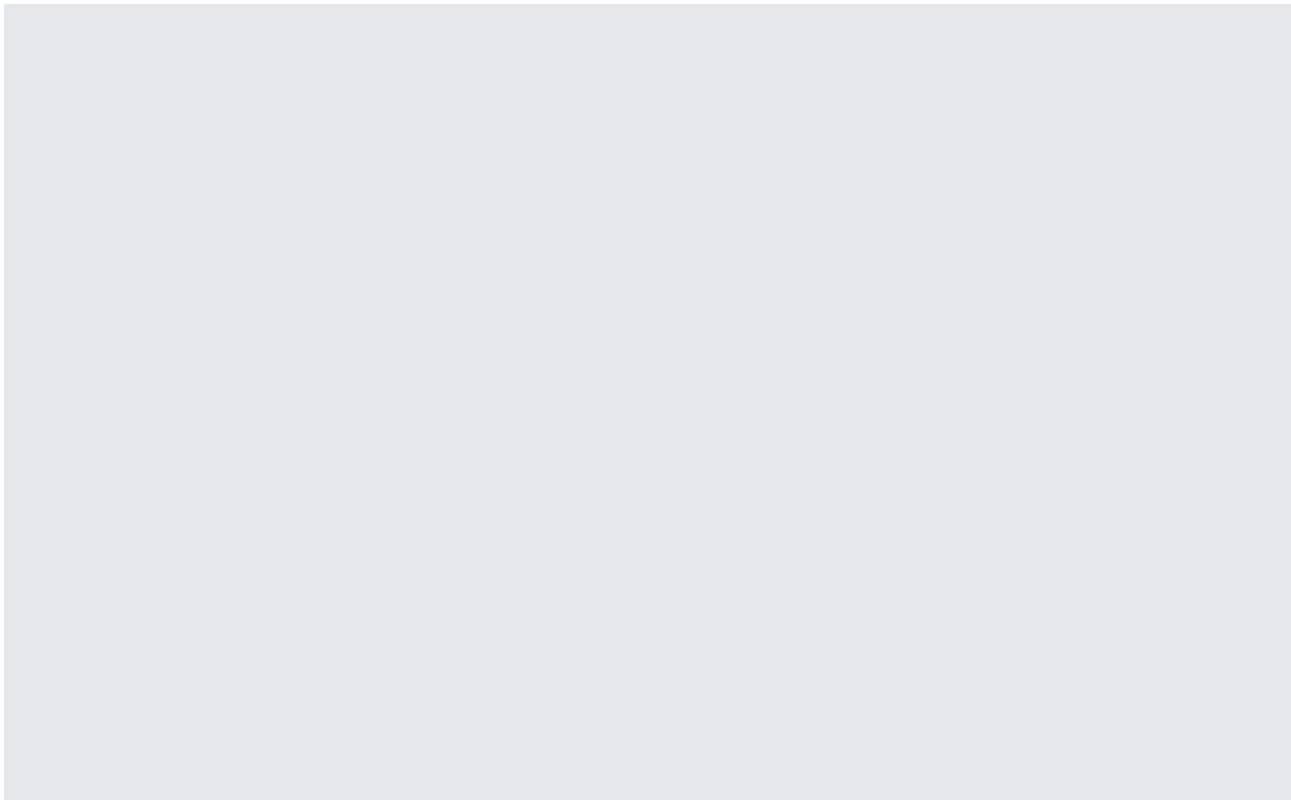
(Source: www.weatherdata.ca/health)



## BENEFITS AND LESSONS

The Alberta HWIS project can be characterized as a success story. Before the initiation of this work, Alberta did not have a coordinated approach or shared understanding of the potential health threat of heat events, mitigation plans or an effective HARS. Collaboration among agencies at the local, provincial and federal levels enabled sharing of expertise, skills and resources to allow for the rapid development and deployment of a province-wide HWIS pilot. Since this was an initial pilot, the health benefits have not been quantified.

Expertise and resources developed by Health Canada (e.g. [www.extremeheat.ca](http://www.extremeheat.ca)) provided the basis for the development of the HWIS and tools used in communications and public messaging. Forecast support for heat events and expertise/data provided by the MSC ([www.ec.gc.ca/meteo-weather/](http://www.ec.gc.ca/meteo-weather/)) allowed for historical analyses to develop meteorological thresholds. AF had unique technical expertise. Having local MOHs champion the project helped create credibility and encouraged other local organizations to participate. The genuine passion and good will exhibited from agencies working on the project contributed to the successful development and execution of the pilot within its two-year time frame.



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## ACKNOWLEDGEMENTS

*The authors acknowledge the efforts by all individuals from the partner organizations who contributed to the successful implementation and ongoing development of this initiative.*





Research

Product & Service Development

# PREDICTING THE IMPACTS OF CLIMATE ON DENGUE IN BRAZIL: INTEGRATED RISK MODELLING AND MAPPING

Authors: P. Pereda (Department of Economics of the University of São Paulo, Brazil), D. Alves (Department of Economics of the University of São Paulo, Brazil).

## CONTEXT

Dengue fever represented 83% of the cases of diseases with mandatory notification in Brazil from 2007–10 and it caused estimated losses of about US\$ 880 million in 2010 (18) (approximately one quarter comprises direct costs and remainder are indirect/productivity losses). Dengue is transmitted by female *Aedes aegypti* mosquitoes and the cycle, reproduction and survival of mosquitoes are highly dependent on weather conditions. This study tests the role of climate on the risk of dengue in Brazil. The climate variability makes Brazil an interesting setting to study.

## NEW APPROACHES

We propose a dengue risk model based on determinants of the disease, in order to control for other variables. The determinants of dengue ( $d$ ) can be sub-divided into four groups (19): environment (climate,  $C$ ; vegetation,  $V$ ; and spatial contagious,  $d_{-j}$ ), socio-demography (mainly income,  $P$ ; education,  $E$ ; and sanitary conditions,  $S$ ), medical factors (local investments in eradication,  $M$ ) and local history of the disease (previous notifications of dengue,  $d^{(t-1)}$ ) (20). The relevant climatic conditions for dengue vector survival and reproduction are: mild average temperature; sufficient humidity to regulate the temperature of mosquitoes; and a reasonable amount of precipitation for the deposition of eggs (large amounts of rain may have the reverse effect). The risk model for dengue is:

$$d_i = g(d_i^{t-1}, d_j, M_i, E_i, f(C_i), F_i, S_i, P_i, V_i) \quad i, j = 1, \dots, N \text{ and } i \neq j,$$

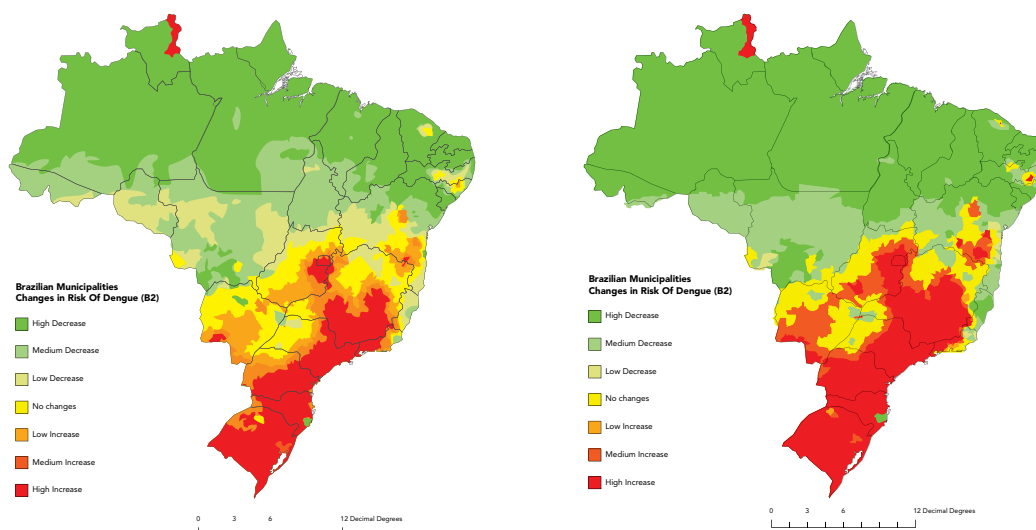
where  $i, j$  identifies Brazilian municipalities. The function can be estimated using count data models (21).

The period analysed was 2010 and data sources were: SINAN (dengue notifications); Demographic Census (socio-demographic variables); National Treasury (local investments in health); Ministry of Health (health information); US National Aeronautics and Space Administration (NASA) and Data Library (Normalized Differenced Vegetation Index); National Meteorology Institute (monthly historical climate: temperature, relative humidity and rainfall); and Centro de Previsão de Tempo e Estudos Climáticos (CPTEC), Instituto Nacional de Pesquisas Espaciais (INPE) (climate predictions). For all the climatic variables, average data over the seasons were created, sub-divided into two groups: 30-year average climatic conditions,  $E(C_{1980-2009})$ ; and deviation from climatic conditions,  $C_{2010} - E(C_{1980-2009})$ .

## BENEFITS AND LESSONS

The climate variables showed statistical relevance to explain the risk of dengue in Brazil. Moreover, if climate change occurs as expected, the results suggest a potential added risk for central–southern areas in Brazil and a risk reduction for northern areas of the country, which can be seen in the maps below (Figure 4.7):

**Figure 4.7** Projected changes in dengue risk due to climate change, 2040–69 (left) and 2070–99 (right), Brazil, Scenario B2. High reduction: < -80%; Medium reduction: from -80% to -40%; Low reduction: -40% to -2%; No change: -2% to 2%; Low increase: 2% to 40%; Medium increase: 40% to 80%; High increase: > 80%.

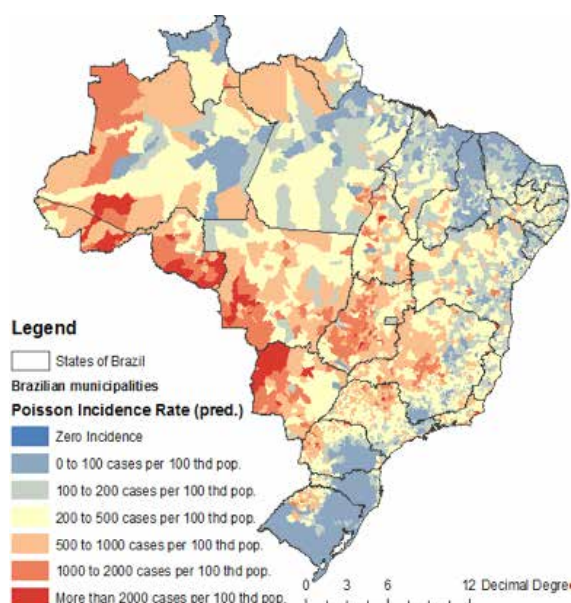


The 3-month predictions from the Instituto Nacional de Meteorologia (INMET) and Instituto Nacional de Pesquisas Espaciais (INPE) could also be used to forecast dengue cases for the next season. The use of precise climate data must be emphasized in order to obtain accurate forecasts. Figure 4.8 shows the model as used to identify the spatial vulnerability index for dengue based on socioeconomic conditions and average climate in Brazil.

## ACKNOWLEDGEMENTS



**Figure 4.8** Dengue vulnerability ratio predicted by the Poisson model, 2010, Brazilian municipalities.

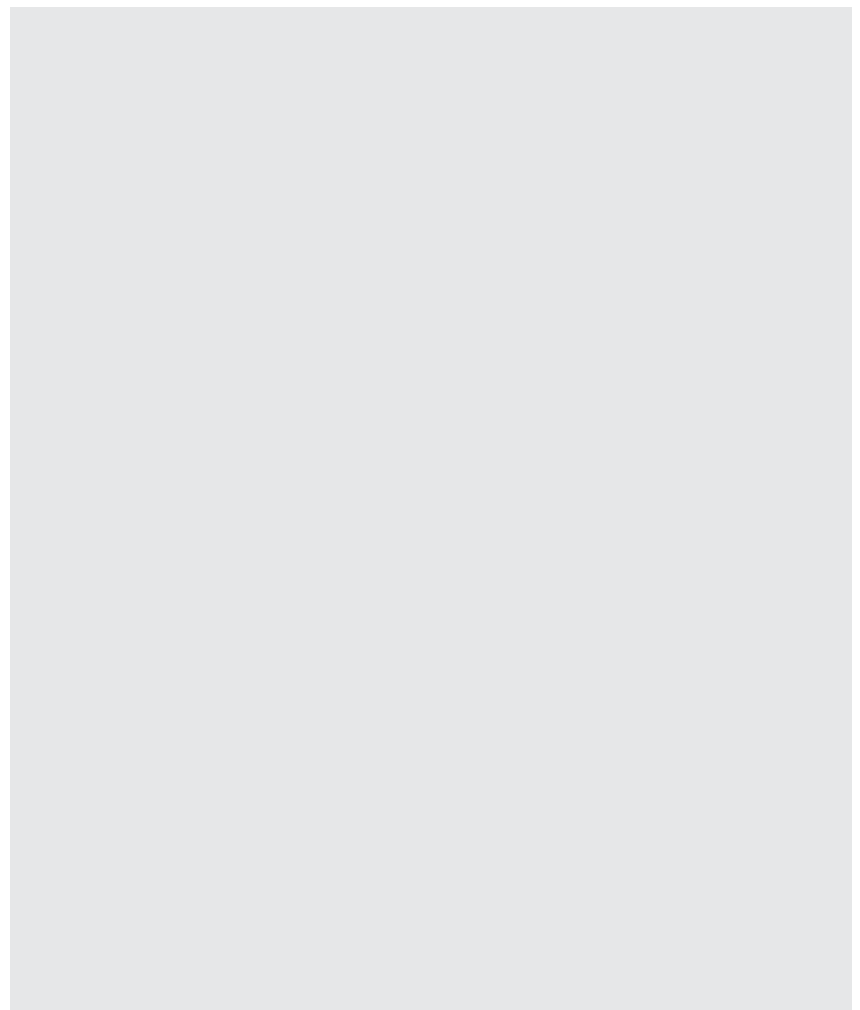


# CcTALK! COMMUNICATING EFFECTIVELY WITH HIGH-RISK POPULATIONS IN AUSTRIA: A FIVE-STEP METHODOLOGY

Authors: T. Grothmann (Dr. Grothmann - Training und Beratung/ Carl von Ossietzky Universität Oldenburg, Germany), A. Prutsch, M. Leitner, N. Glas, V. Wirth, (Umweltbundesamt, Austria), B. Wanschura, W. Gerlich, F. Lorenz, S. Gartlacher (PlanSinn, Büro für Planung und Kommunikation GmbH, Austria)

## CONTEXT

Due to climate change, excessive heat and heat waves are a growing threat to public health, in particular of the elderly. The most widely documented policy for reducing heat vulnerabilities to date is the adoption of heat warnings and air quality alert systems to trigger emergency responses (22). Nevertheless, the evidence for their positive impact is limited and the most vulnerable groups are not being adequately reached (23). In order to reduce the vulnerability of elderly people to heat waves in Austria, we developed and tested a more effective communication approach as part of the CcTalk! Project.



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Capacity Building

Research

Product & Service Development

Evaluation

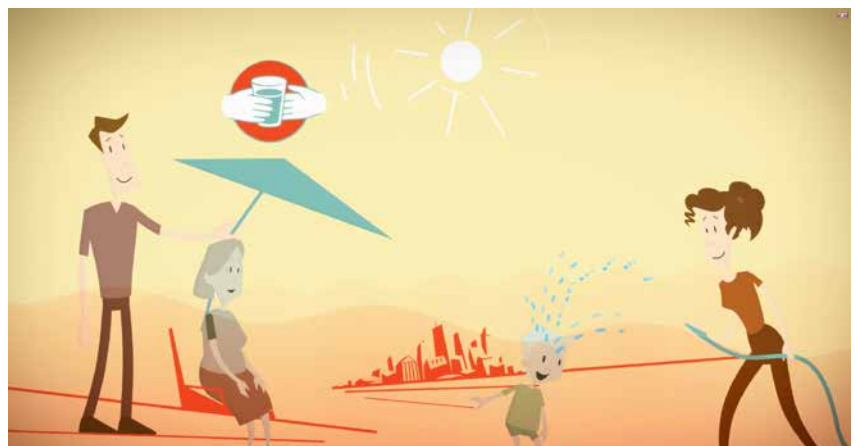
## NEW APPROACHES

We designed and applied an efficient five-step-methodology (24):

1. Target group selection: Via a multi-criteria assessment (including criteria such as expected negative climate change impacts on the group, options for protective behaviour in the group), we looked at various potential target groups, e.g. family doctors, pharmacies and nursing homes. We identified mobile health care nurses as one of the most important target groups in Austria. They can act as multipliers of knowledge, motivators of protective behaviours among vulnerable elderly and as protectors (e.g. by measures to cool down patients' bodies) and thereby partly compensate for the lack of self-protective behaviour among the elderly.
2. Target group analysis: Interviews with mobile health care nurses in Austria identified psychological drivers of and barriers to their current protective behaviour during heat extremes. Prevalent drivers include: climate change perceptions; control beliefs; role models; and consideration of heat and health. Barriers include fatalism and work stress. Furthermore, we identified information needs and preferred information channels of nurses themselves.
3. Development of communication formats: To specifically address the drivers of and barriers to protective behaviour, as well as the expressed information needs and preferred information channels, we designed four communication formats:
  - An innovative social learning workshop for mobile health care nurses (led by a medical doctor and an experienced mobile health care nurse), allowing face-to-face communication.
  - A brochure (30 pages) providing detailed information on health risks of heat extremes, protection measures before and during heat events, diagnosis and treatment of heat-related diseases.
  - Two animated videos (each one minute long), suited to convey basic information on the heat and health topic in an entertaining, emotionalizing and thereby motivating manner.
  - A flyer (two pages) conveying basic information on health risks of heat extremes, protection measures before and during heat events and symptoms of serious heat-related diseases that require emergency medical services.
  - The social learning workshop and the brochure were mainly designed for the mobile health care nurses, whereas the animated videos and the flyer were mainly aimed at the elderly and their relatives.

## CASE STUDY 4.G

Screenshots from animated CcTALK!-videos to convey basic information on the heat and health topic in an entertaining, emotionalizing and thereby motivating manner.



Capacity Building

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4. Pretest of communication formats: The four communication formats were pretested in focus group workshops with mobile health care nurses (combining individual evaluations by questionnaires and collective evaluations by open-ended discussions). Very positive evaluations of the formats revealed that they were effective in increasing heat risk awareness, heat risk competence and protective behaviour, but that some minor modifications to the formats would be useful.
5. Improvement of materials formats: Based on the focus group results, we modified the formats to further improve their effectiveness and practical usability. For example, the social learning workshop concept was changed to be organized as a co-production of knowledge and mutual learning process between the participants.

### BENEFITS AND LESSONS

Two aspects particularly differentiate the five-step-methodology presented here from current practice in climate services for health. First, the methodology builds on psychological knowledge about determinants of protective behaviour regarding health risks (25) and on psychological methods for designing behaviour change interventions (26). Second, the methodology includes an evaluation of the communication formats by focus groups and thereby addresses the lack of evaluations in current practice of climate change adaptation communication (27) and interventions regarding health risks of heat waves (28).

The five-step-methodology has proven effective to produce communication formats that are able to motivate protective behaviour during heat extremes. The methodology can be generalized to other activities where awareness, competence or behaviour shall be increased by means of communication. However, the methodology does not provide exact rules, neither for the selection and development of communication formats based on the target group interview results nor for the improvement of the formats based on the focus group workshop results.

### ACKNOWLEDGEMENTS

*This work was supported by the Klima- und Energiefonds, Austria, within the Austrian Climate Research Programme (ACRP); grant number KR11AC0K00183.*

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# KNOWING WHEN COLD WINTERS AND WARM SUMMERS CAN REDUCE AMBULATORY CARE PERFORMANCE IN LONDON

Author: J. Thornes (Public Health England)

## CONTEXT

As part of a climate change risk assessment, Public Health England took the initiative to analyse the impact of cold winters and warm summers on the number of ambulance call-outs and ambulance response times in London. This study is the first of its kind in the United Kingdom. Initial findings show that there is a clear relationship between air temperature and emergency ambulance calls. Further research shows that as well as developing operational adaptation methods for ambulance trusts using real time incident modelling, it is possible, in the future, to use real-time ambulance response data to feedback timely emergency warnings (29). For example, the percentage of respiratory or cardiac ambulance calls that are considered life threatening can provide valuable early morbidity information for cold-related or heat-related illnesses.

Within England there are currently 11 National Health Service (NHS) organizations that provide ambulance services and more than 9 million emergency calls were received in the year ending March 2013, of which 77% required an emergency response (30). In 2012/13 there were 2.95 million Category A (CatA - life threatening) incidents with a response rate (i.e. arriving at the scene of the incident) of 75.5% within 8 minutes (NHS target 75% within 8 minutes). That is close to 25 000 emergency calls per day of which more than 8000 are triaged as CatA. The total number of emergency patient journeys was 5.02 million and 1.99 million patients were treated at the scene. The total cost of the NHS ambulance service is close to £2 billion per year, of which about £1.5 billion is spent on emergency services and the rest on ambulatory (pre-arranged) services.

The London Ambulance Service employs more than 5000 staff serving the Greater London population of more than 8 million people. In 2013, over 1.7 million emergency ambulance calls were received of which 1.1 million were responded to (on average 3000 incidents/day), of which nearly half a million were considered life threatening. This level of activity is increasing year by year (increasing elderly population, additional tourists, more people with mobile phones etc.), which puts additional pressure on shrinking resources. It was known that hot and cold weather put additional stress on the system but it was not known to what extent.

## NEW APPROACHES

Daily data was obtained from the London Ambulance Service for 2003–2012 including the number of responded calls, the number of CatA calls, the % of responses within 8 minutes (target 75%) and illness codes. This data was then compared to mean daily temperature data from St James Park (SJP) in London, accessed via the UK Meteorological Office. The heatwaves of 2003 and 2006 plus the very cold December of 2010 are included in the dataset, which gives a good cross-section of weather events.

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Data Collection and Management

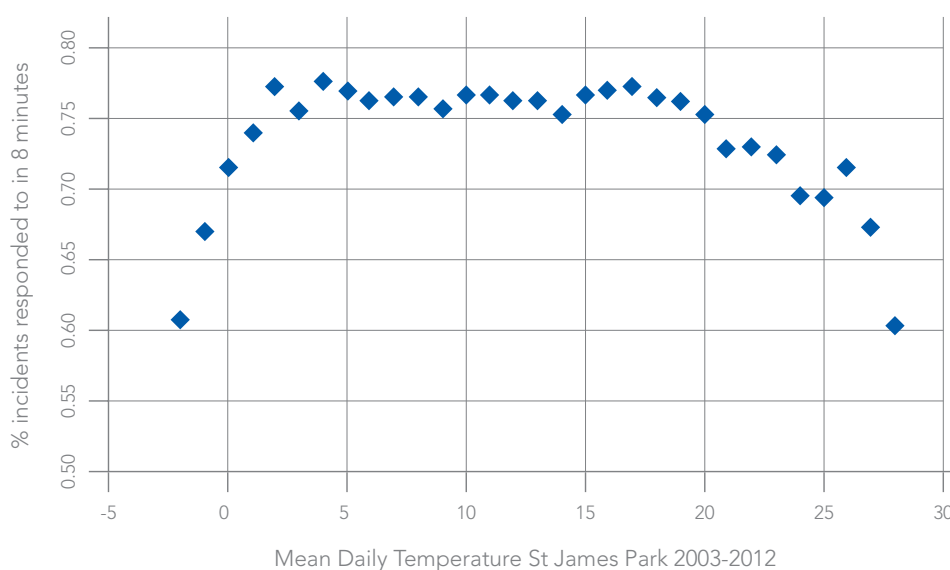
Indicators and Thresholds



Figure 4.09 shows a snapshot of the results obtained (which are discussed in detail elsewhere (31–33)). The overall relationship between the mean daily temperature and the mean percentage of CatA incidents responded to within 8 minutes (performance target) for each temperature is shown. Mean temperature thresholds that influence performance can be identified as above 20 degrees Celsius and below 2 degrees Celsius. More research is required to identify which illnesses increase beyond these thresholds. Figure 4.09 shows that, on average, performance drops off more quickly as the mean temperature drops below 2 degrees Celsius compared to the reduction in performance when the temperature rises above 20 degrees Celsius. This could be partly because performance at low temperatures is also affected by slippery roads due to ice and snow, whereas in warm temperatures the roads are not normally affected. This figure shows that the weather does not have to be severe for an impact on ambulance services to occur.

There is also a seasonal change in the number and type of incidents, which means that the performance of the ambulance service in London is marginally better in Spring and Autumn and worst in summer and winter. Warm and cold weather both exaggerate these variations and cause a significant reduction in performance especially during ‘heatwaves’ and ‘coldwaves’. Ongoing research is being conducted in a collaboration between the London Ambulance Service and Public Health England. It is planned to incorporate weather forecasts into predictions of demand on a daily to weekly time scale.

**Figure 4.09** Mean daily temperature versus % of CatA incidents responded to within 8 minutes (averaged for each temperature, 2003–2012)



#### ACKNOWLEDGEMENTS

I would like to thank Anthony Buckler, Dave Clarke, Robin Hutchings and David Thompson of London Ambulance Service for their very helpful contributions and enthusiastic support.

#### BENEFITS AND LESSONS

The weather impacts directly on day-to-day operations, while the climate contributes to the level of service required (e.g. the number of staff and ambulances). As the climate changes and/or the frequency of hot and cold weather changes, so too must the ambulance service become more resilient and better prepared with bespoke weather forecasts and climate predictions.



Public Health  
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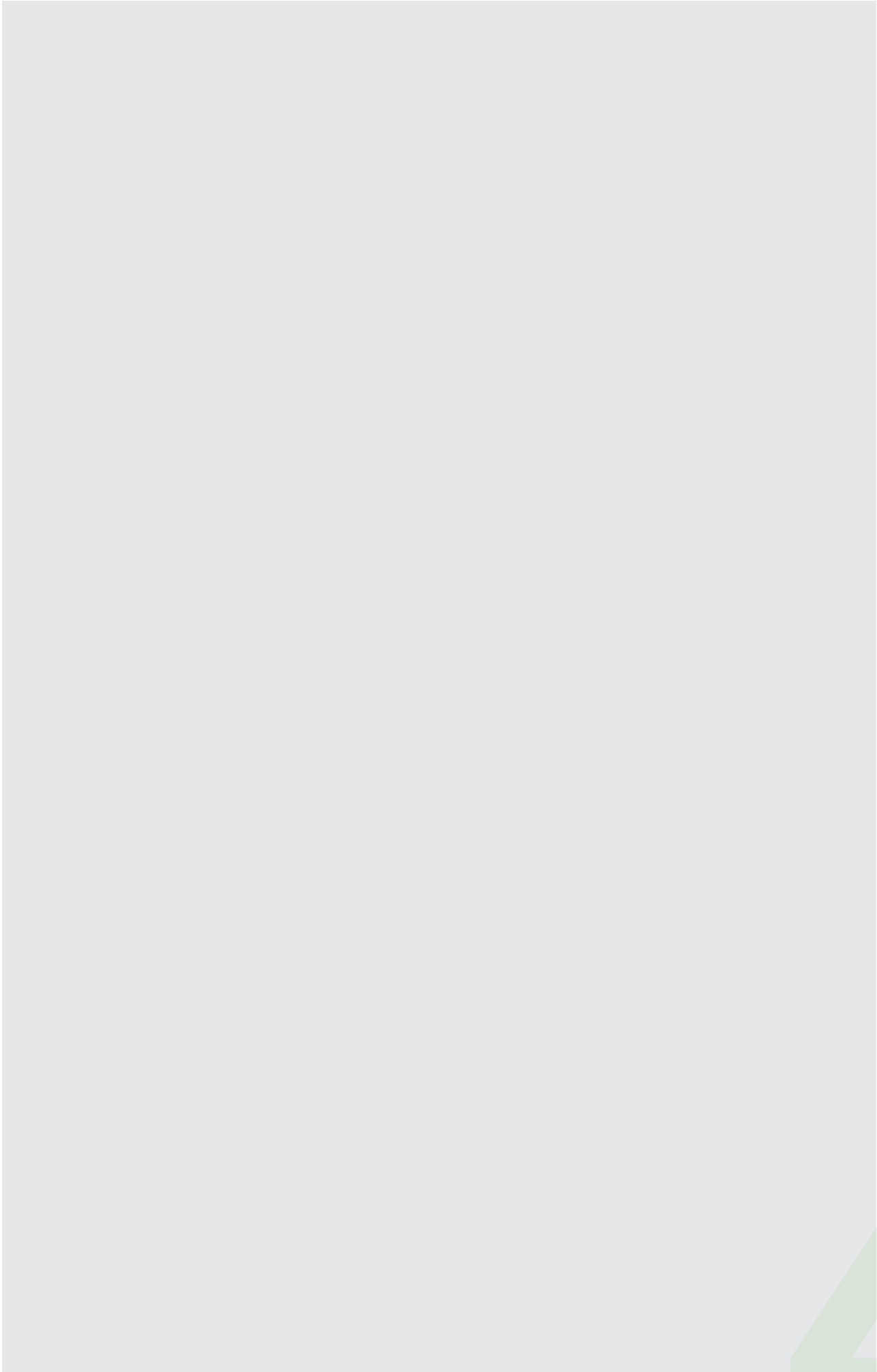
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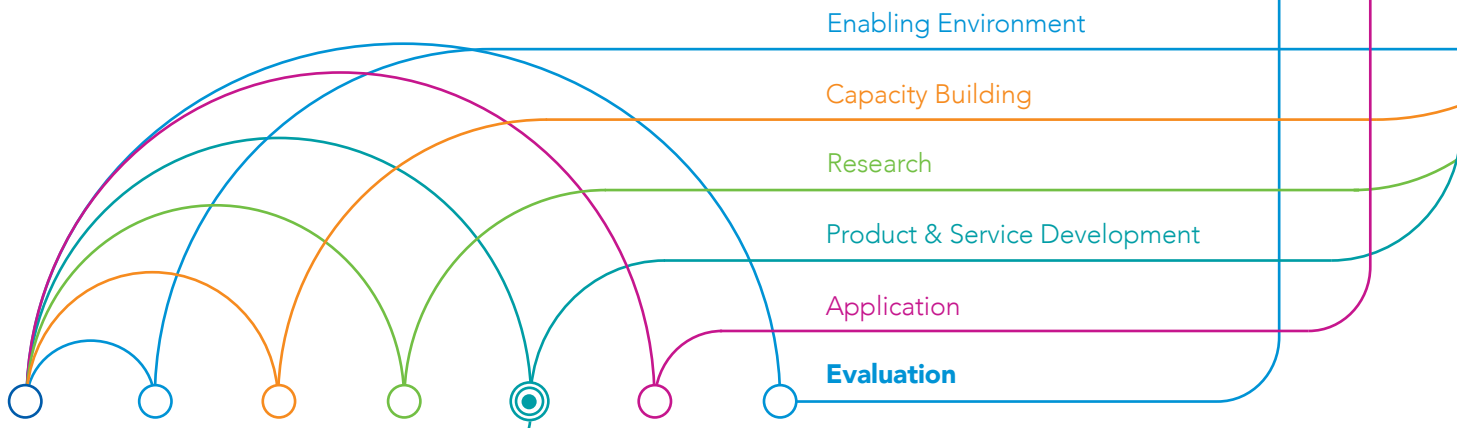
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**CHAPTER 5**

**5**

**CO-DEVELOPMENT AND DELIVERY OF HEALTH-TAILORED CLIMATE PRODUCTS AND SERVICES**

**GOAL** to collaboratively design and create tailored information products that are integrated and interoperable to user specifications, which provide decision-makers and communities with timely and relevant information to manage health risks specific to climate and weather.

Tailored climate products are most frequently the result partnerships that process and present climate data or information, either alone or in combination with other types of data or information, in such a way that makes the information usable for a specific purpose. Climate services, on the other hand, refer to the needs-driven processes that bring about the production and delivery of climate information relevant for managing climate sensitive health risks.

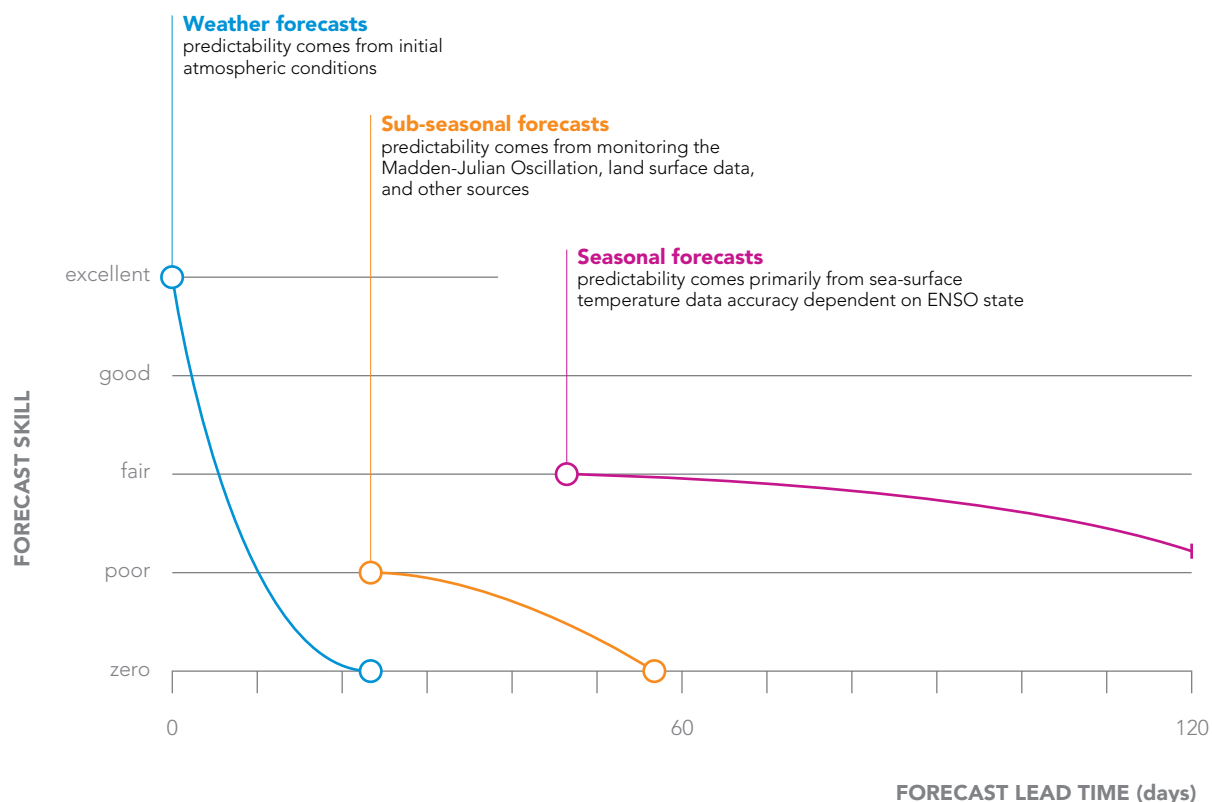
The transformation and translation of climate information products to useful tailored climate-informed health decision tools often involves the development of a combination of separate but interlinked products, which are needed to forecast health risks or produce early warnings. Each product must have a sufficient degree of quality, reliability, usability, suitability and responsiveness to changing needs. The degree to which these criteria are met determines how, and if, the information can be further applied, and whether health decision-makers will trust the information enough to use it confidently for decision-making. Health decision tools which use climate information to understand and predict health risks commonly fall into the following categories:

**Figure 5.2**  
Common health tailored climate products



**Figure 5.1** Rating of skill for short-term weather and climate forecasts

HISTORIC CLIMATE INFORMATION	WEATHER INFORMATION	SHORT-TERM CLIMATE INFORMATION	MID-TERM CLIMATE INFORMATION	LONG-TERM CLIMATE INFORMATION
Past	Hourly to 1 month in the future	1-12 months in the future	Annual to multi-year in the future	10-30 years in the future



### IMPORTANCE OF PRODUCT DEVELOPMENT AND DELIVERY IN THE END-TO-END PROCESS

The technical development of tailored climate products and services is crucial. For product development and delivery to be effective, however, the activities conducted within the other five components must lead up to and support this stage.

Critically, almost all activities to develop health-tailored climate products and services must first begin with looking backwards and working with historical climate data to conduct a combined longitudinal analysis of epidemiological data (or a sensitivity analysis) to identify if climate signals exist, and can be further used to forecast or predict disease outbreaks or other health risks. Therefore, the data sharing policies for the access and use of national climate data should be immediately established as part of an enabling environment and in order to advance to develop applied services.

An enabling environment and sufficient capacity both play a crucial role in ensuring the access, applicability and suitability of the climate products and service developed. Research findings are key to inform the necessary requirements and optimal conditions for further deployment. Evaluation will ensure that services meet the expected quality criteria, serve the functions they were designed for, and provide feedback from users to iteratively improve the product or service.



## COMMON HEALTH-TAILORED PRODUCTS AND SERVICES

A range of decision tools can be developed to inform and bring insight to a vast range of health problems. Common types of health-tailored climate products are briefly explained below:

**a**

**Data collection and management tools** are a foundational element for most climate products and services, and technical data and software requirements vary according to the respective goals of each initiative. Data availability and compatibility are common challenges, and innovative data collection or data preparation techniques are frequently needed to transform or blend data for use. For example, to compensate for the lack of, poor quality, or poor coverage of climate and environmental data, techniques that blend local meteorological or environmental observations with remotely-sensed data are often used. Similarly for health, data from national surveillance systems can be combined with data sourced from sentinel sites, or community-based disease surveillance systems in order to generate comprehensive datasets. Real-time health risk monitoring systems, for instance, may first require automatic data retrieval and validation systems to ensure real-time data inputs, whereas manual data collection and management systems may be preferred for health sensitivity analyses.

Spatial scale is also critical for the usability of climate data. Health decisions are often made at a district/county level, requiring climate or weather forecasts, outlooks or projections to be downscaled to spatial units that are meaningful to health professionals. Climate and health data comparability can be increased when data is collected from meteorological and health stations located in close proximity. Furthermore, in addition to climate and environmental variables, socioeconomic data or other data representing population vulnerability may also be needed for a more comprehensive understanding of the health problem.

**b**

**Monitoring and integrated surveillance systems** for environmental determinants of health typically make use of early detection tools and epidemiological surveillance in conjunction with direct and remote sensing technologies. Collected data can be used to generate dynamic or static central databases where health, climate and other socioeconomic data are integrated. These data are commonly presented through user-friendly interfaces that allow for data to be queried, visualized and downloaded according to desirable criteria (e.g. disease type, risk factors, time interval, future climate scenarios, etc.). Many of these user interfaces were built with input from the public health community, to ensure that the information presented can support health decisions.

**c**

**Health, Risk, climate indicators and thresholds** are typically numerical indices against which health risks or impacts can be measured. Choosing appropriate indicators and thresholds is vital for triggering health alerts, such as air pollution indicators, or UV indices. While there are a wide variety of possible risk indicators that can be used, the main types of information used to construct such indicators are: climate or environmental hazards characteristics (such as severity, starting time, duration, etc.); climate and environment conditions (humidity, temperature, rainfall, etc.); population vulnerability and exposure factors (such as immunity, remoteness, malnutrition or poverty); and the socioeconomic context of a given population (such as conflict, agricultural practices or education level).

**d**

**Risk modelling and mapping tools and methodologies** help illustrate climate related health risks using clear indicators as the basis for building risk maps. Risk modelling and mapping help assess the risks that specific hazards pose to population health, and can illuminate the scale of local needs. Three main types of maps can support climate-smart health decision making: 1) maps presenting the expected frequency of the climate hazards (e.g. expected number of extreme hot days); 2) maps presenting the environmental suitability for (infectious) disease transmission, based on climatic, environmental or ecosystem conditions (e.g. number of days exceeding a certain precipitation rate, altitude, land use, salinity, bird flight patterns, etc.); 3) maps illustrating the probabilistic likelihood of a subsequence (e.g. epidemic outbreaks), based on empirical or deterministic models of a specific disease's transmission.

**e**

**Applications of climate outlooks and forecasts**, can be used to predict health risks. For example, depending on the timescale and information needs, initiatives addressing heat-related health risks may use weather forecasts with lead-times of several days to anticipate heat waves, or long-term climate projections to anticipate the number of extreme hot days. Different health hazards may require weather forecasts with longer-lead times and/or the use of more health specific parameters. Predicting future impacts of climate and environmental conditions on infectious diseases can be estimated using several techniques: by integrating seasonal climate forecasts and projections into mathematical or statistical disease transmission or incidence models that anticipate disease incidence risks in both space and time; so-called 'ensemble' techniques, which use several disease models to yield forecasts and evaluate forecast uncertainty levels; or integrated database systems in which data analysis algorithms automatically produce a forecast, and continuously evaluate the model's predictive skill as observed data becomes available.

**f**

**Early warning systems**, designed to alert health professionals as well as the public of a rapid-onset emergencies such as extreme weather or disease outbreaks, are important in providing additional lead-time for the deployment of relevant preparedness measures and responses. Hazard and exposure thresholds are set to trigger warnings, and are often scaled to trigger varying response actions according to the level of risk encountered. Communication strategies within these systems ensure the proper dissemination of warnings to health decision-makers, emergency response teams, communities and especially to vulnerable groups. Strategies to disseminate warnings include formal partnerships and communication exchange protocols with key stakeholders and the assessment of the most popular and effective communication channels (such as social media and instant messaging platforms, television, radio or websites) to reach out to the greatest possible number of community members.

**g**

**Risk projections and future scenarios** are risk models that are developed to generate projections of health risks up to several decades into the future, commonly based upon IPCC climate change scenarios and regional climate change projections. Risk models can go beyond generating estimations of future health risks of diseases, to incorporate evaluations of the effectiveness of different adaptation strategies in accordance with different climate scenarios.

**5A:** How hot will it be?  
Translating climate model outputs for public health practice in the United States

**5B:** Innovative community-based data collection to understand and find solutions to rainfall-related diarrhoeal diseases in Ecuador

**5C:** Vector-virus microclimate surveillance system for dengue control in Machala, Ecuador

**5D:** EPIDEMIA: Integrating climate information and disease surveillance for malaria epidemic forecasting in Ethiopia

**5E:** The Brazilian Observatory of Climate and Health: Experience of organizing and disseminating climate and health information in Manaus, Amazon region

**5F:** Climate-specific pollen indicators and population exposure monitoring tools to better manage the allergy season in Hungary

**5G:** MalaClim: Climate-based suitability mapping to inform vector control programmes in the Solomon Islands

**5H:** Mapping and modelling plague in Uganda to improve health outcomes

A/B

C/D/E

F

G/H

## CASE STUDIES OF CO-DEVELOPMENT AND DELIVERY

Fifteen case studies help describe how climate products are used to develop decision-tools which can provide insight to health risks and foresight to health decision-makers.

### Data collection and management.

In the first two case studies (5A/5B), two very different approaches are presented for data collection and data management strategies. The first applied statistical down-scaling to translate complex climate model predictions, in order to provide the projected number of future extreme hot days at a meaningful geographic unit of resolution relevant for public health surveillance. The second illustrated the potential of using a community-based surveillance system to complete partial national health data records in Ecuador.

### Integrated disease surveillance systems

Case studies 5C/5D/5E provide examples of climate-enhanced integrated disease surveillance systems. In Ecuador (5C), an integrated dengue vector-virus-microclimate surveillance system produces high-resolution risk information as the basis for improving seasonal dengue early warnings. The epidemiological-climate data repository, managed by a research team uses a secure cloud-based server to store and share information with partners. In Ethiopia, (5D) a software was developed to link environmental and epidemiological databases through a data integration sub-system, to enable forecasting and rapid detection of malaria epidemics. Weekly district-scale health surveillance data are uploaded through a public health user interface, and climate data is predominantly sourced remotely at hourly to weekly frequency at 1–25km spatial resolutions. Case study 5E, shows how in Brazil a data observatory was created to collect information from different partner databases, and how it organizes and disseminates environmental, sociodemographic, climate and population and health data from sentinel sites to analyse and monitor indicators of health effects related to environmental and climate conditions.

### Indicators

Most case studies develop and use indicators in some way. Case study 5F, from Hungary, is a particularly good example of the research required to identify and use climate specific indicators to monitor and forecast pollen conditions.

### Risk mapping and risk monitoring

Case studies (5G/5H) illustrate the development of climate-based risk mapping and risk monitoring of suitability of transmission of vector borne diseases. In the Solomon islands, case study 5G describes how malaria transmission suitability maps were produced at the provincial level based on an environmental risk score, a composite measurement of environmental, population-based, and entomological indicators derived from a variety of sources including remotely sensed data that drive malaria transmission. A customized dry-season forecast produced for the malaria control programme informs when and if rainfall will reach a threshold that favours transmission, in order to inform early preparedness actions up to four months in advance. Monthly outlooks and observations during the transmission season further diagnosis high risk areas according to changes in the environmental risk score. In Uganda (5H), teams created both spatial and temporal risk models for human plague incidence and improved an existing plague transmission risk model by developing a multi-year high spatial resolution climate dataset created using hybrid-dynamic-statistical meteorological down-scaling techniques. The tool helps generate risk maps that are used by the disease control programme to target health interventions, including an enhanced case detection and referral system that trains and uses traditional healers as outreach workers to identify and refer plague patients.

I/J/K

**5I:** Forecasting wildland fire smoke hazards in urban and rural areas in Manitoba, Canada

**5J:** Forecasting malaria transmission: finding the basis for making district-scale predictions in Uganda

**5K:** Bio-climatic bulletins to forecast dengue vectors in Panama

### Health risk forecasts

Case studies (5I/5J/5K) illustrate examples of climate-informed health risk forecasts for hazardous air quality, as well as dengue and malaria transmission. In Manitoba Canada, case study 5I shows how climate and atmospheric conditions are used to monitor, forecast and communicate wildfire smoke risks to the public and disaster and health authorities. Multiple tools are used to observe smoke conditions and provide both real-time monitoring and hour-by-hour forecasts for the next 48-hour period for populated areas where citizens may be at risk of hazardous smoke inhalation. In the second case study (5J), a malaria early warning system in Uganda, uses seasonal forecasts to drive a dynamic malaria model. Validation shows the system produces skilful predictions of malaria transmission four months in advance, providing potential for advanced action to protect over half of the Ugandan population. The third case study (5K), is a dengue early warning system that uses climate information as part of a statistical model to forecast the risk of dengue transmission based on an index of infestation of the *Aedes aegypti* mosquito for the present month and the two following months. The information is distributed in a monthly bulletin that is used by health authorities to inform vector control activities.

L/M

**5L:** SUPREME: An integrated heat health warning system for Quebec

**5M:** Heat wave and health risk early warning systems in China

### Early warning systems

Cases studies illustrating the development of early warning systems are focused on heat waves. The first, developed in Quebec, Canada (5L), comprised an integrated platform that provided access to indicators relating exposure to extreme temperature hazards, socioeconomic characteristics of neighbourhoods, and health problems. It is the sole common source of relevant and real-time information on extreme weather hazards at the provincial level, and provides warnings up to 7-days ahead of extreme heat events, which trigger pre-designated activities. In China (5M), a heat warning system based on city-specific health risk models and four-level response guidance provides timely warnings of health risks due to extreme heat, and specifically developed broad-based risk communication campaign using modern communication technologies (e.g. electronic display screens, mobile text or QQ instant messaging groups).

N/O

**5N:** HEALTHY FUTURES Atlas: A publicly available resource for evaluating climate change risks on water-related and vector-borne disease in eastern Africa

**5O:** Comprehensive climate risk modelling framework to help protect future food and water safety in Canada

### Projections and scenarios

Finally, two case studies provide examples of decision tools using future climate projections to generate scenarios of health risks. In the first (5N), an interactive, web-based mapping and decision support tool constructs future probability of simulated transmission intensity, simulated prevalence and simulated length of transmission season for each decade until 2100 based on multiple ensembles of down-scaled high resolution future climate change projections. In addition, the tool provides temporal trends at locations throughout eastern sub-Saharan Africa and relative values of social vulnerability, as mapped based on a range of indicators of levels of susceptibility to disease. The final case study (5O) developed a risk framework that allows for generation of climate-related risk projections for food- and water-borne diseases in Canada in time frames up to 2100, based upon multi-model averages of future climate projections. It allows for the evaluation of different adaptation options by enabling their inclusion in the projection models.

## DATA COLLECTION AND MANAGEMENT

# HOW HOT WILL IT BE? TRANSLATING CLIMATE MODEL OUTPUTS FOR PUBLIC HEALTH PRACTICE IN THE UNITED STATES

Authors: S. Saha (Centers for Disease Control and Prevention, National Center for Environmental Health, USA), K. Kunkel (Cooperative Institute for Climate and Satellites, NOAA National Centers for Environmental Information and North Carolina State University, USA), E. Hummelman, A. Vaidyanathan, P. Wall, G. Luber (Centers for Disease Control and Prevention, National Center for Environmental Health, USA).

### CONTEXT

What meteorological factors are going to change? How much will they change? Will there be spatial variation? These are foundational issues for public health agencies in preparing for the impacts of climate change. In the wake of the *Building Resilience Against Climate Effects* (BRACE) framework developed by the US Centers for Disease Control and Prevention (CDC), health agencies in the United States are using forecasted meteorological data to monitor health vulnerabilities across populations and places resulting from climate change.

The available suite of climate model predictions – with nuances on spatial scale, range of hypothetical socioeconomic and greenhouse gas emission futures, uncertainties associated with climate predictions, voluminous data and specific data formats – make processing and interpretation of climate projection information challenging for public health professionals. There is a need for translation of complex climate science for public health practitioners for problem assessment and design of health interventions.

### NEW APPROACHES

The CDC responded to this need by collaborating with the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI) to facilitate access to climate projection.

Following record and near record-breaking hot summers in the recent past for regions of the US, local public health agencies have begun implementing heat response plans (1). Availability of information on the location and intensity of increases in future temperature could help agencies design targeted interventions to reduce the adverse impacts of extreme heat.

The recent National Climate Assessment used a comprehensive dataset of projections of daily temperature metrics covering the continental US until 2100. It was produced using a statistical down-scaling method that combined high-resolution observations with outputs from six different global climate models based on two (A2 and B1) future emission scenarios. The gridded output was available at one-eighth degree (approximately 14km) resolution. Projected annual future values were computed as the average of the six models for a 30-year (a standard length for expressing climatological averages) moving window around each year. Thus, the annual value for 2084 is an average of the 30-year period from 2070–2099.

Enabling Environment

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Application

### Data Collection and Management

Indicators and Thresholds

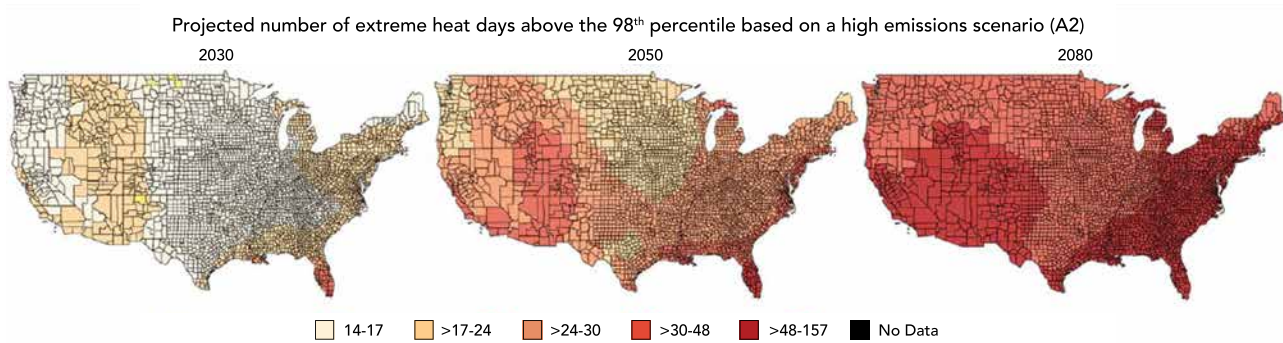
Risk Models and Maps

Projections and Scenarios

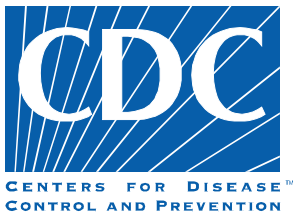
Since a meaningful geographic unit of resolution relevant for public health surveillance in the US is a 'county', information in the gridded output was converted to conform to county boundaries.

Using a geographic information system (GIS), temperatures from grids were assigned to counties. In cases where multiple grids spanned a county, the grids over areas of greater population density were given greater weight while calculating the average temperature value for the county. The data on annual 'projected number of future extreme hot days' by counties is available for viewing and downloading from the CDC Environmental Public Health Tracking Network portal (2). Since the objective was to provide information on extreme heat in the future, a user can query future projections of temperature for counties in the continental US, for any year between the near (2020) and distant future (2084). One could then choose either the A2 or B1 emission scenarios used by the IPCC, and specify an absolute (90oF, 100oF) or relative (98th percentile based on temperature distribution during 1971–2000) threshold to define the extreme hot day. Results are produced in a map, graphical or tabular format. An example of the temperature distribution is shown in Figure 5.3 for 2030, 2050 and 2080.

**Figure 5.3** Example of output from the US CDC Environmental Public Health Tracking Network portal.



#### ACKNOWLEDGEMENTS



#### BENEFITS AND LESSONS

Using this approach as a template, information on projected precipitation included in the National Climate Assessment has also been incorporated into the portal. State public health agencies funded through the Climate Ready States and Cities Initiative (CRSCI) by the Climate and Health Program in CDC are currently using this information to prepare for future vulnerabilities from extreme heat in respective jurisdictions (3). The spatial scale relevant to public health decision-making should be considered when transforming the climate data for use by public health practitioners.



## DATA COLLECTION AND MANAGEMENT

# INNOVATIVE COMMUNITY-BASED DATA COLLECTION TO UNDERSTAND AND FIND SOLUTIONS TO RAINFALL-RELATED DIARRHOEAL DISEASES IN ECUADOR

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### CONTEXT

Climate variability and climate change have the potential to alter the transmission of diarrhoeal diseases, one of the leading causes of death and disability worldwide. The aim of the study was to establish the relationship between seasonal rainfall in the rainy season (December to May) and in the dry season (June to November) with the numbers of registered cases of diarrhoeal diseases (DD), in the canton Eloy Alfaro (population 39,739; Census 2010) located on the north-western part of the coastal region of Ecuador, near the border with Colombia, and subject to the direct influences of El Niño and La Niña Pacific Ocean phenomena (4, 5).

### NEW APPROACHES

The DD information was obtained from data taken from a passive surveillance system grouping data from 12 Ministry of Health (MOH) public health centres scattered in the study area, covering the period 2008–2012 (DD is defined as three or more loose stools in a period of 24 hours, within the last week). This surveillance system is completed with data collected by the Association of Health Promoters Area Bourbon whose members are performing preventive, curative, educational and socioorganizational activities. The community-led epidemiological surveillance system has been active in the area for over a decade and is supported by the Centre for Community Epidemiology and Tropical Medicine (CECOMET) a Catholic nongovernmental organization with close ties to local health authorities, the MOH and the Central University of Ecuador. Information collected in epidemiological notebooks by health promoters is presented at monthly community meetings via 'Life stories', a comprehensive compilation of the stories behind sentinel events (serious cases and avoidable deaths) as the main instrument to analyse the causes behind the events, and to propose feasible solutions.

The study used precipitation datasets recorded by the Cayapas weather station, managed by the National Institute of Meteorology and Hydrology (INAMHI). The precipitation measurements are performed according to international technical standards of the World Meteorological Organization (WMO).

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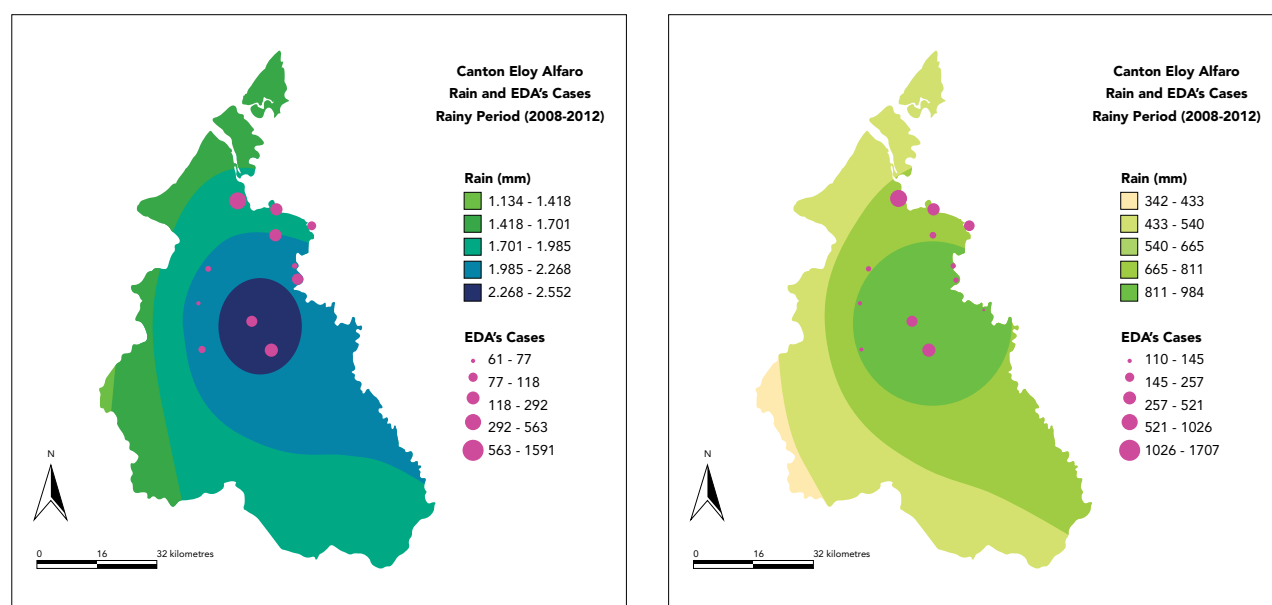
Product & Service Development

Application



The method of principal component analysis and correlation was used for data analysis and it helped establish that the number of DD cases reported during the dry period is larger than the DD cases reported during the rainy season (6). This information was shared with the local authorities and nongovernmental organizations to undertake actions to improve drinking water quality (i.e. proposing chlorination at various points along the distribution systems – for piped systems – and distribution of chlorine tablets in the homes) and with the MOH, to include factors linking climate and health in national health policies (7). Climate information is now being provided, as per request, to the district and zonal health authorities. To fully understand this climate–health relationship, other social, cultural and biophysical factors must be considered.

**Figure 5.4** Influence of climatic seasonality on diarrhoeal disease.



## ACKNOWLEDGEMENTS



The total cases of DD reported in the 12 health centres during the 2008–2012, observed a variation between 61–1591 cases in the rainy season, while it was 110–1707 cases in the dry period. The estimation of the incidence rate indicates that DD is more prevalent during the dry season (51.3 cases per 1000 inhabitants) than it is in the rainy season (with a prevalence of 47.8/1000 (8–14).

## BENEFITS AND LESSONS

There is a need to strengthen the capacities of the regional team responsible for drinking-water safety. Although there is capacity to analyse water samples for microbiological and chemical contamination, increased awareness and capacity at community level are needed to achieve community-led initiatives that will implement water safety principles for their own water sources, distribution and storage systems. One way forward is by facilitating inter-community exchanges, as many such water safety initiatives already exist in neighbouring regions.

## INTEGRATED SURVEILLANCE

# VECTOR-VIRUS MICROCLIMATE SURVEILLANCE SYSTEM FOR DENGUE CONTROL IN MACHALA, ECUADOR

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### CONTEXT

Dengue fever, a mosquito-borne viral illness, is hyper-endemic in coastal Ecuador, requiring tremendous mobilization of resources by the public health sector each year during the rainy season. The National Institute of Meteorology and Hydrology (INAMHI), the Ministry of Health (MSP) of Ecuador, and an international research team have co-developed an integrated dengue–climate research and surveillance platform. The team has generated the evidence base for the effects of climate on dengue fever and strengthened the local research and surveillance capacities. These efforts provide the foundation for a dengue early warning system (EWS) and other climate services that are tailored for the public health sector, ultimately improving the ability of decision-makers to incorporate climate information into public health planning.

Machala, a city located in southern coastal Ecuador, has been a strategic dengue research site since 2010, following one of the largest dengue epidemics on record (Figure 5.5). That year, over 17 000 cases of dengue were reported in the country, with more than 2000 cases in Machala, resulting in a local incidence rate more than three times the baseline rate from 2003 to 2009 (15). The epidemic rapidly surpassed the capacity of local public health services, highlighting the need for alternative prevention and control strategies.

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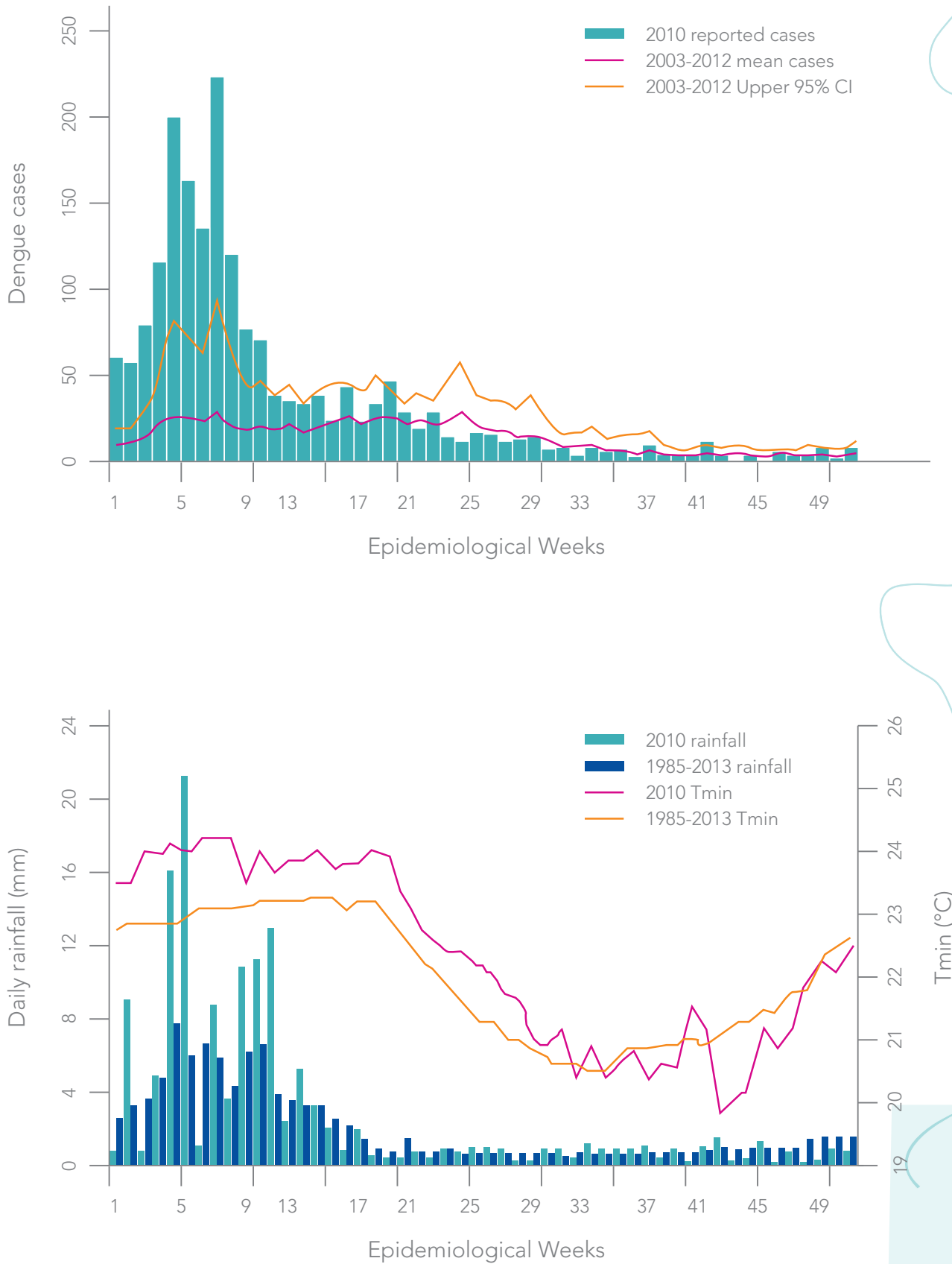
Data Collection and Management

Integrated Surveillance

Indicators and Thresholds

Forecasts

**Figure 5.5** Time series of dengue and local climatic conditions in 2010 and historically in Machala, Ecuador. (A) Weekly reported cases of dengue in 2010 and weekly average cases from 2003 to 2012; (B) weekly averages of rainfall and minimum air temperature (Tmin) in 2010 compared to the climatology (1986 to 2013 average conditions). Reproduced with permission from Stewart Ibarra et al 2014 (15).



## CASE STUDY 5.C



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### NEW APPROACHES

Initial collaborative research efforts led by INAMHI and partners indicated the potential to develop a dengue EWS. Studies showed that the size and timing of dengue outbreaks were associated with a combination of climate and non-climatic factors, including the El Niño Southern Oscillation (ENSO), local climate, the virus serotypes in circulation and mosquito abundance (16). The research team identified key local climatic conditions that likely triggered outbreaks, as observed in 2010 (15). Studies also showed that dengue risk was associated with social vulnerability factors such as housing conditions, demographics, risk perceptions and knowledge (15, 17). Investigators on the team improved the seasonal climate forecasts in the region, generating forecasts with good predictive ability that could be used in dengue forecasts (18). The Latin America Observatory (OLE2), a regional network of climate centres, has provided critical technical support and a means of rapidly disseminating climate products and tools (19).

**Figure 5.6** Active surveillance of lab-validated dengue cases (right) and *Aedes aegypti* (left) in Machala, Ecuador, provides epidemiological information that is paired with local microclimate data to better understand triggers of dengue outbreaks. Photo credit: W. Feuz/2014.



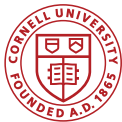
In 2013, the team gained additional support from the Global Emerging Infections Surveillance and Response System (GEIS) to establish an integrated vector–virus–microclimate surveillance system (Figure 5.6). This comprehensive surveillance system is generating fine-scale spatiotemporal data on microclimate, virus and vector dynamics, nutritional status, and sociodemographic risk factors, allowing investigators to determine the true burden of dengue illness and local climate and non-climate triggers. Epidemiological data is generated through passive surveillance of dengue cases from sentinel clinics, combined with active cluster-based surveillance (Ibarra S. et al. in prep). Microclimate information is generated by five weather sensors and an automated full meteorological station operated by INAMHI. An epidemiological–climate data repository is currently stored and shared with partners using a secure cloud-based server managed by the research team.

### BENEFITS AND LESSONS

Important outcomes include improved surveillance infrastructure and field-validated protocols, recommendations for targeted seasonal vector control interventions, high-resolution climate and epidemiological data, exploratory predictive models, risk maps, improved seasonal climate forecasts, and knowledge translation through climate–health forums, press releases, social media outlets (e.g. Dengue REDDES on Facebook) and climate–weather bulletins for the health sector. Team members are providing technical support for the design of the national vector surveillance and febrile surveillance programmes. The surveillance system and previous studies provide the foundation to develop an operational dengue EWS, at seasonal and monthly scales. At a seasonal scale, a climate risk indicator may forecast hot spot regions and levels of dengue, providing useful information for communication and social mobilization measures at sub-regional levels, informing budgeting and resource allocation. At the monthly or weekly scale, real-time local climate, vector and virus surveillance can alert authorities to anomalous increases in key parameters, triggering local measures by the public health and municipal government.

An important component of the ongoing partnership is the tailored trainings to the public health sector and local scientific community, which have included topics in bioethics, research integrity, tools for dengue diagnosis and surveillance, GIS for public health, and disease risk modelling. Trainings provide the foundation for a long-term collaboration with stakeholders, while enhancing transdisciplinary research capacities at local institutions. One of the key lessons learned is the importance of strong institutional partnerships that are developed by building trust and the reputation of the team through long-term engagement in a flexible, innovative and collaborative environment. Finally, through the process of co-development, the team ensures that research and operational activities are driven by national strategic priorities (Plan de Buen Vivir), increasing the likelihood that the public health sectors will utilize climate–health tools that allow decision-makers to more efficiently and effectively allocate resources for dengue control, saving lives and public resources.

### ACKNOWLEDGEMENTS



## INTEGRATED SURVEILLANCE

# EPIDEMIA: INTEGRATING CLIMATE INFORMATION AND DISEASE SURVEILLANCE FOR MALARIA EPIDEMIC FORECASTING IN ETHIOPIA

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### CONTEXT

Malaria epidemics can occur in highland areas of Ethiopia that support unstable transmission, such as the Amhara region. Forecasting the timing and locations of malaria epidemics can facilitate the targeting of resources for prevention, control and treatment. However, these forecasts must be accurate so that real outbreaks are not missed and resources are not wasted responding to predicted outbreaks that do not occur. Beginning in 2009, researchers from South Dakota State University (SDSU), in collaboration with the Health, Development and Anti-Malaria Association (HDAMA) the Amhara Regional Health Bureau (ARHB), and other partner organizations, have conducted research toward malaria early warning in the Ethiopian highlands. Through this work, climatic and landscape determinants of malaria have been identified (20,21). A key lesson learned from this initial research was the importance of linking early warning systems based on climate data from earth-observing satellites with early detection of malaria epidemics based on epidemiological surveillance to generate integrated forecasts (22,23). However, the potential for combining these approaches has been hindered by a dearth of established techniques and available tools. In response to this need, we have developed the Epidemic Prognosis Incorporating Disease and Environmental Monitoring for Integrated Assessment (EPIDEMIA) computer system (24).

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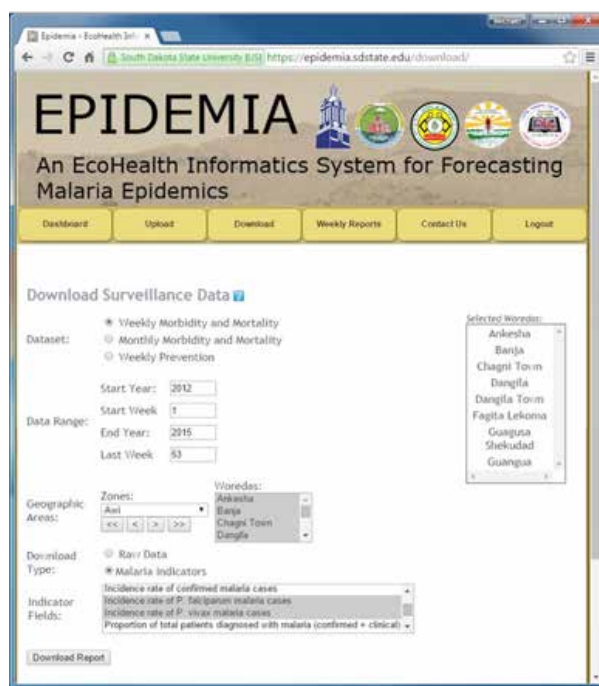
Risk Models and Maps

Forecasts

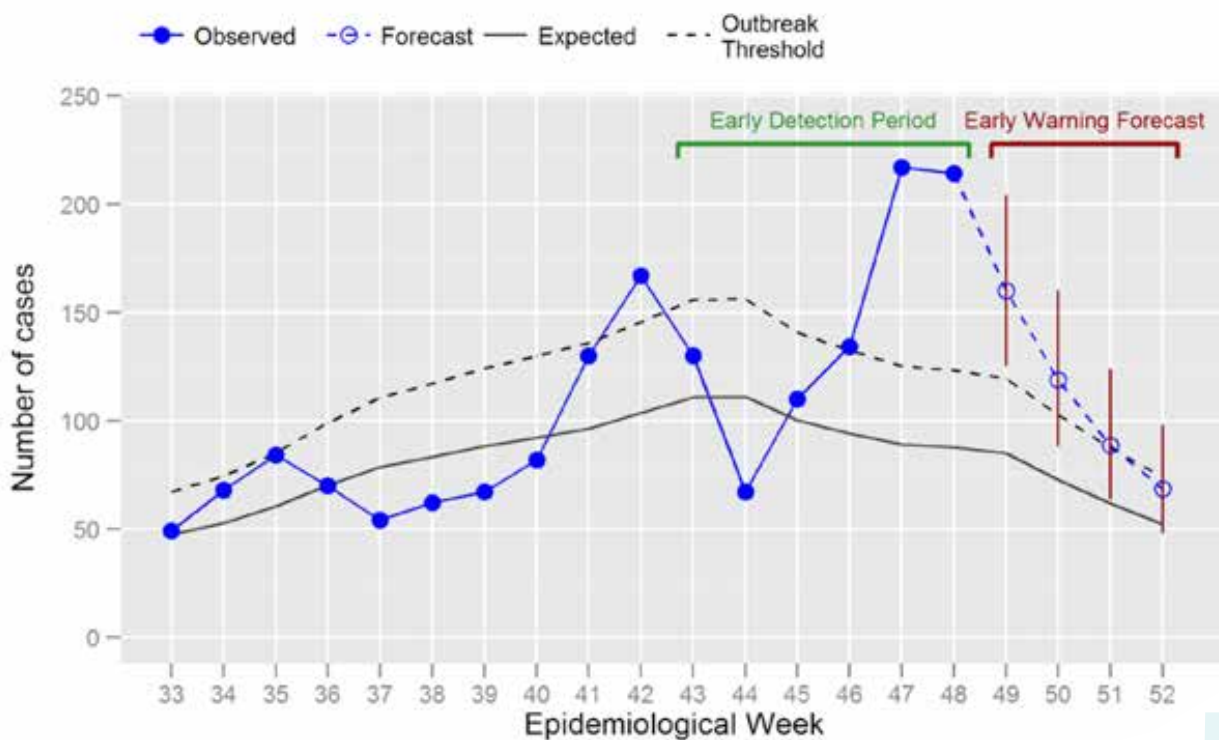
Warnings



Figure 5.7 EPIDEMIA public health interface and an example malaria forecasting chart from a weekly report.



### Epidemiological Week 48, 2015





## CASE STUDY 5.D



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Data Collection and Management

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Indicators and Thresholds

Risk Models and Maps

Forecasts

Warnings

### NEW APPROACHES

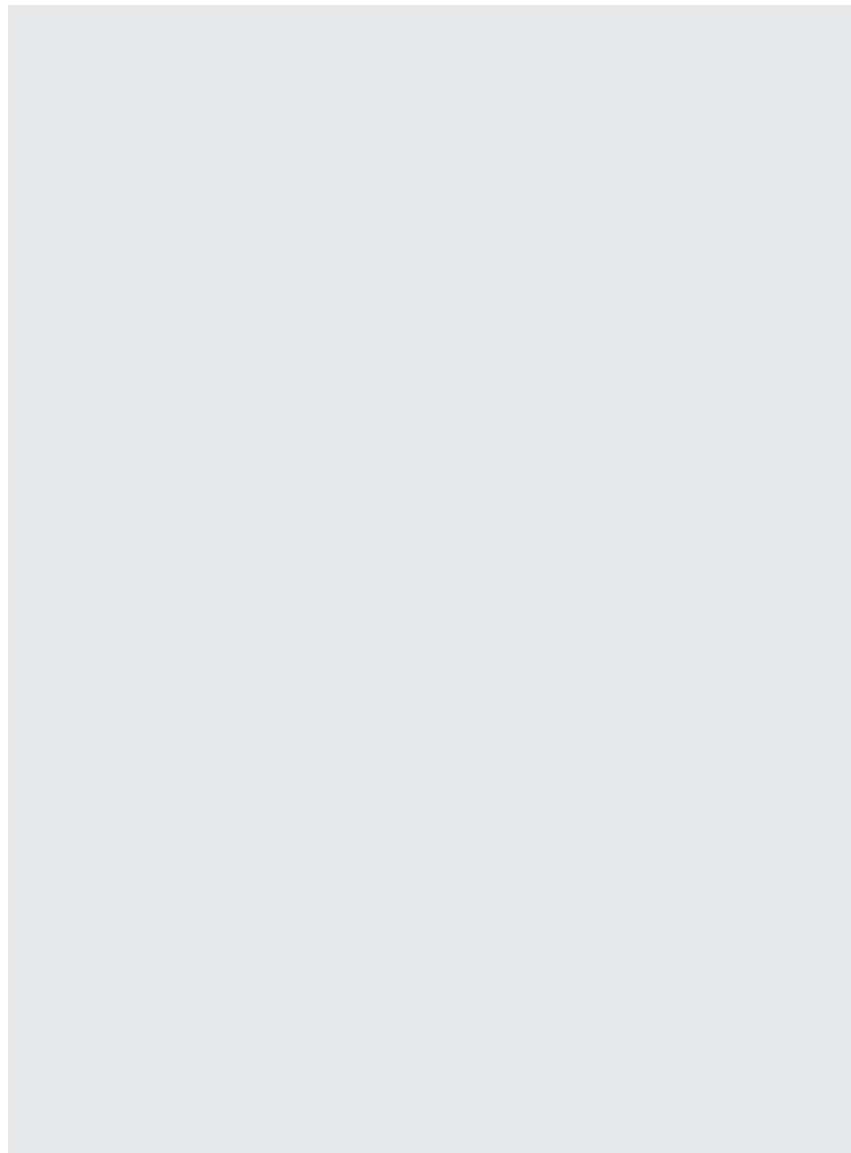
The main goal of EPIDEMIA is to enable forecasting and rapid detection of malaria epidemics by allowing scientists and practitioners to share relevant information in real time via a web-based data processing and modelling system with a user interface targeted to the specific needs of the public health community. The core of the EPIDEMIA system consists of environmental and epidemiological databases that are linked through a data integration sub-system. Surveillance data are uploaded through a public health user interface, and climate data are continually acquired from online earth science archives. A forecasting sub-system implements data assimilation methods that account for climatic anomalies as well as recent trends in malaria indicators. The public health interface supports interactive queries and dissemination of reports, maps, forecasts and epidemic alerts (Figure 5.7). Specific alert thresholds and indicators have been developed in collaboration with public health stakeholders. Accuracy of predictions is being evaluated continuously by validating forecasts with newly-acquired surveillance data, and system usability and adequacy of outputs for decision-making is being assessed through surveys and interviews of system users.

Weekly surveillance data on malaria morbidity and public health interventions are collected from district health facilities by the ARHB, and satellite remote sensing data provide climatic observations at relatively fine temporal resolutions (hourly to weekly) and moderate spatial resolutions (1–25 km). Specific products include rainfall data from the Tropical Rainfall Measuring Mission, temperature and vegetation indices from the MODIS sensor, and actual evapotranspiration modeled using a simplified surface energy balance approach. These environmental data are processed using the EASTWeb software application, which was developed to automatically acquire new data from online repositories. The data are used to fit dynamic linear models that provide outbreak detection thresholds and forecast malaria incidence for four weeks into the future.

An initial workshop was held in July 2014 to develop a design for the EPIDEMIA system, with participation by representatives of SDSU, ARHB, GAMBY, and HDAMA. The workshop included a formal requirements analysis to elucidate a list of baseline features for the public health interface, and a subsequent evaluation training and evaluation workshop was held in March 2015 after the the public health interface was implemented. The EPIDEMIA system began producing weekly forecasting reports in September 2015, and another workshop was held in February 2016 to obtain feedback on the malaria forecasts and alerts.

## ACKNOWLEDGEMENTS

This work is supported by Grant Number R01-AI079411 from the National Institute of Allergy and Infectious Diseases. We acknowledge the contributions of Ahmed Adem, Estifanos Bayabil, Belay Beyene, Michael DeVos, Geoffrey Henebry, Mastewal Lake, Alemayehu Lemma, Yi Liu, Christopher Merkord and Gabriel Senay toward designing and programming the EPIDEMIA system. For more information about the EPIDEMIA project, visit: <http://epidemia.sdstate.edu>



Placeholder for image



## BENEFITS AND LESSONS

We are currently testing the effectiveness of the EPIDEMIA system by implementing it across a network of 30 sentinel districts in the Amhara region. Local institutions of higher education are being engaged to facilitate transfer of knowledge and technology to the public health community in Ethiopia. This innovative translational bioinformatics approach allows assessment of the practical effectiveness of the tools as they are developed and use of feedback from the public health community to upgrade and improve the technologies throughout the project. Major benefits of the project have included the improvement of malaria outbreak detection and forecasting techniques, the development of new graphical techniques for presenting data and forecasts based on feedback from end users, and increased understanding among public health partners of the linkages between climatic variations and malaria outbreaks. Key lessons include the value of automated data processing and report generation tools to ensure that forecasts can be delivered in a timely manner, and the importance of accurately documenting user requirements to ensure that the data products and forecasts can be applied for public health decision support.

## INTEGRATED SURVEILLANCE

# THE BRAZILIAN OBSERVATORY OF CLIMATE AND HEALTH: EXPERIENCE OF ORGANIZING AND DISSEMINATING CLIMATE AND HEALTH INFORMATION IN MANAUS, AMAZON REGION

Authors: C. Barcellos, D. Xavier and V. Pascoal de Matos (Oswaldo Cruz Foundation (FIOCRUZ)).

### CONTEXT

Global environmental and climate changes have been increasing pace over recent decades, and may produce impacts on human health in various ways and intensities. Some of these changes have a direct impact on the health and well-being of the population, such as occurrences of extreme events (e.g. heat waves, hurricanes, storms and floods). However, most of the impacts are indirect and mediated by changes in the environment, such as changes to ecosystems, their biodiversity and their biogeochemical cycles (25). The groups of diseases that may be affected by environmental and climate changes include vector-borne diseases, respiratory and cardiovascular diseases, water-borne diseases and a variety of health problems affected by prolonged drought or floods, such as hunger, malnutrition and mental illness (26).

In view of the complexity of the processes that determine the impact of global environmental and climate change on health, it is essential to bring together and analyse data in such a way as to provide society, government agencies and the media with information on these changes. According to Vera et al (27), the main challenges for that purpose are: construction of partnerships between administrators, users and civil society and climate data producers; translation of long-term data into information a regional and local scales, in accordance with decision-making levels; maintenance of global climate observation systems; and procedures for integration, quality assessment, processing and analysis of relevant data for climate forecasting.

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## NEW APPROACHES

The objective of the Brazilian Observatory of Climate and Health ([www.climasaude.icict.fiocruz.br](http://www.climasaude.icict.fiocruz.br)) is to collect, organize and disseminate environmental, sociodemographic, climate, population and health data, with the aim of enabling the construction of indicators for monitoring the health-related effects of environmental and climate changes. Thematic workshops were held between 2009 and 2012 to define the data to be made available, the data sources and the integration strategies. In the workshops, a set of sentinel sites – settings where some local problems possibly affected by environmental and climate change were being studied – were selected based on the quality of data available, level of participation of local stakeholders (generally research institutions and civil society organizations) and the respective biomes of their location. These sentinel sites allow study of the temporal association between climatic variables and diseases, and act as ‘warning posts’ for changes in health conditions relating to climate.

Among the sentinel sites, Manaus, a large city in the Amazon region, was selected to monitor and analyse the associations between climate variables and water-related diseases.

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## CASE STUDY 5.E

### BENEFITS AND LESSONS

Climate and health indicators are made available by means of dynamic graphs, that allow users to raise hypotheses regarding seasonality, and long-time trends in association between variables. Users' requirements for information are transformed into data queries sent in real time to data producing sources (28). Studies carried out in sentinel sites such as Manaus focus on water-borne diseases (from the Health Informatics Department – DATASUS), land use (from the Institute of Space Research- INPE) and the water level in the Negro River (from the National Agency of Water Resources – ANA). They showed correlations between river water level, precipitation and disease incidence. A website was established to disseminate information in form of media news, scientific papers as well as online climate and health data ([www.climasaude.icict.fiocruz.br/manaus](http://www.climasaude.icict.fiocruz.br/manaus)). The diagram in Figure 5.8 shows the structure of the system.

Figure 5.8 Data loading model for sentinel sites.

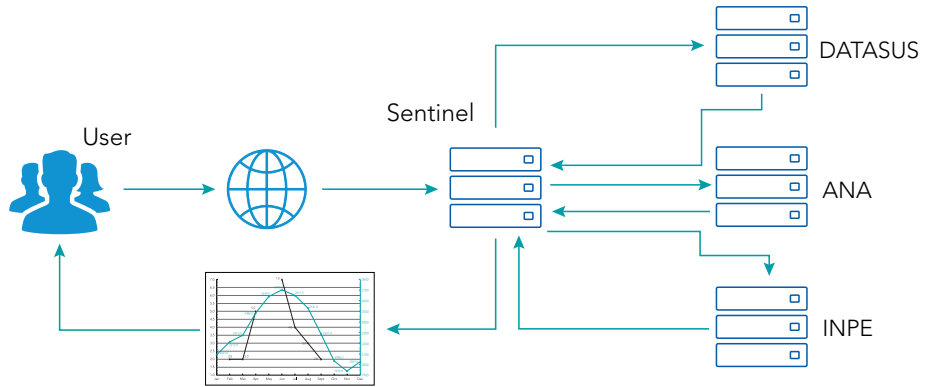
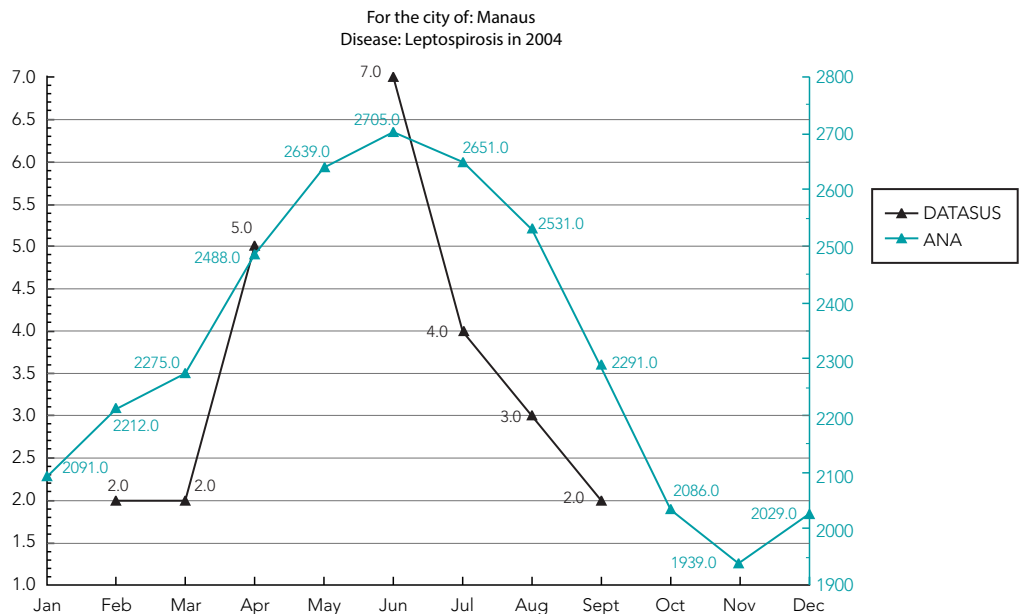
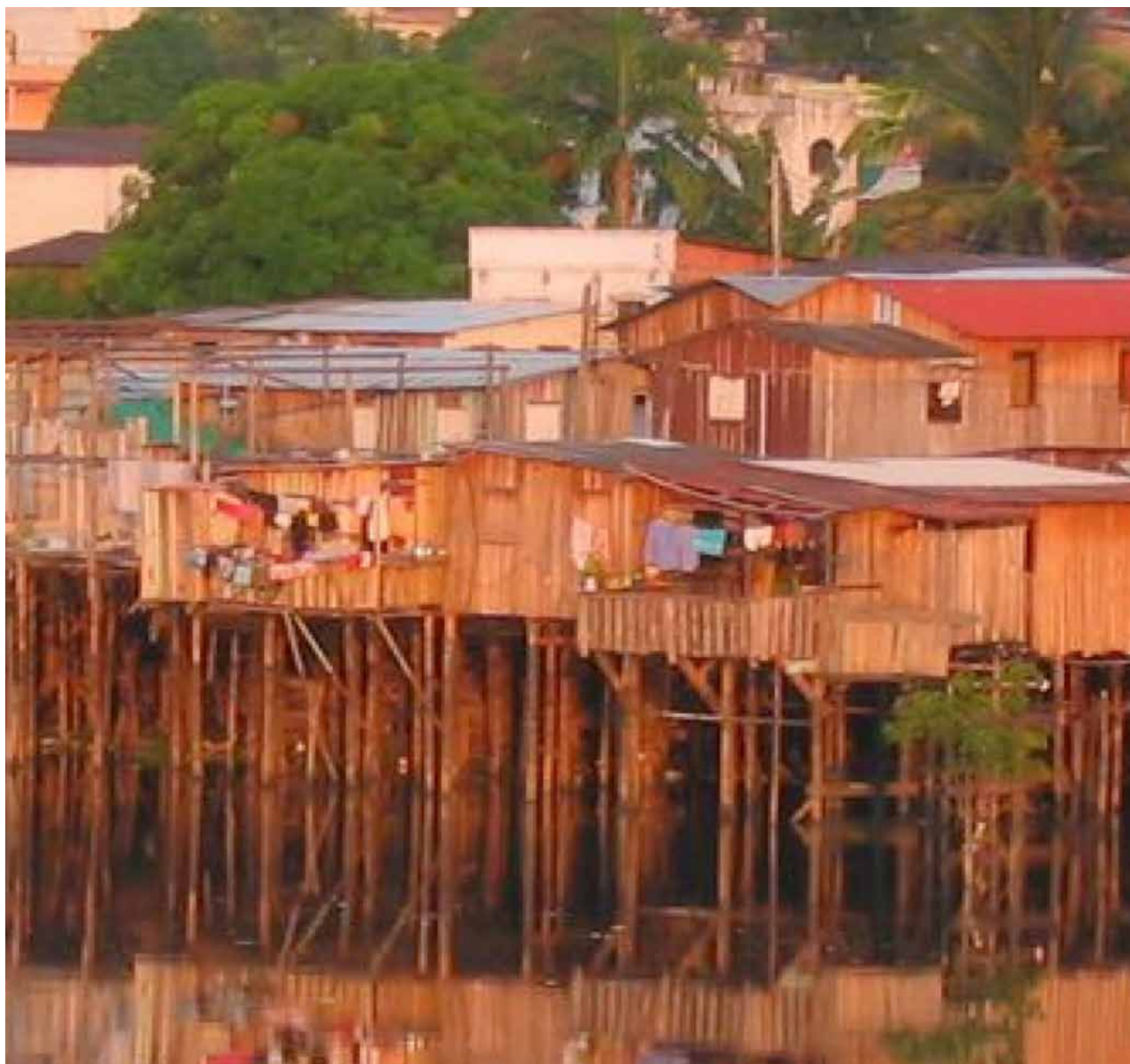


Figure 5.9 shows the graph resulting from a user query. It demonstrates the dynamics of the variables of the climate (i.e. level of the Negro River) and health (i.e. hospital admissions due to leptospirosis) over time. In the months of May to July, the river reaches its annual maximum level, which is immediately followed by an increase in the number of cases of leptospirosis.

Figure 5.9 Dynamic graph of river water level and leptospirosis incidence.



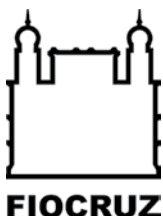
**Figure 5.10** Houses built on stilts (*palafitas*) along the Negro River (Manaus, Brazil).



The level of the Negro River is a strong regulator of the city's social and economic dynamics, a situation that the population has grown accustomed to (29). The persistence of low-cost traditional houses built on stilts, known locally as *palafitas* (Figure 5.10), demonstrates the local population's capacity to adapt to river level variations, provided they occur within a range that does not compromise the functioning of the transportation, water supply, food supply and sewage systems.

Greater variations, in extreme drought and extreme flooding, such as those occurring in the years 2005, 2009, 2012 and 2014, may cause these systems to collapse, increasing the risk for disease transmission. These events have been occurring with greater frequency over the past two decades, providing evidence of the increasing health risk. Adaptation is an urgent priority involving health, urban planning and environmental sectors. One of the recent measures taken was the establishment of a minimum altitude for the construction of residences and sanitation systems, which must now be built above the observed river peak levels.

#### ACKNOWLEDGEMENTS





## INDICATORS

# CLIMATE-SPECIFIC POLLEN INDICATORS AND POPULATION EXPOSURE MONITORING TOOLS TO BETTER MANAGE THE ALLERGY SEASON IN HUNGARY

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### CONTEXT

The 4th Assessment Report of IPCC (30) states that climate change has caused an earlier onset of the spring pollen season in the northern hemisphere. It is reasonable to conclude that allergenic diseases caused by pollen, such as allergic rhinitis, have experienced some concomitant change in seasonality. There is limited evidence that the length of the pollen season has also increased for some species. Furthermore the EU Strategy on adaptation to climate change (31) highlights that climate change might potentially increase the seasonality and duration of allergic disorders such as hay fever or asthma with implications for direct costs in terms of care and medicines, as well as lost working hours. The 5th Assessment Report of IPCC (32) stated that warmer conditions generally favour the production and release of airborne allergens. Progressively increasing temperatures may modify the global pollen load (33). Adaptation measures identified to date include aeroallergen monitoring and forecasting. Therefore it is of high importance to evaluate the pollen exposure of populations living in different geographical and climatic regions in order to adjust information and adaptive measures.

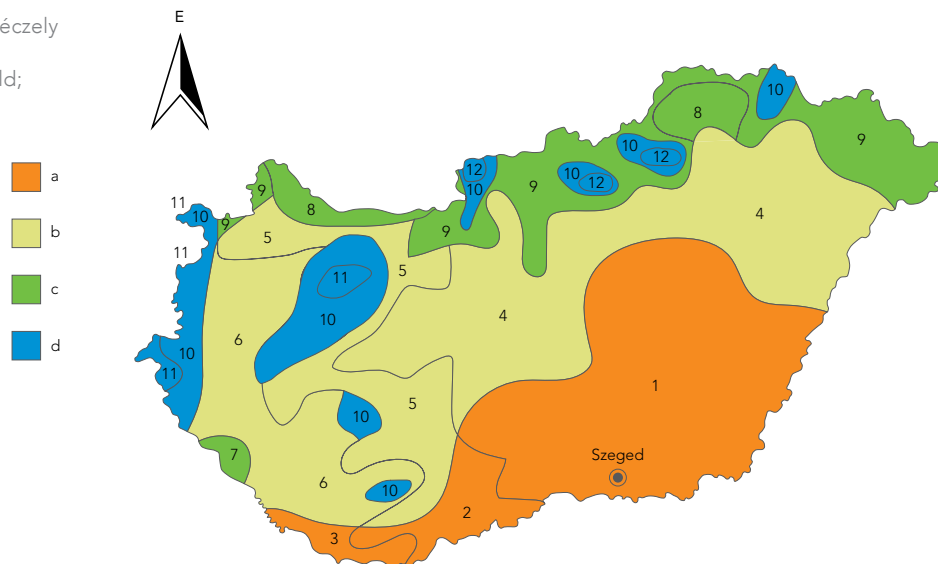
### NEW APPROACHES

The WHO European Centre for Environment and Health (WHO/ECEH), with the contribution of Member States, has developed climate-related indicators as part of the CEHAPIS project.<sup>a</sup> Four allergen plants were selected as indicators: alder (*Alnus* sp.); birch (*Betula* sp.); grasses (*Poaceae* sp.); ragweed (*Ambrosia* sp.). These provoke high sensitization rates, have fairly broad geographical and temporal coverage in the European flowering season (i.e. spring to autumn). The indicator set is based on daily airborne pollen emission measurements in continuous volumetric samplers (e.g. Hirst type, Burkard) with standard methods. Use of data from existing monitoring stations, located in different climatic regions of a given country is recommended. Each climatic zone needs to be characterized with a sufficient number of stations placed in populated areas. The number of inhabitants living in a radius of 10–30 km of the monitoring stations should be noted for weighting purposes.

<sup>a</sup> Climate Change, Environment and Health Action Plan and Information System (CEHAPIS) is co-funded by EC DG Sanco SPC 2007/WHO03.



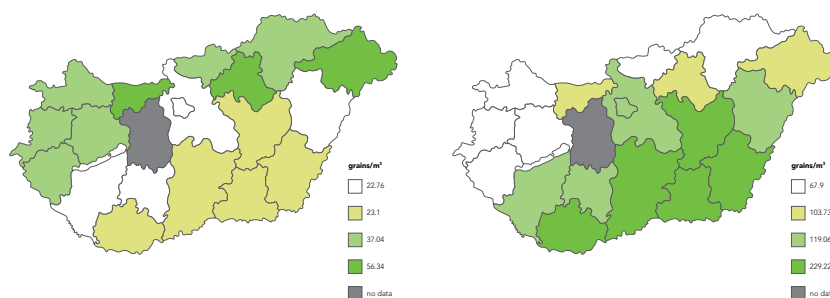
**Figure 5.11** Climatic regions by Péczely (26) in Hungary: (a: warm and dry; b: moderate warm; c: moderate cold; d: cold and wet).



A software tool has been elaborated with the contribution of the National Institute of Environmental Health (NIEH) Hungary (34). The software enables calculation of the start and end, duration (days), severity of the pollen period (annual sum and daily maximum of pollen grains (grains/m<sup>3</sup>) of the current and previous pollen seasons. To characterize the exposure further, population-weighted indicators can be computed: (i) proportion of days (%) with allergenic concentration of pollen ( $\geq 30$  grains/m<sup>3</sup>); (ii) average exposure to the pollen (gr/m<sup>3</sup>); (iii) duration of the pollen season (days).

The software was tested using ragweed pollen data for the period of 2000–2013 of the Hungarian Aerobiological Network run by the National Institute of Environmental Health. The meteorological data were provided by the Hungarian Meteorological Service. Figure 5.11 shows the climatic regions within Hungary (35); Figure 5.12 displays the effect of weather variability on the population-weighted pollen exposure.

**Figure 5.12** Ragweed: Population-weighted average pollen concentration (grains/m<sup>3</sup>). Left: extreme dry summer 2007. Right: extreme wet summer 2010.



## ACKNOWLEDGEMENTS



## BENEFITS AND LESSONS

The software is used by the National Public Health Center (NPHC, formerly NIEH). The results are communicated for the health care system, especially to the allergologists and general practitioners, to help adjust health care for allergenic patients in the short and long term. The results can be used by the agricultural sector to optimize summer weed (especially ragweed) eradication programmes to reduce exposure. The NPHC plans to disseminate the software at the international level, and to make it freely downloadable from its website.



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## RISK MAPPING AND MONITORING

# MALACLIM: CLIMATE-BASED SUITABILITY MAPPING TO INFORM VECTOR CONTROL PROGRAMMES IN THE SOLOMON ISLANDS

Authors: L. Tahani (Solomon Islands Meteorological Services (SIMS), A. Bobogare (National Vector Borne Diseases Control Program (NVBDCP)), J. Smith, S. McGree and G. Beard, A. Amjadali and I. Jeanne (Australian Aid (DFAT) and the Australian Bureau of Meteorology).

### CONTEXT

More than 90% of people in three south-western Pacific countries still live in malaria high-incidence areas (36), despite an improvement of malaria programmes and a huge decrease of the overall number of malaria cases. Solomon Islands and Vanuatu are on the way to eliminating malaria in some of their less populated provinces, but malaria reductions in some high-incidence areas have stalled. One of the major challenges to reaching the next step is the lack of timely access to quality health care (37).

### NEW APPROACHES

A climate-based malaria monitoring and early warning system (MalaClim) is being developed in the Solomon Islands. In September 2014, a pilot season was launched with the release of malaria suitability maps to account for environmental factors and a rainfall-based malaria outlook for the next malaria season.

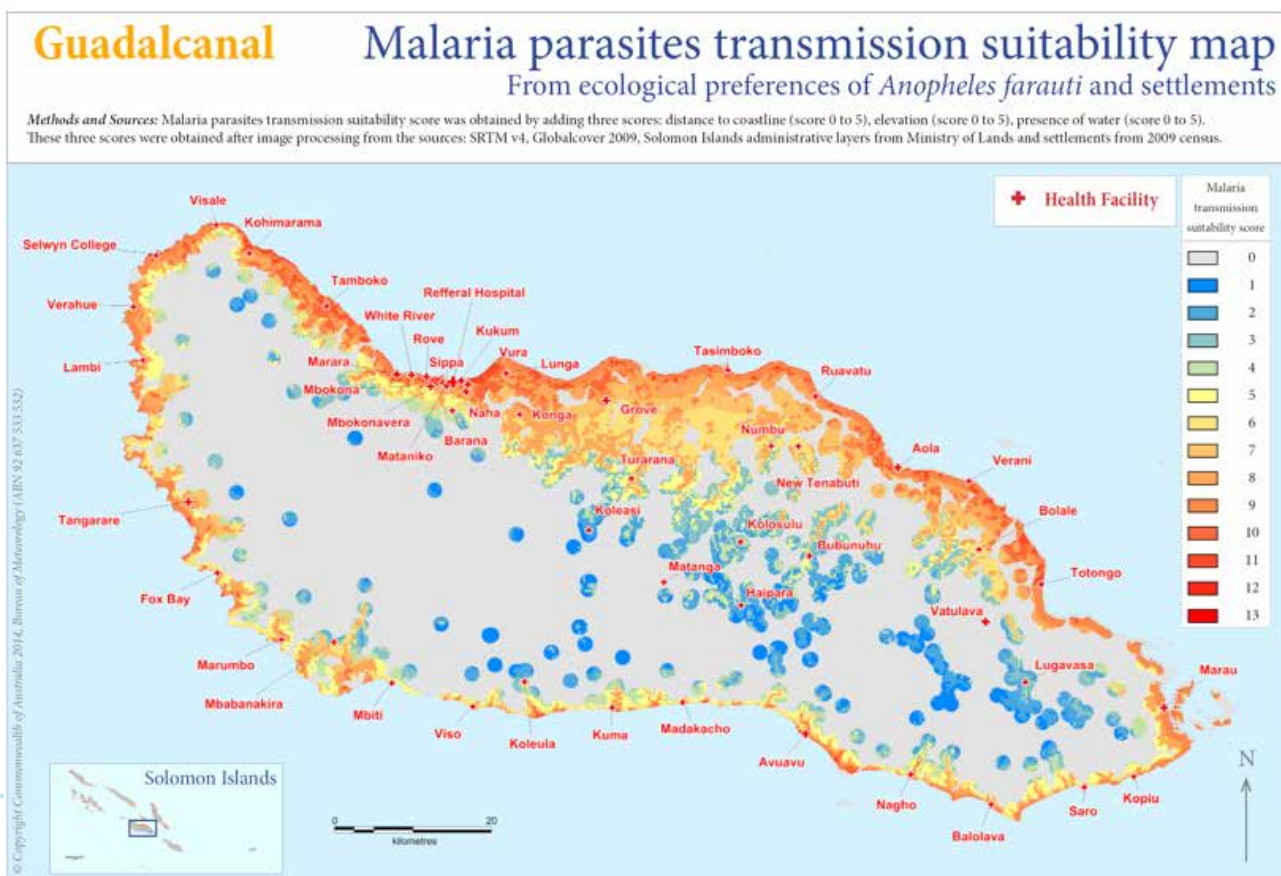
The MalaClim project is part of the Climate and Oceans Support Program in the Pacific (COSPPac), a programme funded by Australian Aid) and run by the Australian Bureau of Meteorology in partnership with several Solomon Islands Government Ministries.

The malaria suitability maps help to refine vector control strategies by identifying target areas such as dense clusters and patchy areas that need to be managed differently. These maps are developed through analysis of the location of human settlements and the ecological preferences of the main remaining mosquito vector (*Anopheles farauti*). Found in creeks or swamps, this very adaptive mosquito (38) tends to stay in coastal regions and at low elevation. From previous entomological studies (39) of these characteristics and thanks to GIS, remote sensing, image processing and spatial analysis, an environment risk score has been established and mapped for all nine provinces where malaria parasites may be transmitted.

The year-to-year and seasonal variability of rainfall significantly influences the availability of mosquito breeding habitats. Each year, a peak in the number of cases of malaria occurs 1–2 months after the beginning of the rainy season. However, during El Nino years, which are typically drier than normal (40), the average number of detected malaria cases is higher. During this project a strong relationship was confirmed between low rainfall in October, November and December (OND) and a high malaria incidence for the following period January to June for some parts of the country. This has allowed the Solomon Islands Meteorological Services (SIMS) to provide monthly a customized OND rainfall outlook for the malaria control service, the National Vector Borne Disease Control Program (NVBDPC).

Knowing whether the OND rainfall will reach a key threshold allows for early preparedness up to four months before the beginning of the malaria season. Updated monthly rainfall outlooks, supplemented by observations, also then allow for adjustments to be made to these actions as the malaria outlook becomes clearer. These actions can include: community awareness, diagnostics and treatments tools allocations, vector control measures spreading.

**Figure 5.13** Malaria parasite transmission suitability map based on the ecological preferences of the main mosquito vector and the location of human settlements.



## CASE STUDY 5.G

**Figure 5.14** Health clinic in Guadalcanal - Pregnant women and children less than five are still the population most affected by malaria.



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**Figure 5.15** Typical breeding site in northern Guadalcanal where the links between rainfall and malaria are strong enough to have allowed the creation of a malaria early warning system based on rainfall outlooks.



## ACKNOWLEDGEMENTS



Australian Government  
Department of Foreign Affairs and Trade  
Bureau of Meteorology

## BENEFITS AND LESSONS

This project could not have been implemented so quickly without the strong partnership with the NVBDCP and the SIMS. In addition to the challenges presented by the lack of human and material resources in health centres, the lack of weather stations also poses a constraint. However, since the start of the project, meteorological and malaria services have worked together to begin installation of 16 new rain gauges located next to health centres in the project areas.

Following the pilot phase, the MalaClim Early Warning System was officially launched in November 2015. The SIMS provides a customized monthly rainfall outlook for the Malaria authority, and regular meetings are conducted between SIMS and NVBDCP. The parasite transmission suitability maps and GIS for all the 9 provinces was very successful and monthly rainfall outlooks for northern Guadalcanal and Central province was issued. The next step should be to analyse the malaria seasonal variability for the other parts of the Solomon Islands, where climate and environment impacts on malaria transmission are more complex and require a better understanding of other parameters in addition to rainfall.

## RISK MAPPING AND MONITORING

# MAPPING AND MODELLING PLAGUE IN UGANDA TO IMPROVE HEALTH OUTCOMES

Authors: L M. Hayden, A. Monaghan (National Center for Atmospheric Research, Boulder, CO, USA); T. Apangu, S. Acayo, Rogers Acidri, L. Atiku, J. Mpanga (Uganda Virus Research Institute, Entebbe, Uganda); K. Griffith, P. Mead, C. Beard, J. Borchert, K. Boegler, E. Zielinski-Gutierrez, K. MacMillan, R. Enscoe, K. Gage, R. Eisen, (Division of Vector-Borne Diseases, Centers for Disease Control and Prevention, Fort Collins, CO, USA)

### CONTEXT

The West Nile region in northwestern Uganda is a focal point for human plague, which peaks in boreal autumn and is spread by fleas that infest rodent hosts (41,42). The U.S. Centers for Disease Control and Prevention (CDC) is partnering with the National Center for Atmospheric Research (NCAR) to quantitatively address the linkages between climate and human plague risk in this region.

### NEW APPROACHES

The primary aim of the research is to advance knowledge of the climatic conditions that may be required to maintain enzootic cycles and to trigger epizootic cycles that lead to human plague cases, and ultimately, to target limited surveillance, prevention and control resources. Because in-situ meteorological records are sparse, a hybrid dynamic–statistical meteorological down-scaling technique was applied to generate a multi-year high spatial resolution climate dataset based on NCAR’s Weather Research and Forecasting Model (43). The dataset was subsequently employed to develop a spatial risk model for human plague occurrence in the West Nile region above 1300 metres (44) that improved upon a previous model (45) developed before validated meteorological data were available for the region. The revised risk model revealed robust positive associations with rainfall at the ends of the rainy season and negative associations with rainfall during a dry spell each summer. A temporal risk model for human plague was also developed for the region with an ensemble-based approach using numerous model-based and remotely-sensed temperature and precipitation records (Figure. 5.16)(45). As with the spatial model results, the temporal model indicates that rainfall is the key driver of year-to-year plague incidence. Ensemble modelling, commonly used in meteorology to predict weather, also worked well in this instance, allowing characterization of uncertainty and, when averaged, providing a robust simulation of year-to-year plague variability. Additional predictive models are being developed that may aid in targeting resources for animal-based surveillance during periods that pose the greatest risk for human plague transmission.

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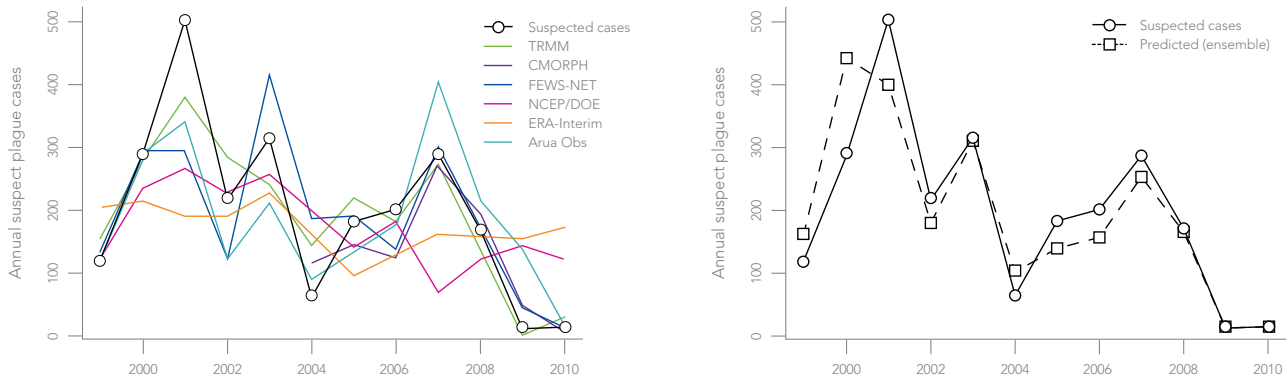
Research

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Application

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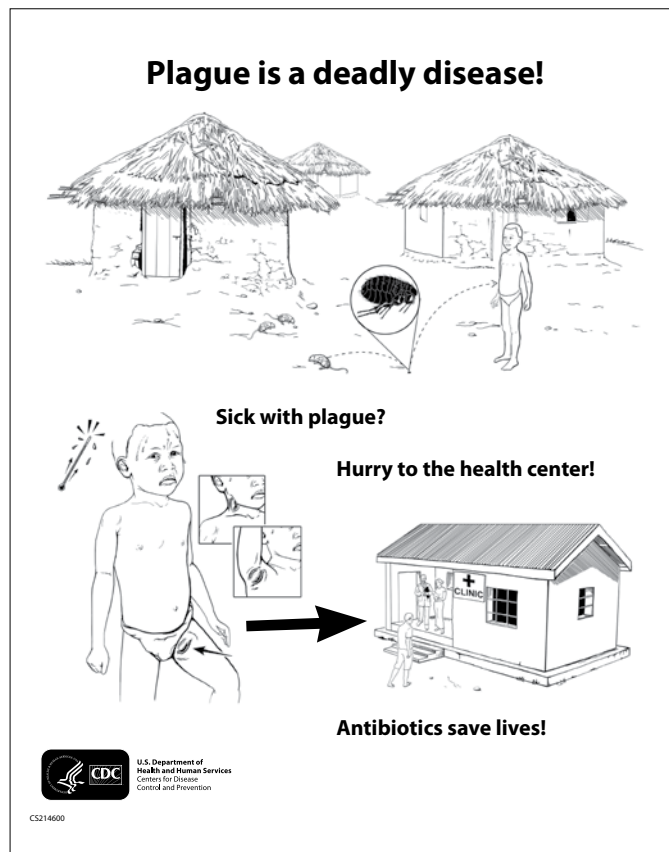
**Figure 5.16** Left Panel: Modelled (color) and observed (black) annual human plague cases in West Nile, Uganda from 1999–2010. Right Panel: Ensemble model average (dotted) and observed (black) annual human plague cases.



### BENEFITS AND LESSONS

Enhancing surveillance for plague to improve health outcomes is also an objective of the partnership. Therefore, CDC and NCAR undertook a unique pilot programme to enroll and train traditional healers in the regions of West Nile above 1300 metres that, compared to surrounding areas, have cooler and wetter climatic conditions that are associated with elevated risk for plague transmission. Healers were trained to recognize and refer plague patients to local health clinics in support of a broader active plague surveillance programme in collaboration with the Uganda Virus Research Institute (Figure 5.17). The programme is in its seventh year and has 45 healers in the referral network. Feedback from community officials indicates the programme has led to hundreds of referrals. A lesson learned is the need to regularly engage the healers in order to update training and reinforce their important role in strengthening public health in the West Nile region of Uganda.

**Figure 5.17** Poster addressing plague in Uganda, jointly developed by CDC and NCAR.



### ACKNOWLEDGEMENTS





RISK FORECASTS

# FORECASTING WILDLAND FIRE SMOKE HAZARDS IN URBAN AND RURAL AREAS IN MANITOBA, CANADA

Authors: J. Paterson (Multilateral Affairs Division, Environment and Climate Change Canada) and P. Berry (Climate Change and Health Division, Health Canada), B. Crumb and D. Oshanski (Office of Disaster Management, Manitoba Health) D. Henderson (Health and Air Quality Forecast Services, Environment and Climate Change Canada).

CONTEXT

Air quality is a significant public health issue in many Canadian communities and will be impacted by wildland fires that are expected to increase with climate change (46). Wildland fires are a common occurrence across Canada where forests cover more than 50% of the country's landmass. In a changing climate, increases of between 75% and 140% in the number of fires have been projected by the end of the 21st century, with significant regional variation (47). Figure 5.18 shows the change in forest fire severity levels projected across Canada from 2050 to 2059, based on second-generation global circulation models.

Exposure to smoke from wildland fires can have direct and indirect impacts on health (Table 5.1). Some individuals are more vulnerable, such as children, seniors, people with pre-existing heart or lung conditions and people geographically, culturally or socially isolated (48).

Table 5.1 Direct and indirect health impacts from wildland fires (Adapted from 49 and 50)

DIRECT IMPACTS	<p><b>Respiratory effects</b></p> <ul style="list-style-type: none"> <li>Asthma exacerbations</li> <li>New cases of asthma or respiratory disease</li> <li>Respiratory symptoms and deteriorating lung function</li> <li>Dyspnoea, cough, chest tightness, wheeze and sputum production</li> <li>Chronic respiratory issues</li> </ul> <p><b>Cardiovascular effects</b></p> <ul style="list-style-type: none"> <li>Heart disease</li> <li>Cardiovascular mortality/ cardiac failure</li> <li>Dehydration</li> </ul>	<p><b>Burns</b></p> <ul style="list-style-type: none"> <li>Direct burns</li> <li>Burn-related casualties</li> <li>Organ failure</li> <li>Inhalational burns</li> </ul> <p><b>Heat induced illness</b></p> <ul style="list-style-type: none"> <li>Heat stroke, heat exhaustion</li> <li>Cardiovascular mortality</li> </ul> <p><b>Ophthalmic effects</b></p> <ul style="list-style-type: none"> <li>Eye irritation</li> <li>Reduced visibility</li> <li>Corneal abrasions</li> </ul>	<p><b>Psychological effects</b></p> <ul style="list-style-type: none"> <li>Anxiety</li> <li>Mental exhaustion</li> <li>Stress from lives lost and impacts to livelihoods, homes and communities</li> <li>Depression (including major)</li> <li>Post traumatic stress disorder</li> <li>Somatisation</li> <li>Hostility</li> <li>Paranoia</li> <li>Chronic psychiatric morbidity</li> <li>Paediatric psychological morbidity</li> </ul>
	<p><b>INDIRECT IMPACTS</b></p> <ul style="list-style-type: none"> <li>Trauma during evacuations</li> <li>Increased demand on health services</li> <li>Inability of patients with chronic health conditions to access health care facilities</li> <li>Diseases associated with water and land pollution</li> </ul>		

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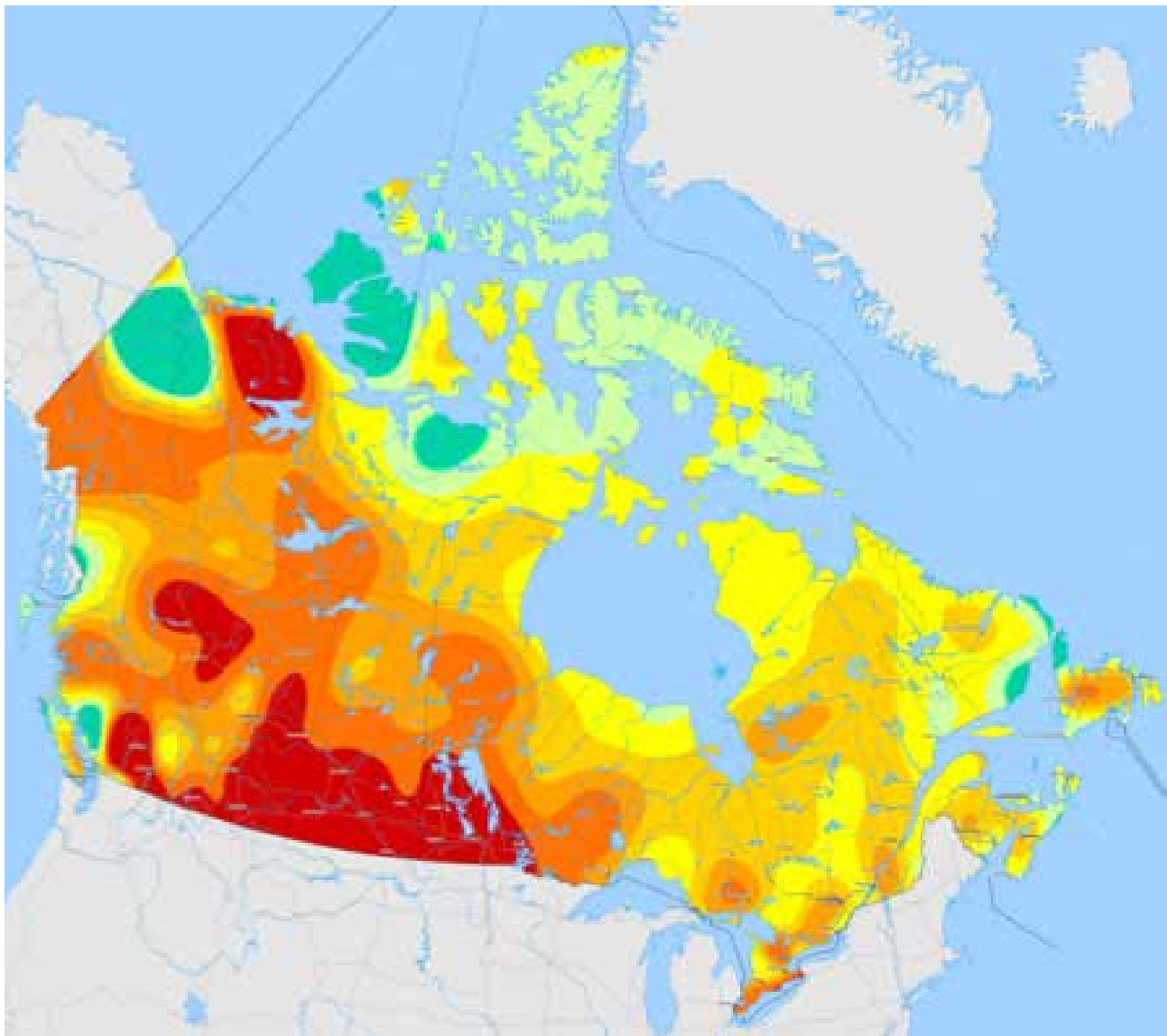
Integrated Surveillance

Indicators and Thresholds

Risk Models and Maps

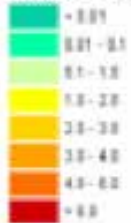
Forecasts

**Figure 5.18** Change in forest fire severity levels across Canada from 2050 to 2059, based on second-generation global circulation models. The seasonal severity rating (SSR) is a measure of fire danger conditions over a complete fire season.



Lambert Conformal Conic Projection, Standard Parallels 49°N and 77°N

**Seasonal Severity Ratings for Forest Fires, 2050-2059**



**Populated Places**

- 1-4 399
- + 5 000 - 49 999
- 50 000 - 99 999
- 100 000 and greater
- ⊙ Provincial and Territorial Capital
- ★ National Capital

**Boundaries**

- ∩ International
- ∩ Provincial / Territorial
- ∩ EEZ (200 miles)
- ∩ Canada / Northwest-Northeast dividing line

**Road network**

- ∩ Road network
- ∩ Ferry route

## CASE STUDY 5.1

### NEW APPROACHES

In Manitoba, wildland fires and extreme weather events already place significant pressures on health and emergency management systems that may be further compromised by climate change (51). The Office of Disaster Management (ODM) within the Manitoba Department of Health is reducing health risks from wildland fires by using a suite of tools to forecast, monitor and communicate risks from wildland fire smoke to partners and the public. The suite of tools includes field-deployable smoke monitors (DustTrak), communications hardware (Thamis), and a map-centric web-based application or 'Common Operating Picture' (COP). These tools provide information on the location and concentration of wildland fire smoke on an hour-by-hour basis up to 48 hours into the future (Figure 5.19). The ODM has been working with Environment and Climate Change Canada and other partners to validate the forecasting system. The DustTrak air quality monitors are pre-positioned across the province and are used to identify smoke hazard risks in populated areas during wildland fires. Using a cellular network, smoke particulate levels picked up from monitors are displayed on the COP to provide health decision-makers with remote, real-time access to air pollutant data.

The COP is built using web-based GIS technologies that provide a graphical yet spatially accurate view of both real-time and forecasted wildfire information. In addition to smoke specific data, many other layers of information can be displayed such as fire boundaries, the location of health care facilities, highway conditions, and administrative boundaries. Decision-makers have been trained to use the COP to implement effective and targeted public health and emergency management measures (e.g. evacuations).

Climate forecasting and wildland fire monitoring data are being used by ODM to reduce risks to health. ODM is determining if the Air Quality Health Index (AQHI), an air quality communications and forecasting system, is an appropriate mechanism to communicate health risks from wildland fire smoke. The AQHI is used in many communities in Canada to provide information on short-term health risks posed by air pollution (52). In Manitoba, the AQHI is currently available in urban areas but not readily available in rural settings where wildland fires are a major contributor to adverse air quality changes. Until the AQHI is developed for use in rural areas, forecasts from deterministic models which account for the emissions and transport of particulate matter will be relied upon to project wildland fire smoke health risks. As of 2015, ODM assessed two such systems: the FireWork forecasting system (53), based on a comprehensive air quality model and operated by Environment and Climate Change Canada as part of its air quality program, and the BlueSky Canada wildfire smoke forecasting system, based on a sophisticated dispersion model and operated by the University of British Columbia as part of a collaboration with various Canadian provincial and federal partners (54). Efforts are being made by the Manitoba Department of Health to develop specific smoke event health messaging for vulnerable groups. Research is also underway to understand the health impacts of smoke events occurring at the same time as extreme heat episodes. If sufficient evidence of risk exists, health messaging for combined health risks of smoke and heat will be developed. Collectively, these tools will help decision-makers target adaptation efforts towards vulnerable individuals and communities (e.g. aboriginal and First Nations) and enhance capabilities for effective risk management and decision making.

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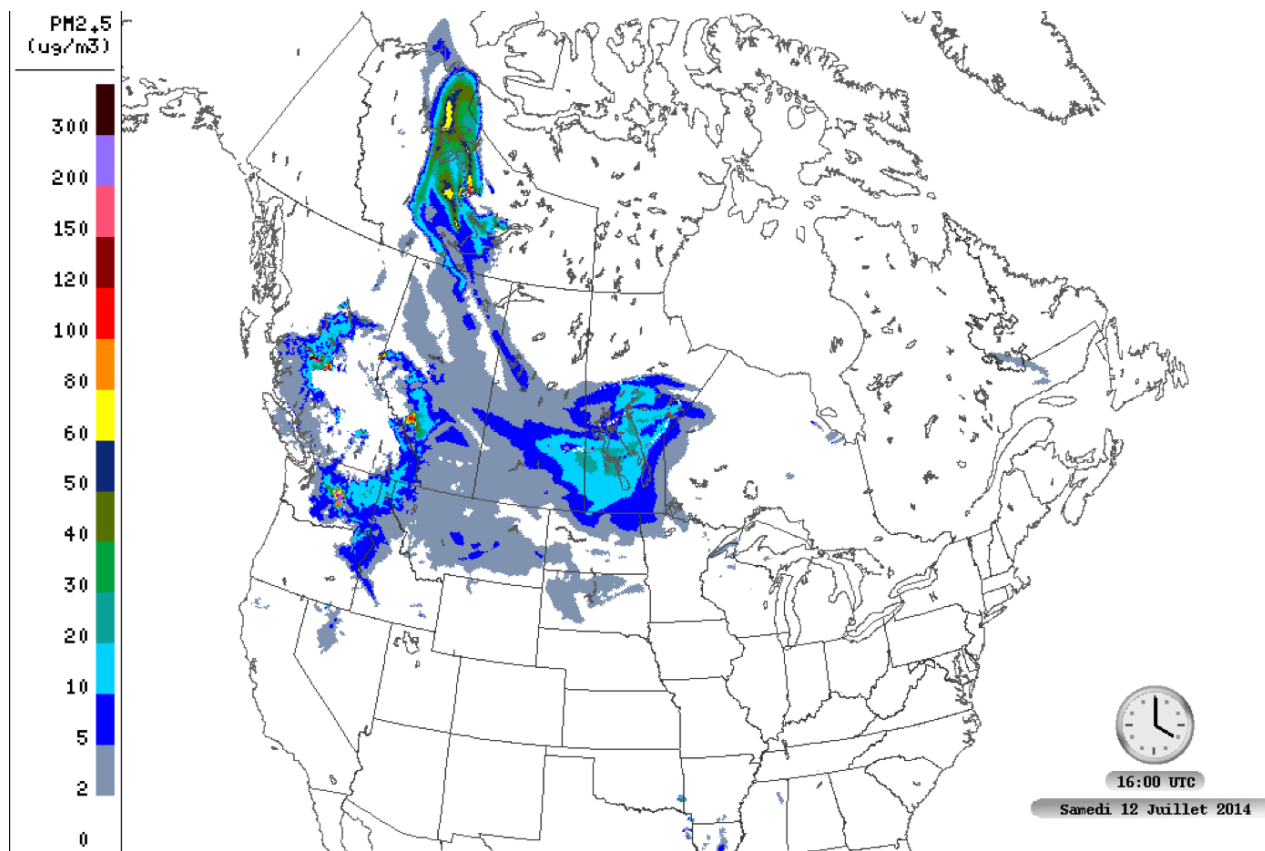
Integrated Surveillance

Indicators and Thresholds

Risk Models and Maps

Forecasts

**Figure 5.19** Sample Firework output of wildfire emission contributions to total forecasted PM2.5 ( $\mu\text{g}/\text{m}^3$ ) in Western Canada on July 12th 2014. Environment and Climate Change Canada, 2014.



### BENEFITS AND LESSONS

The BlueSky and Firework forecasting systems assist ODM officials alert health services and the public of wildland fire smoke risks, inform emergency management actions (e.g. evacuations), and identify and address confirmed risks of smoke and heat exposure. Its operation and testing has demonstrated the need for real-time air quality data to validate predictive models and to combine multiple layers of data into one common view (e.g. COP) to support decision-making. Continued implementation of this system is expected to reduce health risks to Manitobans from wildland fire smoke events.

### ACKNOWLEDGEMENTS



Environment and  
Climate Change Canada



## RISK FORECASTS

# FORECASTING MALARIA TRANSMISSION: FINDING THE BASIS FOR MAKING DISTRICT-SCALE PREDICTIONS IN UGANDA

Authors: A.M. Tompkins (Abdus Salam International Centre for Theoretical Physics, Italy) F. Di Giuseppe (European Centre for Medium Range Weather Forecasts, UK), F.J.Colón-González (Abdus Salam International Centre for Theoretical Physics, Italy), D.B. Namanya (Uganda Ministry of Health, Uganda).

### CONTEXT

Despite a global contraction in range over the past century (55), malaria still imposes a significant health and socioeconomic burden in over 100 countries (56). Every year about 10 million cases and 43 000 deaths occur in Uganda (57), which ranks third for malaria-related mortality in Africa (57). Nearly 50% of all outpatient visits and 35% of hospital admission are malaria-related (58). Malaria is a climate-sensitive disease as some of its key cycles are influenced by temperature and rainfall. Temperature steers several mosquito and parasite traits (development rates, survival and mosquito biting rate) that ultimately determine transmission intensity (59). Rainfall regulates the production of mosquito breeding sites (60). Since monthly and seasonal dynamic climate prediction systems have significantly improved their capability in the tropics over recent years, there is potential to use such forecasts to drive malaria models to provide early warnings of climate-related malaria transmission anomalies several months in advance. These malaria early warning systems (MEWS) would enable decisions concerning human and material resources mobilization to be made in advance, in particular regarding areas of high interannual variability in transmission (epidemic zones).

### NEW APPROACHES

A pilot dynamic malaria prediction system was developed driving the International Centre for Theoretical Physics (ICTP) dynamic malaria model (61) with the operational weather forecast system of the European Centre for Medium-Range Weather Forecasts (ECMWF) up to four months in advance. Temperature and precipitation forecasts were computed using ECMWF prediction systems. The fine spatial scale used allowed predictions to be made at the health district level. The entomological inoculation rate (EIR) was predicted, the logarithm of which is approximately correlated to malaria incidence (62). Malaria forecasts were evaluated over a period of approximately one decade against normalized laboratory confirmed cases obtained from six sentinel sites, and against malaria incidence obtained from the national epidemiological surveillance system.

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**Fig. 5.20** Geographical areas where the MEWS shows skilful predictions four months ahead. Green shaded areas indicate significant correlation between observed malaria incidence and the malaria forecasts four months ahead.

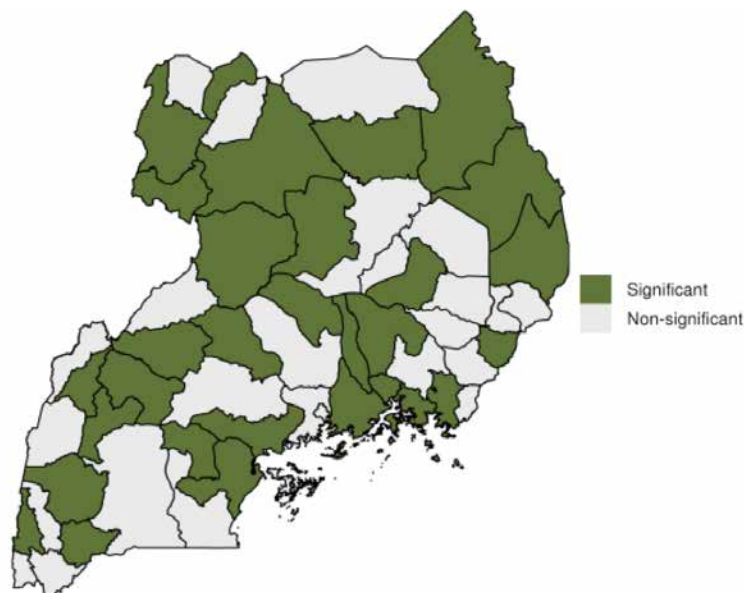


Figure 5.20 presents the areas where the malaria forecasts were skilful (in green) four months ahead, as evaluated against monitored malaria incidence. Statistically significant correlations (Spearman rho range: 0.3 - 0.8) were observed in areas considered of 'very low' and 'low' transmission such as Kanungu, Kabarole, Ntungamo and Mbale, as well as in 'medium-high' and 'very high' transmission areas (e.g. Arua, Moroto, Kotido, and Nakasongola). Areas showing significant correlations contain about 51% of the country's population.

#### BENEFITS AND LESSONS

The results demonstrate potential for skilful malaria predictions up to four months ahead over wide areas of Uganda, a country characterized by highly variable malaria transmission. We show, for the first time, that climate forecasts may usefully extend the early warning available from environmental monitoring across large geographical areas and at the health district scale. They reaffirm the potential importance of accurate climate information for enhancing public health actions. The next stage, currently underway, involves the close collaboration of ICTP, ECMWF with the Ministry of Health to determine the best way to feed information into decision-making processes and policy. Clear and simple metrics will need to be developed, and training given, so that the uncertainty of the system is appreciated by users in the malaria control division. To aid this process, a simple cost-loss analysis of the system is presently being undertaken, using simulated and real cost-loss data for Africa based on the cost-loss ratio methodology developed by Richardson (2000) (63) for estimating the economic value of meteorological forecasts.

Despite considerable evidence that climate information could increase advance warnings, MEWS based on climate monitoring or forecasting have not been widely adopted in operational environments to assist planning anywhere in Africa. Decisions concerning drug distribution and interventions are still mostly based on long-term mean malaria prevalence maps. One obstacle seems to be the unfamiliarity with the operational paradigm of using climate information to predict outbreaks in advance and the complexity of accounting for forecast uncertainty compared to the relative certainty of health surveillance. Integrating climate forecast information into the decision-making process will require extensive and long-term interaction between health ministries and research institutes to ensure the forecast information is provided in a format that is understandable and that end-users are conversant with the uncertainties involved. In preparation for this, the use of MEWS for malaria preparedness and control has been recently incorporated in the *Uganda Malaria Reduction Strategy 2014–2020*. The goal is to pilot the system in an operational setting in Uganda by the end of 2017.

#### ACKNOWLEDGEMENTS

This work was partly funded by the EU-FP7 HEALTHY FUTURES (grant agreement 266327) and QWECI (grant agreement 243964) projects.







## RISK FORECASTS

# BIO-CLIMATIC BULLETINS TO FORECAST DENGUE VECTORS IN PANAMA

Authors: A. McDonald P, (Departamento de Investigación en Sistemas de Salud, Ambiente y Sociedad. Instituto Conmemorativo Gorgas de Estudios de la Salud); A. Cumbra, (Departamento de Investigación en Sistemas de Salud, Ambiente y Sociedad. Instituto Conmemorativo Gorgas de Estudios de la Salud), C. Cruz, (Universidad de Panamá. Escuela de Estadística), A. Ramírez (Departamento de Hidrometeorología. Empresa de Transmisión Eléctrica, S.A.), A. Moreno de Rivera, (Departamento de Investigación en Sistemas de Salud, Ambiente y Sociedad. Instituto Conmemorativo Gorgas de Estudios de la Salud).

### CONTEXT

Climate is an additional determinant affecting the complex human health-disease relationships. Human health can be directly affected by climatic conditions, particularly by extreme weather and climate events. Determining how climate variability impacts human health is a complex process, because human beings have different vulnerabilities to climate, as well as different susceptibilities to diseases.

Climatic conditions can influence the transmission dynamics of communicable vector-borne diseases (VBD), and water-borne diseases (64) and even of some noncommunicable diseases (65).

### NEW APPROACHES

Prior to 2008 in Panama, no projects investigating the relationship between climate and health existed. Therefore, the Gorgas Memorial Institute of Health Studies (GMIHS), and its Department of Health Systems, Environment and Society Studies (ISISAS) addressed this gap and defined this new area of national research by formalizing two scientific collaborations with the Cuban Institute of Meteorology (INSMET) (for its experience in climate and health) and with the Panamanian Electrical Transmission Company (ETESA), responsible for the administration of meteorological information in Panama.

With the basis of these partnerships, an inter-institutional working group was established composed of medical researchers with public health expertise (GMIHS), statisticians (University of Panama), specialists in geographic information systems (GMIHS) and meteorologists (ETESA). They also invested in training this group in statistics (time-series analysis), GIS and climate information management systems, all focused on health applications, with the aim of also developing parallel knowledge in health of all team members.

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## INFORME BIOCLIMÁTICO

INSTITUTO CONMEMORATIVO GORGAS DE ESTUDIOS DE LA SALUD (IGGES);  
EMPRESA DE TRANSMISIÓN ELÉCTRICA, S.A. (ETESA); MINISTERIO DE SALUD  
(MNSA); UNIVERSIDAD DE PANAMÁ, DEPARTAMENTO DE ESTADÍSTICA.



### INFORME No.12 – Mes de diciembre de 2015.

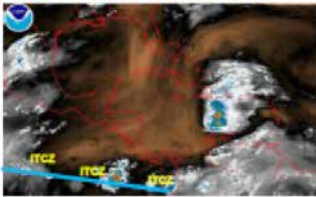


La Convención Marco sobre el Cambio Climático de las Naciones Unidas (Conferencia de las Partes), realizada en diciembre de 2015 en París, Francia, señala que se debe promover la elaboración y difusión de herramientas y metodologías para la ejecución de las medidas de fomento de la capacidad para el abordaje del cambio climático, fomentar la cooperación mundial, regional, nacional y subnacional (<http://www.unfccc.int/Transparency/2015/2015-07-15-01a.pdf>).

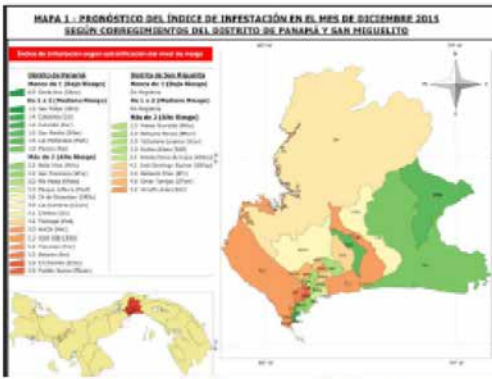
Al respecto, la Organización Mundial de la Salud (OMS) instó a que se promueva el incremento de la financiación destinada a la adaptación al cambio climático, que incluya la adopción de medidas de salud pública encaminadas a reducir los riesgos derivados de los fenómenos meteorológicos extremos, las enfermedades infecciosas, la menor disponibilidad de agua y la inseguridad alimentaria (<http://www.who.int/kalixto/diario/2015/04/2015042719a/>).

En Panamá, el mes de diciembre es considerado de transición de la temporada lluviosa a la seca. Climatológicamente, la Zona de Convergencia Intertropical (ITCZ) empieza su retorno migratorio más al sur (Figura 1), debido al empuje de los vientos del sistema de alta presión semipermanente de Las Azores-Bermudas, situación que la aleja de nuestro país. Esto conlleva a una menor cantidad de días nublados y un menor volumen de precipitación, lo cual tiene un efecto sobre las enfermedades sensibles al clima.

Figura 1 - ITCZ, MES DE DICIEMBRE



En Panamá, el mes de diciembre es considerado de transición de la temporada lluviosa a la seca. Climatológicamente, la Zona de Convergencia Intertropical (ITCZ) empieza su retorno migratorio más al sur (Figura 1), debido al empuje de los vientos del sistema de alta presión semipermanente de Las Azores-Bermudas, situación que la aleja de nuestro país. Esto conlleva a una menor cantidad de días nublados y un menor volumen de precipitación, lo cual tiene un efecto sobre las enfermedades sensibles al clima.



Según el modelo matemático utilizado para el pronóstico del Índice de Infestación de *Aedes aegypti*, basado en las condiciones climáticas, se estima que el mes de diciembre culmine con niveles de alto riesgo (> 2) en los corregimientos de Bela Vista, San Francisco, Río Abajo, Parque Lefevre, 24 de Diciembre, Las Cumbres, Chilbré, Pedregal, Ancon, Juan Díaz, Tocumen, Betania, El Chorrillo y Pueblo Nuevo. En el caso del distrito de San Miguelito, el modelo se mantiene estimando que todos los corregimientos presentarán índices de infestación > 2, Mapa 1.

The Panama Climate and Health Group has the main goal to generate scientific evidence at a national level about the influence of climate on specific diseases. This information serves as a technical asset for the Ministry of Health to make decisions and develop public health interventions.

Based on established knowledge presented by the World Health Organization (WHO) that climate variability influences vector-borne disease transmission, and considering that dengue is an important public health concern Panama, the GMIHS initiated a project with state financing and support of Cuban INSMET to develop and validate a statistical model to estimate the index of infestation of the mosquito *Aedes aegypti* in the Panama district (capital of the country) based on climatic conditions.

At a given point in time, the mathematical model estimates the index of infestation of *A. aegypti* for the present month and the two following months, using information on the climatic conditions for the study areas. The outputs of the model provide information that can be used for vector surveillance and control.



The Ministry of Health, Vector Control Unit, and ETESA Department of Hydrometeorology (Meteorological Service) are highlighting the importance of the data generated by Vector Control Inspectors during community visits, and meteorological observations provided by ETESA. This continuous process of participation and sensitization has enabled the tool to be accepted and used by health authorities. The staff of the meteorological services have been similarly empowered through their engagement with health partners.

To evaluate the use of the *Bio-climatic Bulletin*, each year a working meeting is held with members of the Climate and Health Group and the technical health authorities of the sanitary areas where the project is being developed. This helps maintain awareness about the project and availability of the tool.

In the future, we seek to expand the Bio-climate Bulletin to provide evidence regarding other climate-sensitive diseases that can help the health system to plan health promotion and disease prevention strategies. Also, in the future, we hope to extend this information to the community level, via social media and conduct knowledge, attitudes and practices (KAP) studies to identify community groups with high-risk behaviors, that can be targeted in community health promotion and prevention activities.

The implementation of this project has demonstrated the importance of forming multidisciplinary and intersectorial teams for research in climate and health. Another important aspect is the essential need for community participation in climate and health actions, to increase awareness of protective and high-risk behaviours for health protection from vector-borne diseases.

The development of this project has brought together resources and efforts of institutions, with which the health sector had not previously worked. This project has enabled the Working Group to form networks with countries from the region via the Inter American Institute for Global Change Research (IAI) and collaborate in climate change and health initiatives elsewhere in Central America.

## ACKNOWLEDGEMENTS



## EARLY WARNING SYSTEMS

# SUPREME: AN INTEGRATED HEAT HEALTH WARNING SYSTEM FOR QUEBEC

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### CONTEXT

The southern and central regions of Quebec can experience heat waves that are responsible for a substantial increase in human death and morbidity over urban and suburban areas (67). By 2050, significant growth in summer temperatures is very likely (68), along with a probable increase in the occurrence and severity of heat waves. The rapidly aging population in Québec, the management of heat waves, the capacity of the population to adapt in urban areas, all constitute a major challenge for public health authorities. These problems cannot be addressed without the exchange of expertise between the health and hydro-meteorological communities.

### NEW APPROACHES

We present here an integrated platform developed for emergencies (weather vigilance), the result of a collaboration between the Institut National de Santé Publique du Québec (INSPQ), the Ministry of Public Security (Québec), and Environment and Climate Change Canada's (ECCC) Meteorological Service of Canada (MSC).

The SUPREME system, developed by the INSPQ in 2010 (69) together with a users committee, provides access to indicators that relate exposure to hazards (temperatures, urban heat islands, etc.), socioeconomic characteristics of neighbourhoods (population density, deprivation index, etc.), health problems (deaths, emergency room admissions, etc.), and follow-up during and after an intervention by field teams. Post-event reports are produced regionally and aggregated annually.

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Integrated Surveillance

Indicators and Thresholds

Risk Models and Maps

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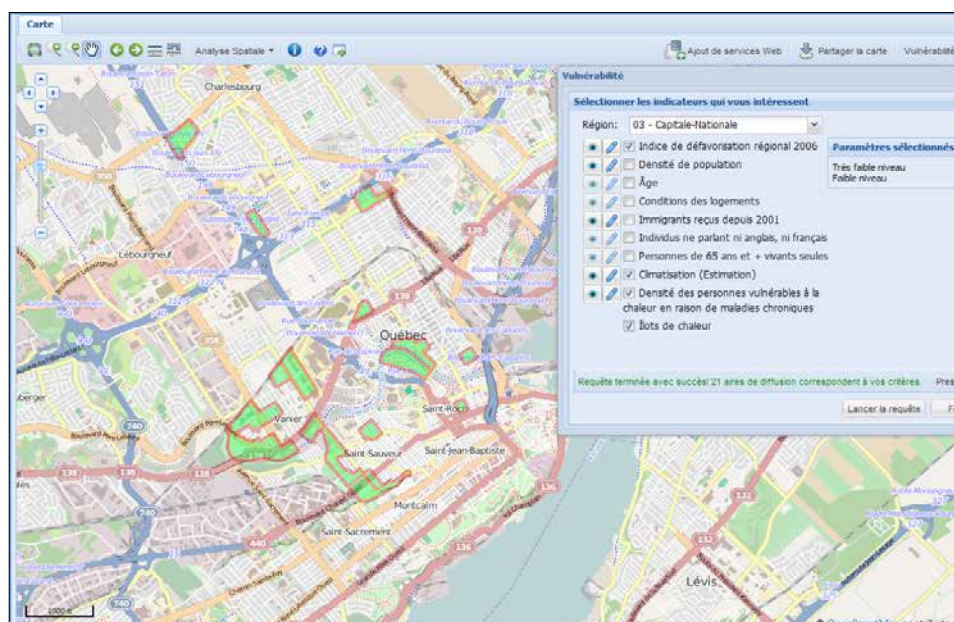
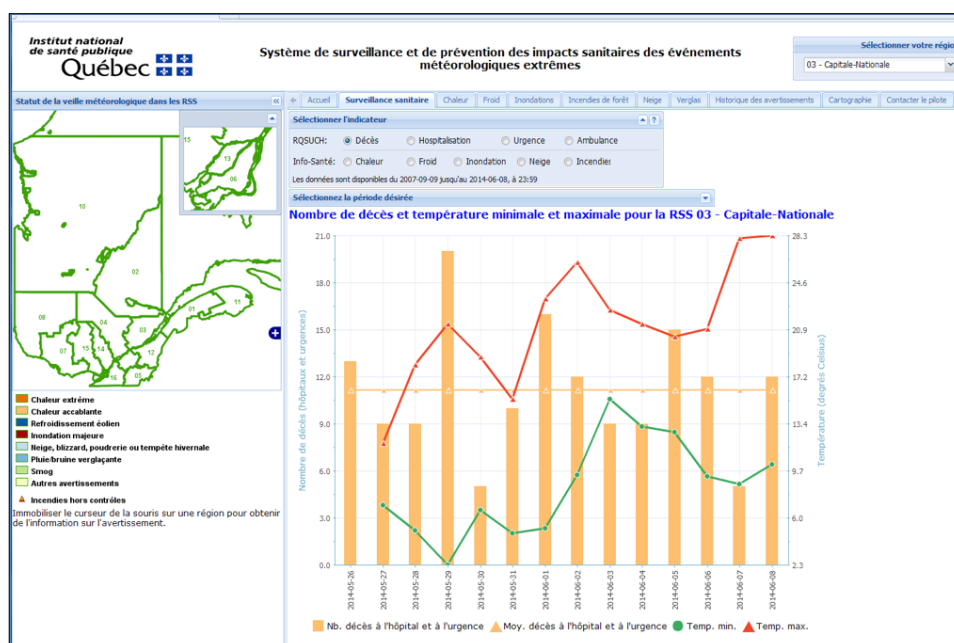
**Warnings**

Projections and Scenarios



In Québec, SUPREME (Figure 5.21) currently represents the sole common source of relevant and real-time information at the provincial level for extreme weather hazards. The SUPREME system was implemented through group training sessions in 2010 and 2011, which helped develop a common understanding of extreme heat thresholds and essential preventive interventions. The system stimulates mobilization and collaboration between neighbouring regions, the Ministry of Health, and the INSPQ that now cooperate for field intervention harmonization and comparison of vulnerability analysis. In 2008, the definition of intervention thresholds and the need for public health authorities to better understand the strengths and limits of weather forecast lead to an intense collaboration between the INSPQ and the MSC that has endured.

**Figure 5.21** Upper) Home page for the SUPREME system, surveillance component; and Lower) Example of a result of a query on heat vulnerability in Québec City: The zones in green simultaneously present a very high deprivation index, a very high chronic disease index and location within an urban heat island.





## CASE STUDY 5.L

### BENEFITS AND LESSONS

Since 2010, weather warnings from the ECCC MSC have fed SUPREME. The MSC can also provide early notification (up to a week ahead of the expected event) to INSPQ and the health network about upcoming threatening conditions.

In metropolitan areas, regional health agencies base their heat alert thresholds and mortality/morbidity statistics on official weather stations, mostly located at airports, which are protected from urban influence. With environmental characteristics of residential areas significantly different from those found at airports, urban meteorological monitoring has now demonstrated that heat alert thresholds can be reached in certain localized areas (see Figure 5.22) before being observed at those official stations (70).

Such meteorological measurement campaigns – for example the ones conducted during the summers of 2013 and 2014 in Montreal – allow the ECCC MSC to provide more precise air temperature information, allowing for targeted intervention strategies to help mitigate the risk from heat-stress on more vulnerable populations located in various urban sub-regions.

Risk communication theory highlights the importance of reaching vulnerable people and the general public with one voice. Working together on the heat health warning system enabled an essential understanding between partners to communicate heat health risk with one consistent risk communication.

The development of an integrated heat, health and warning system requires a robust understanding of meteorological and climatic conditions, and of the factors affecting population health, including vulnerability and exposure. The system discussed has also been applied to other hydro-meteorological hazards (cold waves, flood events, etc.) and over other areas, such as Northern Québec, where vulnerability and adaptation vary significantly.

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Indicators and Thresholds

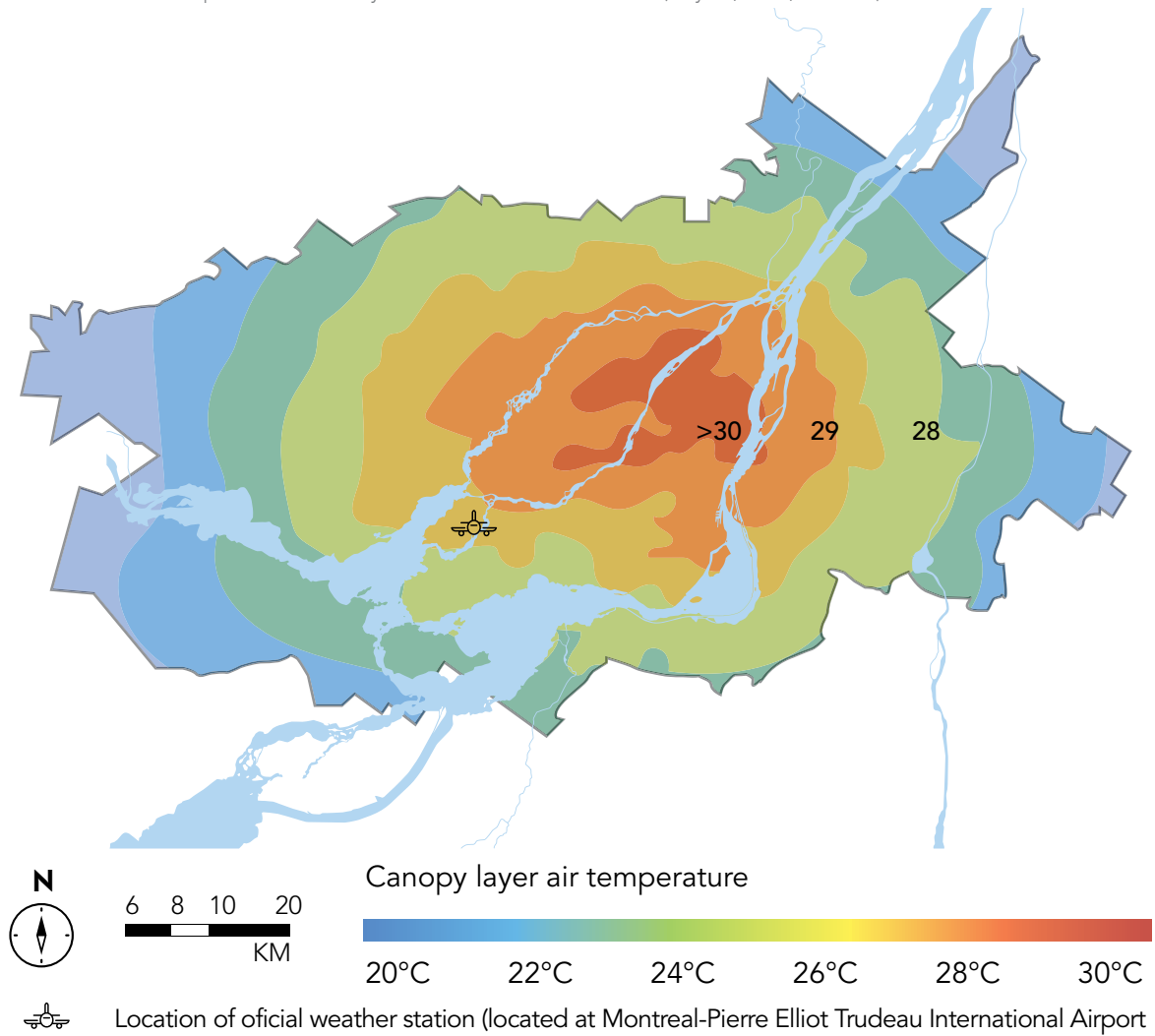
Risk Models and Maps

Forecasts

**Warnings**

Projections and Scenarios

**Figure 5.22** Intra-urban air temperature variability in the Greater Montreal area (July 16, 2013, 9:00 PM).



**ACKNOWLEDGEMENTS**

This work has been made possible under the Green Fund of the Government of Quebec, the initiative IRIACC-FACE (<http://face.ete.inrs.ca/fr>) and the financial support of Environment and Climate Change Canada and the INSPQ.



The system has been evaluated twice since 2010 for level of use, usefulness and general satisfaction. The system is considered very useful and overall satisfaction of the public health authorities using it was very high.

A simpler version of the system was also recently implemented in Niger and Morocco as a common platform to manage various weather-related problems (71), and to serve as a climate service for health application. This capacity-building initiative was part of five-year research programme in climate change adaptation between governmental and academic institutions from Canada, Niger and Morocco, funded by the International Development Research Centre (IDRC), Canadian research agencies and various levels of Government.

## EARLY WARNING SYSTEMS

# HEAT WAVE AND HEALTH RISK EARLY WARNING SYSTEMS IN CHINA

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(\*Corresponding author)

### CONTEXT

Climate change is increasing the frequency, intensity, and duration of extreme ambient temperature, especially heat waves. There is worldwide evidence that extreme high temperatures are associated with excess deaths in summer (72–74). All these deaths are preventable. Early warning systems are a key approach to reducing the morbidity and mortality associated with heat waves. This project, which is part of a broader WHO/UNDP Global Environment Facility (GEF)-funded project, developed and implemented a heatwave early warning system to reduce the health risks and to increase the capacity of health systems and community residents to prepare for and cope with periods of extreme temperatures. The National Steering Committee leading the project was composed of officials and experts from the National Health and Family Planning Commission (NHFPC), National Development and Reform Commission, Ministry of Finance, Meteorological Bureau, Ministry of Environmental Protection, Ministry of Technology and Science, WHO, the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP), and was headed by NHFPC. The committee is responsible for reviewing and supervising the work plan, implementation and progress of the project.

The project was piloted in four cities: Harbin, Nanjing, Shenzhen and Chongqing, located in different climate zones within China.

### NEW APPROACHES

The heat wave early warning systems were developed by:

- Establishing city-specific health risks models to describe the associations between daily mortality and hospital outpatients with meteorological (daily minimum and maximum temperature and humidity) and air pollutants data (PM<sub>10</sub>, SO<sub>2</sub>, NO<sub>2</sub>). Analyses were conducted using generalized additive models. The health monitoring data, meteorological and air pollution data were collected from the health system, meteorological bureau and environmental protection agency, respectively. Grading the health risks into four levels was done to help enhance understanding of the risks by the public. These levels were used to develop guidance for multi-level responses to health risks.
- Risks models were used to develop and pilot the heat wave early warning system (EWS) in the selected communities. The system includes data input, the health risk models, and communication modules including for multi-level response measures. The predicted health risks include total health risks, the risks of cardiovascular disease, respiratory disease, children’s respiratory disease, and heatstroke.

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Figure 5.23 Homepage of EWS software.



Figure 5.24 Data input module.

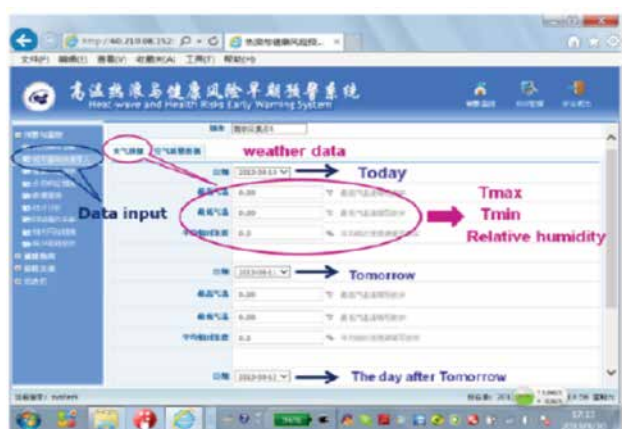
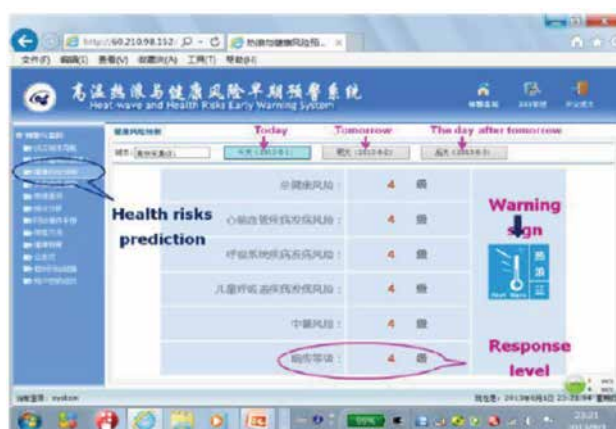


Figure 5.25 Health risks prediction module.



## ACKNOWLEDGEMENTS

This work was made possible by funding from WHO-UNDP-GEF Piloting Adaptation to Climate Change Project and the National Basic Research Program (973 programme) of China (grant number 2012CB955502, to Y. Jin). Thanks to Professor Kristie L. Ebi, from the Department of Global Health and Department of Environmental and Occupational Health Sciences, School of Public Health, University of Washington, for her help on the editing and revision of this report. Members of Jiangsu Provincial CDC, Shenzhen CDC, Harbin CDC and Chongqing CDC made the same contribution to this work.



The early warning system was implemented through the local CDCs in the project cities. The system was designed for timely issuance of warnings of health risks due to extreme heat. Information on health risks was delivered to the community health service centres and community residents (especially vulnerable populations with cardiovascular disease, respiratory disease, diabetes etc.). Information also was communicated through fixed electronic display screens in the community, mobile text, instant messaging (QQ) group, and television through the daily weather forecast. At the same time, health education on how to read the early warning information and how to protect health during heat waves was provided in various forms, such as posters, fliers, internet, newspapers and a painting contest among the pupils on adaptation to heat waves, etc.

The risk models were partially verified by comparing registered daily health outcomes, such as the observed daily deaths, with predicted parameters.

The specificity, reliability and practicality of the early warning system, including the establishment of the model, the multi-level response guidance, health risk information issuing and health education, etc. were evaluated by the experts in different fields of statistics, health, meteorology, environmental protection, and health education through experts evaluation meetings.

## BENEFITS AND LESSONS

The EWS provides the health system and community residents with information about health risks before a heat wave occurs, providing valuable time to take appropriate action to prepare for and reduce potential risks, thereby decreasing morbidity and mortality. Multisectoral cooperation is an indispensable element for the smooth design and implementation of the EWS.

## PROJECTIONS AND SCENARIOS

# HEALTHY FUTURES ATLAS: A PUBLICLY AVAILABLE RESOURCE FOR EVALUATING CLIMATE CHANGE RISKS ON WATER-RELATED AND VECTOR-BORNE DISEASE IN EASTERN AFRICA

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### CONTEXT

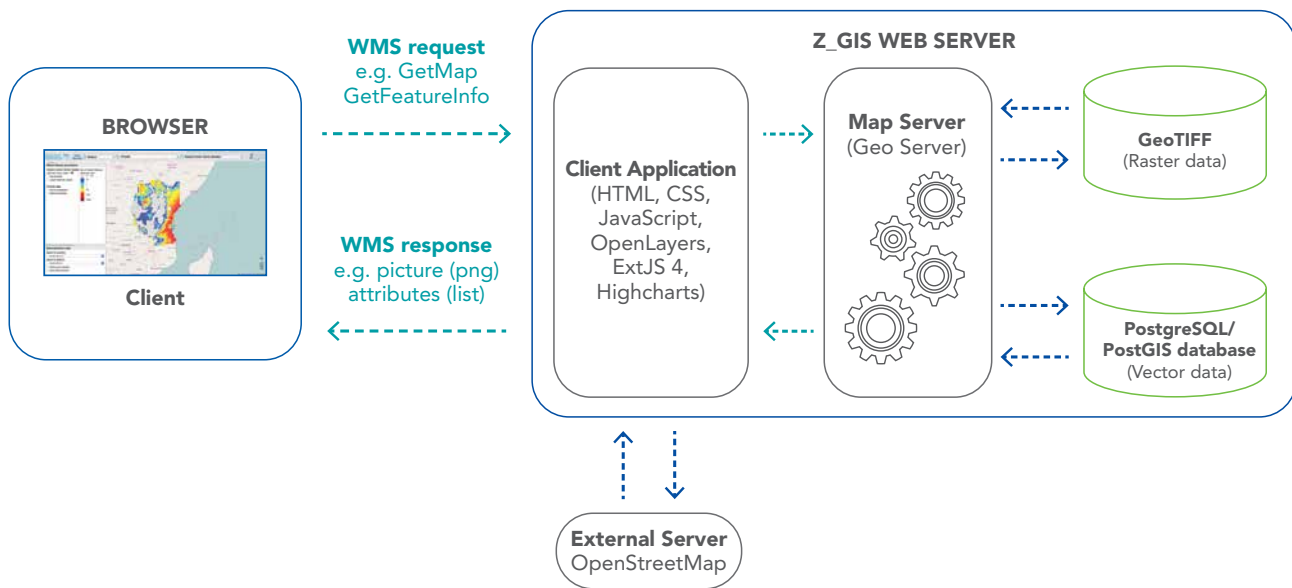
Global climate change is projected to have geographically varied and potentially substantial, negative effects on health (75), with sub-Saharan Africa a focus of adverse health impacts (76). Malaria remains one of the world's most devastating infectious diseases, particularly in sub-Saharan Africa, with both the malaria vector and pathogen affected by climatic conditions (77). Prevailing levels of social vulnerability are increasingly recognized as critical determinants of impact (78). Recent reports call for assessments of vulnerability and risk to be at the centre of future assessments of climate change impacts, and for increased research on effective decision-support systems (8).

The EU-funded HEALTHY FUTURES (79) research project was completed at the end of 2014. The project responded actively to calls for vulnerability and risk to be at the core of assessments of climate change impacts: The utility of the HEALTHY FUTURES Atlas, an output of the project, is being communicated to senior decision-makers in national and international bodies that have an interest in human and animal health in the East African Community (EAC) area of eastern Africa.

## NEW APPROACHES

HEALTHY FUTURES Atlas is an interactive, web-based mapping and decision support tool, built within an open-source framework, which aims to provide meaningful and guided access to information on climate change, potentiality of disease occurrence and population vulnerability to vector-borne diseases (Figure 5.26). Currently, HEALTHY FUTURES Atlas focuses on three water-related, vector-borne diseases (malaria, schistosomiasis and Rift Valley fever) in eastern Africa that have major human and economic impacts. Here we provide a brief introduction to the malaria component, and an indication of the potential utility of HEALTHY FUTURES Atlas in supporting decisions over the present and future allocation of health resources, as well as the identification of targeted and location-specific intervention options. The HEALTHY FUTURES Atlas adds value through facilitating the preparation of health policy and planning strategies and plans, and, more widely, by providing a basis for research and education in the fields of climate change and environmental health.

Figure 5.26 HEALTHY FUTURES Atlas WebGIS Architecture.

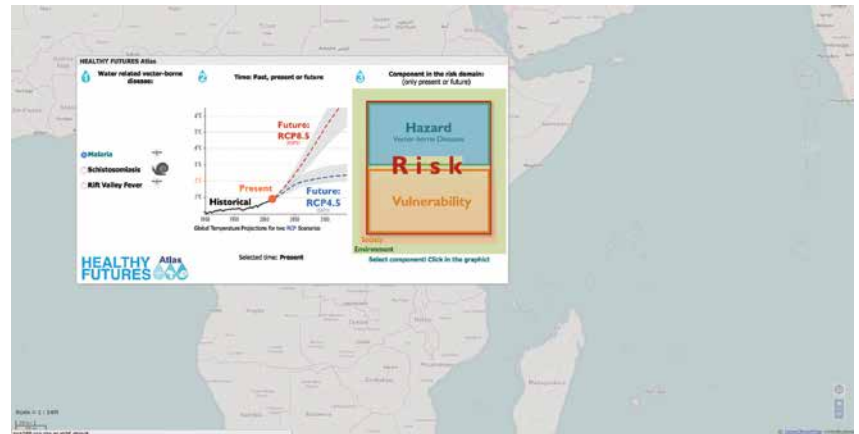


Health and meteorological partners were involved in the development of the HEALTHY FUTURES Atlas, including through feedback following hands-on exposure to earlier versions of the platform at dedicated workshops. The platform integrates a range of modelled and observational climate, health and socioeconomic data from multiple sources. A core objective of HEALTHY FUTURES Atlas is to communicate and visualise complex information in a guided and simple, yet interactive manner. Information can be queried based on three prime selection criteria: (i) infectious diseases targeted by the HEALTHY FUTURES project; (ii) time, allowing comparisons of current conditions with a range of future projections, while also allowing access to information on historical outbreaks; and (iii) different components of risk, in accordance with the IPCC AR5 (Figure 5.27).



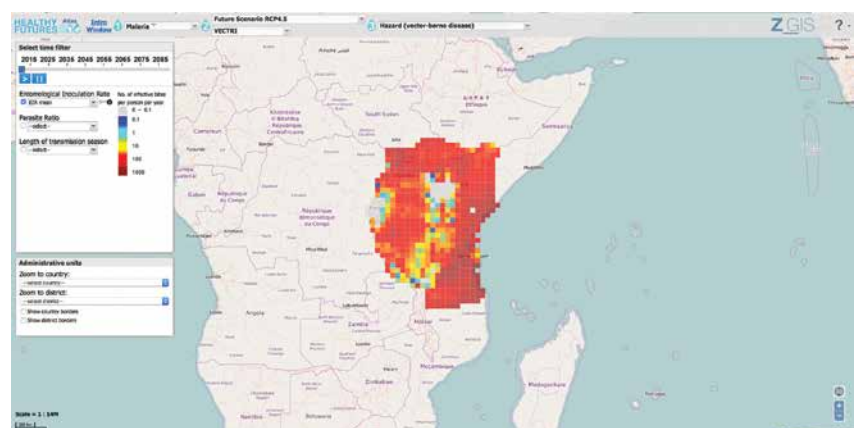
## CASE STUDY 5.N

**Figure 5.27** Screen-shot of Introduction Window of HEALTHY FUTURES Atlas.

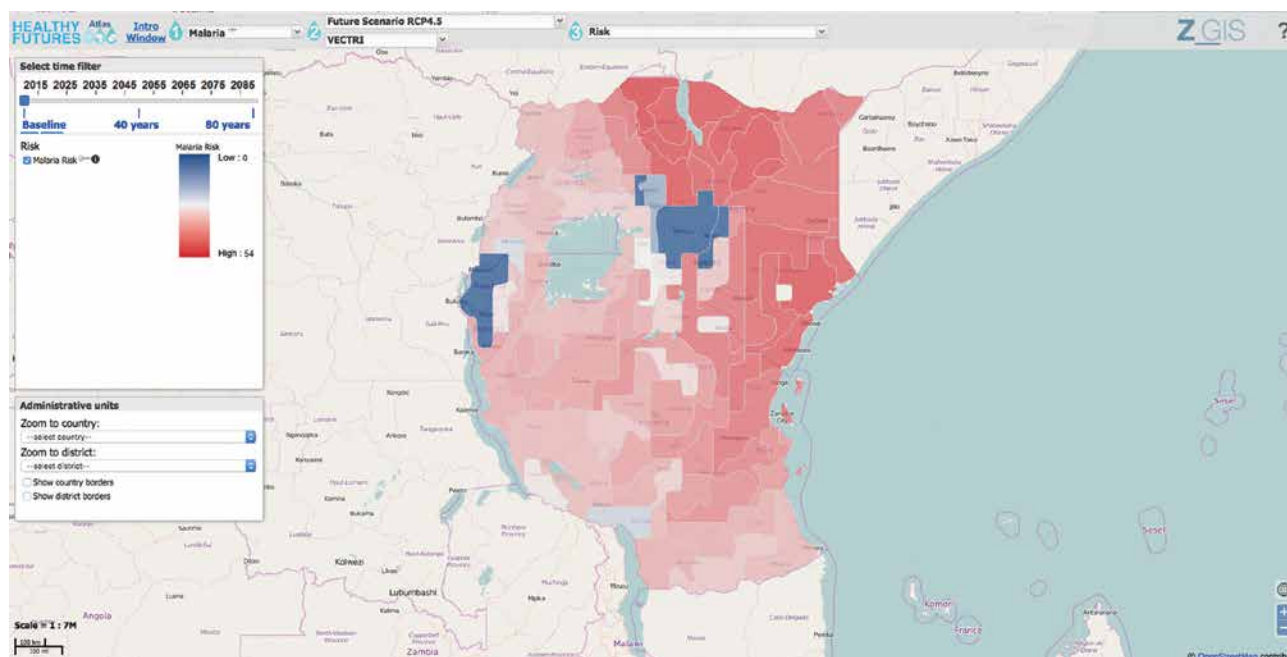


HEALTHY FUTURES Atlas integrates multiple ensembles of down-scaled and bias-corrected, high-resolution, future climate change projections, which are based on two emission scenarios (RCP4.5 (mid-level change) and RCP8.5 (high-level change)) used in IPCC AR5 (80). The projected climatic conditions drive two state-of-the-art dynamic malaria transmission models (LMM and VECTRI) (81) that provide information on the present and future probability of simulated transmission intensity (entomological inoculation rate – EIR), simulated prevalence and simulated length of transmission season (Figure 5.28). Each decade to 2100 can be sequentially examined using a slider function in the tool. In addition, temporal trends at locations throughout the study area can also be viewed. Relative values of social vulnerability are mapped based on indicators of levels of susceptibility to disease (e.g. immunity, malnutrition, poverty, conflict, remoteness) and lack of resilience (e.g. education level, health facilities, number of dependents). These indicators have been weighted and combined into a spatially explicit composite indicator, which can be decomposed into its underlying indicators to assess the factors contributing to vulnerability at a particular location. Combining spatial assessments of disease transmission intensity, susceptibility to illness and lack of resilience permits the interactive mapping of variations in estimated disease (in this case malaria) risk in eastern Africa.

**Figure 5.28** Screen shot of projected hazard of malaria (EIR) under high-estimate of projected climate change (scenario RCP8.5) for period 2045–2055. Hazard projected according to VECTRI model. National and health district boundaries shown for EAC countries.



**Figure 5.29** Screen shot of projected malaria risk under high-estimate of projected climate change (scenario RCP8.5) for period 2045–2055. Underlying EIR hazard projected according to VECTRI model; index of social-vulnerability determined through discussions with experts. National and health district boundaries shown for EAC countries.



## BENEFITS AND LESSONS

The HEALTHY FUTURES research project aimed ultimately to support the decision-making processes in national and international bodies that have an interest in the most effective utilization of scarce health resources. Key challenges in translating HEALTHY FUTURES research outputs into usable formats have been the identification of human (and animal) health decision-makers in the region, the types of decisions they are likely to need to make (and when, over what policy planning and implementation periods and how) and the kinds of support they need in order to make the best decisions. In permitting identification of likely hotspots for infectious disease risks under different climate change scenarios and at policy-relevant time-steps over the current century, HEALTHY FUTURES Atlas is an important part of meeting the aims of the project. In addition to providing a means of assessing spatial variations in risk throughout eastern Africa, HEALTHY FUTURES Atlas can be used to generate visualization aids for incorporation in policy and planning documents, for example, and to target surveillance and intervention strategies. The tool has been rolled-out through a series of stakeholder meetings in East African Community (EAC) countries hosted by HEALTHY FUTURES.

The stakeholder meetings involved key health partners, identified at an early stage in the HEALTHY FUTURES project, most notably ministries of human and animal health in eastern Africa, the Health Desk of the EAC, national and international nongovernmental organizations. HEALTHY FUTURES had less success in engaging with meteorological service providers in eastern Africa, although the project consortium included climate modellers based in South Africa and in Europe. Additionally, HEALTHY FUTURES Atlas adds value to outputs from Group on Earth Observation (GEO), Copernicus and GMES for Africa by providing an integration of a range of datasets that were partly developed and disseminated within and through these initiatives.

National meteorological and health services – and climate change adaptation in general in eastern Africa – need to cooperate and integrate more smoothly, particularly at regional (e.g. EAC) levels, as both climate change and infectious diseases are transboundary challenges.

## ACKNOWLEDGEMENTS

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement no. 266327 (HEALTHY FUTURES, <http://www.healthyfutures.eu/>).



## PROJECTIONS AND SCENARIOS

# COMPREHENSIVE CLIMATE RISK MODELLING FRAMEWORK TO HELP PROTECT FUTURE FOOD AND WATER SAFETY IN CANADA

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### CONTEXT

Infectious disease transmission through food and water is impacted by weather and climate variables including temperature, precipitation, extreme weather events, and ocean warming and acidification. Alteration of these variables through a changing climate will affect the occurrence and fate of existing and emerging pathogens in the environment, production facilities, and distribution systems (82). There is a need for risk modelling tools to project the impacts of weather, climate and climate change on human health, and to assess the effectiveness of potential adaptation responses (83).

A risk and adaptation modelling framework was developed for use in projecting the impacts of climate and climate change on public health risks from biological hazards in food and water to inform health decision-makers (84). Several example risk modelling case studies were modeled. Potential risk management measures, from short-term surveillance, advisories (e.g. boil water advisories), and targeted public health messaging for extreme weather events, to long-term climate adaptation planning for policy, infrastructure development, and changes in food and water production and processing (enhanced water treatment, food processing etc.) can be evaluated and compared across multiple diseases and commodities to inform decision making.

Future risks can be assessed by integrating climate projections into the framework alongside knowledge synthesis, data storage, and stochastic modelling components (Figure 5.30). Projections were used to estimate future public health risks, expressed as disability-adjusted life years (DALYs), in different locations of Canada from several pathogen/commodity combinations and to assess the effectiveness of various adaptation responses. Typical climate/weather variables considered in these risk models are shown in Table 5.2.

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Figure 5.30 Key components of the framework.

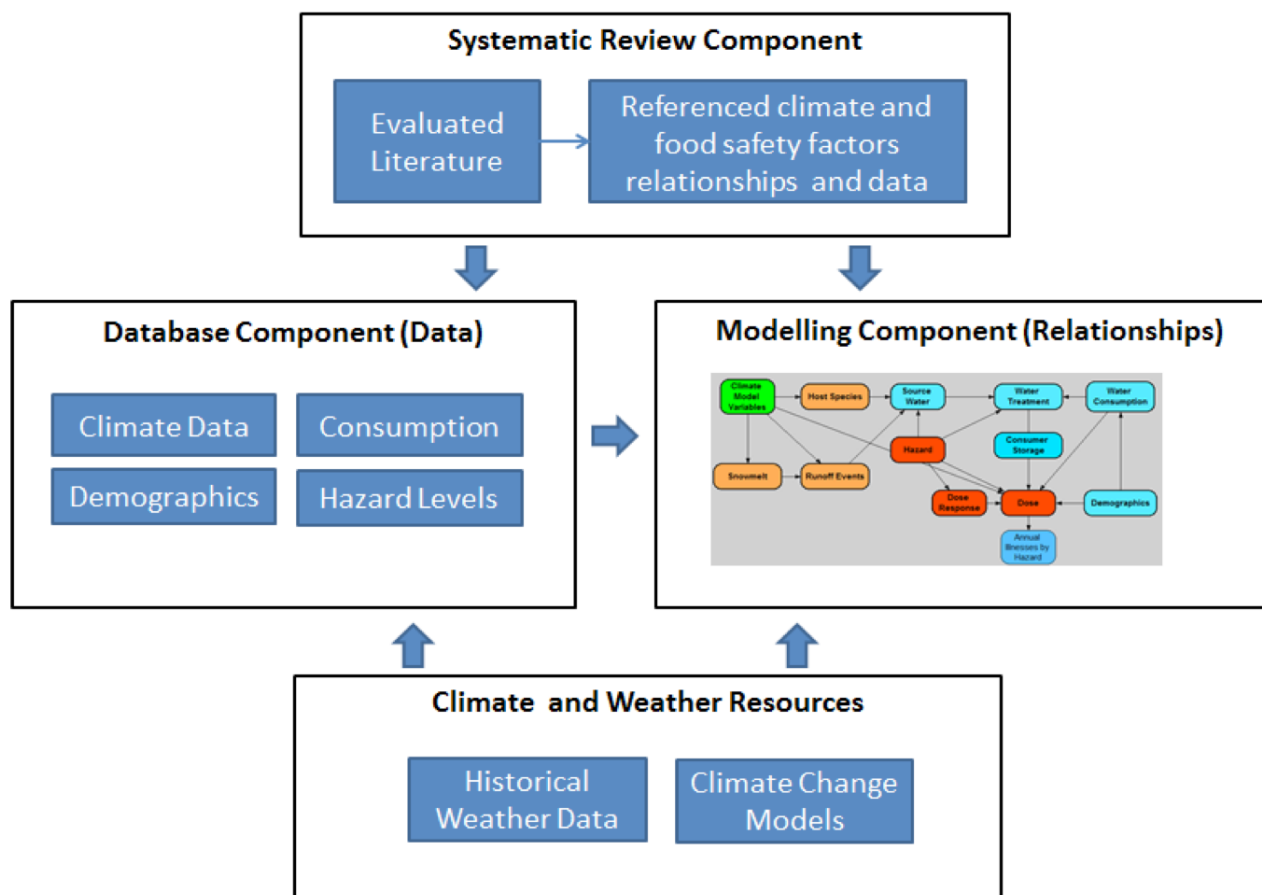


Table 5.2 Summary of case studies developed using the risk modelling framework to project the impacts of climate change on food and water safety.

HAZARD	EXPOSURE SOURCE	LOCATION	PROJECTED TIMEFRAME	CLIMATE VARIABLES
Cryptosporidium and Giardia	Drinking water	Northern Canada	2041–2070 and 2071–2100	Precipitation
<i>Escherichia coli</i> O157	Lettuce	Québec, Canada	2011–2040 and 2041–2070	Air temperature and precipitation
Ochratoxin A	Wheat	Saskatchewan, Canada	Annually through 2060	Air temperature
<i>Vibrio parahaemolyticus</i>	Oysters	British Columbia, Canada	Annually through 2060	Air and water temperature

## CASE STUDY 5.O

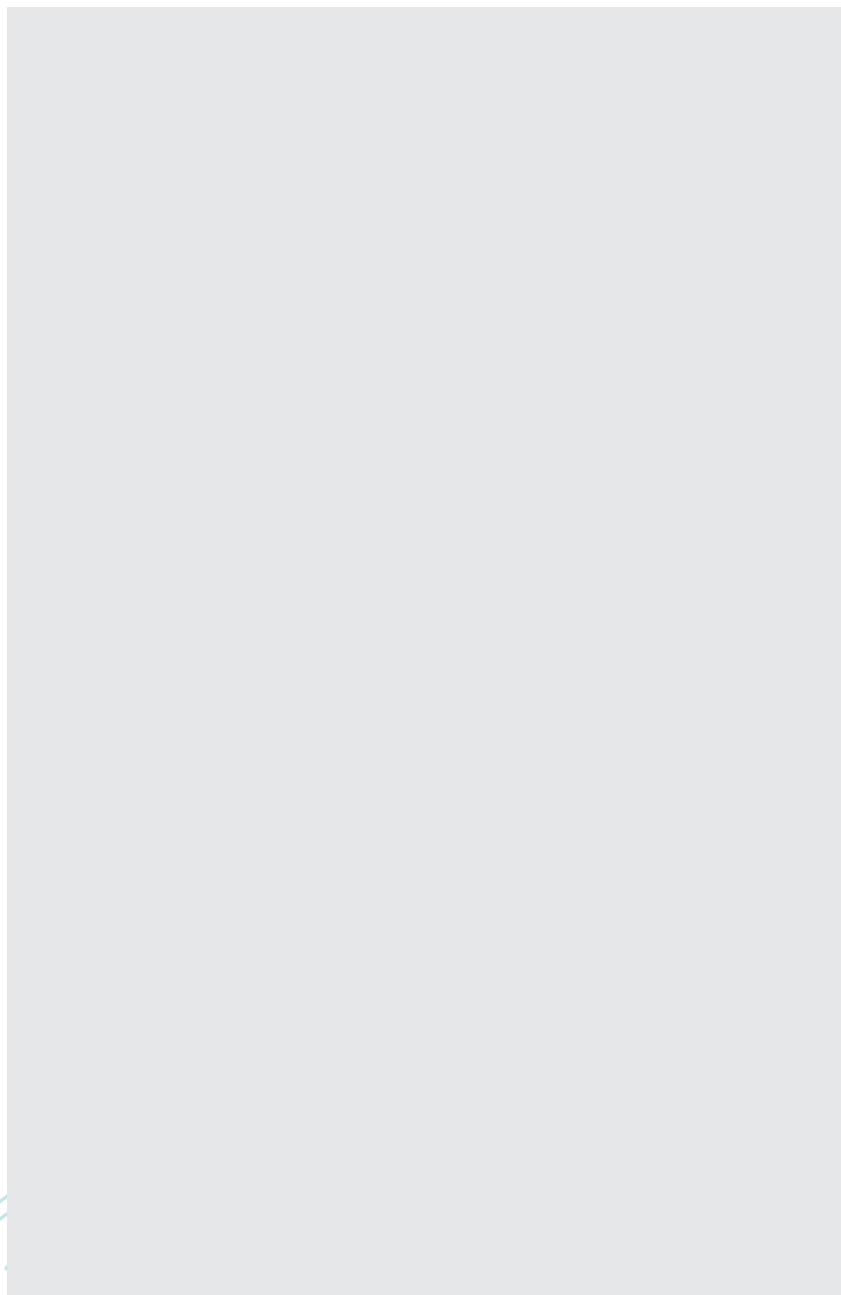


### NEW APPROACHES

Prototype climate services were assessed on a case-by-case basis. Climatologists, meteorologists and health risk modellers determined weather and climate data needs early in the development of the risk models so that necessary information could be obtained, analysed and applied effectively. The climate data used were publicly available. A series of algorithms were developed to compute seasonal water and air temperatures and precipitation amounts/frequency for current and projected timeframes. Climate data and future projections were obtained from the Environment Canada National Climate Archive (<http://climate.weather.gc.ca>) (85), and the World Climate Research Programme (86). Meteorological and climate information varied for each risk model (Table 5.2), and was captured in various scenarios within the framework. The future climate changes were determined by use of ensemble (multi-model) average projections from the most recent AR5 Intergovernmental Panel on Climate Change (IPCC) report.

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Placeholder for image

## BENEFITS AND LESSONS

Public health risks were projected to increase under climate change for all case studies; comparison of the relative projected increases in DALYs for each case study allows for identification of priority climate change impacts on public health. Explicit consideration of potential adaptation efforts in the risk modelling framework allows for identification and assessment of interventions that can be implemented to reduce risks under the current climate and under climate change. For example, the models identified that improved water treatment and boil water advisory compliance could reduce the current and projected increases to risks from some parasites in drinking water in northern Canada. Enhanced pathogen surveillance and altered oyster harvest procedures for Pacific Coast regions that could reduce public health risks under short-term climate events (e.g. strong El Niño event) or longer-term climate change can be evaluated. Various meteorological and health partners have expressed interest in using the framework to prioritize resources for adaptation to climate change. For example, federal and municipal governments and private industry are engaged in development of a new risk model to predict current risks and project climate change and adaptation impacts on drinking water in a small community; location-specific meteorological, hazard and demographic data will be used while also leveraging existing data and relationships stored within the framework.

In order to evaluate the framework approach and obtain feedback, a workshop involving multiple government agencies and departments was organized. An evaluation of the broader programme is underway and expected to be finalized in 2016.

Integrating climate change adds an additional level of complexity and uncertainty into quantitative microbial risk assessment. Often, it is necessary to simplify multifaceted phenomena for incorporation in risk models. Climate projections were simplified to discrete distributions of values or static values for inclusion in risk models. Some climatic variables, such as humidity, were not explicitly considered in risk models due to lack of data, even though it is likely that they influence public health risks from some hazards and in some commodities. Also, climate and climate projection data aggregated at a higher level or from a nearby location are sometimes used as a proxy depending on the size and location of the study area. In some regions, weather, climate and climate change can vary significantly over a small distance, and these limitations should be highlighted. The use of stochastic simulation allows for sensitivity analysis to explore the impacts of these assumptions and exploration of alternative climate scenarios.

## ACKNOWLEDGEMENTS





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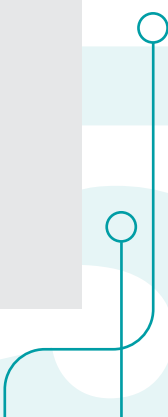
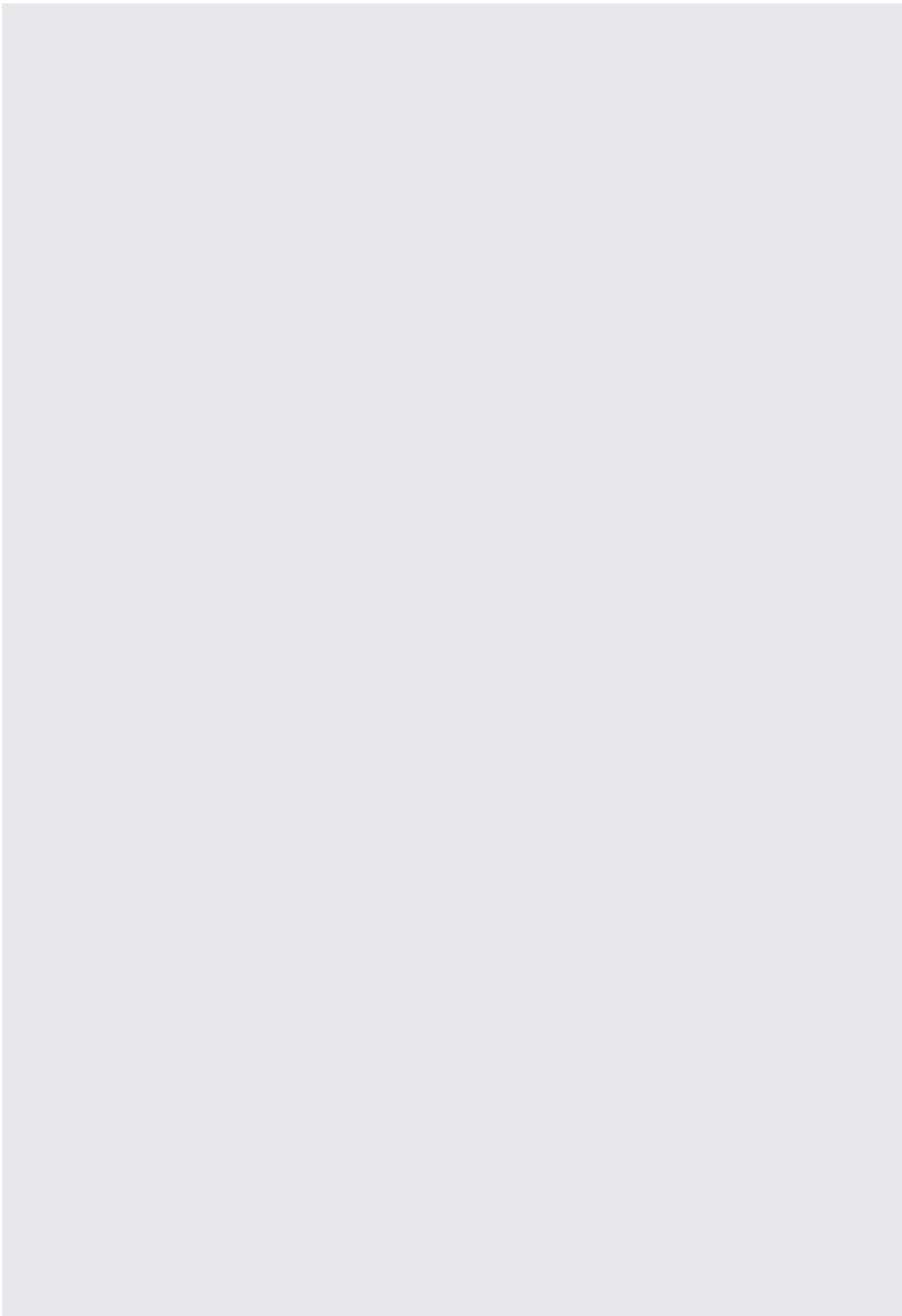
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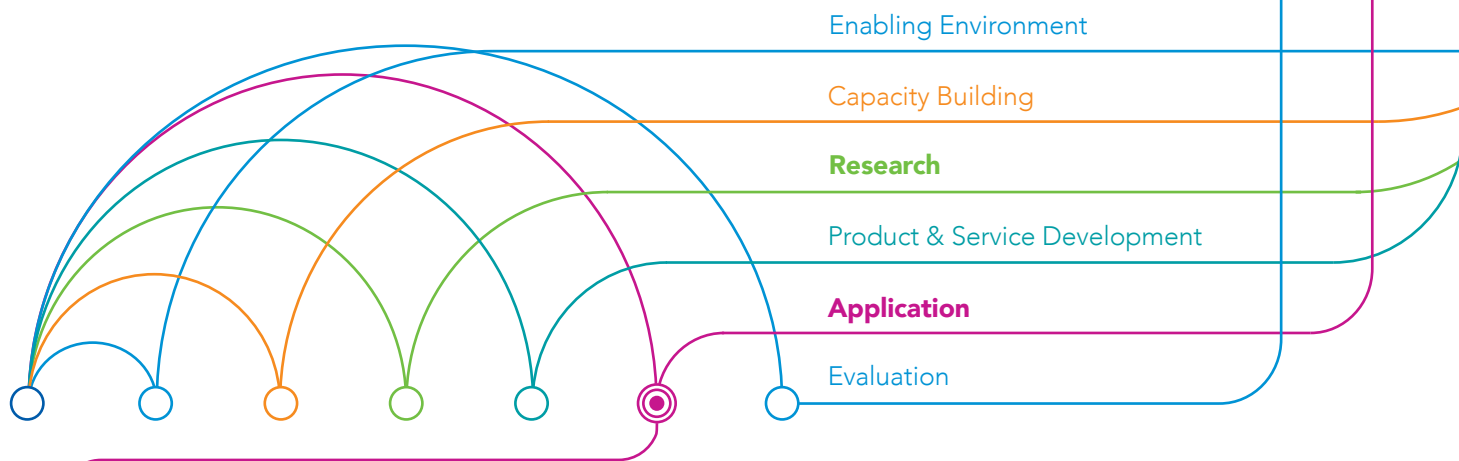
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## CHAPTER 6

# APPLYING CLIMATE KNOWLEDGE TO PRACTICE

**GOAL** Applying climate knowledge to bring benefits to individuals and communities.

The ultimate goal of developing tailored climate services is to apply the climate knowledge to answer a specific health question or provide a solution to a health risk management problem. Applying climate products and services bridges the gap between the largely theoretical research or development process and applying the outputs to real-world problems. The successful application of knowledge entails activities that help appropriately communicate information, and work to integrate climate knowledge, decision-tools and information effectively within health decision-making and protection measures.

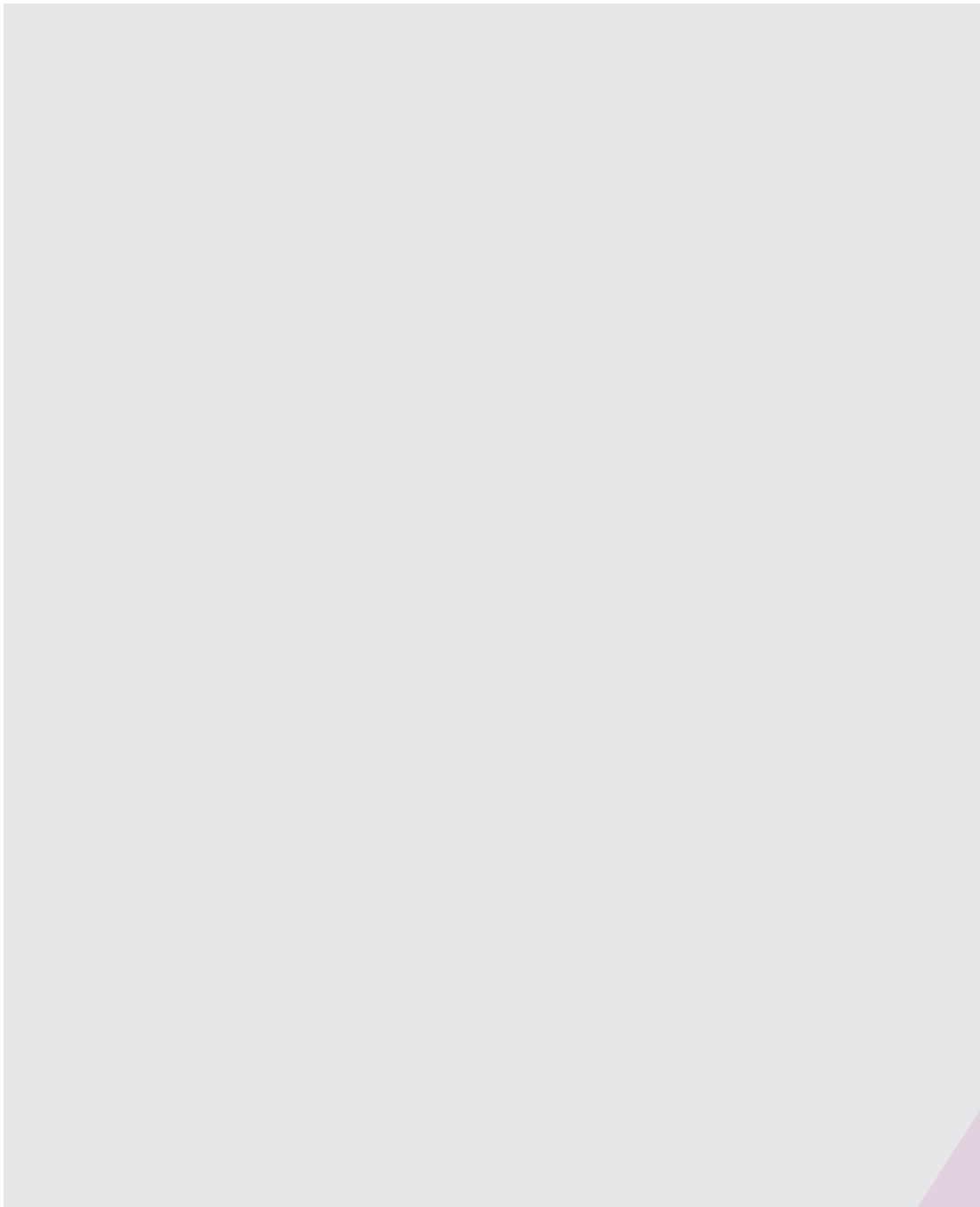
The scope of application is extensive. Relevant and tailored climate information are commonly used to enhance health decision tools, such as risk assessments, risk monitoring and disease surveillance; emergency response planning; health services planning and delivery; resource allocation; facilities siting and maintenance; evaluation of health interventions; health policy, standards and norms formulation; public safety advisories and community health education, etc.

Steps to ensure resulting climate information and decision-tools are effectively applied and maintained must be intentionally incorporated into the process starting at the very beginning of the project or partnership. In addition to products and services meeting expectations to produce quality, reliable, usable, suitable and responsive information – experiences show for a climate service to become applied and useful, the application process should guarantee that the climate knowledge generated is relevant; accessible; credible; and can be sustainable over time. Projects that do not meet these criteria often result in unused or unsustainable products and wasted resources.



### IMPORTANCE OF PRODUCT DEVELOPMENT AND DELIVERY IN THE END-TO-END PROCESS

The application of a climate service will test whether other process components have been adequately met, such as if the user needs were clearly defined and whether adequate capacity was developed to ensure information is of high quality and is relevant to the last mile. Trialing the product in real time is also crucial for generating a feedback on its performance and impact to make future investments or improvements. The timely identification of weaknesses and non-performing service features aids adjustment in time to ensure usability and applicability.



Placeholder for image



## COMMON APPROACHES

Several strategies can help operationalize and maintain climate services, as well as increase user appreciation and willingness among decision-makers to support and integrate such products and services. These strategies include:

- Mainstreaming partnerships and information products into health policies and programmes, by justifying the dependencies on climate information to improve health system performance and health outcomes.
- Jointly engaging ministries of health and national meteorological services to endorse, launch, and sponsor projects to increase acceptance and value of the climate service.
- Holding workshops to co-develop research and climate service features with national health authorities, to ensure that they are driven by national strategic health priorities.
- Providing open access to processed information and promote available resources.
- Encouraging open discussion and feedback opportunities on climate products and services to increase understanding, ownership, and facilitate agreement on the essential climate service features, and to ensure optimal fit-for-purpose and value-add to health decision needs.
- Communicating local evidence of climate and weather impacts on community health, and highlight climate-informed risk management opportunities.
- Pilot testing the service prior to extensive implementation.
- Providing decision-makers with hands-on exposure to prototypes or preliminary versions of the services.
- Increasing capacity among medical professionals and health decision-makers to value and use the information generated by the climate service.
- Supporting national agencies in technical implementation to address capacity gaps and maximize quality and reliability of information.
- Encouraging regional knowledge exchange to ensure local lessons are shared.
- Ensuring appropriate and adequate investment in communications and capacity building of end-users and ultimate beneficiaries.
- Partnering with the media and use social media and other communication technologies to conduct extensive communication campaigns.
- Holding evaluation meetings or using survey instruments to collectively evaluate and improve sub-optimal performing aspects of a service.
- Measuring and communicating the value and impact of using the climate information on health outcomes and health system performance.

## CASE STUDIES OF APPLIED CLIMATE KNOWLEDGE

The following six case studies provide examples of how the knowledge generated by a climate service is being systematically applied to inform health decisions and has become an integral part of routine health preparedness and health services delivery in these countries.

A

**6A:** Innovative heat wave early warning system and action plan in Ahmedabad, India

First from India, case study 6A, describes a complete end-to-end climate service used to inform city-scale heat health action plans and improve local health professionals' awareness of predicted extreme heat events improving their preparedness and capacity to care for patients with heat-related illnesses.

B

**6B:** Managing the health impacts of drought in Brazil: A comprehensive risk reduction framework

In Brazil, case study 6B shows how information on drought conditions can be applied using a national disaster risk reduction framework for drought management specifically tailored to inform public health protection strategies from drought-related health impacts.

C

**6C:** Early warning systems to guide infectious diseases control in Europe

The third case study 6C describes a regional product, the E3 Network, a European integrated data management and monitoring system that provides processed open-access information of past, present, and future disease environmental suitability. The partnership driven data system is actively used across the European Union to inform malaria prevention planning in Greece, and public health decisions related to West Nile virus in Europe and *Vibrio sp.* in the Baltic Sea.

D

**6D:** Improving malaria evaluation and planning with enhanced climate services in East Africa

In Tanzania, case study 6D describes the application of Enhancing National Climate Services (ENACTS) products which provide quality assured, high-resolution climate data and information products for mapping populations at risk of malaria in Tanzania. The national malaria program use the products to investigate the seasonality and timing of interventions, monitor year-to-year trends, target resources, and evaluate the effectiveness of malaria interventions and advocating for early preparedness.

E

**6E:** Using climate information to predict and control meningitis epidemics in West Africa

In Burkina Faso, case study 6E tells how meningitis outbreak forecasts are developed, validated, and delivered to reinforce the national meningitis epidemic surveillance, and provide early warnings of outbreaks to inform meningitis control strategies.

F

**6F:** Using climate knowledge to guide dengue prevention and risk communication ahead of Brazil's 2014 FIFA World Cup

In Brazil, case study 6F presents how a comprehensive dengue risk analysis and risk communication exercise ahead of the FIFA World Cup in Brazil in 2014, was used to improve disease control planning and inform local populations and international visitors of disease risks ahead of the mass gatherings.



# INNOVATIVE HEAT WAVE EARLY WARNING SYSTEM AND ACTION PLAN IN AHMEDABAD, INDIA

Authors: T. Shah (Ahmedabad Municipal Corporation), D. Mavalankar, P. Ganguly, P. Shekhar Dutta, A. Tiwari, A. Rajiva (Indian Institute of Public Health, Gandhinagar (IIPH)/Public Health Foundation of India), A. Jaiswal, K. Knowlton, M. Connolly, N. Kaur, B. Deol (Natural Resources Defense Council (NRDC)), J. Hess (University of Washington), P. Sheffield (Icahn School of Medicine at Mount Sinai), P. Webster, V. Toma (Georgia Institute of Technology).

## CONTEXT

More than 7 million people live in the rapidly urbanizing city of Ahmedabad, located in Gujarat state of Western India. Heat waves have already proven to be dangerous in the city, leading to heat stress, heat stroke and heat-related illnesses. With climate change creating higher daily peak temperatures and longer, more frequent and intense heat waves, and following a deadly heat wave in May 2010, the Ahmedabad Municipal Corporation (AMC) realized that coordinated action was needed to protect its residents from extreme heat and to become more climate-ready (1).



Figure 6.1 Ahmedabad survey respondents, 2011.



Photo credit: Kathy Tran/Gulrez Azhar

## NEW APPROACHES

A coalition of academic, health and environmental groups partnered with the AMC in 2011 to create an early warning system (EWS) and heat preparedness plan as a roadmap to save lives during dangerous heat waves (2). When the project began in 2011, communication of impending extreme heat was limited among municipal agencies. At the time, the India Meteorological Department (IMD) issued two-day forecasts daily, but the AMC and other experts indicated a need for forecasts with a longer lead-time and coordinated action to alert the local government, health care centres, and the public of impending heat waves with formal communication channels to disseminate these warnings.

The team aimed to improve heat disaster response planning at the local level by developing an interagency heat action plan, including longer-term forecasting, to provide early warnings for extreme temperatures and increase heat-related capacities in local health centres. Based on scientific research identifying the city's most vulnerable residents (including children, elderly people, slum communities and outdoor workers), the coalition developed a Heat Action Plan to increase the climate resilience of the most at-risk residents as temperatures rise. Ahmedabad's groundbreaking plan includes three key strategies:

1. Building public awareness and community outreach on the risks of heat waves and practices to prevent heat-related illnesses. Ahmedabad agencies host trainings and disseminate multilingual pamphlets, advertisements and other informational materials on heat-stress prevention and heat wave safety tips.
2. Initiating an EWS to alert residents and coordinate an inter-agency emergency response effort when heat waves are forecast. Formal communication channels were created among government agencies, health officials, emergency response teams, community groups, and media outlets to disseminate heat alerts, and longer-term forecasts were developed.
3. Increasing capacity among medical professionals to recognize and respond to heat-related illnesses. Trainings better equip medical professionals to offer heat-specific advice on display of symptoms, diagnosis and treatment, and reduce mortality and morbidity through standard surveillance protocols (3). Advanced warnings help health professionals to be on alert for heat-stress patients and prepare additional resources such as ice packs.

In April 2013, the AMC and partners launched the city's initial Heat Action Plan, becoming the first city in South Asia to comprehensively address the health threats of extreme heat (4). The AMC designated its Health Department and a deputy health officer as lead agency and lead officer, respectively, with the overarching responsibility to coordinate all related municipal activities (5). The lead officer monitors daily temperature forecasts, sends heat alerts and disseminates public health messages to local government departments, health services and the media.

## CASE STUDY 6.A



### BENEFITS AND LESSONS

The team developed an innovative seven-day temperature forecast with international experts that complements IMD's forecast, which is sent daily to the lead officer during the hot season. This daily email contains the forecast and weather warnings provides a longer lead-time and robust, reliable weather information for the lead officer to accurately determine when to declare a heat alert and initiate the inter-agency response. Now the local IMD has increased its own capacity to provide the 5-7 day forecast to AMC.

A new scale of coordinated action between local government and health professionals on heat wave preparedness and forecasting, with input from regional and international health and climate experts, was essential to minimize the dangerous health effects of heat stress and increase vulnerable populations' resilience to rising temperatures in India. To evaluate the effectiveness of the Heat Action Plan during the initial 2013 and 2014 hot seasons, the team conducted questionnaire-based interviews with stakeholders actively involved in the plan. The survey focused on whether stakeholders believe the plan was successfully administered, and effectively reached vulnerable populations with preparatory materials and heat alerts. Early findings show that many lives have likely been saved, local health professionals' awareness of predicted heat waves and capacity to care for patients with heat-related illnesses have increased and, overall, Ahmedabad is now much more prepared for heat waves (6).<sup>i</sup> Other cities, states and regions across India are now developing their own Heat Action Plans based on the Ahmedabad model to increase their own residents' resilience to the impacts of climate change, including the states of Maharashtra and Odisha. The National Disaster Management Authority has added information on heat waves to its website and the IMD has adapted how it forecasts temperatures and heat wave conditions, in addition to strengthening inter-agency communication. IMD now provides a 5-day forecast to more than 100 cities around India to increase cities' capacity to warn citizens and respond to impending heat waves.



<sup>i</sup> Locally, the lead agency and lead officer are referred to as the 'nodal agency' and 'nodal officer'.





ACKNOWLEDGEMENTS



INDIAN INSTITUTE OF PUBLIC HEALTH GANDHINAGAR



UNIVERSITY of WASHINGTON



# MANAGING THE HEALTH IMPACTS OF DROUGHT IN BRAZIL: A COMPREHENSIVE RISK REDUCTION FRAMEWORK

Authors: A. Sena, C. Barcellos, C. Freitas (Oswaldo Cruz Foundation - FIOCRUZ) and C. Corvalan (University of Canberra).

## CONTEXT

Drought is largely a hidden risk and its health impacts are poorly understood and recorded. In contrast to other climate-related events, drought appears slowly and silently, showing neither an evident onset nor immediate impacts in the short term. Yet the impacts can last for years, even after rainfalls resume, and poor and vulnerable populations tend to suffer the greatest consequences (8, 9). Droughts can have impacts on known health risk factors such as use of inadequate or unsafe water for consumption and sanitation, increased population displacement, and disruption of local health services. It also impacts acute and chronic health effects including malnutrition, increased risk of communicable diseases, respiratory conditions, psychosocial stress and mental health disorders (10–15).

Between 1960 and 2013, 612 drought events resulted in 2.19 million deaths and 2.14 billion affected persons globally (16). In Brazil, disaster notifications are issued by municipalities, and between 1991 and 2010, there were close to 17 000 drought events recorded in 2944 municipalities, making it the most frequent disaster by type. Of a total of 96 million people affected by natural disasters in these 20 years, 48 million (50%) were affected by drought (flash floods and other floods made up to 40%); and over a total of 2475 registered deaths, roughly 10% were drought related (17). Some parts of the country undergo sporadic dry seasons, while other parts are permanently dry. Given the increase in temperature and decrease in rainfall expected throughout the current century, there is a risk that the semi-arid areas located in the northeast of the country, home to over 22 million people, will begin a process of desertification. This fact highlights the necessity of gaining a better understanding of the health impacts of drought in Brazil and taking action accordingly.





Home in drought affected area in Rio Grande do Norte, Brazil Photo credit: Aderita Sena.

### NEW APPROACHES

Given the slow onset and the large lag-time to identify measurable health impacts, drought can be seen as a chronic emergency, which tend to attract less attention than acute emergencies. This has consequences for health preparation and response. The Ministry of Health in Brazil decided to establish a clear management process to implement actions of risk reduction, disaster management and recovery, and adaptation. Drought conditions may be monitored by a variety of indicators such as accumulated precipitation, temperature, humidity and vegetation status (18). These data are now being made available by governmental agencies; and their joint analysis is an important strategy to identify the extension and magnitude of droughts.

Disaster risk reduction in the health sector in Brazil follows a well-documented framework, which includes three stages: risk reduction, disaster management and recovery (19). This framework is adapted for drought management, emphasizing the concept of adaptation. The steps are shown in Figure 6.2, with examples of community participation.



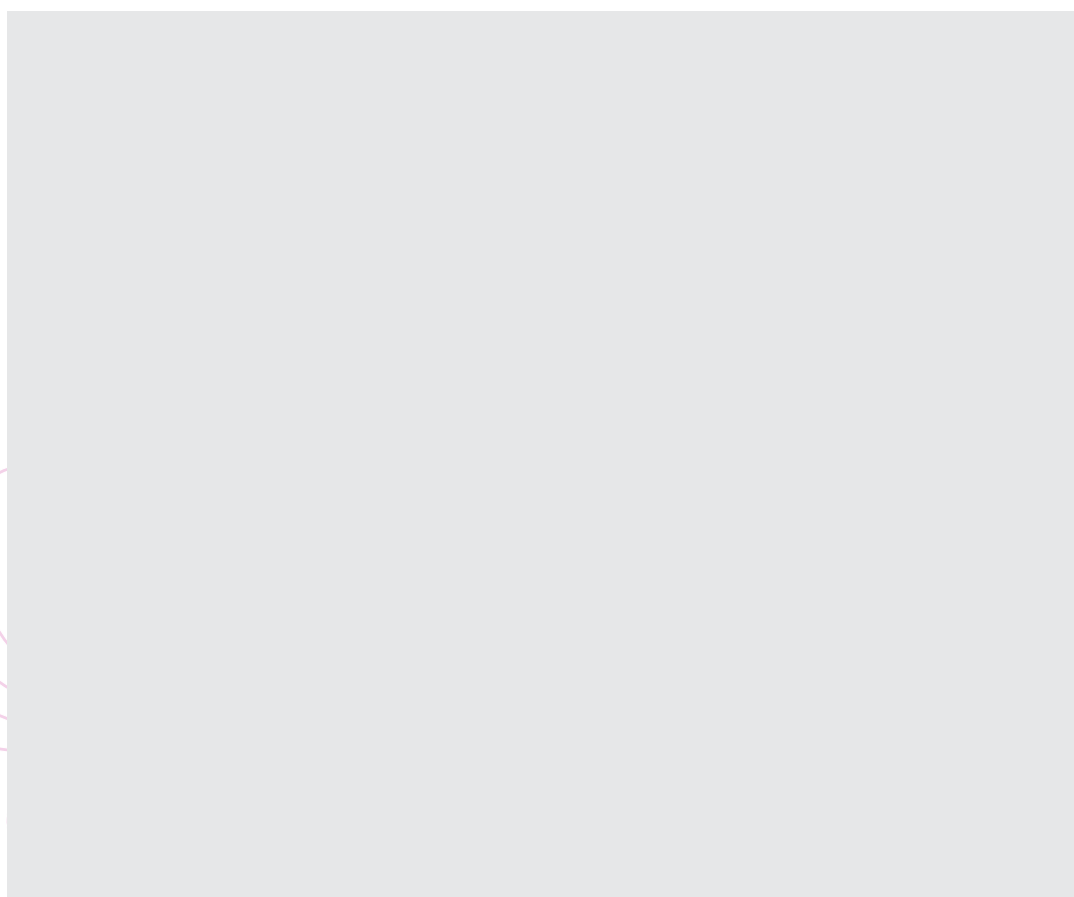
## CASE STUDY 6.B



### BENEFITS AND LESSONS

Important progress has been made in Brazil in reducing social and economic vulnerability to droughts. Social programmes such as the conditional cash transfer programme known as 'Bolsa Familia' and health programmes such as 'Family Health' have contributed to reducing the impact of the most recent drought (2011–2013), ensuring the country will never again experience past catastrophic events. In the drought of 1877–1878, there were some 500 000 deaths from drought and smallpox. More recently, the drought from 1979–1983 was responsible for tens of thousands deaths (20).

Local governance and complete community participation are necessary for successful and sustainable actions (21). Although progress has been made in recent years, much more is needed to ensure health is seen as a key partner in drought risk management. Expected global climate changes are likely to make drought events more serious in the next few decades (22). As a consequence, it is necessary to address policies to reduce social and economic vulnerability to droughts combined with the development of adaptive capacity and resilience at the local level. Although not highlighted specifically as health sector actions to reduce vulnerability, programmes for household water storage, expanding cisterns to collect rainwater before drought, building dams and drilling wells, financial support to agriculture, and ensuring a minimum income during drought are some examples of interventions with positive impacts on health and population well-being. Alerts for intense drought are important tools for sector-specific interventions, such as for the agricultural sector in order to prevent larger impacts in the local economy and inform water resource managers to conserve and prioritize water usage.

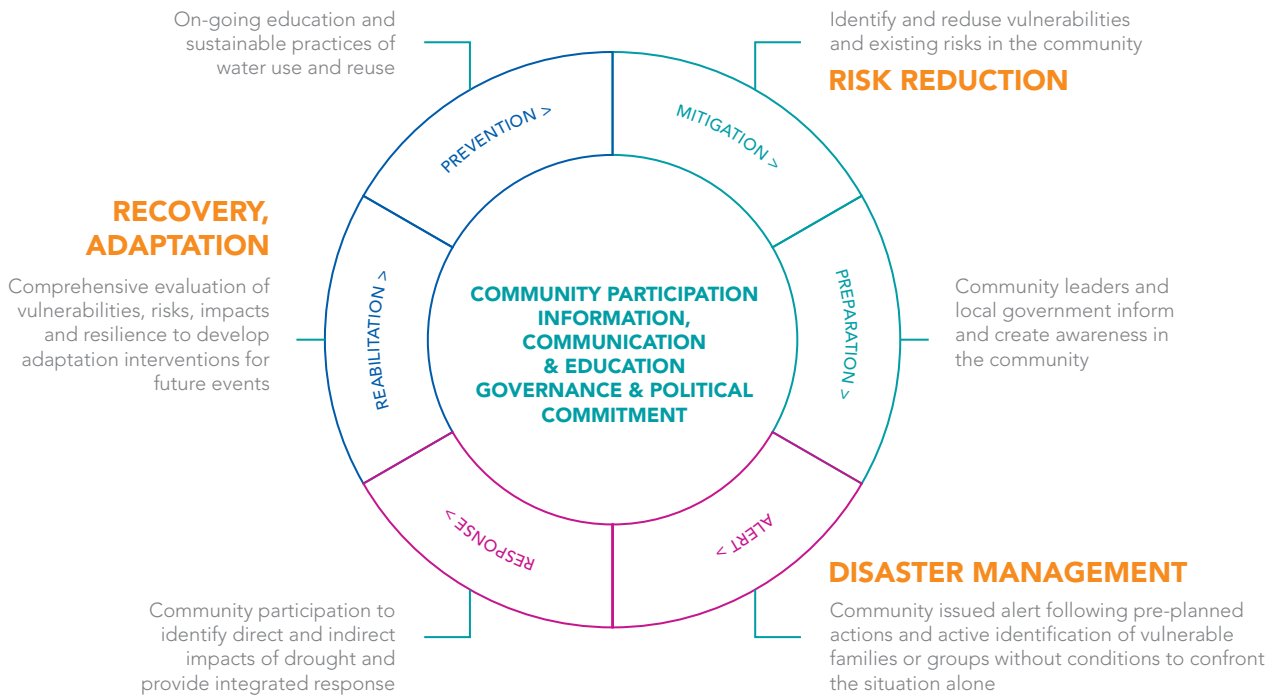


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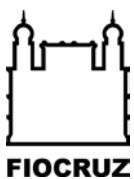
The health sector also has a key role promoting awareness of health risks and the social and environmental vulnerabilities of specific areas and communities, and to find mechanisms to increase the resilience of local communities and local government health services. The health sector needs to ensure that all health risks, from the most immediate and visible (such as infant diarrhoeal diseases), through to the longer term yet visible impacts (such as malnutrition), to the less visible and delayed in time (such as mental health conditions and other chronic diseases), are fully included in its assessments and response. This will also ensure coherence with the Sustainable Development Goals (23).

For further information on this case study, refer to Sena et al (24).

**Figure 6.2** Adapted disaster risk reduction framework, highlighting community participation (24).



**ACKNOWLEDGEMENTS**





# EARLY WARNING SYSTEMS TO GUIDE INFECTIOUS DISEASES CONTROL IN EUROPE

Author: J.C. Semenza (European Centre for Disease Prevention and Control).

## CONTEXT

Globalization and environmental change, social and demographic determinants, and weak health system capacity are significant drivers of infectious diseases. Monitoring changes in these drivers can help anticipate, or even forecast, an upsurge of disease (24).

## NEW APPROACHES

The European Centre for Disease Prevention and Control has developed the European Environment and Epidemiology (E3) Network to help monitor drivers related to infectious disease threats (Figure 6.3) (25). A large set of climatic, environmental and social data have been aggregated, processed and stored in the E3 Network repository and are accessible through the E3 Geoportal (25). For example, biophysical parameters for temperature and precipitation that have been Fourier-processed have been made available, as well as data on evapotranspiration, vegetation, topography etc. Estimates for 2020/50/80 scenarios for certain climatic variables are also retrievable. The overall data management and dissemination function of the E3 Network adheres to protocols, procedures and workflows with metadata standards that are based on the INSPIRE directives. The E3 metadata standards cover all the types of resources that are provided via the E3 service such as map files, documents, tools, live map services, etc. Advanced mathematical modelling (e.g. non-linear discriminant analysis) has been used to compute the risk maps and forecasting tools.

## BENEFITS AND LESSONS

This resource has been applied to a number of infectious diseases in Europe. For example, it was used to predict the environmental suitability of malaria transmission in Greece (26). Malaria was eliminated from Greece in 1974, but in 2009 (and subsequent years) local transmission occurred. Remotely sensed E3 data were analysed to delineate the environmental and climatic conditions where future transmission could occur in the country (26). They were characterized by low elevation, warmer temperatures and intensive, year-round irrigated agriculture with complex cultivation patterns. The predictors in this model are probable contributing factors to mosquito presence and, potentially, to malaria transmission (26). Defining the areas of high risk made it possible to guide the public health responses with targeted epidemiological and entomological surveillance, vector control activities, and awareness-raising among the general population and health care workers, in the areas environmentally suitable for transmission; transmission was subsequently interrupted in 2013 in these areas by using EU structural funds for these intervention entry points.

Enabling Environment

Capacity Building

Product & Service Development

Application

Evaluation

Data Collection and Management

Integrated Surveillance

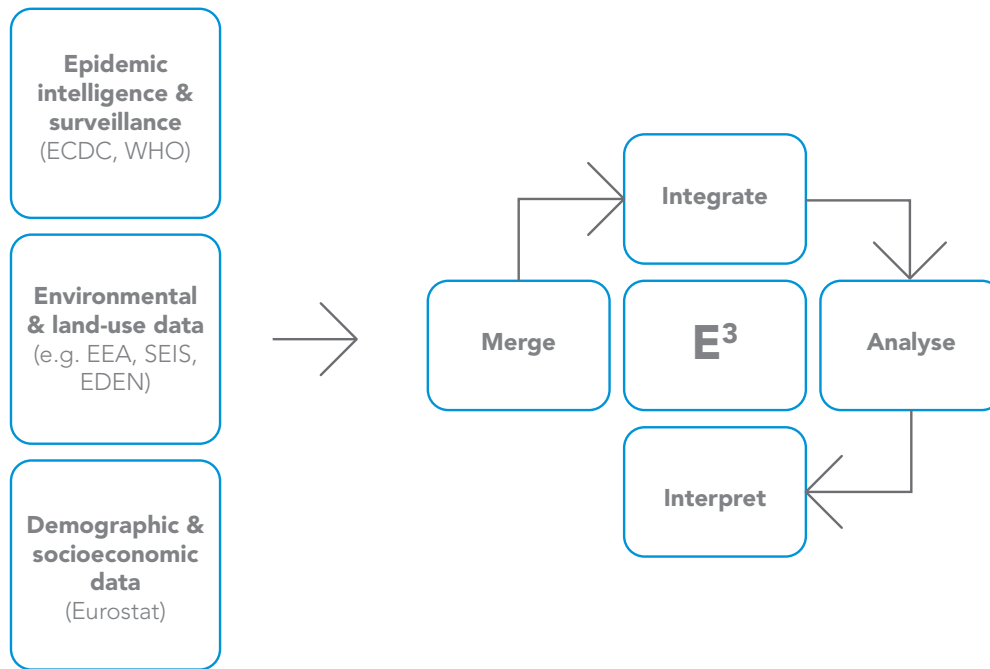
Indicators and Thresholds

Risk Models and Maps

Forecasts

Warnings

**Figure 6.3** The European Environment and Epidemiology (E3) Network.



The E3 Geoportal also operates a tool for the real-time assessment of environmental suitability of *Vibrio* sp in the Baltic Sea (and internationally), based on sea surface temperature and salinity. Infections caused by *Vibrio* species (other than *V. cholerae*) can result in wound infections, gastroenteritis or septicaemia, with a relatively high mortality rate among immunocompromized individuals, although the overall occurrence of vibriosis in the Baltic is generally low. Significant and sustained warm water anomalies in the Baltic Sea correspond with increases in reported *Vibrio*-associated illness (27). There is a highly significant association between mean summer temperature increase and the number of reported human cases of vibriosis. The output of the model presented on the E3 Geoportal delineates coastal areas with environmental conditions suitable for the occurrence of human pathogenic *Vibrio* sp. that can drive the emergence of infections. The tool provides short-term forecasts, present and past environmental suitability for these *Vibrio* sp. It can be used to initiate beach closures and public alerts, particularly to immunocompromized individuals who are at elevated risk from vibriosis.

Another disease of interest in Europe is West Nile fever (WNF), which is transmitted between birds via mosquito vectors, while humans are accidental dead-end hosts. Both biotic (e.g. host abundance and diversity) and abiotic (e.g. physical features of the environment) conditions are important determinants of WNF epidemiology. Since 2010, recurrent West Nile fever outbreaks have occurred in South/eastern Europe. Temperature deviations from a thirty year average proved to be associated with these outbreaks (28). Drivers of subsequent outbreaks were computed through multivariate logistic regression models and included in prediction models (29). We found temperature anomalies, a water index and bird flight patterns to be predictive. Environmental monitoring for WNF should integrate these climatic and environmental variables in order to improve public health surveillance for WNF (29).

To date several workshops have been held with Member State representatives to train them on the E3 functions. This will ensure the systems developed can effectively assist public health decision-making in Europe.

Such early warning systems, based on climatic and environmental conditions, can help improve and accelerate alert and public health response capabilities and provide the evidence base for strategic public health action (24).

## ACKNOWLEDGEMENTS





# IMPROVING MALARIA EVALUATION AND PLANNING WITH ENHANCED CLIMATE SERVICES IN EAST AFRICA

Authors: B. Platzer (*Mobilizing Action Toward Climate Change and Health*), T. Dinku (*International Research Institute for Climate and Society*), S. Ferazzi (*Roll Back Malaria Partnership*), Thomas Teuscher (*Roll Back Malaria Partnership*), Aduugna Woyessa (*Ethiopian Public Health Institute*), Melesse Lemm (*Ethiopian National Meteorological Agency*) Renata Mandike (*Tanzanian Ministry of Health and Social Welfare- National Malaria Control Programm*), Hellen Msemo (*Tanzanian Meteorological Agency*), Christine Hershey (*USAID/President's Malaria Initiative*), Sergio Rene Salgado (*USAID/President's Malaria Initiative*), Madeleine Thomson (*International Research Institute for Climate and Society*).

## CONTEXT

National malaria control programmes and national meteorological agencies in East Africa are pioneering new decision-support tools and partnerships to address the historical impact of climate on malaria transmission and to better prepare for the future (32). This case study highlights, in particular, country efforts underway in Ethiopia and Tanzania with technical support from the International Research Institute for Climate and Society (IRI), the Columbia Global Centers/Africa (CGC/Africa), the Roll Back Malaria (RBM) Partnership and the US President's Malaria Initiative (PMI). Lessons learned from incorporating climate data into malaria impact assessments (30), and other aspects of malaria planning (31), can benefit the broader development of climate services that deliver relevant and robust information to often underserved health stakeholders.

## NEW APPROACHES

The Ethiopian National Meteorology Agency and the Tanzanian Meteorological Agency (TMA) have launched groundbreaking initiatives on Enhancing National Climate Services (ENACTS) to dramatically improve the availability, access and use of climate data and information relevant to decision-maker needs through partnered consultation across government ministries and sectors. National malaria control programmes, in particular, have provided a pathway to demonstrate the value of this newly available information to communities in need of quality assured, high-resolution data and tools for mapping populations at risk of malaria, investigating the seasonality and timing of interventions, monitoring year-to-year trends, targeting resources and advocacy for early preparedness (33).

This nationally rigorous climate information, which leverages all ground-based observations available at the country level with proxy satellite and other data, is especially valuable to historical impact assessments of malaria control. Understanding how the past climate has impacted malaria transmission and control is critical to current national evaluations, future financing and the ability to respond to malaria risks in a changing climate going forward. The ENACTS products have already supported several Roll Back Malaria-led impact assessments, including in Ethiopia, Tanzania and Rwanda (with other country evaluations in development).

Enabling Environment

Capacity Building

Research

Product & Service Development

Application

Evaluation



Figure 6.4 Fact sheet on ENACTS.



**ENHANCING NATIONAL CLIMATE SERVICES**

**Targeted Climate Information for Decision Making**  
 Ensuring development interventions consider the effects of a changing climate is critical across a range of sectors to demonstrate impact and sustainability. Enhancing National Climate Services (ENACTS) is a unique initiative developed by the IRI and partners to provide reliable and readily accessible climate data at high resolution to decision makers in Africa. The ENACTS initiative delivers robust climate data, targeted information products and training specifically relevant to user needs, enabling them to apply climate information to decision making with confidence.

**Observations Make All The Difference**  
 Ground observations are essential for ensuring robust climate data for national decision making. Observations capture small-scale geographic variability in precipitation and temperature that can have a significant impact on development outcomes. Climate information produced at the global level does not fully exploit information from national observational data. Despite significant advances, even the highest-definition satellite data may not provide the level of detail required for the smaller scales of government decision making.  
 In many African countries, gaps in observational records result in poor quality data, undermining the reliability of climate analysis, short-term forecasts and long-term projections. By integrating local observations and global monitoring data, the ENACTS initiative strengthens policy analysis by providing national coverage with greater accuracy at smaller spatial and temporal

scales while building local capacity. This higher definition in climate data assists targeted decision making to consolidate development gains in the face of climate variability and change and improve the resilience of vulnerable communities.

**Understanding the Past, Monitoring the Present, Forecasting the Future**  
 ENACTS enables analysis of climate data at multiple scales to enhance development decisions.

**It uses detailed historical climate data to:**

- + Understand natural variability in temperature and precipitation over national, regional and district scales and assess the impacts on development outcomes.
- + Understand climate sensitivity to map populations and systems at risk of climate variability and change.
- + Improve the timing and scale of climate-sensitive interventions and design early warning systems.

**It provides the ability to monitor current climate and to develop forecasts to:**

- + Trigger early warning systems to alert for potential food insecurity, infectious disease epidemics and hydro-meteorological disasters.
- + Strengthen activities to support climate-smart development, such as climate-resilient crop planting, weather index-based agricultural insurance, and improve efficiency in energy and water usage.

By integrating observations with proxy data, ENACTS overcomes issues of data scarcity and poor quality and introduces



*Training workshop on climate data management and seasonal forecasting held in Niamey, Niger. Francesca Fiondella/IRI*

**International Research Institute for Climate and Society**  
 EARTH INSTITUTE | COLUMBIA UNIVERSITY

As is well documented, the East African climate is a key driver of spatial and temporal variability in malaria transmission in the region. Populations with high malaria prevalence are historically found in the humid lowlands (such as those surrounding Lake Victoria), while populations prone to climate-related epidemics are found in marginal transmission zones such as semi-arid regions (including northeastern Kenya, for example) and the East African highlands. Thus control efforts, especially those being evaluated over the past decade, must be understood in this context of underlying variability with interventions more likely to succeed in areas with lower climate suitability for malaria.



## CASE STUDY 6.D



Historically well-understood malaria stratification may be changing, however, due to recent climate trends (see Figure 6.5). Thus high-quality climate services are more crucial and in demand than ever (35). East Africa has made headlines with a series of severe drought events, experienced since 1999 particularly during the long rainy season, which typically runs from March to May. The most recent of these events triggered a humanitarian crisis in the Horn of Africa. These recent droughts, while exacerbating threats to food security and livelihoods, may have in fact contributed to malaria declines in the region, indirectly increasing the impact of government and donor investments in malaria control and elimination. However, the favourable environment for malaria control in East Africa may not last. A study on the causes of the recent drying suggests that the alternating dry and wet periods in this region are associated primarily with natural climate variability operating on a decadal time-scale (31). Long-term climate change projections may have further implications for the climatic suitability of malaria transmission.

Short-lived phenomena, such as El Niño (which tends to increase rainfall during the short rainy season of East Africa and bring warmer temperatures across the tropics) can also disrupt the steady progress made by national malaria control programmes in this region, at a time when interventions are facing more constrained resources than experienced in the past decade. The ENACTS products were used, in particular, by national malaria control programmes and their partners in Ethiopia and Tanzania to monitor and prepare for the forecasted 2014 El Niño and its associated risk of increased malaria transmission.

**Figure 6.5** Implications of climate suitability for malaria transmission and impact assessments

CHANGES IN CLIMATE SUITABILITY FOR MALARIA TRANSMISSION FOLLOWING INTERVENTION (RELATIVE TO BASELINE)	CHANGES IN OBSERVED MALARIA FOLLOWING INTERVENTION (RELATIVE TO BASELINE)	
	decrease ↓	no change or increase ↑
Increase ↑	may underestimate impact of intervention	may obscure impact of intervention
no change (average)	no effect	
decrease ↓	may overestimate impact of intervention	may obscure extent of failure of intervention

## ACKNOWLEDGEMENTS

The partnerships and innovations mentioned here have generously been supported by the World Meteorological Organization (WMO), NASA SERVIR and the US President's Malaria Initiative (PMI). Support to ENACTS has also been provided by Google.org and the CGIAR Research Programme on Climate Change, Agriculture and Food Security (CCAFS). The authors also thank the countless colleagues and partners that have contributed to this work through active collaborations and leveraged resources.



While climate is not the only driver of changes in malaria risk (effectiveness of malaria interventions, poverty reduction, education, urbanization, etc. are also significant factors), countries and the global malaria community should be aware of the potential risk linked to climate variability and change and take measures accordingly. Lower transmission risk during a favourable (dry) climate should also be taken advantage of, in particular to reduce the impact of a return to a wetter environment and to drive down this devastating disease overall. Variations in malaria outcomes that result from a changing climate should be factored in as part of malaria control and elimination strategies and should not be interpreted as programme failure. This can be supported through dedicated trainings and stakeholder consultations responding to national needs. Through ENACTS partnerships, on-site training and extended technical visits have been held at the national meteorological agencies in Ethiopia and Tanzania, for instance, along with tailored workshops for communities of practice (ranging from health professionals and decisions-makers to local public health researchers). National exchange has also been supported through regional stakeholder meetings to ensure country lessons are shared. Ministry of health and national meteorological agency staff have also been supported for technical trainings and collaborations hosted at the International Research Institute for Climate and Society at Columbia University in New York.

## BENEFITS AND LESSONS

The added value of the decision-support tools and partnerships pioneered in East Africa has been demonstrated by a growing demand for the ENACTS products. Uptake of these tools has been evaluated through workshop assessments and follow up, as well as project surveys and monitoring of access to web-based platforms and requests made to national authorities for ENACTS products and training. Ongoing systematic evaluation, including national surveys on the wider use of climate information by health practitioners, is a priority for collaborators to ensure continued relevance of products to country needs.

Advances in nationally available historical climate data and information, available through the online climate and health 'map rooms' of Ethiopia and Tanzania, should be further leveraged locally and internationally to better understand, monitor and manage climate-related risks to malaria control and elimination. In addition, understanding the spatial extent of the current drought in Eastern Africa, its severity, its likely cause and if and when it may end, are important for decision-makers and other stakeholders, including development partners, to better target current malaria interventions and improve allocation of shrinking resources, while preparing for new challenges ahead.

# USING CLIMATE INFORMATION TO PREDICT AND CONTROL MENINGITIS EPIDEMICS IN WEST AFRICA

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## CONTEXT

Meningococcal meningitis (MCM) is a contagious infection disease caused by the bacteria *Neisseria meningitidis*. MCM epidemics occur worldwide but the highest incidence is observed in the 'meningitis belt' of sub-Saharan Africa, stretching from Senegal to Ethiopia. The severity of the MCM epidemics varies from year to year with the number of cases in the region ranging from 25 000 to 250 000. Children under 15 are particularly affected. Mortality rates average around 10%, with 10 to 20% of survivors affected by serious neurological repercussions.

The factors behind these epidemics are not fully understood but are known to involve a complex interplay of social interactions, new bacterial strains, population vulnerability, asymptomatic carriage and environmental conditions. Climatic conditions are also considered to be important in influencing the seasonality and interannual fluctuations of MCM outbreaks, which is roughly circumscribed to the ecological Sahelo-Sudanian band. In fact, MCM epidemics usually occur during the dry, hot and dusty season (February–April), and end with the onset of rains (rainy season).

## NEW APPROACHES

Climate data from national synoptic stations, re-analysis data from the National Centers for Environmental Prediction (NCEP), and annual epidemiological data from the World Health Organization (WHO) and the Burkina Faso Ministry of Health have been used to identify statistically significant links between the severity of MCM epidemics and climate variability. In particular, time-lag relationships between climate anomalies and epidemic outbreaks have been established (38).

Enabling Environment

Capacity Building

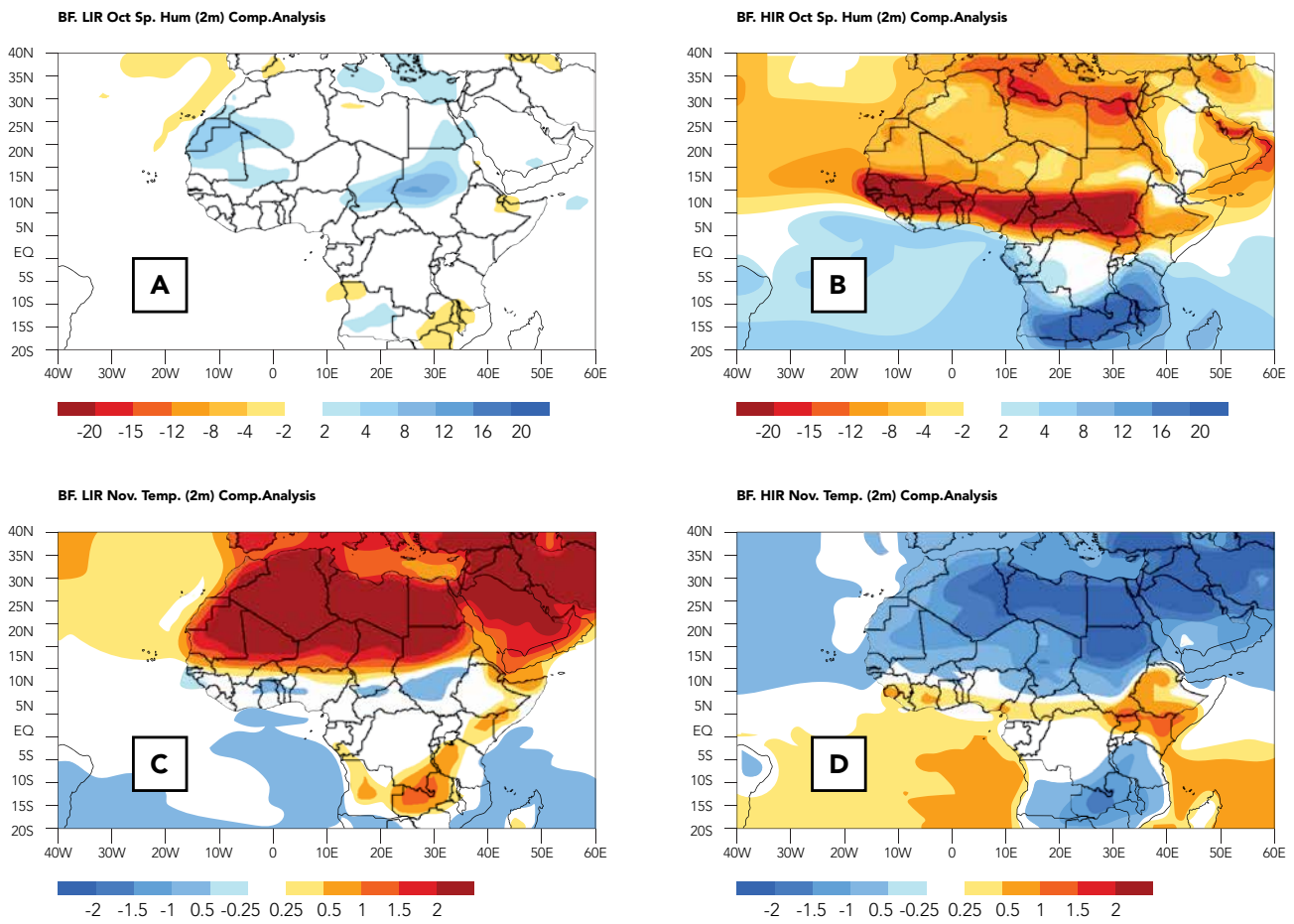
Research

Product & Service Development

Application

Evaluation

**Figure 6.6** Anomaly composite of specific humidity during low MCM incidence rate period (a); high MCM incidence rate period (b); air temperature during low MCM incidence rate (c) and during high MCM incidence rate (d).



## CASE STUDY 6.E



### BENEFITS AND LESSONS

One of the key findings of this study is that enhanced easterly winds (Harmattan) at the beginning of the dry season, particularly the meridional component of the wind over Burkina Faso in October, and over Niger in November and December, have been associated with MCM epidemic outbreaks during the following year (38). In addition, composite analysis of specific humidity and air temperature from October to December revealed specific patterns typical of MCM high incidence rate (HIR) and low incidence rate (LIR) occurring in Burkina Faso (BF) and Niger the following years (40).

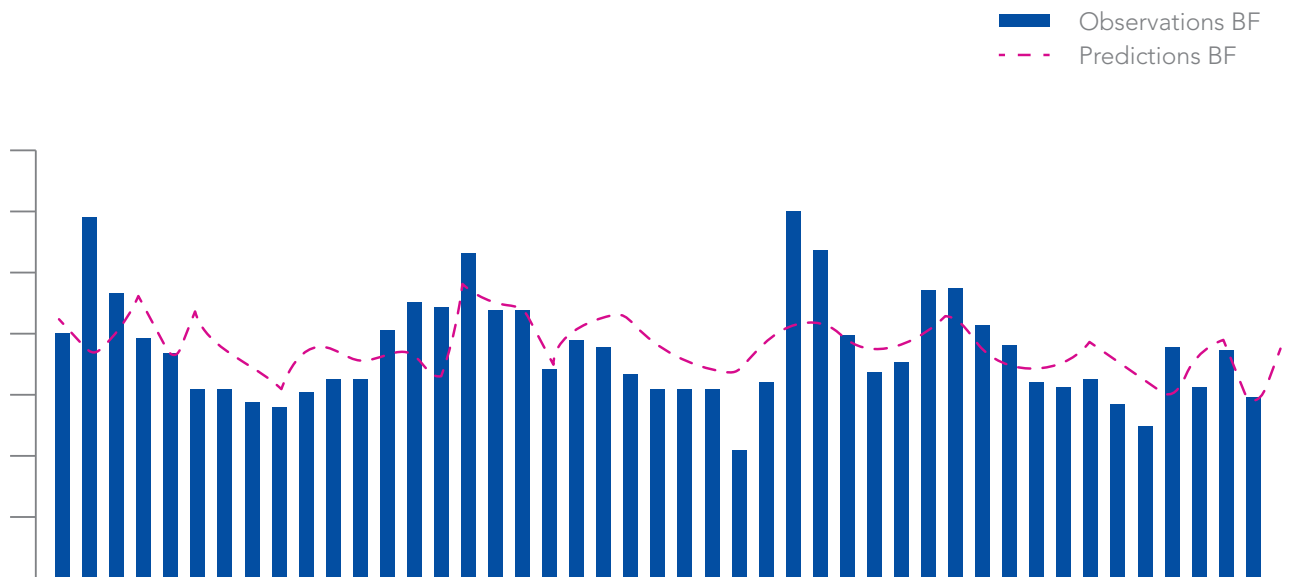
This study has resulted in experimental predictions of MCM outbreaks in Burkina Faso. A national Working Group on Climate and Health consisting of professionals from several scientific disciplines and various sectors including civil society organizations, has been established in Burkina Faso. With support from the Laboratory of Ocean and Climate Science: Experimentation and Numerical Approach and the National Oceanic and Atmospheric Administration's Climate Prediction Centre, predictions of MCM incidence in Burkina Faso are made annually before the onset of the outbreak season, usually in December (39). Health and climate professionals and students have been trained on building and updating the forecast models that link climatic factors and meningitis. An evaluation of the performance of the forecast model is also carried out each year.

Placeholder for image

Both forecasts and verifications are made available to the public in a bulletin form and officially distributed to the national authorities in charge of health, climate, environment, nongovernmental organizations, financial and technical partners and decision-makers involved in the control of MCM epidemics and the promotion of climate-sensitive diseases studies (39).

The forecasts are integrated into the national system of surveillance and early warning of MCM epidemic outbreak and contribute to reinforcing the strategies to control MCM epidemics, through education, fundraising for vaccines, putting staff and health equipment in place in case of MCM upsurge.

**Figure 6.7** Meningococcal meningitis incidence rate predicted and observed in Burkina Faso from 1969 to 2014, The x-axis indicates the years and the y-axis the logarithm of MCM annual incidence The bar graph represents observed MCM logarithm incidence rate from 1969 to 2013 and the dashed line graph represents the predicted MCM logarithm incidence rate from 1969 to 2014.



ACKNOWLEDGEMENTS





# USING CLIMATE KNOWLEDGE TO GUIDE DENGUE PREVENTION AND RISK COMMUNICATION AHEAD OF BRAZIL'S 2014 FIFA WORLD CUP

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## CONTEXT

Brazil has reported more cases of dengue fever than any other country this century (41), with more than 7 million cases (until 2013). Many cities have tropical and sub-tropical climatic conditions that allow the dengue mosquito to thrive during warmer, wetter and more humid months, particularly in densely populated urban areas. Dengue epidemics depend on mosquito abundance, virus circulation and human susceptibility. In order to prepare for dengue epidemics, early warning systems, which take into account multiple dengue risk factors, are required to implement timely control measures. Seasonal climate forecasts provide an opportunity to anticipate dengue epidemics several months in advance.

## NEW APPROACHES

A new predictive model framework for climate-sensitive diseases was developed (42–44) as part of the Leverhulme network project EUROBRISA (45) (led by the University of Exeter and the Brazilian Centre for Weather Forecast and Climate Studies, CPTEC)<sup>j</sup>, which explored how European seasonal climate forecasts could be better exploited to improve climate resilience in South America (46). In collaboration with European and Brazilian climate services, universities and the Brazilian Climate and Health Observatory, data from different sources and spatial/temporal scales (e.g. dengue, climate, cartographic, demographic and socioeconomic) was collated to formulate the model, which produces probabilistic dengue predictions for the 553 microregions of Brazil. By assessing the past performance of the model, optimum trigger alert thresholds were identified to maximize 'successful prediction' and minimize 'false alarms' for scenarios of medium-risk and high-risk of dengue, according to incidence alert levels defined by the Ministry of Health.

Enabling Environment

Capacity Building

Research

Product & Service Development

Application

Evaluation

Data Collection and Management

Indicators and Thresholds

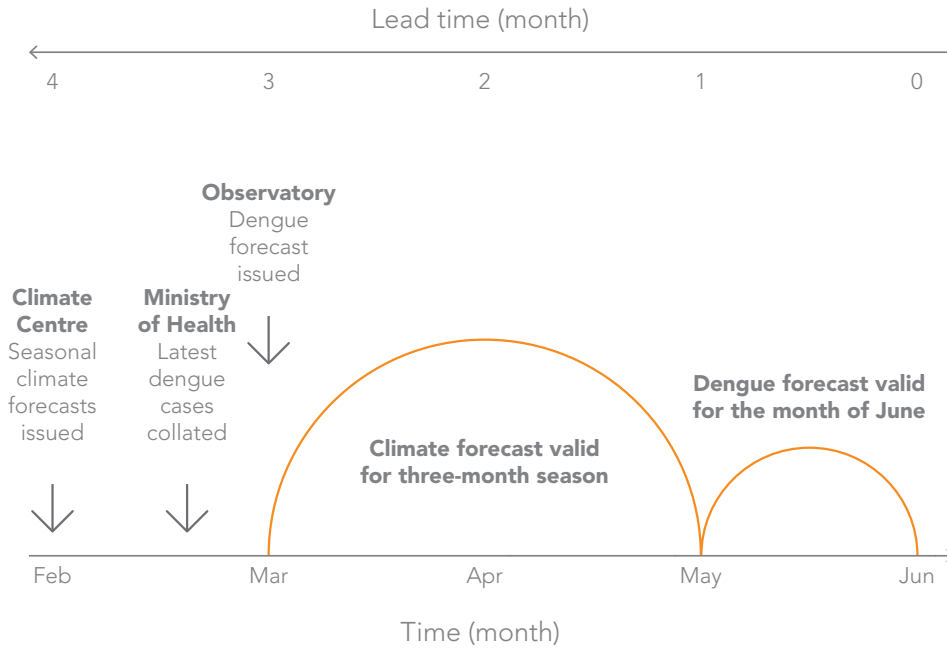
Risk Models and Maps

Forecasts

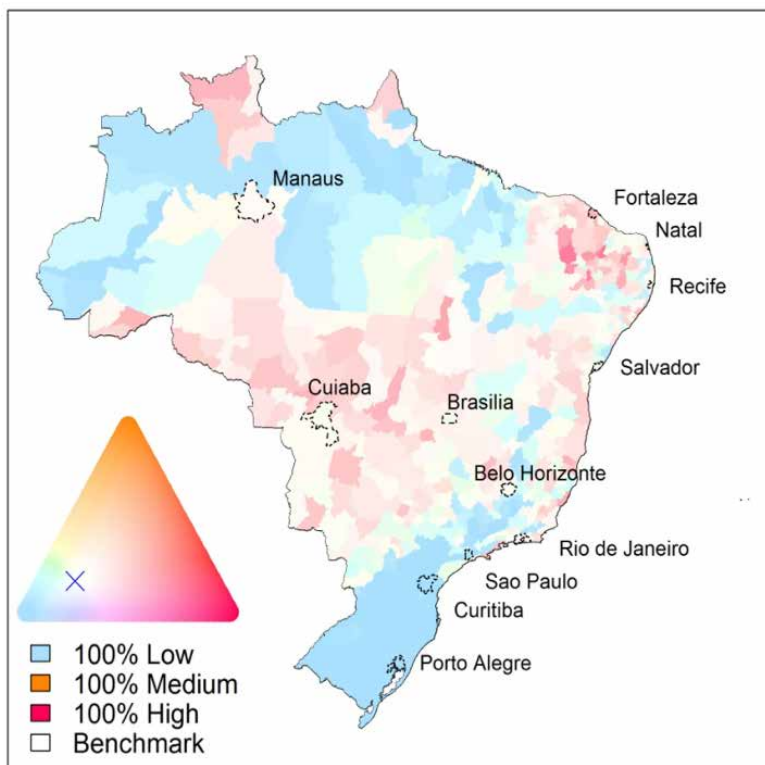
Warnings

<sup>j</sup> One of the twelve global producing centres (GPC) of long-range forecasts designated by the World Meteorological Organization (WMO).

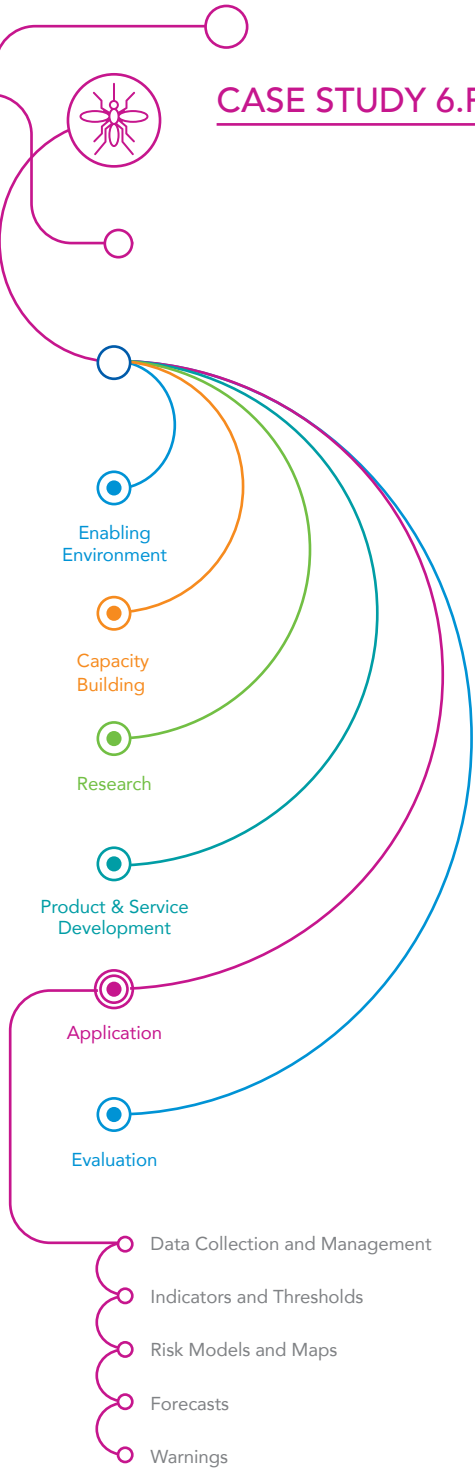
**Figure 6.8** Dengue forecast lead-time schematic. Schematic to show lead-time gained from using the combined and calibrated multi-model 3-month average (March, April, May) precipitation forecasts from the EUROBRISA integrated system and temperature forecasts produced with the empirical model described in (Coelho et al), produced in mid-February by the Brazilian Centre for Weather Forecast and Climate Studies (CPTEC) and the latest dengue cases from the Ministry of Health, Brazil (February estimate collated during March). The probabilistic dengue forecast, driven by climate forecasts and current dengue risk, could be issued by the climate and health observatory by mid-March. The system provides a forecast lead-time of 3 months (Source: Lowe et al).



**Figure 6.9** Probabilistic dengue forecast for Brazil, June, 2014. The continuous colour palette (ternary phase diagram, see Jupp et al) conveys the probabilities assigned to low-risk, medium-risk, and high-risk dengue categories. Category boundaries defined as 100 cases per 100 000 inhabitants and 300 cases per 100 000 inhabitants. The greater the colour saturation, the more certain is the forecast of a particular outcome. Strong red shows a high probability of high dengue risk. Strong blue indicates a high probability of low dengue risk. Colours close to white indicate a forecast similar to the benchmark (long-term average distribution of dengue incidence in Brazil, June, 2000–13:  $p_{low}=68\%$ ,  $p_{medium}=16\%$ ,  $p_{high}=16\%$ ), marked by a cross (Source: Lowe et al).

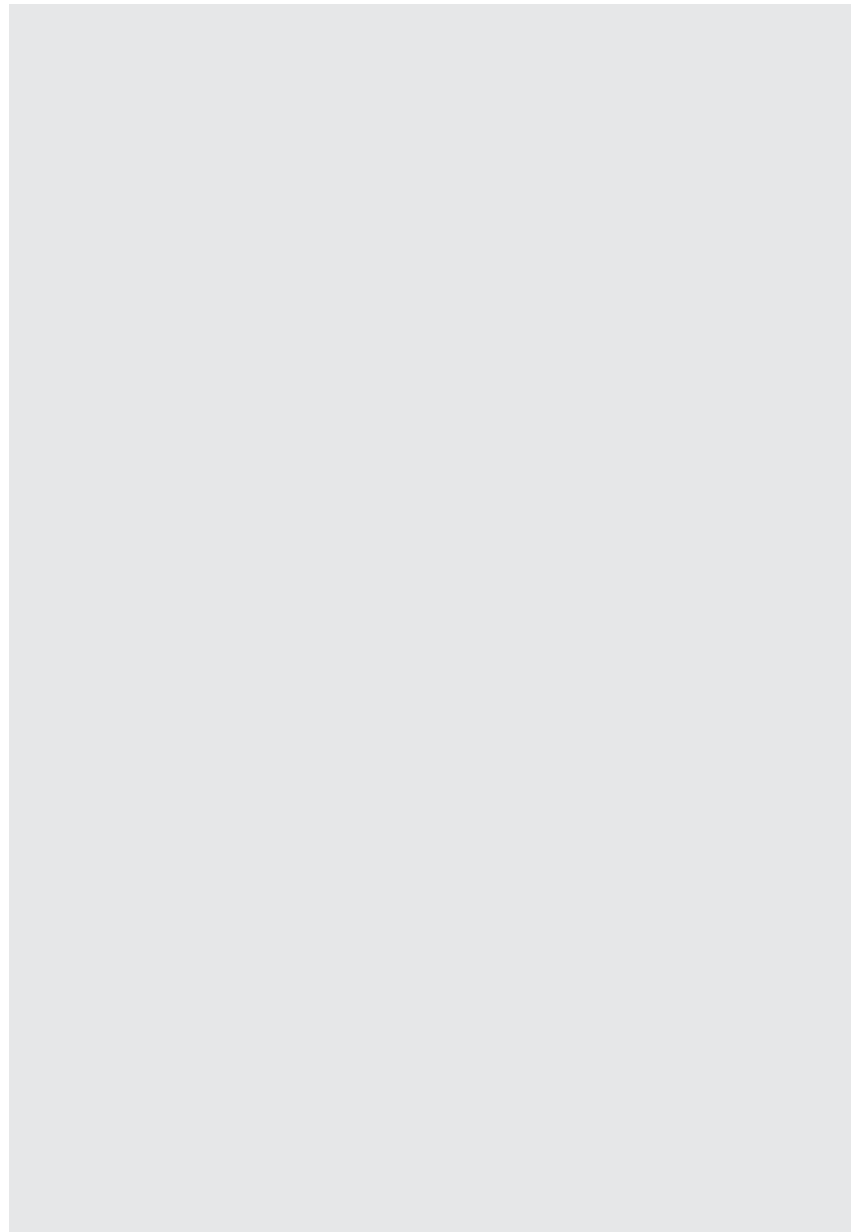


## CASE STUDY 6.F



The model was applied to predict the risk of dengue during the 2014 FIFA World Cup in Brazil, a mass gathering of more than 3 million Brazilian and international spectators (47). The timely production of the forecast relied on close collaboration between public health specialists, climate scientists, and mathematical modellers to incorporate real-time seasonal climate forecasts (EUROBRISA system) and epidemiological data into the model framework several months ahead of the event (Figure 6.8) and effectively present model results into an understandable format for stakeholders (Figure 6.9).

According to the model, the most likely scenario for all twelve cities was for low risk. However, there was a greater probability of outbreaks in the north-eastern cities of Natal, Fortaleza and Recife (48). Along with the forecast, decision-makers were provided with an assessment of past performance of the model. Over the past 14 years (2000–2013) the early warning system performed better than assuming the incidence each year will be equal to the long-term average in all twelve World Cup host venues, particularly in the northeast region.



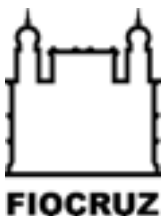
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## ACKNOWLEDGEMENTS

The research leading to these results has received funding from the DENFREE project (grant agreement no. 282378), EUPORIAS project (grant agreement no. 308291) and SPECS project (grant agreement no. 308378) funded by the European Commission's Seventh Framework Research Programme. CASC was supported by Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) process 306863/2013-8. MSC received funding from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ). The dynamic ensemble forecast data were kindly provided by ECMWF as part of the EUROBRISA licence agreement.



Ministério da  
Saúde



## BENEFITS AND LESSONS

This timely dengue early warning assisted the Ministry of Health and local authorities in implementing appropriate, city-specific mitigation and control actions up to three months ahead of the World Cup. Financial resources were increased to reduce mosquito populations and a multilingual information campaign was launched to inform visitors how to protect themselves from dengue. The National Dengue Control Programme implemented control measures such as house-to-house visits to destroy potential mosquito breeding sites. For example, stagnant water can accumulate in plant pots, bottle tops and discarded tyres. Campaigns were also launched to inform and educate the local communities in higher risk areas to clear containers that might collect water, protect themselves from mosquito bites and recognize the symptoms. The early warnings were also disseminated to the general public and visitors travelling to Brazil. For example, the predictions were incorporated into the European Centre for Disease Control (ECDC) health risk assessment (49), reported by the UK National Health Service (NHS) (50) and published by more than 18 international press outlets, including the BBC (51). Therefore, this study further contributed by raising general awareness about dengue fever and the risk of contracting the disease when travelling to endemic regions.

As the World Cup games took place during the southern-hemisphere winter, the risk was expected to be relatively low compared to summer (52). Overall reported dengue cases for 2014 were much lower than the previous year (53) although some outbreaks were observed in the southeast and northeast regions. A full evaluation of the June 2014 forecast, using reported case data for the Brazilian microregions is now available (54).

Communication of probabilistic dengue risk forecasts has proven to be challenging. Although the risk was low for most cities, it was comparatively higher in three out of the twelve cities where World Cup matches were played. The choice of wording to explain these forecasts has implications for the interpretation and understanding of the forecasts by users.

To our knowledge, this is the first example of a climate service for public health, ahead of a major global event. This framework may be useful, not only ahead of mass gatherings, but also before the peak dengue season each year, to control or contain potentially explosive dengue epidemics. The operational use of seasonal climate forecasts in routine dengue early warnings is now a priority for the Brazilian Climate and Health Observatory (55), in collaboration with the Brazilian Institute for Space Research (INPE).

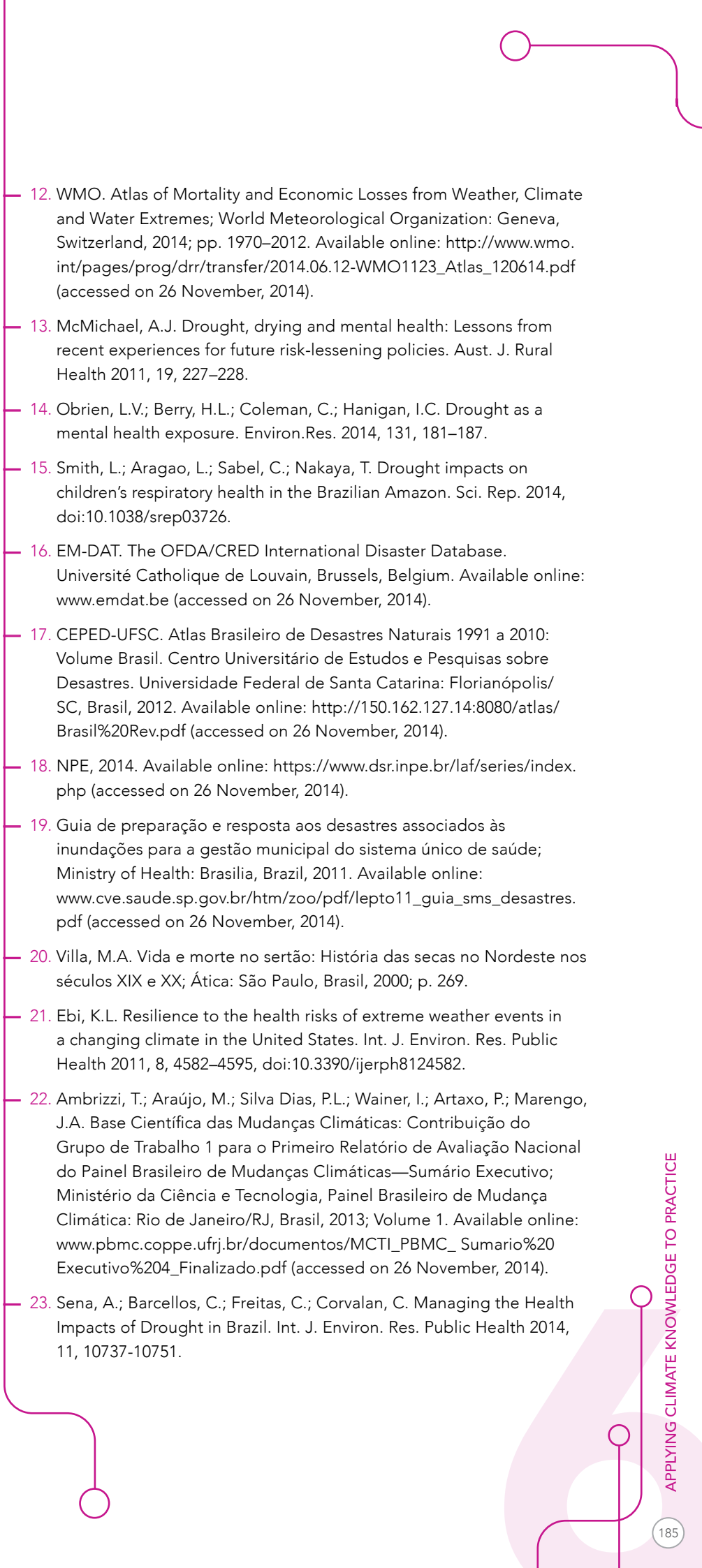
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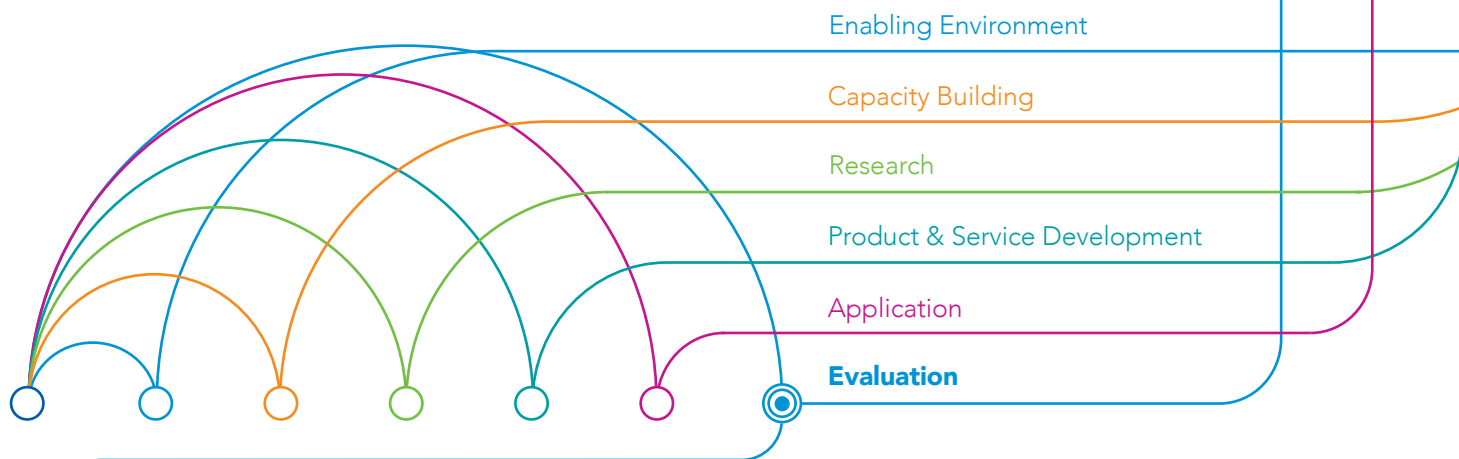
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## CHAPTER 7

# EVALUATION AND FEEDBACK TO IMPROVE HEALTH DECISION SUPPORT

**GOAL** to provide evidence on the performance, effectiveness and cost-effectiveness of climate services to save lives and reduce climate health risks.

Measuring how well a climate service meets its intended goal and providing feedback on benefits, impacts, and user-satisfaction is extremely important to maintain and improve future services. Early in the development processes all stakeholders should be involved in discussing and agreeing on how to measure success and the methodologies that will be used for monitoring progress and collecting key information. Open discussion can help to ensure that all stakeholders participate in and become aware of the expected achievements.

An evaluation commonly assesses three aspects of a given climate service:

- Performance of the products and services (i.e. its credibility, availability, reliability, usability, usefulness, suitability, responsiveness, sustainability and accessibility);
- Effectiveness to have positive health impacts (i.e. its value to save lives and improve health outcomes);
- Cost-effectiveness of the service in comparison to other alternative tools.

Other factors related to process undertaken and the adequacy of the enabling environment or capacity are also frequently measured, including community perceptions, institutional capacity and partnership efficacy, ethical dilemmas encountered, etc.

## IMPORTANCE OF EVALUATION IN THE GLOBAL PROCESS

Evaluation allows for the iterative feedback and improvement of the climate services, notably to generate evidence that can increase the level of trust of health decision-makers in the service, and identify good practices as well as limitations, barriers, and threats. Evaluation is a fundamental exercise that requires planning and coordination. When done properly, evaluation can reveal whether activities were sufficient and balanced to meet the service's goals. Active and transparent participation of all stakeholders is important to identify service strengths and weaknesses, detect potential risks to service provision or application, and to define strategies to improve the service. The results of an evaluation will, in turn, define the needs for specific activities that can reinforce and improve the application and effective functioning of the service.

## COMMON APPROACHES

Evaluation approaches of climate products and services are often adapted from those used in public health to measure health system performance or health intervention efficacy. Important outcomes and impacts to evaluate include:

- increase in community protective behaviours;
- increase in human and institutional capacity;
- improvement in health service delivery;
- lives-saved;
- cost-effectiveness;
- improvements in timeliness, accuracy and credibility of decision-making;
- climate and health data availability at adequate spatial and temporal scale;
- climate service usability (user-friendliness);
- climate service sustainability.

## CASE STUDIES

The case studies in this chapter show the importance and approaches to evaluating different aspects of a climate service in order to improve the overall delivery, impact or uptake of information.

The first case study from Australia (7A) illustrates that it was essential to conduct an impact evaluation of the heat early warning systems in place in Australia in order to demonstrate that forecasts and alerts save lives.

The second case study from Spain (7B) is an example of a performance evaluation that demonstrated the economic benefits that could result from adjusting the current heat wave temperature threshold in the national heat early warning system.

The third case study (7C) evaluated the performance of a specific climate and health project that started in Ethiopia in 2008 and identified several lessons learned that will be useful for the future development of climate services.

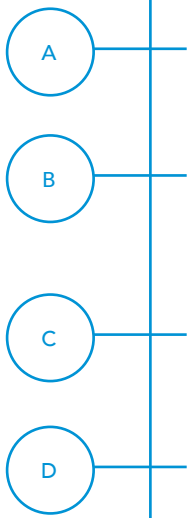
The final case study (7D) evaluated how warnings issued in Germany on health risk of UV radiation, extreme heat, pollen and ozone conditions help individuals and families make behaviour changes that can prevent negative health consequences.

**7A:** Building evidence that effective heat alert systems save lives in southeast Australia

**7B:** Finding the right thresholds to trigger action in heat wave early warning systems in Spain

**7C:** Looking back: Documenting lessons learned from a climate and health project in Ethiopia

**7D:** How to reach vulnerable populations? Evaluation of UV index, heat warning system, air-borne pollen and ozone forecasts in Germany



MEASURING HEALTH OUTCOMES OF CLIMATE SERVICES

BUILDING EVIDENCE THAT EFFECTIVE HEAT ALERT SYSTEMS SAVE LIVES IN SOUTHEAST AUSTRALIA

Authors: N. Nicholls, M. Loughnan, and N. Tapper (School of Earth, Atmosphere and Environment, Monash University, Australia).

CONTEXT

Record heat waves in southeast Australia in January 2009 and January 2014 led to an increase in mortality and morbidity, in excess of the rates expected for the time of the year. Both heat waves recorded daily maximum temperatures well in excess of 40°C over three- and four-day periods respectively, and minimum temperatures above 25°C, with both heat waves concluding on Fridays.

NEW APPROACHES

In the January 2009 heatwave, a prototype heatwave alert system had just been introduced, based on research identifying a threshold temperature above which excess mortality occurred in Melbourne, Australia (1). By the time of the January 2014 heat wave, the heat alert system had been considerably refined, based on further scientific work (2-4) and intense interactions between climate scientists and public health authorities. The excess mortality associated with the 2014 heat wave was substantially lower than in 2009, even though the 2014 heat wave lasted longer.

BENEFITS AND LESSONS

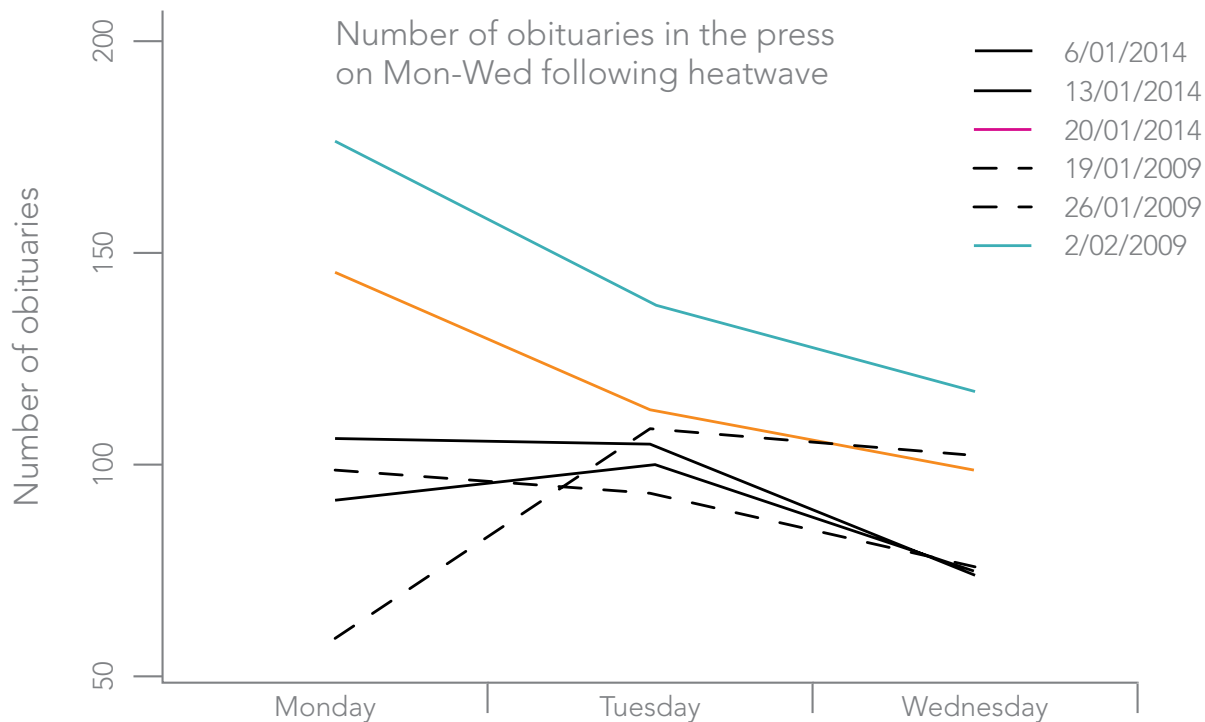
The mortality associated with the two heat waves is illustrated in Figure 7.1, which shows the number of obituaries published in a major Melbourne newspaper on the Monday–Wednesday after the two heat waves. In the days after the 2009 heat wave deaths increased by 60% (blue line), relative to the weeks before and after the heat wave (the numbers of obituaries for these weeks are shown by black broken lines). After the 2014 heat wave, deaths increased by 25% (orange line), relative to the mortality in the weeks before and after (shown by the black full lines). The only substantial difference between the two heat wave events was the better-developed and implemented heat wave alert system in 2014. This suggests that the heat wave alert in 2014 saved many lives.

Enabling Environment

Capacity Building

Evaluation

**Figure 7.1** Number of post-heat wave obituaries in the press, 2009 and 2014.



The heat alert system relies on predicted daily temperatures routinely provided by the Bureau of Meteorology. When the temperature at any time in the next seven days is predicted to exceed the threshold identified as triggering excess mortality, a heat wave alert is issued to local government authorities, emergency services, the health and aged care sectors, government departments and agencies, and major metropolitan service providers (5). Media briefings also alert the general community to the actions that could be taken to minimize health risks associated with high temperatures. The recently increased quality of the temperature forecasts issued by the Bureau of Meteorology in Australia means that these forecasts provide credible warning of heat waves (6). This increased forecast quality, and the introduction of heat wave alert systems, have come at an important time, as record heat waves become more frequent and severe. Without the improved weather forecasts and the scientific work to develop credible heat wave alert systems, continued global warming will lead to excess deaths (7).

ACKNOWLEDGEMENTS





## EVALUATING PRODUCT PERFORMANCE AND SKILL

# FINDING THE RIGHT THRESHOLDS TO TRIGGER ACTION IN HEAT WAVE EARLY WARNING SYSTEMS IN SPAIN

Authors: C. Linares (National School of Public Health, Carlos III Institute of Health), Y. Luna (AEMET-Spanish Meteorological Agency), A. Chiabai (Basque Centre for Climate Change), R. Carmona (National School of Public Health, Carlos III Institute of Health), A. Morata (AEMET-Spanish Meteorological Agency), J. Spadaro (Basque Centre for Climate Change), J. Díaz (National School of Public Health, Carlos III Institute of Health).

### CONTEXT

In Spain, the State Meteorological Agency (AEMET) has been successful in using weather predictions models to forecast short- and medium-range extreme temperatures, and an early warning system (Meteolerta) has been implemented in cooperation with European EUTMENET member countries (MeteoAlarm). Enhanced extreme temperature forecasts for future climate-change scenarios have significant human health implications, including increased mortality and morbidity, thus indicating a clear need to mitigate these effects and adapt to climate change. In this regard, Spain's Ministry of Health, Social Services and Equality implemented a National Plan for Preventive Actions against the Health Effects of Excess Temperatures (8) as long ago as 2004, from June to September annually, which is activated when the AEMET's forecasts indicate that a given threshold temperature will be exceeded.

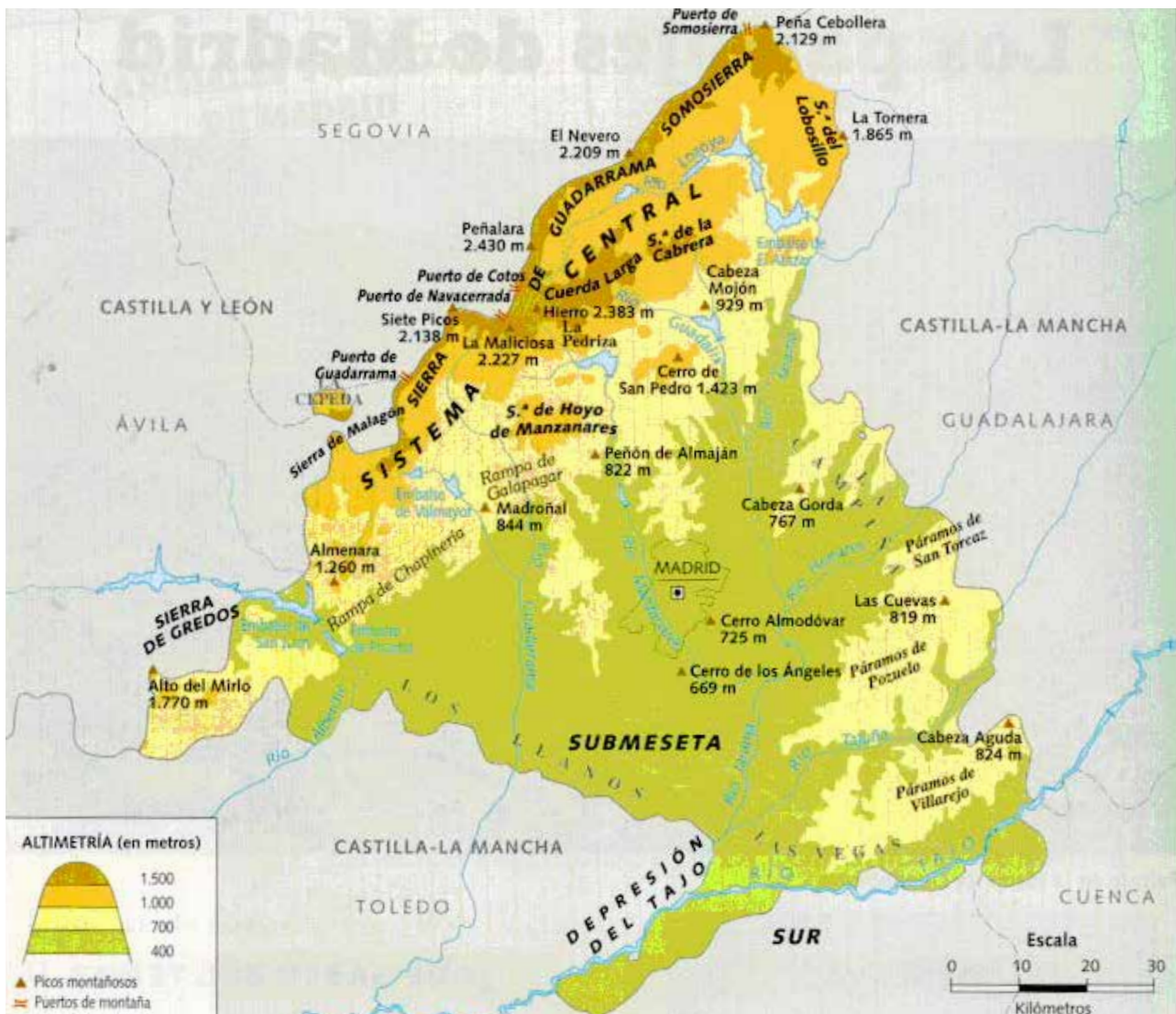
The determination of such a heat-related mortality trigger temperature is a key element, not only when it comes to impact on mortality (9,10) but also for the implementation of prevention plans (11). In addition, the current trend in the population pyramid, namely an expansion in the over-65 age group – a cohort that is particularly vulnerable to extreme thermal events (12) – means that this temperature must be re-designated on the basis of new climate and mortality data.

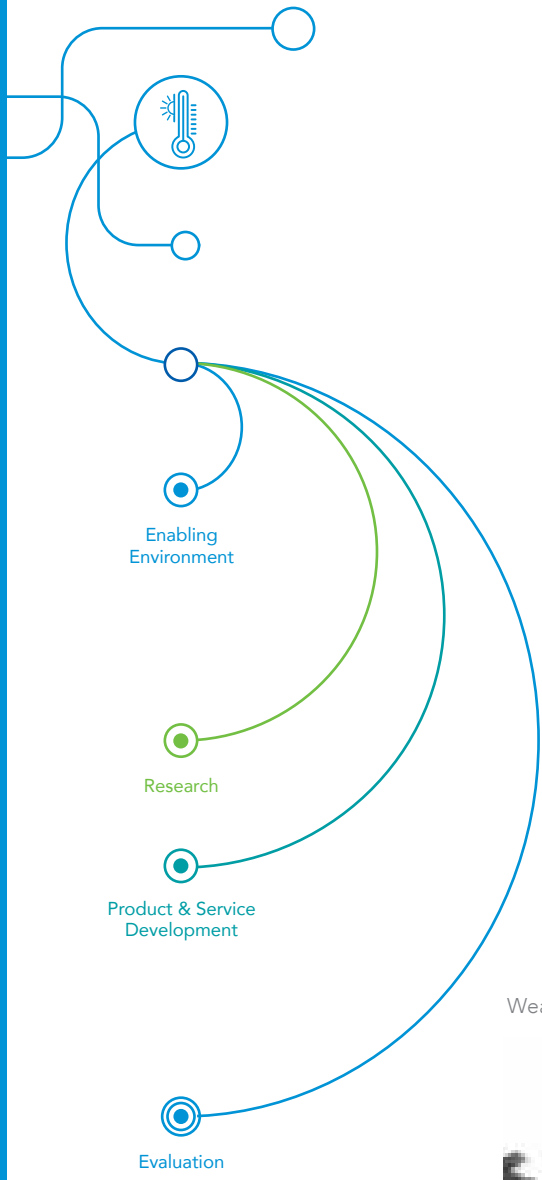
## NEW APPROACHES

The aim of this study was thus twofold: Firstly, to determine the daily heat-related mortality trigger temperature in Madrid for the period 2001–2009 and compare it to that which had been previously calculated for the period 1986–1997; and secondly, to quantify heat-related mortality in these two periods and establish whether a change in threshold temperatures might result in a reduction in such mortality and could be assessed in economic terms.

Data on the daily number of deaths due to natural causes (ICD-10: A00-R99) in the Madrid municipal area during the period 1 January 2001 to 31 December 2009, across all age groups, were sourced from the Madrid Regional Revenue Authority. Daily maximum temperature records from the Madrid Observatory were supplied by the AEMET. A scatter-plot diagram was then constructed showing residuals obtained from daily mortality pre-whitened using a univariate ARIMA model and daily maximum temperatures and grouped in pairs. Heat-related mortality was calculated by determining the attributable risk (AR) of mortality, calculated for each period using generalized linear models (GLM) with Poisson response and link-log. We controlled the models for various confounding variables, including trend, periodicity and the autoregressive nature of the series.

Fig 7.2. Map of the area where the study was conducted.



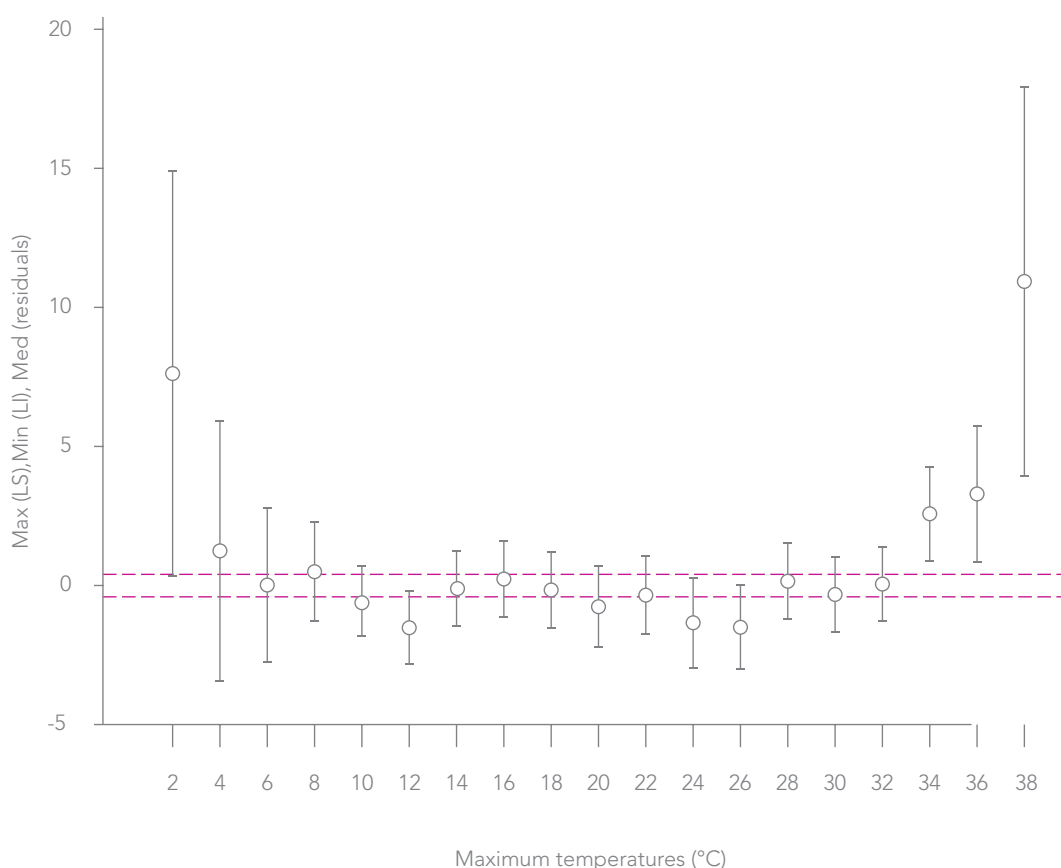


The heat-related mortality trigger temperature in the city of Madrid across the study period was set at a daily maximum temperature of 34°C (Figure 7.3), which coincided with the 82nd percentile of the maximum daily temperature series for the summer months (i.e. June–September). In the period 1986–1997, this temperature had been 36.5°C (95th percentile). The threshold of 34°C was exceeded on 198 days, with a mean excess value of 1.54°C/day. The AR calculated for this period was 6.55% (95%CI: 4.36-8.72) for each degree whereby the daily maximum temperature exceeded said threshold, so that heat-related mortality was estimated at 1150 (95%CI: 764–1524) people. If, however, the GLMs were repeated by setting the threshold at 36.5°C, then the AR would be 20.7% (95%CI: 7.57–33.24), with this threshold being exceeded on 41 occasions with a mean excess value of 0.76°C/day, which translates as an associated mortality of 371 (95%CI: 136–596) people. Hence, the avoidable mortality in response to a change in the prevention plan activation threshold would be 779 persons (95%CI: 628–928). The annual economic benefit is valued at 7.7 million €2013 (95%CI: 6.3–9.3 million €2013), assuming each death results in an average reduction of life expectancy of 1 year and that each year of life lost equals 90 000 €2013 (13).

Weather station which have been obtained temperature data for the study , Madrid- Retiro.



**Figure 7.3** Scatter plot of daily maximum temperature and mortality residuals, for a given heat-wave definition



### BENEFITS AND LESSONS

The use of updated climate data to determine prevention plan trigger temperatures could significantly reduce heat-related mortality. In the case of Madrid, our calculations suggest an annual average reduction in mortality over the period 2001–09 of 86 deaths (95%CI: 70–103). This would be the expected benefit if the effectiveness of the current heat warning system was improved by changing to the threshold temperature of 34°C.

The national health authorities have been informed and have welcomed the results of the study. We believe that the new thresholds could be implemented in the summer of 2015.

### ACKNOWLEDGEMENTS

**bc<sup>3</sup>**  
 BASQUE CENTRE  
 FOR CLIMATE CHANGE  
 Klima Aldaketa Ikergai



# LOOKING BACK: DOCUMENTING LESSONS LEARNED FROM A CLIMATE AND HEALTH PROJECT IN ETHIOPIA

Author: WHO Ethiopia Country Office

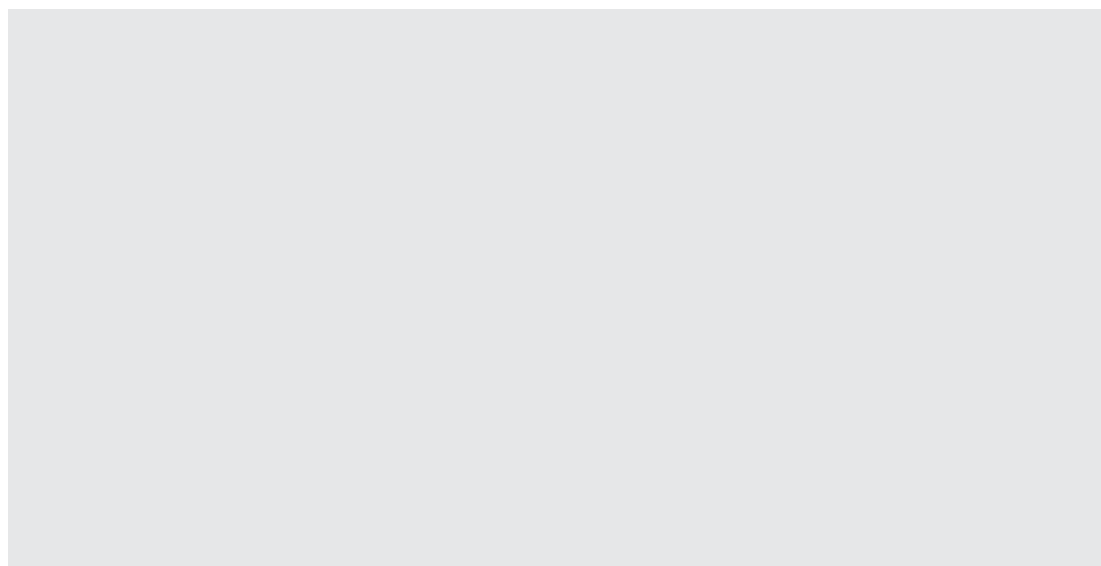
## CONTEXT

Climate change and variability are the main drivers of several infectious diseases and non-infectious diseases that are of great public health importance. Malaria is one such disease and a disease of great public concern in Ethiopia, where over five million cases are estimated to occur each year, resulting in tens of thousands of deaths. A series of resolutions and proclamations have been made at global, regional and national levels based on the recommendations of the scientific community to mitigate the public health impact of climate change and variability. But in practice, the outcomes of research activities on the topic are not incorporated into programmatic activities for mitigating the health impact of climate change at various health care levels.

## NEW APPROACHES

The Health, Development and Anti-Malaria Association (HDAMA) in Ethiopia was established to respond to the 1998 catastrophic epidemic that occurred in prone highland areas and was largely attributable to climate abnormalities linked to the El Niño Southern Oscillation and an increased rate of resistance to antimalarial drugs. One of the HDAMA work focuses has been climate and health. In 2008, HDAMA initiated a Climate and Health Working Group (CHWG), that initiated a project entitled 'Weather and climate impact on community health and public health services'. The project was aimed at improving malaria epidemic early warning through coordination and collaborative efforts between the health and climate communities.

Evaluation



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## BENEFITS AND LESSONS

An evaluation of the project over three of the six implementation areas used largely qualitative data such as document analysis, indexed individual interviews and focus group discussions, as well as secondary data on climate and health, supplemented by field observations.

HDAMA has organized various workshops and provided trainings on how to integrate climate and health information, bringing together experts from meteorology and health offices, research and academic institutions/universities, and other key stakeholders. This has strengthened national awareness of the importance of climate information for mitigating public health effects, in particular in relation to malaria. Regional Health Bureaus collected historical climate and malaria data and made efforts to work together to integrate and analyse collected data. However, a lack of user-friendly tools for the prediction and early warning of probable epidemics at regional and district levels was encountered.

Quarterly bulletins related to climate and health issues were generated and posted on various institutional websites and although the bulletins serve to increase awareness, the models used to generate such bulletins are static and have never been tested.

Implementation of the project suffered from lack of agreed institutional arrangements and coordination among stakeholders at all levels. There were no terms of reference agreed with stakeholders before implementation of the project; the National Meteorological Service Agency (NMSA) and the Federal Ministry of Health (14) were not actively involved in site selection and implementation arrangements; the quarterly reports produced by local experts were not communicated to respective district, regional, and national offices; and the monthly reports are not discussed at the regional and national levels. As a result, the project is perceived by most partners as an independent research project and not part of the health system.

The CHWG was disbanded, and was replaced by a new Climate and Health Task Force that has been established at the Federal Ministry of Health, but to which HDAMA programme activities are not yet linked.

From the information obtained at the field level and HDAMA, supportive supervision has been provided only two times using checklists during project implementation period. Lack of close follow-up and regular supportive supervision has negative effect on project implementation and in solving problems at the field level.

The climate and health project initiated and implemented by HDAMA shows practically how to integrate and analyse climate and health information. Establishing forecasting and an early warning system are still not well developed, and thus there is a lot of work to be done, however, the apparent promising PHEM 95% reporting completeness at district level will be essential for district level malaria risk mapping. In addition, there is a need to reorganize institutional arrangements and coordination mechanisms for effective implementation of the project before considering scaling-up to a national level or to other climate-sensitive diseases.

The evaluation results will be used in developing the national framework of climate adaptation for the health sector and are expected to be used in the current assessment of health and in the preparation of the H-NAP.

## ACKNOWLEDGEMENTS





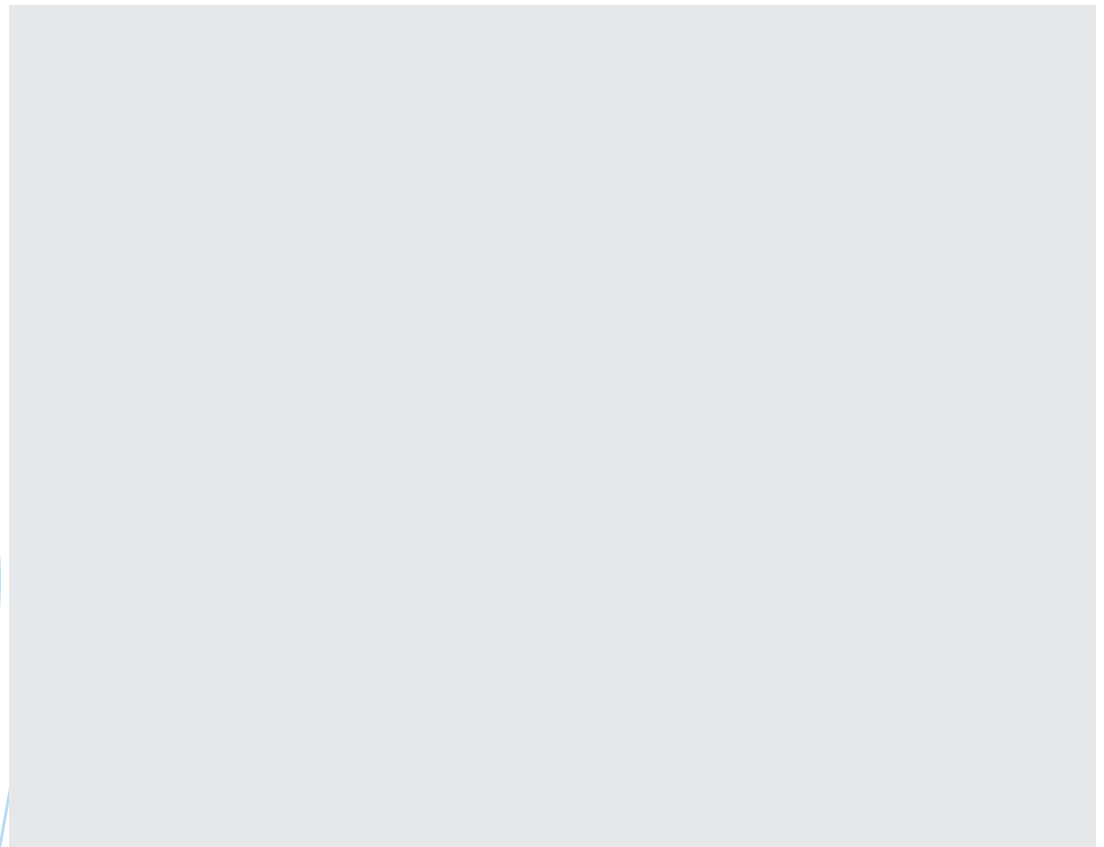
# HOW TO REACH VULNERABLE POPULATIONS? EVALUATION OF UV INDEX, HEAT WARNING SYSTEM, AIRBORNE POLLEN AND OZONE FORECASTS IN GERMANY

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## CONTEXT

In Germany, there are national systems that provide information and early warnings for climate change and related environmental health risks (e.g. UV index, heat health warning systems, pollen and ozone forecasts). The German Weather Service (Deutscher Wetterdienst/DWD) offers newsletters with UV index warnings, heat health warnings and pollen forecasts, and the Federal Environment Agency (Umweltbundesamt/UBA) offers a newsletter with ozone forecasts. This information supports adaptation by the public, such as personal or family related behaviour change that can prevent negative health consequences.

Evaluation



Placeholder for image

## NEW APPROACHES

These systems were evaluated in relation to how well known they are, their use by the public and environment and health care institutions, and the adaptation measures that they promote. In performing this evaluation, a distinction was made between institutionalized communication, such as from the health ministries of federal states (Länder) to health care institutions (especially for inpatient care); and non-institutionalized communication such as subscription to newsletters by citizens or information disseminated by the media. The evaluation results informed a communication strategy so that these services can better reach vulnerable populations, and trigger protective behaviours.

The following methods were used for the evaluation:

- A comprehensive search of the German environmental webportal ([www.portalU.de](http://www.portalU.de)) identified target groups and adaptive measures.
- The scientific literature was reviewed and sorted.
- DWD and UBA were asked for circulation data of their newsletters.
- State (Land) health ministries were asked (by questionnaire) what newsletters were received and the specific health institutions that were directed to receive them.
- Several health department offices (Gesundheitsämter) were surveyed using a questionnaire.
- Mass media were monitored during summer 2013 to determine the extent to which they reported the early warnings and forecasts.
- Physicians and nursing services/ facilities were requested to complete an online questionnaire.
- An extensive, representative poll of the population was carried out in summer 2013. 4000 people answered questions about their health, their behaviour with regard to information, their perception of risk and their awareness of warning systems. Additional, special questionnaires about the four information and early warning systems and appropriate protective actions were answered by groups of up to 400 people who met the criteria for vulnerability (Table 7.1).

**Table 7.1** Assignment of pool participants to the special questionnaires

CRITERIA	QUESTIONNAIRE
Age over 60	Heat
Allergic asthma by pollen	Pollen
Hay fever	Pollen
More than 15 hours per week outdoors	UV
More than two hours per week strenuous exercise outdoors	Ozone



## CASE STUDY 7.D

### BENEFITS AND LESSONS

The use of institutionalized information<sup>k</sup> about health risks is extremely inconsistent. Of the multiple climate services for health evaluated, only heat health warnings are received by almost all federal states, but the forwarding of the information is not uniform. In some states, the public health agencies distribute the information to elderly care homes and nursing facilities, while in other states such facilities are required to use the heat health warnings of the weather service directly. In yet other states, there is no directive and health care facilities obtain information about extreme weather events at their own discretion. Interviews with health department personnel at various levels did not disclose a uniform mode of communication. However, the study showed institutional dissemination of at least heat health warnings, which cascade from the DWD, via state health ministries to the subordinate health department offices, and from there to the nursing facilities. Whether or not the arrival of heat health warnings in elderly care homes and nursing facilities leads to practical consequences could not be determined.

Critically, it was found that physicians, who have an important role because of possible interactions between certain medications and hot weather, are neither integrated in the institutionalized information channels nor do they broadly subscribe to heat health warnings. Information and early warnings about the other environmental factors (i.e. UV radiation, ozone and pollen) are subscribed to or forwarded by way of institutionalized communication in only a few states.

Public awareness of information and warning systems is strongly dependent on the information system involved. Warnings and forecasts reach the population primarily by way of non-institutionalized communication. 86.8% have heard or read about pollen forecasts, but only 29.5% about the UV index. Heat health warnings (71.0%) and ozone forecasts/warnings (54.2%) lie in between. Awareness of warnings and forecasts most often come through television, radio, newspapers or magazines, or the Internet.<sup>l</sup> The observation of mass media showed they inform primarily about heat, but neither uniformly nor reliably. The number of subscribers to the newsletters of the information systems is negligible compared to the size of the population.

In order to determine to what extent warnings and forecasts trigger protective behaviours, a logical framework was developed including various factors favourable to taking protective measures. Findings showed, that if a measure is considered personally suitable, the probability that it will be implemented increases. Measures considered 'very effective' are implemented more often. Since the perceived suitability of a measure depends on personal attitudes and on personal situations, individual communication must be considered. Conversation (for example with a physician) was often named as a desirable source for warnings.

<sup>k</sup> The Umweltbundesamt (UBA) and the Deutscher Wetterdienst (DWD) are the origins of the institutionalised information channels. Heat warnings are sent (independent of a subscription to the newsletter) to the agencies of the states. For example, heat warnings in Thuringia are sent to county administrations and non-county cities, which in turn forward them to nursing homes and hospitals (Sperk & Mücke, 2009). Health facilities in some states subscribe to the heat newsletter. These communication channels are regulated by administrative arrangements and are referred to in the following as "institutionalised communication channels". The noninstitutionalized information channels are other possible ways in which a warning or a forecast can reach health facilities or the population.

<sup>l</sup> The websites of the DWD and UBA were excluded from this question.

Evaluation

## ACKNOWLEDGEMENTS

*This investigation was carried out as part of the project 'Adaptation to Climate Change: Evaluation of Existing National Information Systems (UV-Index, Heat Health Warning System, Airborne Pollen and Ozone Forecasts) From a Public Health Perspective – How to Reach Vulnerable Populations?' of the environmental research plan of the Federal Ministry for Environment, Protection of Nature and Building and Reactor Safety (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit) under the research ID 371262207.*

*The final report of the project can be found here <http://www.umweltbundesamt.de/publikationen/evaluation-of-information-systems-relevant-to>*



The perception of risk ("How high do you think your risk from [heat, UV radiation, pollen, ozone] is?") has significant and moderate influence on taking protective measures. Awareness of risk depends on a variety of factors including the presence of risk in daily life<sup>m</sup> and the degree of personal involvement<sup>n</sup> had the greatest influence on the perceived degree of risk.

Awareness of risk is greatest for heat. 51% of the vulnerable people and 39% of all participants thought of heat as a health risk at least once during the two weeks before the poll. UV radiation takes second place for immediacy with 37% of participants overall (36% of the vulnerable). Far fewer people view pollen (22% overall, vulnerable: 17%)<sup>o</sup> and ozone (21%, vulnerable: 23%) as health risks.

The evaluation concluded that there is a necessity for continuous monitoring of how risk information is accessed and acted upon by the public. The concept of health-relevant behaviour should be augmented to include some measure of health literacy. In addition to ordinary knowledge and abilities, for example, knowledge of risks and protective measures – including the ability to find and use health-relevant information – are important components of health literacy. The goal of improved health literacy can be achieved only by continuous education.

Currently in Germany, awareness of protective measures and of the information services for health has no statistically confirmed influence on health protective behaviours. People who are aware of the information systems under consideration do not take any more protective measures than those who are ignorant of them. This result can be partly explained by an analysis of the content of the newsletters: three newsletters make no specific behaviour recommendations; the exception being the newsletter for the UV index. The evaluation noted information and warning systems mainly provide information mostly about dangers, without including behavioural recommendations, which should be as specific as possible to enable the public to carry out protective measures.

A further concern is that communicating the presence of risks and possible undesirable effects can cause apprehension in the population. Apprehension can positively trigger preventive measures, but it is itself an impairment of well-being, and thus of health. This dilemma can be solved by taking a health promotion approach: that does not seek to avoid illness but promotes and preserves health. This emphasizes aspects of well-being that can be gained through preventive measures, rather than dangers to health due to the environmental influences.

Protective measures against heat and pollen were found to be implemented most, since these risks acutely afflict vulnerable people and some protective measures provide immediate improvement.

<sup>m</sup> The presence of risk in daily life is documented by the response to the following: "Please tell me how often you have thought of risk during the last two weeks. Answer with: not at all, once or twice, 3 to 5 times, or more often!"

<sup>n</sup> Personal affliction was documented inconsistently. (For heat: "Do you personally tolerate heat very well, well, less well, or not at all?"; for UV radiation: "Has skin cancer or cataract been diagnosed among your friends and relatives (yes, skin cancer/yes, cataract/both/no, neither one nor the other)?"; For pollen: "How high do you estimate the risk for your own health if you had contact with allergenic pollen (high/fairly high/fairly low/very low)?" Personal affliction was not documented for ozone.

<sup>o</sup> The scant perception of risk in relation to pollen may be due to the time of the interrogation (August 26, 2013 to October 8, 2013), which lies outside of the main season for airborne pollen.

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Enabling  
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Building

Research

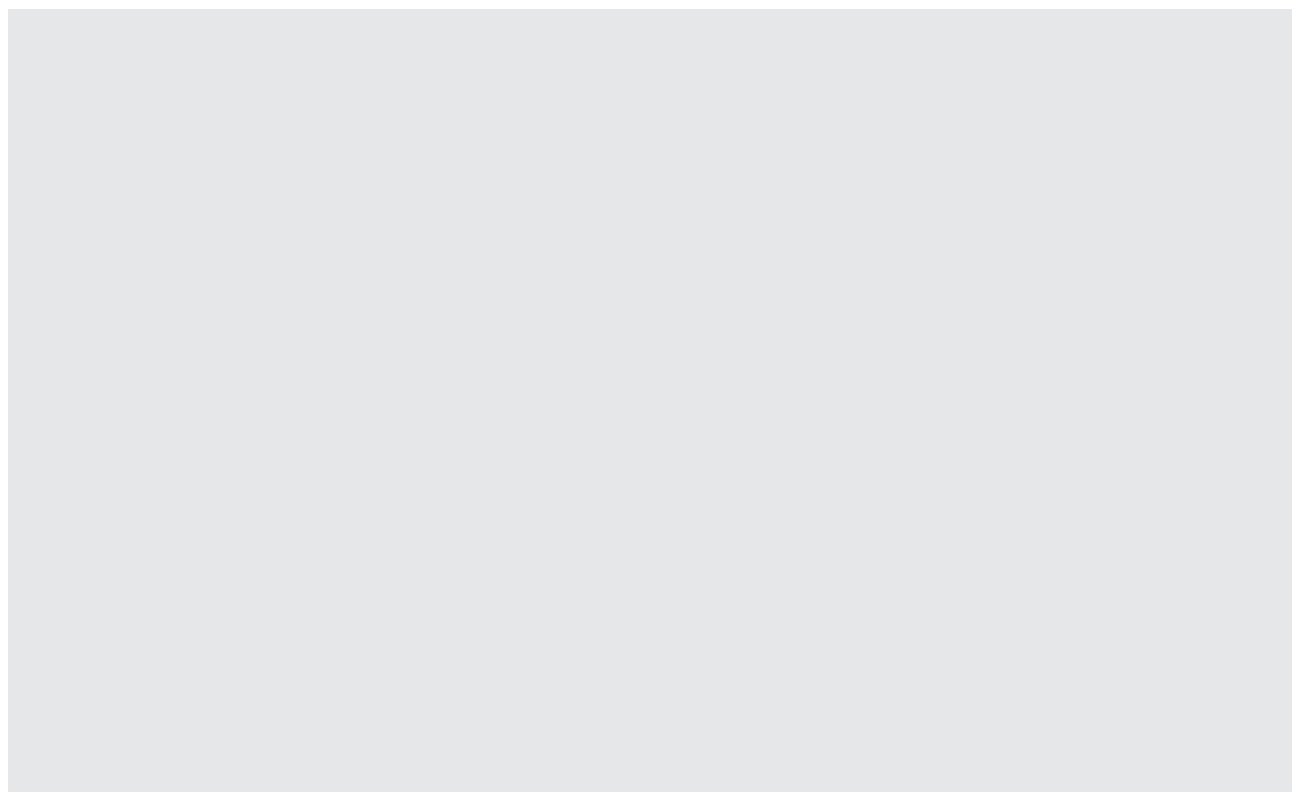
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Development

Application

Evaluation

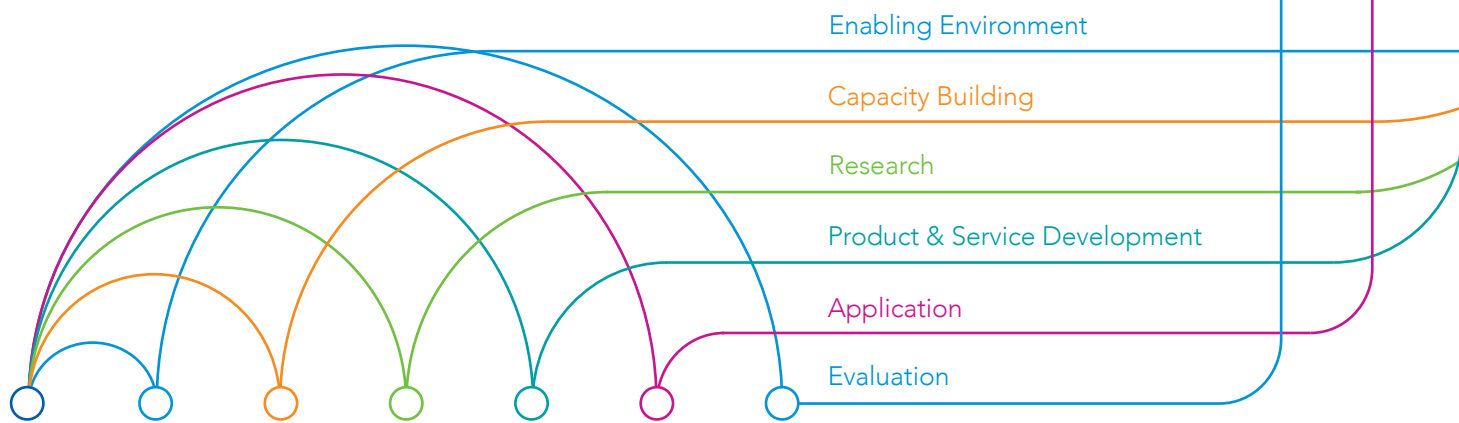
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## THE FUTURE - CHAPTER 8

# 8 SOLUTIONS TO COMMON CLIMATE SERVICE CHALLENGES

A key element of accelerating climate services for health is to share the valuable insights, tools and lessons from the global community of practice. In this relatively new field, there are limited formal evaluations of climate service performance, process development and impacts.

However, an analysis of the current case studies identified five common challenges that teams frequently had to overcome:

- to match available data in ways that respond to the space and time dimensions of the health challenge in question;
  - to develop reliable, high quality and fit-for-purpose products and services;
  - to generate adequate support to mainstream climate service application;
  - to secure sufficient financial and human resources to develop and sustain services;
  - and to communicate climate information and risks effectively with communities.
- By learning from the solutions employed to address these challenges, other projects may be able to reduce or eliminate them in future initiatives.

# CHALLENGE 1:

## DEFINING AND MATCHING DATA TO MEET SPATIAL AND TEMPORAL KNOWLEDGE NEEDS

Teams frequently reported the **challenge of identifying, collecting, cleaning and preparing climate and health data to be interoperable** at the spatial and temporal scales that allowed alignment with the decisions that need to be made. Health decisions are most often made at the local level, from district or county level, down to specific point locations of health facilities and villages. Climate data often do not meet these criteria, and have a range of other gaps and inaccuracies. Many global climate data sets provide useful information at the national scale but, depending on the complexity of the local climate, they may not provide the quality of information needed for district-based health decision making, for example. For climate information to be useful for health research or planning, climate data should have both national coverage and local relevance.

**Temporal alignment** can also be a challenge. Environmental and climate global products are often disseminated at 10 day (dekadal) or monthly timescales. While monthly data is relevant to the time step used in many health information systems, dekadal data is not perfectly matched with the weekly data used for epidemic surveillance.

The **mismatch of data** collected from various sources, and the complexity of some data formats and archiving methods, are common challenges, which can often render existing data unusable and block further advances. The lack of **customized data collection and formatting methods** to meet the specific service needs was a key constraint for some projects. Furthermore, **access to daily data** required for establishing the climate and health outcome linkages, in many countries is limited by data dissemination policies of the national meteorological agencies.

### SOLUTIONS:

Some case studies **created new datasets** to simultaneously resolve data mismatch and gap problems. For example, the Enhanced National Climate Services Initiative is creating national climate products that are a blend of the best available global products and the national meteorological monitoring and archived data. Daily products under development in certain locations can be aggregated to weekly time scales that match surveillance data. Tools, such as the IRI Data Library, and the E3 geoportal can be used **to resample climate and health data to common time and space scales.**

## CHALLENGE 2:

### DEVELOPING RELIABLE, HIGH-QUALITY AND FIT-FOR-PURPOSE PRODUCTS AND SERVICES

In many countries, **limited infrastructural and institutional capacity** of the NHMS and health partners hinders both the technical feasibility of developing fit-for-purpose products, as well as appreciation for the potential opportunity to develop alternative products and services.

Teams often reported being unable to meet project goals or develop a skilful product, due to: *data limitations* (i.e. poor availability, quality, homogeneity and good spatial and temporal resolution, as well as coverage of data at local and regional levels); *core system capacity* such as a lack of data management and analysis tools; false expectations and lack of understanding about *scientific limitations*, such as inadequate forecast skill to be used for local decision making; and the *inability to find alternatives* that can solve these problems.

**Weak underlying capacity of core observational and data management systems** (i.e. in both the health and climate fields) is a particular limitation in developing countries. The limited number, location and functioning of weather stations, non-digitized historical climate and health information records, the lack of agreement on the time and spatial scale of the measurements across different health bureaus, are all cited as common challenges to identifying technically feasible and reliable analytical and forecast products. Data quality issues arise based on the method of collection, handling and storage of data. Understanding how errors occur is critical to understanding how they might be removed. This usually requires some expert knowledge and awareness of appropriate methodologies. Within the health and climate communities, standard protocols exist that can help 'clean' the data, but this knowledge is often not understood by those who are working with data from another community.

#### SOLUTIONS:

The quality and reliability of a product will depend on the quality of the original available data. To clean climate and health data, it is important to **go back to the origin of the data** wherever possible. Monthly data may already mask data gaps or outliers. Daily meteorological data can be aggregated to weekly or monthly timescales but may not have the coverage needed for national planning. It is also important to have appropriate expectations of what is scientifically feasible, and the skill of available climate and weather information products described in (Table 1. 1). **Communication and dialogue** with local expert climate scientists about the products are essential to understand the reliability and uncertainty of probabilistic information products and how they should be used.

Time and resources are required to **improve underlying capacities for robust data collection and management**, upon which reliable services can then be built. Policy advocacy and strong documentation for investment in surveillance systems and observations are needed, and contribute to long-term strengthening of NHMS and health sector capacity.

In the short term, case study authors referred a range of innovative and alternative approaches to overcoming shortcomings in data, data management and analysis, and to improve product quality.

**Pilot programmes** have proven crucial as a mean to test and improve products and services, facilitating the identification of errors, data gaps, and underperforming and dysfunctional features. **Workshops and meetings** with key stakeholders can be instrumental in receiving such feedback, conducting performance evaluations, and planning iterative improvements in the climate service development or delivery.

**Partnerships** with project teams with greater experience in the topic, can be helpful in identifying alternative approaches, as well as opening doors to expertise, mentoring and technology transfer programmes. Mapping out current and potential national and international collaborators and their specific capabilities is useful to explore how to leap-frog capacity gaps. For example, accessing remotely sensed climate data and information (such as rainfall data from the Tropical Measuring Mission, the Global Precipitation Missions and the Soil Moisture Missions, or temperature and vegetation data from MODIS) have been used to compensate for the lack and poor quality of rain gauge data.

Involving regional and international partners can also **facilitate access to global climate data products**, which can sometimes be downscaled to provide relevant local information. In addition, **cloud-based servers** or remotely based data-management systems have allowed local teams to access more robust data management software, avoid system interruption by loss of electricity and internet connectivity, and work collaboratively with international partners more effectively. Several **software and web-based applications** were developed that provide efficient and user-friendly online and offline tools, that help visualize and use local data, as well as fill the gap of locally available data analysis and prediction tools by integrating global or regional climate products. **Large data integration and processing efforts** have compensated for the heterogeneous local data formats and led to the creation of consolidated databases and tools that present information on several variables, in addition to climate and health. Across several case studies this approach led to a more comprehensive analysis of health risks and to the disaggregation of risk factors. Automatic data retrieving systems have been used to achieve robust, real-time monitoring systems.

## CHALLENGE 3:

### BUILDING ENABLING ENVIRONMENTS ADEQUATE TO MAINSTREAM CLIMATE SERVICES

The **difficulty of mainstreaming the use of the climate services**, as a regular resource for health decision-making tools, was a commonly cited challenge. This is often a due to health planners being **unfamiliar with** using climate information for health planning, tending to **mistrust non-health related information**, which may not be collected according to expected health information standards and/or **lack of understanding of the uncertainty** associated with climate-based disease forecasts. The limited number of evaluations demonstrating the value of climate informed health programming and policies remains a key hindrance to building strong business cases for mainstreaming climate services in the health sector.

Another barrier to using climate services for health is the **poor involvement** of either health or climate authorities in the service development process. In some instances when the development of the service was led strictly by academia, difficulties in engaging and identifying key decision-makers or professionals in the health and climate sectors were reported. This **lack of involvement** can lead to a **poor sense of ownership** and **products that inadequately respond** to operational health decision needs. The lack of involvement also results in **misunderstanding and underestimating the value** of climate knowledge, and can diminish the willingness for sharing data and information.

Data access is also a challenge when data are seen by authorities either as **highly sensitive or as an economic asset**. As a consequence, data owners are often reluctant to make data available as needed for routine operational climate services, unless a clear value is shown for doing so. The continued access to data is sometimes threatened by **the move of personnel, changes in their responsibilities and roles, and administrative changes**. The lack of sufficient **in-country coordination at the national, sub-national and local levels** sometimes threatened the application of the climate services.

#### SOLUTIONS:

In many case studies, **multi-sectoral and multidisciplinary groups** have been created at the beginning of the process. These groups have often included researchers, public officers from the health and climate sectors, public officers from other sectors, and community leaders. The creation of these groups and their continuation along the entire service development and application process has shown many benefits. These groups allow for the identification of decision needs and the selection of the most appropriate service features to meet these needs; increases the sense of ownerships; improves perceptions towards the value of climate services; builds capacity; and aligns stakeholders' objectives and expectations. The collaborative and communicative environment that the groups generate reinforces trust among stakeholders and facilitates the exchange of feedback at every step of the development process. In these environments the opportunity for academia to play a facilitating and mediating role has been emphasized.

To improve coordination and inclusiveness of a wide range of actors at regional, national, and local levels, some of the services used **local academic or non-governmental institutions to coordinate** activities in partnerships with government institutions; and to engage community-based organizations to participate in the data collection systems.

The formulation of **bi-lateral agreements and memoranda of understanding** have been instrumental to facilitate access to data and define respective roles and responsibilities in a mainstreamed service. Some case studies led to the improvement of national data exchange policies between partners and government agencies. The responsibility of researchers and project managers to fully comply with data access and use policies has been highlighted as a useful means to increase the level of trust and credibility.



## CHALLENGE 4:

### SECURING ADEQUATE FINANCIAL AND HUMAN RESOURCES TO DEVELOP AND SUSTAIN SERVICES

**Lack of sustained funding** was a reported reason for the interruption of service provision, cancelled products or services, and/or inability to advance from product R&D to application. This occurred particularly in cases where the service was developed as part of an externally funded project. Teams found it impossible to maintain the salaries of the personnel and other running costs required to sustain the service. Similarly, the **lack of adequately trained staff, lack of access to training or sufficient engagement of experts** to develop and use the product slowed or hampered local progress.

#### SOLUTIONS:

**Research and evaluations** are extremely important to generate adequate evidence, and to increase awareness about the need and value for tailored climate services. In order to transition from project-based funding to leverage core budget resources (e.g. from ministries of health or vertical health programmes) some groups conducted cost-effectiveness or cost-benefit evaluations to strengthen the business case for the climate service.

**Strong arguments** for mainstreaming climate-based information and services can then supported by showing how climate informed decisions can improve health service provision, save lives through anticipated planning, and save costs to the health system. Furthermore, studies that document **public appreciation and value for services** – for example, that early warning and action systems make them feel safer and more aware of the action they should take to avoid harm – can be helpful in obtaining political and financial support to maintain and mainstream services, and to invest in core capacities such as improving data quality and availability.

The lack of human resources is often tackled through **partnerships**, either locally or internationally. Many case studies have involved multiple institutions, which often include international experts who provide access to required expertise. Hands-on experience working with experts is often the best way to build capacity, and increasing the number of climate and health seminars and workshops, and/or specific analytical skill-based trainings, was shown to be beneficial. Other approaches include student and staff exchanges, and attending international training courses and masters programmes, although funding is often a limitation.

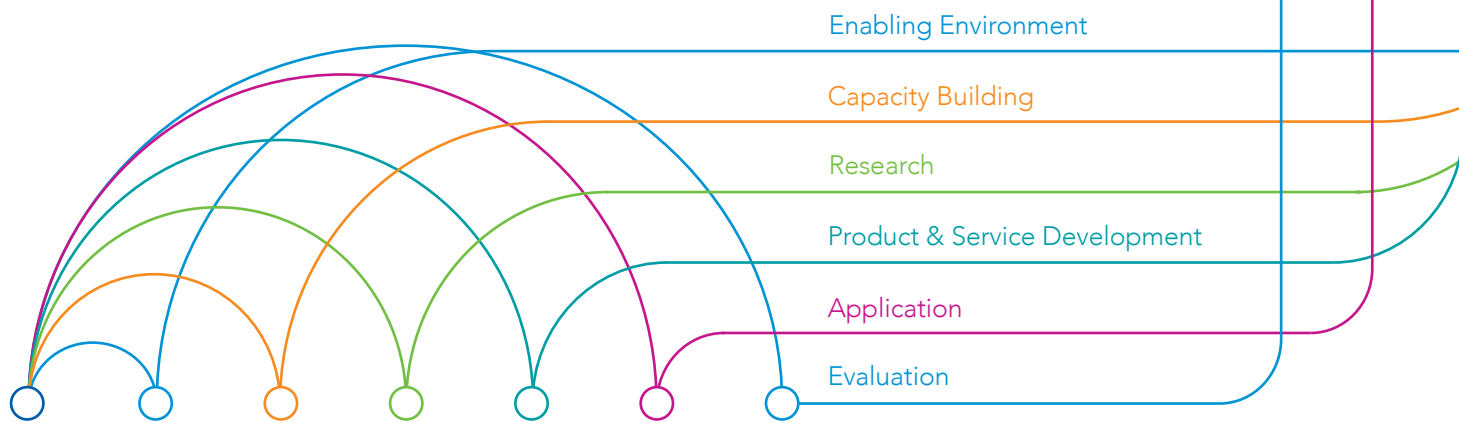
## CHALLENGE 5:

### COMMUNICATING CLIMATE INFORMATION AND RISKS EFFECTIVELY WITH COMMUNITIES

Communicating climate information and risks to non-technical audiences is a frequently reported challenge. Some services were reportedly not used when local communities did not understand risk warnings, value or trust the information, or have adequate information about actions that should be taken. The development of specific materials tailored to communicate with particular populations, such as vulnerable groups, was reported as essential for climate service messages to effectively reach communities.

#### SOLUTIONS:

To address this challenge, many case studies drew upon community-based surveys in order to **better understand the local risk perceptions** of target audiences, and to improve the effectiveness of public outreach strategies and messaging. The **use of modern communication technologies** (such as QQ (an open source instant messaging software in China), text messages and web-portals), the identification of community agents with the potential of acting as knowledge disseminators, and the design of population-specific communication strategies, can all help reach more individuals. Partnerships with local and global **media** (global TV channels and newspapers) have also been efficient to communicate messages on the presence or absence of disease risks, for example ahead of international mass gatherings that may affect international travel. The **inclusion of community representatives** in the development of communication materials is extremely important. Some projects consulted or included indigenous leaders or the elderly in the project development process, to ensure translation into local languages are appropriate and messages are tailored appropriately. To engage communities in more effective health prevention and promotion, the use of **narrative 'life stories'**, was shown to be helpful in translating relatively technical disease incidence data in ways that help communities better understand and contextualize risks. Furthermore, the effective use of **data visualization** in the form of well-designed graphs, infographics and other figures can help decision-makers navigate and interpret complex information more easily.



## THE FUTURE - CHAPTER 9

# 9 BENEFITS OF CLIMATE SERVICES TO HEALTH POLICY AND PROGRAMMING

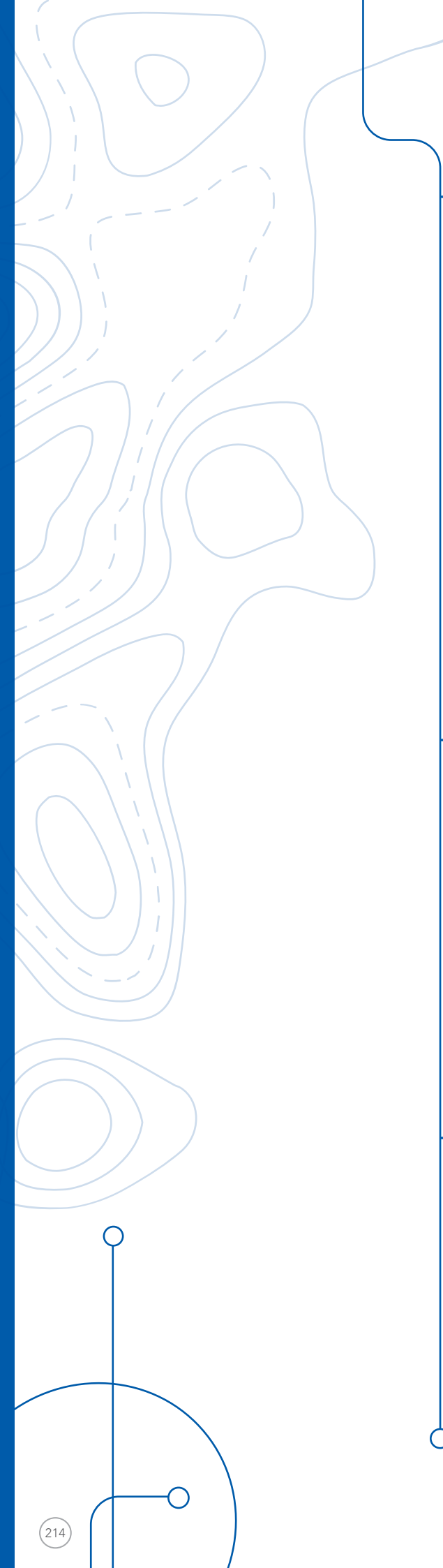
Greater consideration of climate and meteorological information in health science, practice and policy-making can help the health sector better understand and document the influence of climate on health; anticipate who is at greatest risk of harm, when and where; and become better prepared to manage the impacts of increasing climate variability and longer term climate change. The value of climate services are best measured in social and economic terms. Thus, users of climate services share the responsibility of evaluating climate services and providing feedback to service providers on the measured value, effectiveness and utility of the climate products and services. The case study experiences from around the world show the broad range of modes through which tailored climate services are helping to enhance the information and suite of tools available to health professionals, communities and individuals to make health-protective decisions.

As a result of alignment with climate services, most case studies reported having **stronger contacts and collaboration between the NHMS and health agencies**, often bringing these partners together for the first time. Furthermore, to understand the complex interactions between health and climate, the relations and **collaborations with other health-determining sectors also improved**. For example in Hungary, collaboration was forged not only with the NHMS but with the agricultural sector to reduce pollen exposure. In Brazil, in order to comprehensively monitor risks for water-borne diseases, partnership with the National Water Agency was needed to integrate river level information with national health surveillance data.

Additionally, since neither epidemics nor climate zones are constrained within national borders, climate services are shown to help **open doors to regional collaboration**. In Peru and Ecuador, where intense commercial and touristic activity sees high cross-border human mobility, the creation of a bi-national dengue surveillance network has promoted technical cooperation and can help the health authorities in both countries better understand and manage disease risks as well as align control strategies on each side of the border.

**Climate-services can improve health research and risk assessments to provide a more comprehensive understanding of immediate, short- and long-term health risks** that enable health professionals to take more timely and appropriate preparedness and response actions **to save lives**. For example in Uganda, the climate-informed spatial risk model helped authorities better identify communities at high risk for plague, and scale up efforts to enhance early detection and referral. As a result, hundreds of additional patients received medical care at the closest clinic. In Brazil, research to model and forecast dengue risk using climate information prior to the soccer World Cup, was able to provide evidence to inform a multilingual risk communication campaign for local communities and international visitors, and helped health authorities raise financial resources to scale up vector control in high-risk areas.

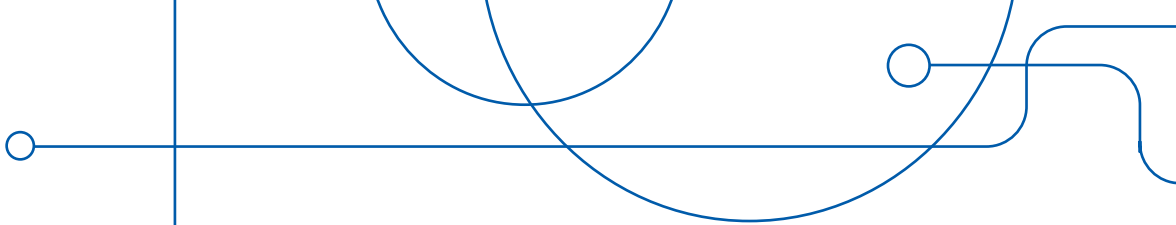
**Climate Services can** provide new knowledge on the linkages between health and climate to **enhance integrated disease surveillance and monitoring systems**. Climate-enhanced surveillance can improve the monitoring of climate conditions and climate-affected risk factors, and allowing public health teams to take advantage of environmental signals to better detect and anticipate health risks. For example, the customized on-line integrated health surveillance databases developed in Europe, Brazil and Ethiopia allow health researchers and experts to monitor and analyse real-time environmental and climatic conditions for early disease detection and triggering health prevention. The E3 portal is used in Europe to track the environmental suitability for various health-related risks: Such as predicting Vibrio cholera risk in the Baltic Sea, to initiate beach closures and public alerts, and protect immunocompromised individuals; delineating areas suitable for malaria transmission in Greece, to guide public health response; and investigating West Nile epidemic drivers in South/Eastern Europe. Similarly, the Brazilian Climate and Health Observatory helps to monitor, model and rapidly detect climate-related disease risks, such as increasing river levels and the risk of leptospirosis. In Ethiopia, EPIDEMIA the web-based processing and modelling system, has improved the rapid detection and forecasting of malaria epidemics.



**Climate Services can provide tactical information to improve health service design and delivery.** Climate information can help hone in on high risk conditions and populations, as well as when health service delivery itself is hampered by climate conditions, such as shown in London where analysis of demand for emergency services demonstrates fluctuations in relation to heat and cold episodes, helping support management changes to improve emergency response. In Hong Kong, climate information is used to design and provide personalized health care to the elderly during extreme heat episodes. In the Solomon Islands, customized rainfall outlooks are used by the National Vector Control Programme to plan community awareness and vector control activities and to allocate diagnosis and treatment resources more efficiently. In Burkina Faso, the national disease surveillance teams depend on a climate service to help predict meningitis incidence and plan responses for the upcoming epidemic season. Risk maps and advisories inform estimated needs for resource mobilization, the location and timing of awareness and vaccination campaigns, and the allocation of staff and health equipment. In Panama, a monthly bulletin predicting the *Aedes aegypti* infestation rates during the following three months, is shared with the Ministry of Health, city mayors, researchers and national Environmental Authorities to raise awareness of climate risks for dengue, and is used by the Vector Control Department to plan their activities.

**Climate Services can provide timely and usable climate and extreme weather information for Health Early Warning Systems and response plans that** directly inform health emergency response to save lives and protect health. In Ahmedabad, India, the creation of an Early Warning System and Heat Preparedness Plan is increasing the resilience of the most at-risk residents to extreme temperatures. It *has improved the capacity of health professionals* to care for patients with heat-related illnesses, and has been demonstrated to reduce deaths during recent heatwaves. A Heat Health Warning Systems in Quebec uses urban meteorological monitoring systems to design targeted intervention strategies to mitigate risks of heat-stress on vulnerable populations in various urban sub-regions. Finally, and also in Canada, ground-level monitoring of wildfire smoke and plume modelling, provide forecasts of rural and urban areas that may be affected by poor air quality, and allowing the Office of Disaster Management to protect communities in harm's way from the adverse health effects of wildfire smoke.

**Climate Services can help to increase risk awareness** and thus encourage protective behaviours, increase autonomous adaptation and community capacity to respond to health risks. The case studies show risk communication is often part of more comprehensive risk management approaches, and is sometimes the central goal, particularly in reaching targeted vulnerable populations. This is the case of CcTalk in Austria, which developed communication materials on the impacts of excessive heat on health for the elderly and identified the most effective modes of communication to motivate protective behaviours. A project in East Africa used climate information to design community health-related contingency plans, educational materials and to inform community interventions on water and sanitation, hand-washing practices, kitchen utensils handling and pit latrine constructions, which were proven to reduce the level of community risk behaviours.



In Ecuador, diarrheal disease incidence data was transformed into 'life stories' (a comprehensive compilation of the story behind a sentinel event) to allow communities to analyse and understand the relation of diarrhoea to rainfall and propose feasible solutions. In China, a Heat Wave and Heat Risk Warning System, allows communities and health workers to take appropriate action, as a result of timely information on heat-related health risks being made available to community health centres and communities; and triggering advisories and awareness to residents, especially vulnerable populations, via multiple means of communication (TV; mobile text newspapers, painting contests, QQ groups and electronic display, etc.)

**Climate Services can** provide tailored information about future climate **to help stakeholders imagine plausible future conditions and inform health sector adaptation planning.** The National Disaster Risk Reduction Framework to drought management in Brazil is a good example: This was motivated by the observed severe health effects of past drought events, and concern about the future projections for drought events in the different climate zones in the country. And in Canada, where a risk modelling framework for food and water safety provided projections of potential climate impacts on food and water safety up to 2100. It also incorporated scenarios of adaptation options to allow decision-makers to compare and select mitigation and adaptation strategies across multiple diseases and commodities. In eastern Africa, a web-based mapping tool helps visualize current and future risks of malaria, schistosomiasis and RVF, at different time scales and provides a detailed analysis of long-term future disease risk, including the opportunity to disaggregate composite risk indicators to help promote understanding of the significance of individual risk factors for these diseases.

**Climate services can** also become a critical asset to health professionals needing **to evaluate the performance of health services and interventions**, which may be influenced by extreme weather, seasonal or inter-annual climate conditions. For example in Ethiopia, the influence of seasonal and long-term climate was included in the evaluation of the malaria control programme performance, and helped account for the potential confounding effects of climatic conditions on the observed efficacy of vector control interventions.





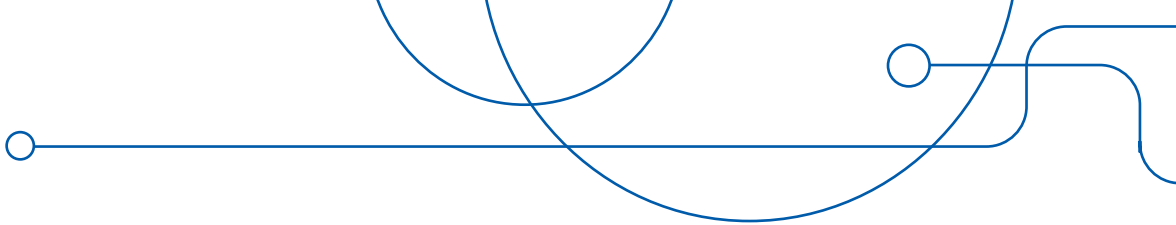
# CONCLUSIONS: UNPACKING THE POTENTIAL OF CLIMATE SERVICES

This collection of pioneering experiences in applied climate and health science demonstrates that opportunities, expertise, techniques and good practice already exist to enable climate-informed health decision-making. Today, health practitioners, researchers, policy-makers and individual citizens have greater access than ever to relevant and real-time information about hazardous conditions. Learning to harness climate knowledge can provide insights to anticipate problems and target interventions. The integrated use of climate knowledge results in more lives saved, more cases treated, reduced disease burdens, and cost savings in health service delivery. It results in a new type of health service that aids the health sector to become smarter and more agile in an uncertain and increasingly extreme climate; it results in 'climate services for health'.

Addressing the climate risks to health calls for a transformation in how we approach such complex problems, particularly by employing more inclusive, multidisciplinary and interactive tactics. Unlocking the power of climate science and technology for health applications will be a major part of this transformation. Over the last few decades, there has been tremendous progress in climate and meteorological science. Less than 20 years ago, climate and weather models were only able to forecast conditions a few days ahead of time, with a limited degree of reliability in parts of the world. Today, real-time, remotely-sensed and ground-based observations can be used to monitor and predict weather conditions weeks to months in advance, with increasing precision and reliability. Location-specific predictions of hazardous conditions, such as cyclone landings, air quality or extreme temperatures, are extremely relevant to emergency health services.

The case studies in this book illustrate that, by using our increased predictive skill and knowledge on the linkages between health and climate, powerful tools can be developed, which can help decision-makers to anticipate risks and protect populations. Many climate services are highly transferrable to sectors or countries that share similar risk, and present scalable solutions and sharable expertise.

Tapping the potential of other available and new technologies will also be essential to accelerate climate service applications. Improvements to data collection and management, real-time information transfer, increasingly personalized climate services, and more effective global collaborative networks all offer tantalizing possibilities for public health management. Expanded use of data visualization techniques, in particular, can help make complex data much more accessible, understandable and usable for decision-making. By helping to tell a story, data visualization can clearly communicate climate knowledge to the public and professionals.



But new science and technology are only part of the story. Equally important in the current publication's case studies are inclusive, multidisciplinary and interactive tactics, which show how climate services can empower communities and individuals to play a greater role in their own health and protection. Providing citizens the opportunity to participate in science- and technology-driven decision-making processes is critical to change the established "trust us, we're experts" science-society relationship. Aiding individuals and communities to make good decisions based on fit-for-purpose and well-tailored climate services should therefore be encouraged.

Efforts must be made to further capture lessons, through documenting evidence of what is working and what is not, and by enhancing the sharing of helpful climate knowledge and action. This will entail more data sharing and better access to technology, to develop appropriate tools and methodologies. It also calls for more effective communication with end-users and communities.

Climate services for health are a sound investment. But such services need long-term, coordinated commitment and cooperation among a wide range of partners, especially if we are to scale up and expand them. The lack of institutional and national capacity, as often seen in the most vulnerable countries, as well as insufficient financial and human resources, are major obstacles. Tackling these challenges requires that national and international partners, from private and public sectors, must come together, also working with affected communities. Investments are needed to maintain and enhance both the global and national climate monitoring systems and the capacity of meteorological services to assist climate-sensitive sectors, such as health, to manage climate risks.

Finally, a transformative approach to climate and health requires empowering other sectors that affect health, to also protect health. Climate services provide an excellent platform to encourage multistakeholder climate action, bringing together agents from a variety of sectors such as agriculture, disaster risk reduction, water management and energy. These sectors also have powerful climate knowledge resources and are essential actors in protecting health from disease, undernutrition and disasters. The case studies demonstrate the mutual benefits of closer collaboration between NMHS and health agencies, which often positively spirals to include other sectors such as agriculture. Climate services also open doors to regional collaboration, which is particularly critical in light of epidemics and climate zones that spread across national borders.

Unlocking the untapped potential for greater collaboration between the health and climate sectors is a collective journey of many actors. However, the need to build the resilience of climate-sensitive sectors such as health has never been greater, and the opportunities for change and empowering communities and professionals with actionable knowledge are abundant. Climate services for health can and do exist. The time to use them is now. The challenge is to make them available to all of those in need, in our generation and in future ones.



WORLD  
METEOROLOGICAL  
ORGANIZATION



**World Health  
Organization**

**JOINT OFFICE FOR CLIMATE AND HEALTH**

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