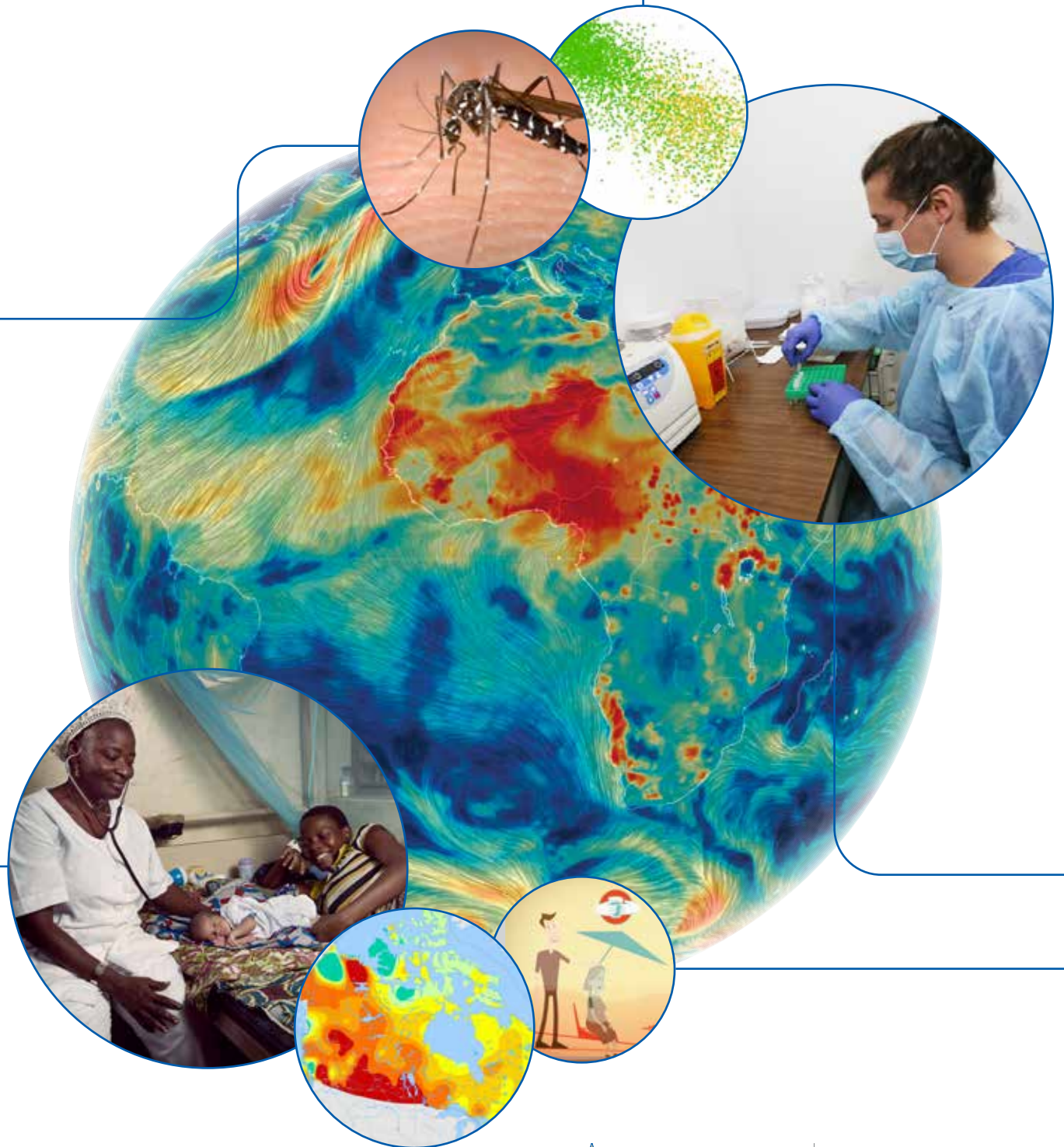


CLIMATE SERVICES FOR HEALTH

Improving public health decision-making in a new climate





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.

© World Meteorological Organization and World Health Organization, 2016

Photo credits | Front cover © Stephan Gladieu / World Bank

ISBN pending

Subject headings are available from WHO institutional repository.

The right of publication in print, electronic and any other form and in any language is reserved by WMO and WHO. Short extracts from WMO publications may be reproduced without authorization, provided that the complete source is clearly indicated. Editorial correspondence and requests to publish, reproduce or translate this publication in part or in whole should be addressed to: WHO Press, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland (tel.: +41 22 791 3264; fax: +41 22 791 4857; e-mail: bookorders@who.int).

Requests for permission to reproduce or translate WHO publications – whether for sale or for non-commercial distribution – should be addressed to WHO Press through the WHO website (www.who.int/about/licensing/copyright_form/en/index.html).

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by the World Health Organization in preference to others of a similar nature that are not mentioned. Errors and omissions excepted, the names of proprietary products are distinguished by initial capital letters.

All reasonable precautions have been taken by the World Health Organization to verify the information contained in this publication. However, the published material is being distributed without warranty of any kind, either expressed or implied. The responsibility for the interpretation and use of the material lies with the reader. In no event shall the World Health Organization be liable for damages arising from its use.

Graphic design and layout
ACW, London, UK
www.acw.uk.com



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 National Oceanic and Atmospheric Administration (NOAA) for financial contribution to the publication, to Inis Communication for technical editing support, and to Artifex Creative Webnet (ACW) for design and layout services. The current publication was conceptualized and developed by Joy Shumake-Guillemot (WMO/WHO Joint Office) and Lucia Fernandez-Montoya (WMO Consultant).

CONTENTS

Foreword - page 6

Executive summary - page 8

Chapter 1

Health-tailored climate services - page 14

- 1.1 Why does the health community need climate services?
- 1.2 What are health-tailored climate services?
- 1.3 How can climate information and services help the health community?
- 1.4 What kind of climate and weather information is useful to health partners?
- 1.5 Why is co-production important?
- 1.6 Developing climate services for health: a holistic process

Introduction

Case Studies

The Future

Accelerating climate services for health innovation and partnerships

Chapter 8

Solutions to common climate service challenges - page 204

Chapter 9

Benefits of climate services to health policy and programming - page 212

Chapter 10 – Conclusions

Unpacking the potential of climate services - page 216

Chapter 2 Creating an enabling environment - page 24

Case study 2A Ecuador–Peru cooperation for climate-informed dengue surveillance: creating an interdisciplinary multinational team.

Case study 2B Addressing impacts of poor air quality on health in India: integrating air quality, health and meteorological expertise.

Case study 2C Long-term climate and health collaboration to forecast malaria outbreaks in Ethiopia.

Case study 2D Madagascar Climate and Health Working Group.

References

Chapter 3 Building capacity for climate services - page 48

Case study 3A Training a new generation of professionals to use climate information in public health decision-making.

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

Case study 3C Working with communities in East Africa to manage diarrhoeal disease and dengue risk in a changing climate.

References

Chapter 4 Research to inform climate services - page 64

Case study 4A Vulnerability and adaptation assessment: Identifying climate information and decision needs in Bhutan.

Case study 4B Understanding the sensitivity of dengue to climate and urban risk factors in Minas Gerais State, Brazil.

Case study 4C Analysis of the health impacts of climate variability in four major South American cities.

Case study 4D Malaria sensitivity to climate in Colombia: The importance of data availability, quality and format.

Case study 4E Iterative development and testing of a heat warning and information system in Alberta, Canada.

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

Case study 4G CcTalk! Communicating effectively with high-risk populations in Austria: A five-step methodology.

Case study 4H Knowing when cold winters and warm summers can reduce ambulatory care performance in London.

References

Chapter 5 Co-development and delivery of health-tailored climate products and services - page 96

Case study 5A Innovative community-based data collection to understand and find solutions to rainfall-related diarrhoeal diseases in Ecuador.

Case study 5B Vector-virus microclimate surveillance system for dengue control in Machala, Ecuador.

Case study 5C EPIDEMIA: Integrating climate information and disease surveillance for malaria epidemic forecasting in Ethiopia.

Case study 5D The Brazilian Observatory of Climate and Health: Experience of organizing and disseminating climate and health information in Manaus, Amazon region.

Case study 5E Climate-specific pollen indicators and population exposure monitoring tools to better manage the allergy season in Hungary.

Case study 5F MalaClim: Climate-based suitability mapping to inform vector control programmes in the Solomon Islands.

Case study 5G Mapping and modelling plague in Uganda to improve health outcomes.

Case study 5H Forecasting wildland fire smoke hazards in urban and rural areas in Manitoba, Canada.

Case study 5I Forecasting malaria transmission: finding the basis for making district-scale predictions in Uganda.

Case study 5J Bio-climatic bulletins to forecast dengue vectors in Panama.

Case study 5K SUPREME: An integrated heat health warning system for Quebec.

Case study 5L Heat wave and health risk early warning systems in China.

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

Case study 5N Comprehensive climate risk modelling framework to help protect future food and water safety in Canada.

Case study 5O How hot will it be? Translating climate model outputs for public health practice in the United States.

References

Chapter 6 Applying climate knowledge to practice - page 158

Case study 6A Innovative heat wave early warning system and action plan in Ahmedabad, India.

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

Case study 6C Early warning systems to guide infectious disease control in Europe.

Case study 6D Improving malaria evaluation and planning with enhanced climate services in East Africa.

Case study 6E Using climate information to predict and control meningitis epidemics in West Africa.

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

References

Chapter 7 Evaluation and feedback to improve health decision support - page 188

Case study 7A Building evidence that effective heat alert systems save lives in southeast Australia.

Case study 7B Finding the right thresholds to trigger action in heat wave early warning systems in Spain.

Case study 7C Looking back: Documenting lessons learned from the implementation of a climate and health project in Ethiopia.

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

References

Case study themes:

Diseases



Vector-borne disease



Water-borne disease



Hepatitis



Meningitis

Hazards



Heat stress



Air quality



Extreme events



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' publication profiles 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: The health problem being solved, including timescale and types of decision needs requiring climate or weather information; the type of climate services developed, including a description of the process used to develop and apply the services; the benefits of the approach to the health community; and 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. Over time, new project information and results that 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 to 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, each of which are 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, when 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 (such as 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 that 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. Extreme weather events are forecasted farther in advance. Satellite imagery and air quality monitoring data are being blended to model and predict where and when air quality may become a public health hazard. Environmental conditions that can compromise water quality or provide perfect conditions for disease vector breeding are now identifiable. 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 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 seasons informs allergists of when season will start and end, and how severe it is likely to be for their patients. This serves to trigger environmental remediation and health service planning. 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.

CLIMATE SERVICES FOR HEALTH CASE STUDIES

Enabling environment

Case study 2A Ecuador–Peru cooperation for climate-informed dengue surveillance: creating an interdisciplinary multinational team.

Case study 2B Addressing impacts of poor air quality on health in India: integrating air quality, health and meteorological expertise.

Case study 2C Long-term climate and health collaboration to forecast malaria outbreaks in Ethiopia.

Case study 2D Madagascar Climate and Health Working Group.

Capacity-building

Case study 3A Training a new generation of professionals to use climate information in public health decision-making.

Case study 3B Protecting the elderly from heat and cold stress in Hong Kong: using climate information and client-friendly communication technology.

Case study 3C Working with communities in East Africa to manage diarrhoeal disease and dengue risk in a changing climate.

Research

Case study 4A Vulnerability and adaptation assessment: Identifying climate information and decision needs in Bhutan.

Case study 4B Understanding the sensitivity of dengue to climate and urban risk factors in Minas Gerais State, Brazil.

Case study 4C Analysis of the health impacts of climate variability in four major South American cities.

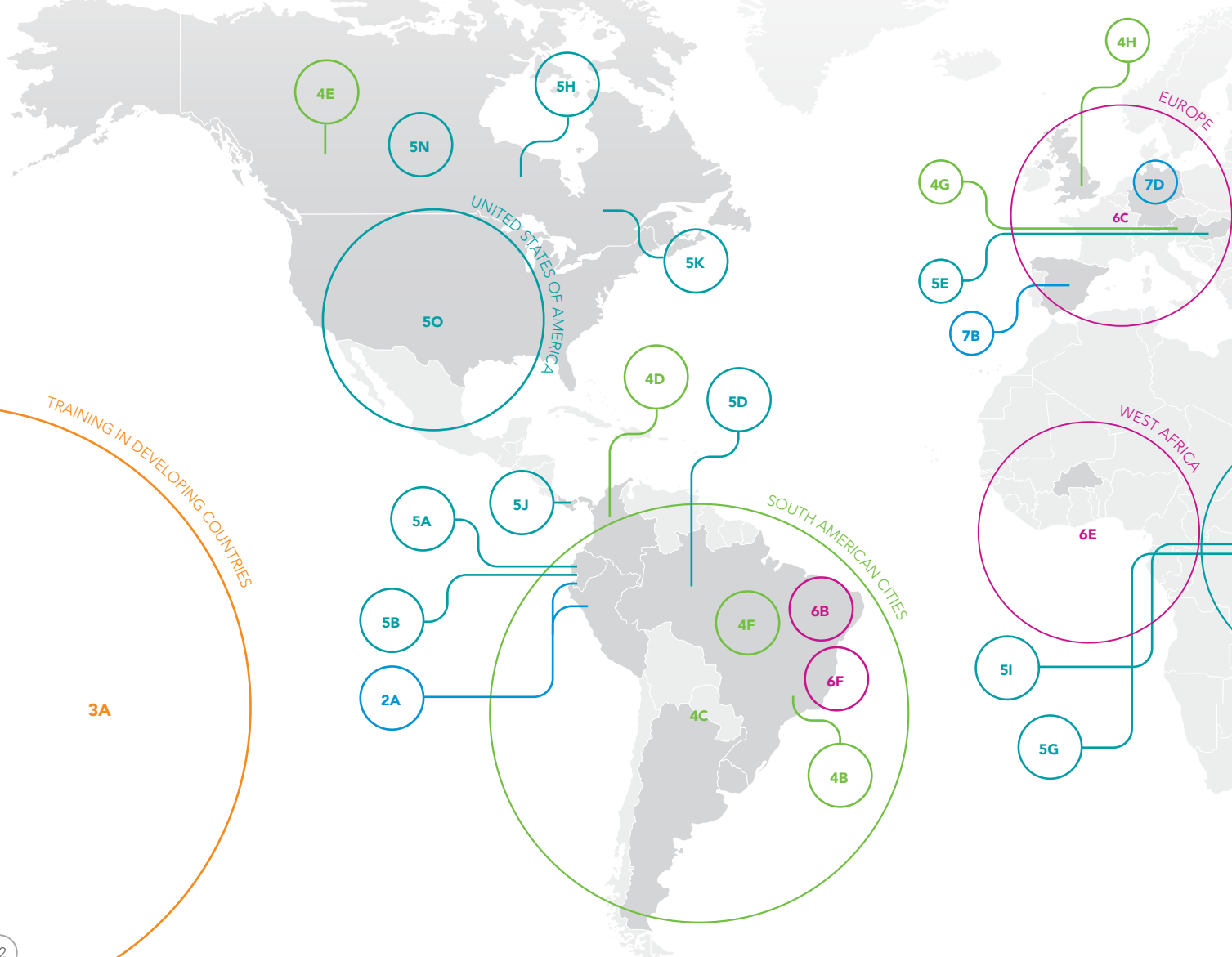
Case study 4D Malaria sensitivity to climate in Colombia: The importance of data availability, quality and format.

Case study 4E Iterative development and testing of a heat warning and information system in Alberta, Canada.

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

Case study 4G CcTalk! Communicating effectively with high-risk populations in Austria: A five-step methodology.

Case study 4H Knowing when cold winters and warm summers can reduce ambulatory care performance in London.



Produce and service development

Case study 5A Innovative community-based data collection to understand and find solutions to rainfall-related diarrhoeal diseases in Ecuador.

Case study 5B Vector-virus microclimate surveillance system for dengue control in Machala, Ecuador.

Case study 5C EPIDEMIA: integrating climate information and disease surveillance for malaria epidemic forecasting in Ethiopia.

Case study 5D The Brazilian Observatory of Climate and Health: Experience of organizing and disseminating climate and health information in Manaus, Amazon region.

Case study 5E Climate-specific pollen indicators and population exposure monitoring tools to better manage the allergy season in Hungary.

Case study 5F MalaClim: climate-based suitability mapping to inform vector control programmes in the Solomon Islands.

Case study 5G Mapping and modelling plague in Uganda to improve health outcomes.

Case study 5H Forecasting wildland fire smoke hazards in urban and rural areas in Manitoba, Canada.

Case study 5I Forecasting malaria transmission: finding the basis for making district-scale predictions in Uganda.

Case study 5J Bio-climatic bulletins to forecast dengue vectors in Panama.

Case study 5K SUPREME: an integrated heat health warning system for Quebec.

Case study 5L Heat wave and health risk early warning systems in China.

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

Case study 5N Comprehensive climate risk modelling framework to help protect future food and water safety in Canada.

Case study 5O How hot will it be? Translating climate model outputs for public health practice in the United States.

Application

Case study 6A Innovative heat wave early warning system and action plan in Ahmedabad, India.

Case study 6B Managing the health impacts of drought in Brazil: a comprehensive risk reduction framework.

Case study 6C Early warning systems to guide infectious disease control in Europe.

Case study 6D Improving malaria evaluation and planning with enhanced climate services in East Africa.

Case study 6E Using climate information to predict and control meningitis epidemics in West Africa.

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

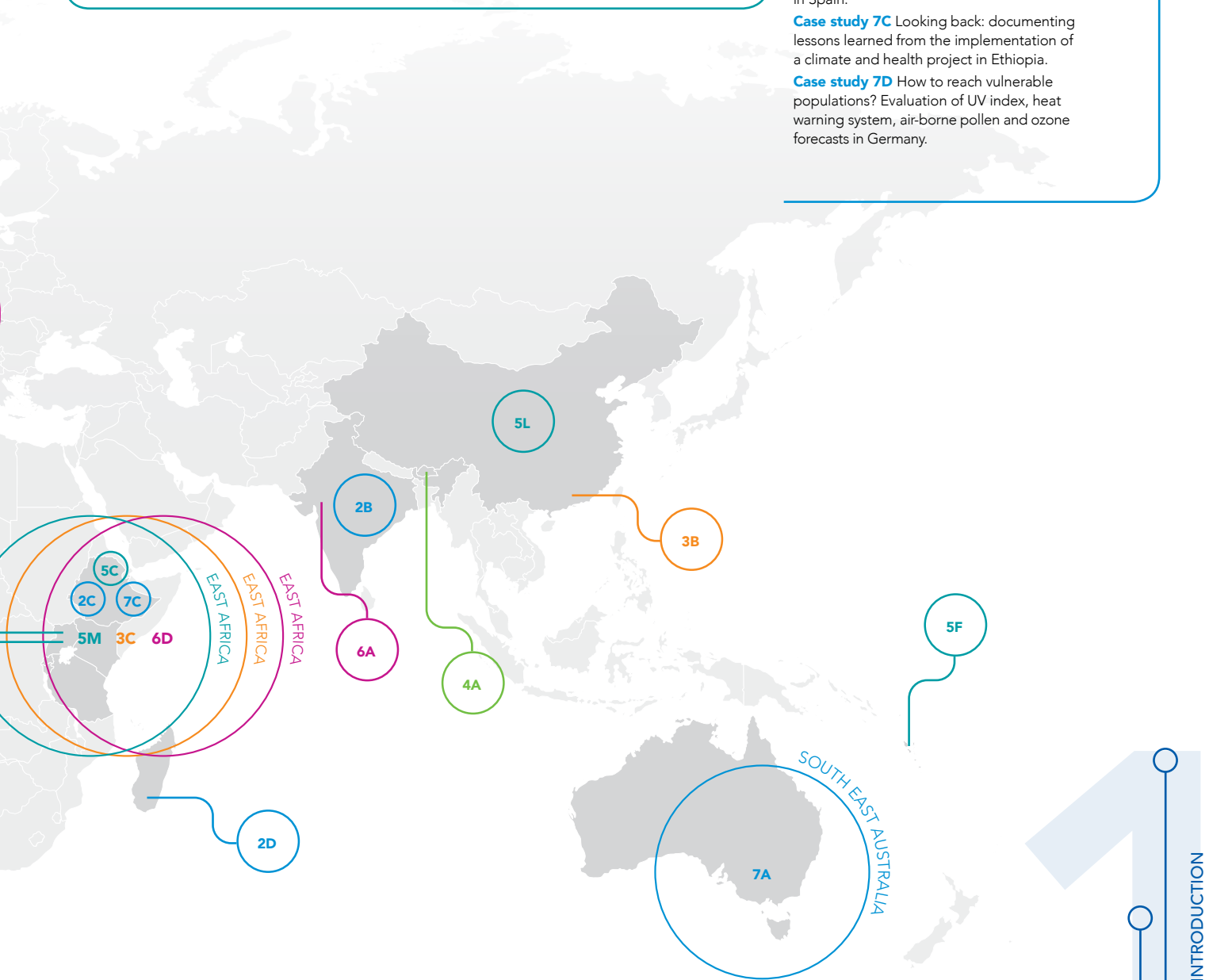
Evaluation

Case study 7A Building evidence that effective heat alert systems save lives in southeast Australia.

Case study 7B Finding the right thresholds to trigger action in heat wave early warning systems in Spain.

Case study 7C Looking back: documenting lessons learned from the implementation of a climate and health project in Ethiopia.

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





CHAPTER 1

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 are complex but 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 changing climate conditions can influence many global health priorities has recently unlocked a strong demand for improved 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. 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.

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.

1.2 WHAT ARE HEALTH-TAILORED CLIMATE SERVICES?

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 weather, climate, 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 health, social, cultural, environmental or other information, particularly about population vulnerabilities and exposures, in order to create tailored information products that inform and communicate understandings of climate risk.

In the health sector, this blending requires a range of techniques to integrate spatial and time-scaled weather and climate information in combination with clinical, epidemiological and other health data to understand and apply knowledge about how climate in the past, present, or future influences health outcomes, health risks, and health service delivery. Thus by definition, the processes of tailoring climate information for use in the health sector requires strong partnerships and collaborative efforts between the producers and users of climate information.

It is for this reason, 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.”

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 National Meteorological and Hydrological Service; 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 disease early warning systems. 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, and take appropriate action.

Table 1.1 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 and epidemic disease risk factors or climate summary statistics, historical 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. Examples are early warning systems, integrated monitoring systems or risk forecasting systems.

1.3 HOW CAN CLIMATE INFORMATION AND SERVICES HELP THE HEALTH COMMUNITY?

Climate services for health can facilitate access to multidisciplinary risk knowledge and increase capacity. Customized tools can be developed to identify and target the most vulnerable areas or populations. Analytical diagnostics can 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. Future climate scenarios can be explored to hypothesize how service delivery may perform under diverse climatic conditions and evaluate which health interventions are most likely to be effective at different times of the year.

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, pesticide and vaccine supply flow;
- health infrastructure siting and maintenance;
- emergency preparedness;
- community education and public health information dissemination, such as 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;
- impact assessment of climate sensitive interventions.

Climate services for health have been 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 map disease transmission risks at high spatial resolution to better target vector control interventions and train traditional healers; to provide real-time and customized information for high-risk populations during heat waves; or to understand changing drought risks and reduce vulnerabilities to rapid and slow-onset impacts of droughts.

There are many measurable benefits of climate-informed decisions resulting from applied climate services. Lives can be saved and case burdens reduced. Health systems and communities can become better prepared for extreme weather events. Health intervention can become more cost-effective.

1.4 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 decision needs, 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.

The second determining factor of what climate information may be decision relevant is the time frame 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 1.2 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).

Table 1.2 General status of climate and weather information relevant for health decision-making.


| Timescale | Forecast & records' period and lead times | Example of climate information products available | Example of health-decision applications |
|---|---|--|---|
| <p>HISTORIC RECORD OF CLIMATE OBSERVATIONS</p> <p>(Observational, gridded data sets and reanalysis).</p> <p>OPERATIONAL</p> | <p>Hourly, daily, monthly or annual records of past climate conditions.</p> | <p>Historical data on rainfall, temperature, humidity, wind, dust, pollution, etc.</p> <p>Model-driven reconstruction of historical climate records.</p> <p>Summary statistics of past climate (e.g. rainfall seasonality, 30- average temperature and rainfall monthly means, geographical rainfall distributions, etc.).</p> <p>Drought monitoring (intensity, duration).</p> <p>Summary statistics of extreme events (e.g. number of days of heavy rainfall, per week, month, year; number of cyclones per season).</p> | <p>Epidemiological trend and regression analysis to understand associations of climate and health, set risks thresholds and inform disease control plans.</p> <p>Analysis of extreme events impacts to identify high-risk areas and populations and define priority high impact extreme events for design of response plans.</p> <p>Production of baselines to monitor future evolution of climate risks.</p> |
| <p>WEATHER MONITORING AND NOWCASTING PRODUCTS</p> <p>OPERATIONAL</p> | <p>Current weather conditions provided in real-time or with some delay, and very short-term predictions.</p> | <p>Tracks and intensities of cyclones and storms.</p> <p>Temperature, wind speeds, humidity, rainfall intensities for the current day and next few minutes or hours.</p> <p>Accumulated rainfall, average/ maximum/ minimum temperatures for the current day and next few minutes or hours.</p> | <p>Trigger emergency response plans when pre-fixed risk thresholds are exceeded.</p> <p>Guide emergency interventions (e.g. identify flooded areas, potentially damaged health infrastructure, isolated communities; decide on staff deployment, delivery of supplies, and public protection needs).</p> <p>Trigger preparedness plans when conditions indicate that certain slow-onset hazards are evolving (e.g. local strong storms).</p> |
| <p>WEATHER FORECASTS</p> <p>OPERATIONAL</p> | <p>Hourly or daily weather conditions forecasted multiple times a day from hours to around 12 days ahead.</p> | <p>Real-time monitoring of daily weather: temperature, precipitation, humidity, wind speed and direction, etc.</p> <p>Hourly and daily rainfall probability and temperature ranges.</p> <p>Daily risks levels of extreme events (heat wave, strong winds, storms, snow, frosts, haze) and probabilities for different intensities.</p> <p>Maps of extreme event risks.</p> | <p>Trigger preparedness plans when hazards are forecasted (e.g. heavy rainfall, cyclone, strong winds). Example decisions: Identify at risk populations and disseminate public health advisories; initiate evacuations; activate emergency committees and response teams; pre-position emergency supplies; estimate needs of and strengthen emergency services; activate health impacts monitoring mechanism.</p> |
| <p>SUB SEASONAL CLIMATE FORECASTS</p> <p>UNDER DEVELOPMENT</p> | <p>Average climate conditions over a week (approx.) forecasted from 2 weeks to 60 days ahead.</p> | <p>Research is being undertaken to identify the probability of high-impact extreme events, such as heavy rainfall, heat waves, cyclones, dust or landfalls 2-3 weeks ahead of occurrence.</p> | |
| <p>SEASONAL CLIMATE FORECASTS</p> <p>OPERATIONAL</p> | <p>Seasonal climate conditions forecasted up to 6 months ahead.</p> | <p>Seasonal probability of temperature and rainfall exceeding normal conditions (upper tercile, lower tercile or user defined thresholds).</p> <p>Probability of occurrence of La Nina and El Nino phases of El Niño Southern Oscillation (ENSO).</p> | <p>Trigger operational decisions months ahead of time when increase risk is forecasted.</p> <p>Example decisions: supplies procurement and pre-positioning; health workforce deployment; initiate communications campaigns with communities; strengthening disease surveillance and outbreak prevention and control mechanism in at risk areas and drought response when needed; initiate communication with relevant partners to prepare response actions.</p> |
| <p>INTER-ANNUAL CLIMATE FORECASTS</p> <p>UNDER DEVELOPMENT</p> | <p>Seasonal climate conditions forecast around 1 year ahead.</p> | <p>Probability of extreme events occurring during the season (e.g. droughts outlooks).</p> | <p>It is recommended to integrate seasonal forecast with monitoring system to forecast in context.</p> |

| Timescale | Forecast & records' period and lead times | Example of climate information products available | Example of health-decision applications |
|---|--|--|--|
| DECADAL CLIMATE FORECASTS UNDER DEVELOPMENT (Mainly focused on temperature and temperature related extreme events, first operational products available). | Multi-annual climate conditions forecasted annually. | 5 year mean temperature conditions compared to previous periods. 5-year probability of temperature conditions exceeding certain lower or upper normal thresholds. Multi-year predictions of hurricane frequency. | Inform 1-5 year policy decisions for heat related health outcomes in areas with strong temperature change trends. Example decisions: create or strengthen early warning and risk monitoring mechanism; initiate community awareness campaigns; revise health supply needs and distribution; establish cool centers; strengthen disease surveillance systems; retrofit health infrastructure; train workforce in disease diagnosis and identification of vulnerable populations. |
| DECADE TO CENTURY CLIMATE INFORMATION (Climate projections). OPERATIONAL | Conditions expected at different points in time the next 30 to 100 years and run every 5 years or upon specific needs. | Average patterns of temperature and rainfall in 30-40-50-80-100 years-time at different spatial scales (continental, regional or downscaled to country level). Prospects of frequency and intensity of extreme weather events and sea level rise. | Inform long-term policy decisions and investments for research a development and infrastructure. Example decisions: investment in drought resistance crops, vaccine development, heat resilient cold chains, water systems for health facilities, uninterrupted power supplies, workforce development. |

Summary of weather and climate information, including historical records, current conditions and forecasts, at different time scales for health applications. It is importance to notice that 1) the ability to produce reliable products is different at different time scales and 2) the reliability of each of the products listed vary across regions and seasons. The status of development of the products at different time scales has been classified in this table as Operational (products being release on a regular basis for operational purposes by different producing centers) or Under Development (products that are in an experimental phase and not yet released regularly). For example, currently weather forecast techniques are much more developed and, hence, yield more reliable results than decadal forecasting does. To better understand the reliability of individual products for an specific region or season expert advice should be seek. It is recommendable to contact the national and local met service or the Regional Climate Centers for further information.

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 availability, accessibility, 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.

The availability, reliability and quality 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.

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, (such as climate-appropriate investments in and deployment of health care's 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.

For national or subnational health decision-making, a first step to identifying the relevant, available, and accessible weather and climate information is a discussion with the National Meteorological and Hydrological Services, which is most often responsible for collecting and producing climate and weather information, and understanding local data-sharing policies.

1.5 WHY IS CO-PRODUCTION IMPORTANT?

Climate services represent a process of 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.

Different levels of collaboration may be called for depending on the activity. 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 services and data sharing policies that will allow health partners to build the evidence base for identifying further potential climate service needs.

However, when the public health problem requires 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, it also 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 collaborative 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.

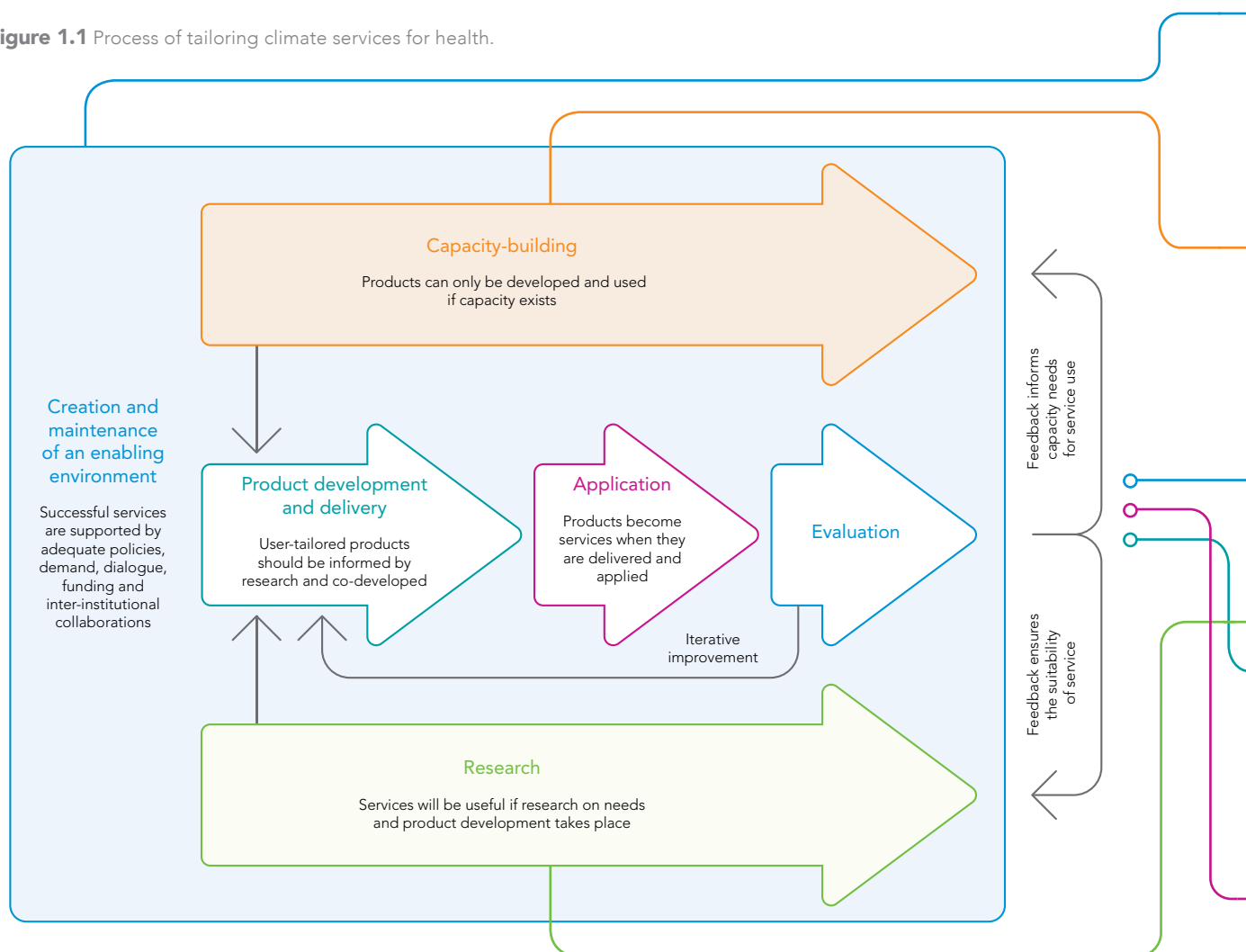
The development process for creating usable climate products and services for robust public health decision-making may take months to years, and commonly requires iterative rounds of trial and error, capacity-building, and refinements through active partner engagement and collaboration. Furthermore, 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 for uptake and use.

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 1.1.

Figure 1.1 Process of tailoring climate services for health.



It is highly recommended that an assessment of readiness is conducted to identify available building blocks, resources, and the level of readiness for each phase of development. Although this is not a strictly sequential process, the components of enabling, the components of enabling environment, capacity, and research set the foundations and readiness levels to adequately advance to product and service development and delivery, application and evaluation. Additionally, maintaining the enabling environment and strengthening capacities should occur in parallel to activities focused on the design, development, and application of 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.

Table 1.3 Goals of individual process components.

ENABLING ENVIRONMENT

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

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

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

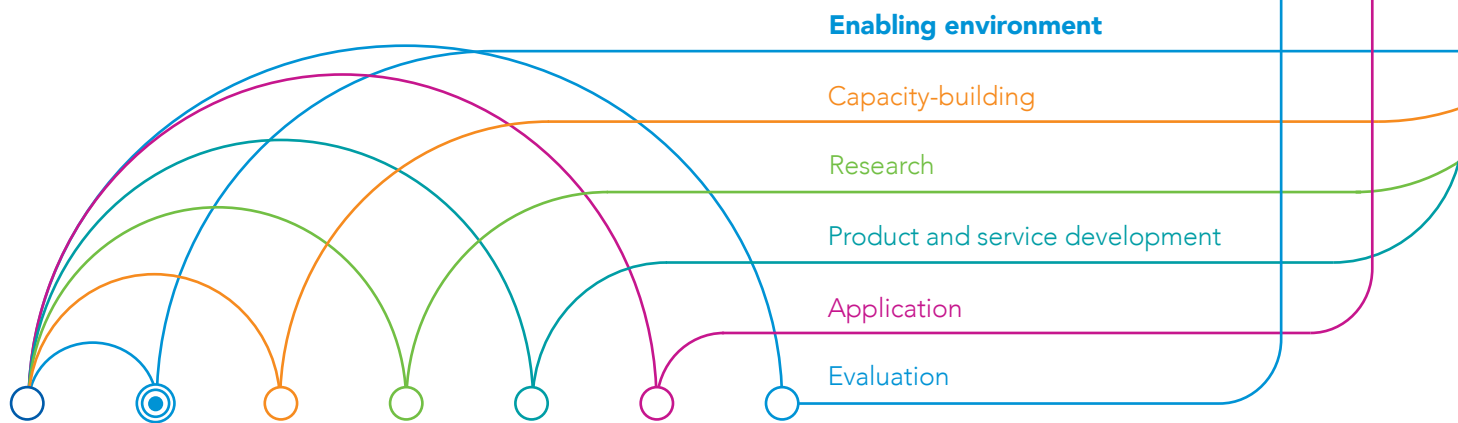
Collaboratively design and create tailored information products that are integrated and interoperable to user specifications, which provide decision-makers and communities with timely and relevant information to manage health risks specific to climate and weather.

APPLICATION

Apply climate knowledge to bring benefits to individuals and communities.

EVALUATION

Provide evidence on the performance, effectiveness and cost-effectiveness of climate services to save lives and reduce climate-related health risks.



CHAPTER 2

2

CREATING AN ENABLING ENVIRONMENT

GOAL: 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 knowledge to solve problems within a health system on a sustainable basis. An enabling environment is formed by the:

- national policy and financial landscape
- problem awareness and scientific and programmatic demand
- institutional mandates, procedures, and capacities
- multi-sectoral partnerships and communication mechanisms

Recognizing and understanding the enabling environment is critical for climate services to generate relevant knowledge, become integrated with the health system, and improve decision-making on a sustainable basis where needed. Simple organizational and institutional steps can markedly improve the enabling environment, such as increasing risk communications and local evidence which enhance problem understanding, as well as forging structured partnerships. Certain actions can help 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 knowledge products be confidently endorsed and applied by users to improve health decision-making. Communication of evidence of local climate and health linkages, and evaluating and demonstrating the added value of understanding climate influences on health and using this knowledge to improve programmatic decision-making, is also a fundamental part of enabling, sustaining, and justifying the value of investments in tailored climate service developments.

IMPORTANCE OF AN ENABLING ENVIRONMENT TO EFFECTIVE CLIMATE SERVICES

An enabling environment should be fostered and maintained throughout the whole climate service production process. In the initial stages of new activities, the following intentional actions should be undertaken:

- Clearly define the health problem being solved and its space and time dimensions.
- Envision together with relevant actors the scope of the type of climate products and services to be developed. Create mechanisms and norms for dialogue between partners to set appropriate expectations, and understand each other's needs, interests and limitations, including data sharing and resource exchange policies.
- Evaluate the readiness for the specific products/service development, including capacity, research, political support, application requirements, financial and technical resources.
- Explore feasibility and sustainability of different implementation models. Define a service development progress monitoring system to identify and manage setbacks and breakthroughs.
- Establish rules and procedures for engagement (such as meeting schedules, memorandums of understanding, timetables, data sharing arrangements).
- Create a plan for evaluating, providing feedback, and making needed adjustments.
- Ensure the right policies and mandates are established to develop and apply the service. Generate a strategic plan for long-term financial sustainability.

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

- Maintain and boost communication channels for partners to exchange data and information.
- Identify and solve problems related to testing and application.
- Evaluate and provide constant mutual feedback.
- Monitor usage, value, and sustainability of services.
- Identify new needs and/or expand the applications and partnerships in relation to real-time challenges. Inform the education sector and partners of the skills and education needed to enable the workforce.

COMMON APPROACHES

Enabling environments are fostered 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:

- Assessing readiness and defining demand for climate services;
- Mapping national partners' interests and strengths;
- Collaborating 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 and enabling key activities such as data exchange;
- Adopting common standards and schedules;
- Revising institutional mandates and policies, including formulating effective 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;
- Partnering with academia and civil society organizations as neutral actors working between national health and climate authorities;
- Engaging and communicating actively with donors to ensure future sustainability.

WHO IS OFTEN INVOLVED?

Health professionals: 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: Meteorologists, climatologists, and researchers from the National Meteorological Services, academia, or applied institutes.

Professionals from health-determining sectors: 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: Information and communication technologists, project managers, policy-makers, legal experts, statisticians and community representatives.

Community members: 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: Ecuador–Peru cooperation for climate-informed dengue surveillance: creating an interdisciplinary multinational team

Case study 2A shows how a collaboration between experts in Ecuador and Peru was established to address a shared problem of endemic dengue transmission 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 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 the 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 the Climate and Health Working Group has been active 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 Public Health with information and evidence related to climate variability and change.



Enabling environment

Research

ECUADOR–PERU COOPERATION FOR CLIMATE- INFORMED DENGUE SURVEILLANCE: CREATING AN 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 include the creation of partnerships with organizations such as WMO, and should take into account 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 3 227 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, the Binational Development Plan was established along the Ecuador–Peru border. It was designed 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 was 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 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 website.
- 2.3 Obtain official government approval and support for the establishment of the dengue surveillance network.

CASE STUDY 2A

Enabling
environment

Research

Establishment of a baseline of current 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) has led major research processes using climatological information for predictability models for vector-borne diseases (10).

Figure 2.1 *Aedes Albopictus*. Photo credit: Centers for Disease Control and Prevention, part of the United States Department of Health and Human Services. Photo credit: James Gathany/CDC.



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 the existence of 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 assimilable 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 for 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.

ACKNOWLEDGEMENTS



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 include seeking official recognition for the dengue surveillance network to implement its workplan as part of the Binational Development Plan and become an official part of the regional and local community development plans.

Enabling environment

Research

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

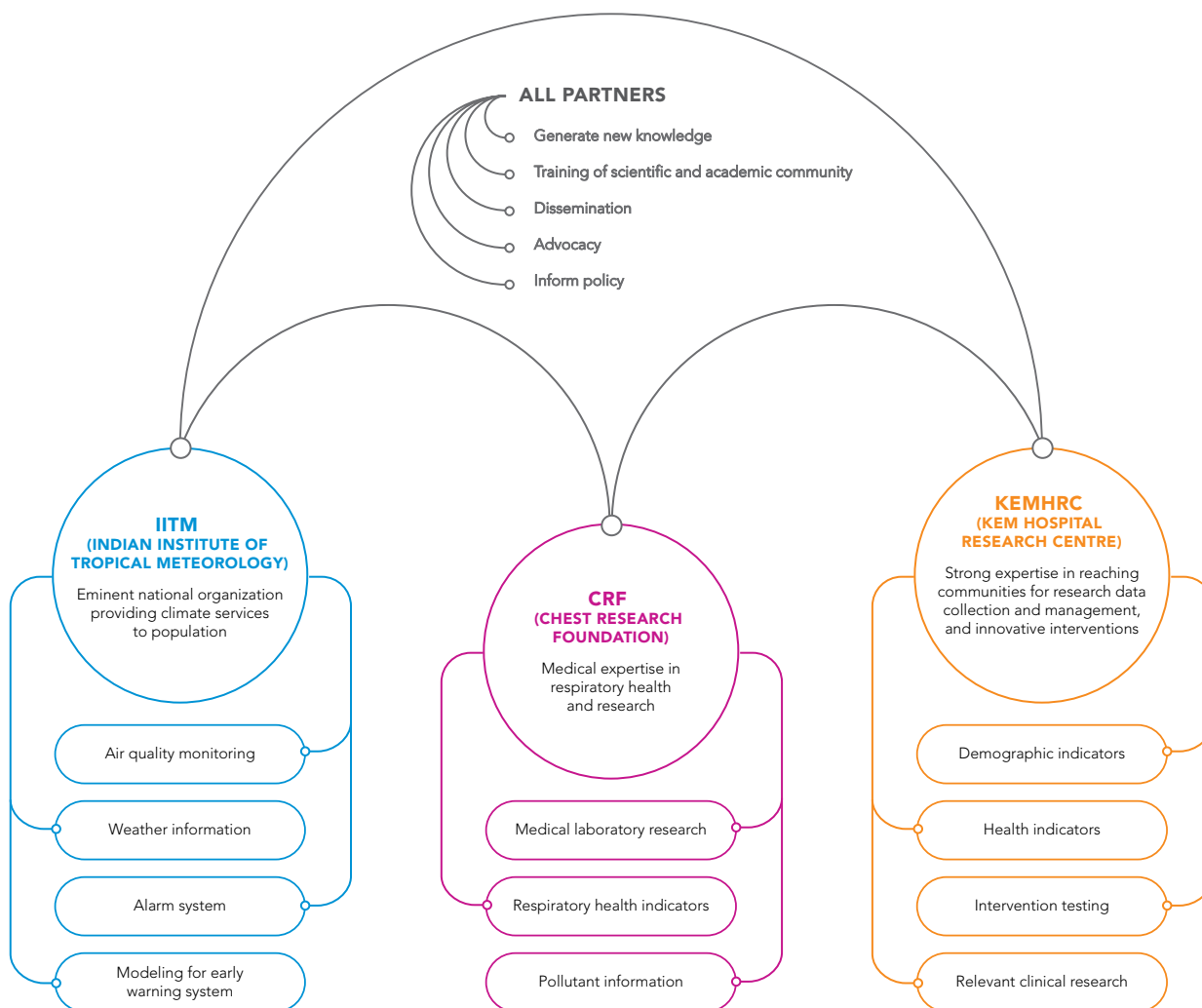
Climate change is poised to worsen air quality globally. In India, one of the fastest-growing global economies, air quality is deteriorating at a rapid pace.

Figure 2.2 In India, residents burn more than 40 recognised and other dangerous forms of firecrackers, releasing toxic fumes into the dense winter air. Photo credit: Ishan Khosla.



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 2.3 presents a schematic diagram of the framework.

Figure 2.3 Framework for uniting air quality, climate change and health research in India.



NEW APPROACHES

The System of Air Quality and Weather Forecasting and Research (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 mesoscale 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_{2.5} and PM₁₀^d, 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. The Chest Research Foundation (CRF) 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. The KEM Hospital Research Centre (KEMHRC) 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).

^d Particulate matter less than 2.5 and 10 micrometres in diameter, respectively.

CASE STUDY 2B

Enabling environment

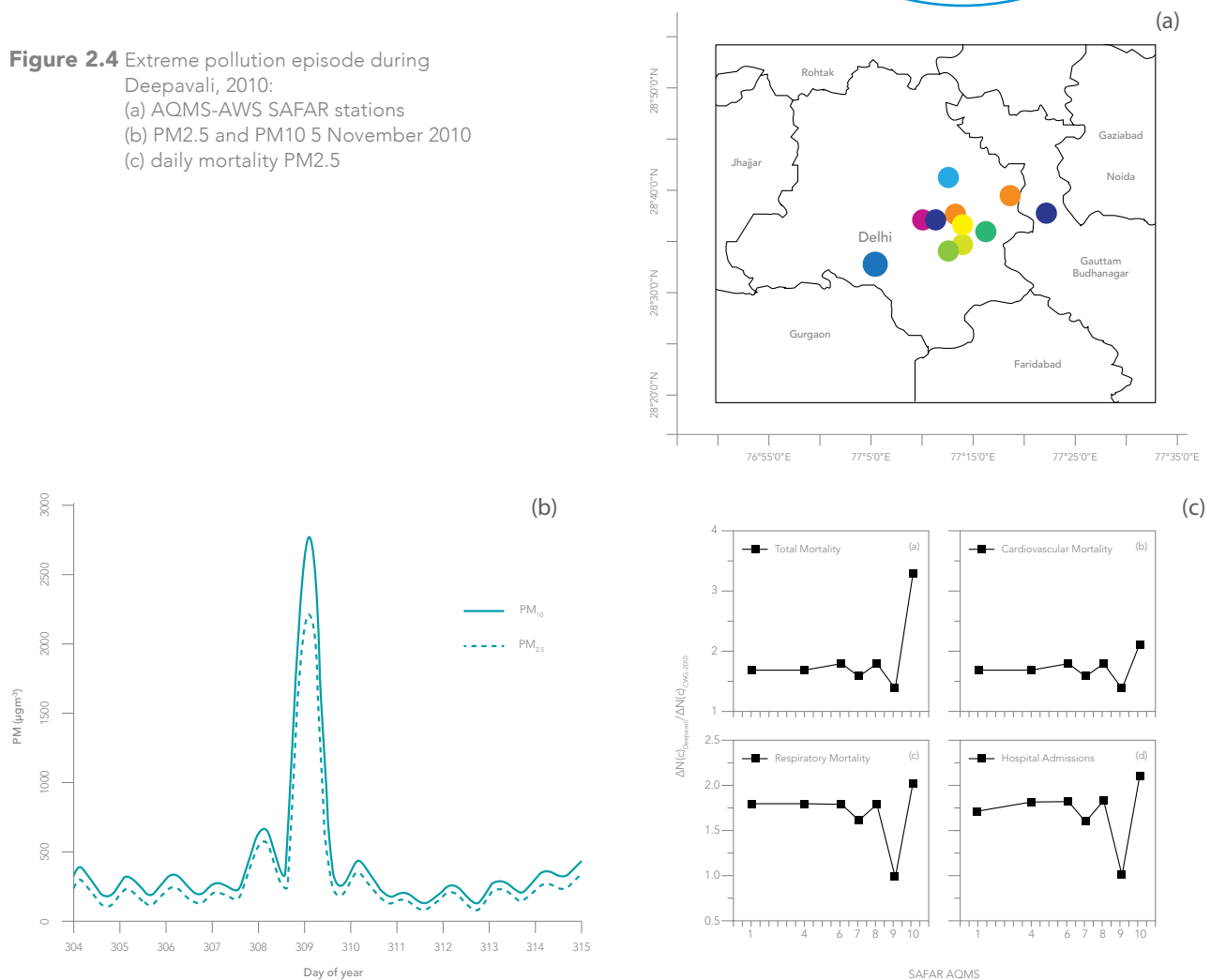
Research

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 (12). 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 (13). 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 3 500 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_{2.5} levels up to 500µg per cubic metre (24-hour average) with hourly peaks reaching 2 000µg 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 chronic obstructive pulmonary disease cases (Figure 2.4) (14).

Figure 2.4 Extreme pollution episode during Deepavali, 2010:
 (a) AQMS-AWS SAFAR stations
 (b) PM_{2.5} and PM₁₀ 5 November 2010
 (c) daily mortality PM_{2.5}



ACKNOWLEDGEMENTS



BENEFITS AND LESSONS

- The Indian framework for air quality and health has the following goals:
- Increase understanding of the relationship between air pollution, climate change and disease;
 - Establish an operational forecast model (or module/tool) to issue health advisories; and
 - Provide climate–health predictions to the public and provide guidelines on preventive measures.

Collaboration between the institutions was found to be robust and provided scientific evidence that 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.

The format of the data needs to be agreed by partners, since overlapping periods of data collection on various parameters by different partners could result in significant statistical uncertainty of the findings.

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

Authors: A. Woyessa and D. Jima (Ethiopian Public Health Institute); W. Deressa (School of Public Health, Addis Ababa University); M. Assefa and H. Solomon (National Malaria Control Programme of Ethiopia); H. Teka (President's Malaria Initiative) and D. Korecha (National Meteorology Agency of Ethiopia); T. Dinku and M. Thomson (International Research Institute for Climate and Society, Columbia University).

CONTEXT

Malaria is a major health problem in Ethiopia, with almost 60% of the total population (around 52 million) at risk of infection (15). Altitude and climate are major determinants of malaria epidemiology (16), and those variables are used for stratification to support the design of malaria interventions (Figure 2.6). Moreover, malaria transmission is seasonal and unstable, resulting in occurrence of epidemics overlapping with abnormal weather conditions (17–19). This implies that monitoring of climate information is helpful in predicting malaria ahead of time and to guide early preparedness.

Figure 2.5 Community collecting water from a suitable *Anopheles* breeding site.
Photo credit: UNICEF - For non-commercial reuse.



Enabling environment

Capacity-building

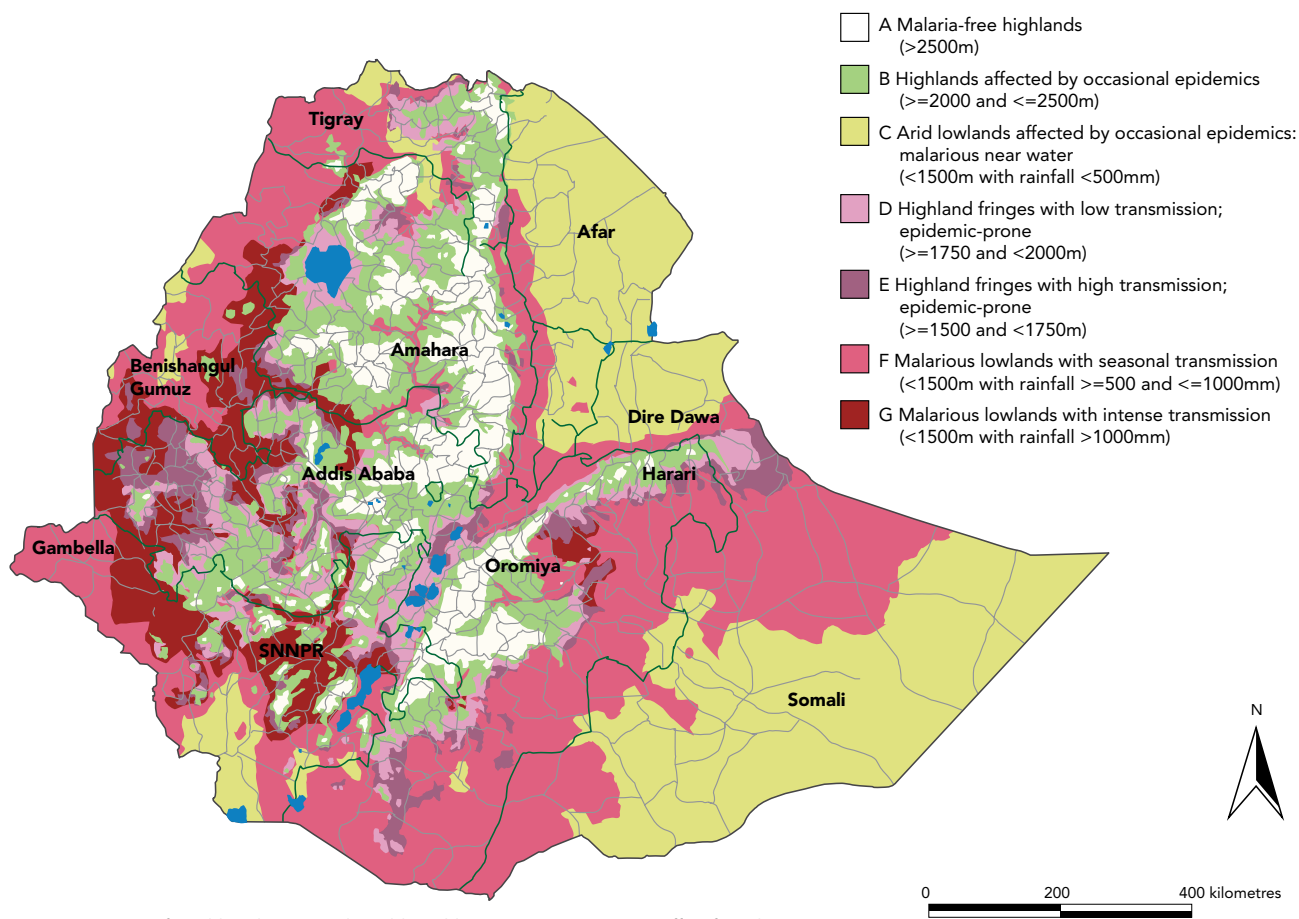
Research

Product and service development

Application

Evaluation

Figure 2.6 Altitude and rainfall-based stratification of malaria in Ethiopia, 2007.



© 2007 Ministry of Health, Ethiopia, and World Health Organization Country Office for Ethiopia

Note: Figure developed by Ministry of Health of Ethiopia and WHO Ethiopia Country Office as part of a proposal for the Global Fund to Fight AIDS, Tuberculosis and Malaria. 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 prone to epidemics, 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 2C



Enabling environment

Capacity-building

Research

Product and 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 Partnership that began in 1998 (20). During 2000, the first Five-Year Strategic Plan for Malaria Prevention and Control (2001–2005) was designed as part of the RBM initiative (21), 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 (18, 22, 23). 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 (24). 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.

ACKNOWLEDGEMENTS



Federal Democratic Republic of Ethiopia
Ministry of Health

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 now 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 (25). Similarly, the National Meteorology Agency has given attention to improving the quality of climate information and generating quality data (26). Moreover, the climate and health community established the 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 (29) and related technical support have resulted in improved 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.

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 Meteo Madagascar (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.

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.

One of the main outcomes of these joint training workshops was the identification of the health sector needs in climate data and information. WMO provided individual 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.

Figure 2.7 Climate monitoring station at the health sentinel site in Ambositra.



CASE STUDY 2D

These efforts have resulted in the development of a seasonal and intraseasonal climate outlook, which provides 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 World Meteorological Organization Public Weather Service Programme (WMO/PWS), 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. These workshops share the use and benefits of climate stations on the health sentinel sites in order to assess the gaps and needs and define future workplans in climate and health.

Figure 2.8 Participants at climate and health workshop, September 2015, Antananarivo.



CLIMATE AND HEALTH WORKING GROUP MEMBERS:

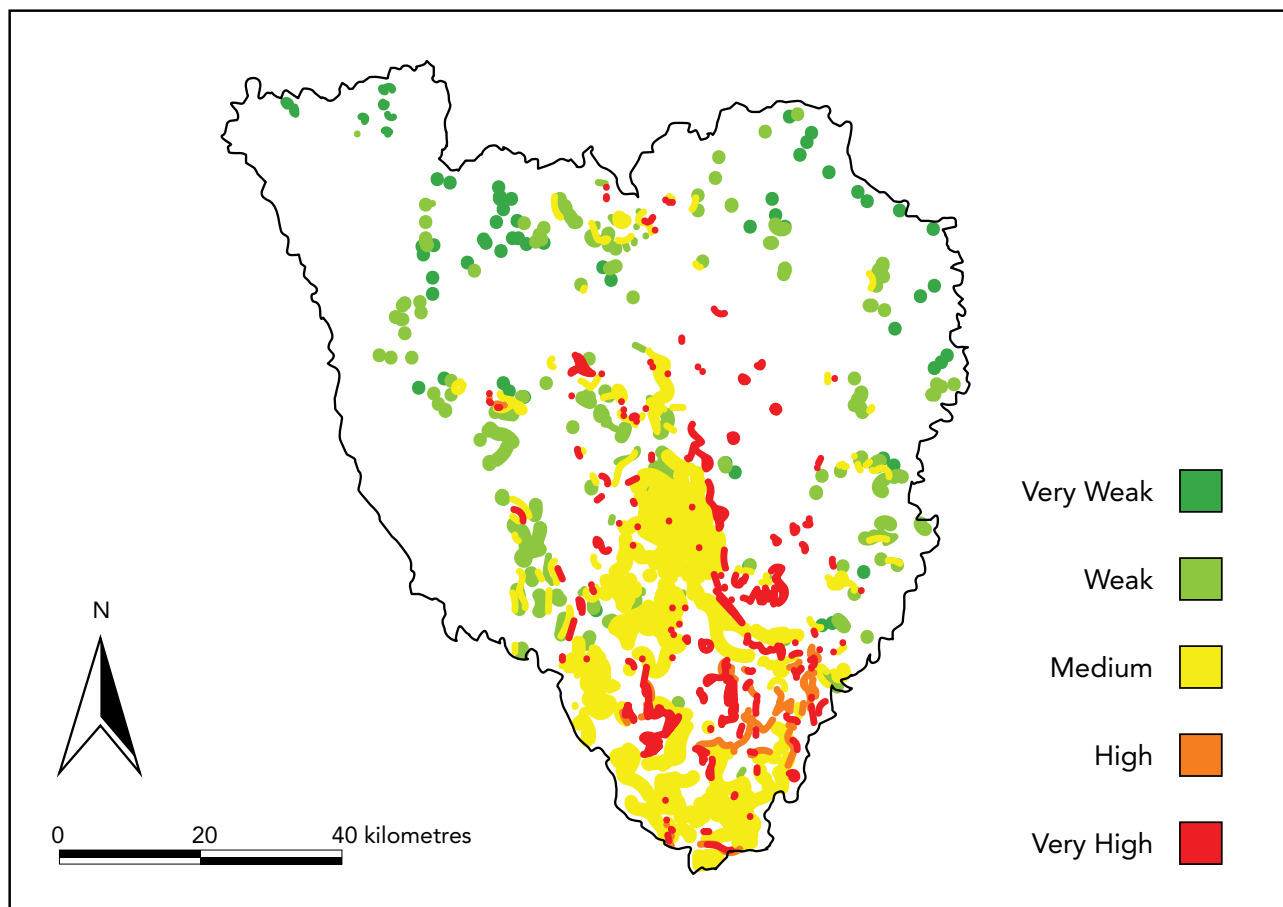
Climate Experts:

Dr Nirivololona Raholijao
Ms Sahondra Ranivoarisoa
Ms Vaohanginirina Ramiandrisoa
Mr Andrianjafinirina Solonomenjanahary

Health Experts:

Dr Yolande Raelina
Dr Alain Rakotoarisoa
Dr Marie Clémence Rakotoarivony
Dr Fanjasoa Rakotomanana
Dr Madeleine Razafindramavo
Dr Manuela Christopher Vololoniaina
Dr Huguette Ramiakajato
Dr Lalao Sabas Rabesahala
Dr Norohasina Rakotoarison

Figure 2.9 Risk gradient for Ankazobe district of Madagascar.



Research is also one of the CHWG activities. 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 used to assess epidemiological risk and support decision-making. GIS and weighted linear regression techniques identify priority areas for indoor residual spraying. Figure 2.9 shows mapping of the risk gradient for the 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 2D



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 2.10).

Figure 2.10 Alert detection using climate and environmental data, based on real-time data from sentinel sites. Florian Girond, Madagascar Pasteur Institute.



ACKNOWLEDGEMENTS

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



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.

Figure 2.11 Patients waiting for diagnosis outside a clinic, which is part of the fever and climate sentinel surveillance system.



REFERENCES

ECUADOR-PERU

1. Pan American Health Organization. Alerta temprana de enfermedades relacionadas con el clima (Spanish). Bulletin of the Pan American Health Organization. Available at: http://www.paho.org/spanish/dd/pin/ahora16_abr05.htm. (Accessed 1 Oct 2017).
2. Ministerio de Salud Pública de Colombia. Gestión para la vigilancia entomológica y control de la transmisión del dengue. Colombia, Ministerio de la Protección Social.
3. Sanchez L et al. Intersectoral coordination, community empowerment and dengue prevention: six years of controlled interventions in Playa municipality, Havana, Cuba. *Tropical Medicine and International Health* 2009 Vol 14. Pp 1356–64.
4. Pai H, Hong Y and Hsu E. Impact of a short-term community-based cleanliness campaign on the sources of dengue vectors: an entomological and human behavior study. *Journal of Environmental Health* 2006 Vol 68(6). Pp 35–9.
5. Ministerio de Salud Pública. Boletín epidemiológico de la situación del dengue en el Ecuador, No. 41, 12 noviembre 2012. (Spanish).
6. La Salud Pública en las Américas. Nuevos conceptos, análisis del desempeño y bases para la acción. *Publicación Científica y Técnica* 2002 (Spanish) (589). Washington, DC: OPS/OMS.
7. Ministerio de Salud Pública. Boletín epidemiológico No. 44. Lima: Red Nacional de Epidemiología, 2012 (Spanish).
8. Secretaria Nacional de Planificación y Desarrollo. Plan Binacional de Desarrollo de la Región Fronteriza Ecuador-Perú. 1998 (Spanish). Available at: <http://planbinacional.gob.ec/>. (Accessed 30 Oct 2017)
9. Curso Andino en Clima y Salud "Uso de Información de Clima para la Salud Pública (Spanish). Available at: http://ciphan.iri.columbia.edu/curso_andino/ (Accessed 1 Oct 2017).
10. Stewart Ibarra AM et al. Dengue vector dynamics (*Aedes aegypti*) influenced by climate and social factors in Ecuador: implications for targeted control. *PLoS ONE* 2013 Vol 8(11): e78263. doi:10.1371/journal.pone.0078263.

INDIA

11. SAFAR – India: System of Air Quality and Weather Forecasting and Research. Available at: <http://safar.tropmet.res.in>. (Accessed 1 Oct 2017).
12. Kodgule RR et al. Reference values for peak expiratory flow in Indian adult population using a European Union scale peak flow meter. *Journal of Postgraduate Medicine* 2014 Vol 60. Pp 123–9.
13. Ingole V et al. The short-term association of temperature and rainfall with mortality in Vadu Health and Demographic Surveillance System: a population level time series analysis. *Global Health Action* 2012.
14. Beig G, et al. Evaluating population exposure to environmental pollutants during Deepavali fireworks displays using air quality measurements of the SAFAR network. *Chemosphere* 2013 Vol 92. Pp 116–24.

Enabling environment

Capacity-building

Research

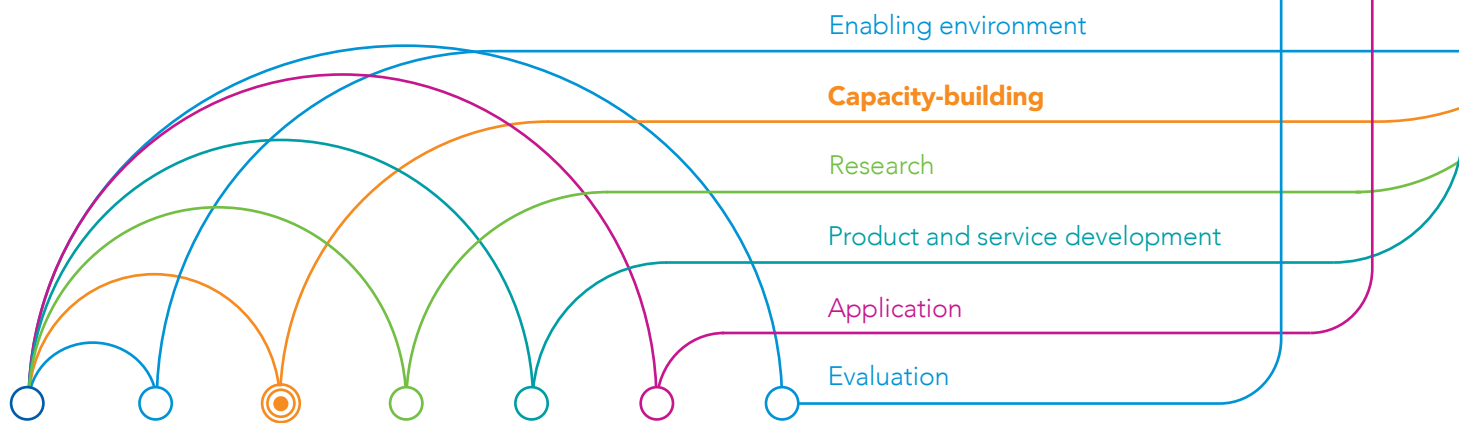
Product and service development

Application

Evaluation

ETHIOPIA

15. Federal Ministry of Health, Ethiopia. National Malaria Strategic Plan: 2014–2020. 2014. Addis Ababa.
16. Adhanom T et al. Malaria. In: Berhane Y, Hailemariam D and Kloos H, editors. Epidemiology and ecology of health and disease in Ethiopia 2006 Vol 556. P 76. Shama Books, Addis Ababa.
17. Fontaine R, Najjar A and Prince J. The 1958 malaria epidemic in Ethiopia. *American Journal of Tropical Medicine and Hygiene* 1961 Vol 10. Pp 795–803.
18. Abeku T et al. Spatial and temporal variations of malaria epidemic risk in Ethiopia: factors involved and implications. *Acta Tropica* 2003 Vol 87. Pp 331–40.
19. Negash K et al. Malaria epidemics in the highlands of Ethiopia. *East African Medical Journal*. 2005 Vol 82. Pp 186–92.
20. Nabarro D. Roll Back Malaria. *Parassitologia* 1999 Vol 41(1–3). Pp 501–4.
21. Roll Back Malaria and Ministry of Health. Five-Year (2001–2005) National Strategic Plan for Malaria Prevention and Control in Ethiopia. 2000. Addis Ababa, Ethiopia.
22. Abeku TA et al. Effects of meteorological factors on epidemic malaria in Ethiopia: a statistical modelling approach based on theoretical reasoning. *Parasitology* 2004 Vol 128(6). Pp 585–93.
23. Abeku TA et al. Malaria epidemic early warning and detection in African highlands. *Trends in Parasitology* 2004 Vol 20(9). Pp 400–5.
24. Grover-Kopec EK et al. Web-based climate information resources for malaria control in Africa. *Malaria Journal* 2006 Vol 5. P 38.
25. Lindtjørn B et al. Strengthening malaria and climate research in Ethiopia. *Malaria Journal* 2014 Vol 13(Suppl.1). P 56.
26. Dinku T and Sharoff J. ENACTS Ethiopia: partnerships for improving climate data availability, accessibility, and utility. Ethiopia National Meteorology Agency, International Research Institute for Climate and Society, University of Reading. Available at: http://www.climate-services.org/wp-content/uploads/2015/09/ENACTS_Case_Study.pdf. (Accessed 30 Oct 2017).



CHAPTER 3

3

BUILDING CAPACITY FOR CLIMATE SERVICES

GOAL: 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 and resources needed to enhance human resource knowledge and technical skills, institutional abilities, and infrastructural capacities to generate and apply climate knowledge to decision-making.

Fundamentally, the underlying state of the science and functional capacities of national hydrological and meteorological services 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 includes: observation of 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 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 to appropriately package and communicate tailored products. Health partners or authorities can parallel these services with health surveillance, data management procedures, epidemiological analysis, and the familiarity and confidence to use probabilistic risk information for intervention monitoring and planning.

Figure 3.1 Students of the Computer Sciences at Khowaja Institute of Information Technology (KIIT) in Hyderabad, learn computing skills. The KIIT provides training and skill development programmes to help graduates rise to the challenges. Photo credit: Visual News Associates / World Bank



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 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)

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; engage in multidisciplinary dialogue; 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; identify which populations are most vulnerable; interpret public service messages; and and take actions at the community and individual levels to protect health.

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

| | Meteorological professionals need capacity to: | Health professionals need capacity to: | Multi-disciplinary health relevant partners need capacity to: | Citizens need capacity to: |
|--------------------------------|---|---|---|--|
| ENGAGEMENT | 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. |
| RESEARCH | 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. |
| PRODUCTION AND DELIVERY | 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. |
| APPLICATION | 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. |
| EVALUATION | Use resources and methods that measure reliability and validity of products, as well as user-uptake and satisfaction. | Use resources and methods that measure and evaluate impacts. | Use resources and methods that measure and evaluate cross-sectoral impacts. | 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 resources that help generate, archive, ensure quality control, communicate, exchange and use climate data and decision-relevant information and products, including both supply and demand 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 health sector 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 the National Meteorological and Hydrological Services 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 (such as public, private and community, including international collaboration).

On the health side this 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 (such as nongovernmental organizations, research institutions and universities) 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 epidemiologists.

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.
- Strengthening the enabling environment to reinforce institutional capacities.
- Investing in, and upgrading information technology and communication equipment and systems.
- 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 engaging 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 the WMO 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 programme 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 the 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 an innovative service and mobile phone application for families of senior citizens to locate and contact them during high risk periods of 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 diarrhoeal 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 were put into place. 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.

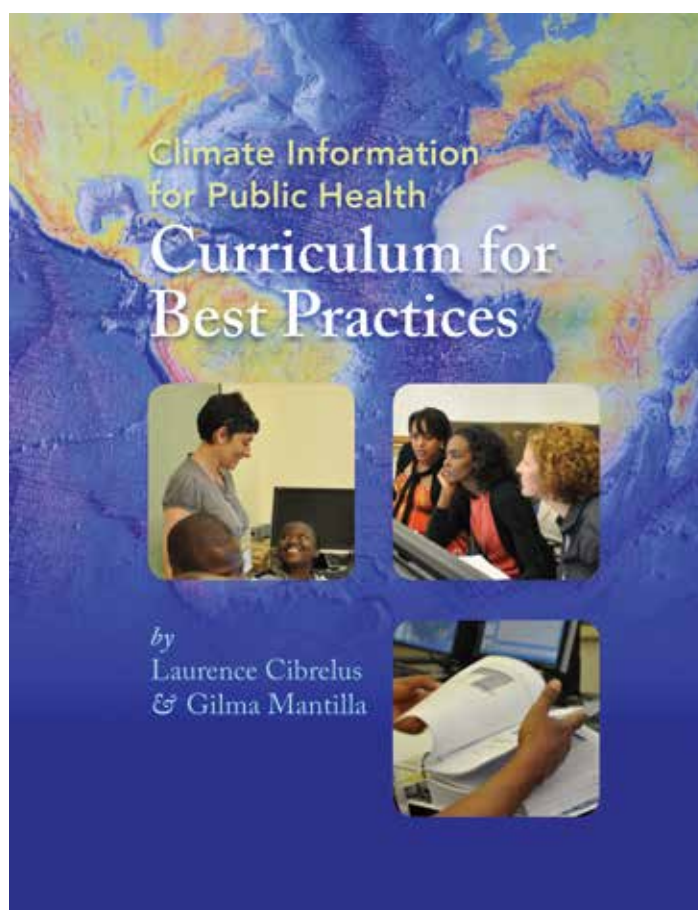
TRAINING A NEW GENERATION OF PROFESSIONALS TO USE CLIMATE INFORMATION IN PUBLIC HEALTH DECISION-MAKING

Authors: R. Lowe (Institut Català de Ciències del Clima, Spain); G. Mantilla (International Research Institute for Climate and Society, Columbia University, USA and Pontificia Universidad Javeriana, Bogotá, Colombia); P. Ceccato (International Research Institute for Climate and Society); M.S. Carvalho, C. Barcellos (Oswaldo Cruz Foundation, Brazil); A.M. Tompkins (International Centre for Theoretical Physics, Italy).

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.

Figure 3.2 *Climate information for public health: A curriculum for best practices*
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) publication, *Climate information for public health: A curriculum for best practices (2)*, several international and regional climate and public health schools and side events emerged 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 WMO, IRI, Southern Common Market's (MERCOSUR) 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). Hosting at locations such as ICTP permits pan-global participation and the efficiencies afforded by the dedicated training facilities and infrastructure. Additionally, organizing regional activities bring together a wide spectrum of participant expertise and occupations, allowing 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 United Nations agencies and 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 3A

Capacity-
building

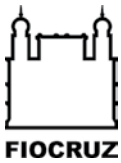
Figure 3.3 Description of the domains addressed in a Climate Information for Public Health training and their associated competency statements.

| 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. |

Figure 3.4 Students learning how to use software and tools to analyse climate and health data. Photo credit: Brian Kahn.



ACKNOWLEDGEMENTS



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).

Figure 3.5 Group photo of training course faculty and participants.
Photo credit: Brian Kahn.



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

Authors: T. 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 24-hour personal emergency support and caring service to elderly citizens in Hong Kong.^e

NEW APPROACHES

The climate data of Hong Kong Observatory (HKO) was used to study the effect of weather on the health of elderly people and their help-seeking behavior. The number of users activating SCHSA's personal emergency and caring service requiring hospitalization was analysed. 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. Dry weather (relative humidity at 70% or below) had a 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.

^e 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.

ACKNOWLEDGEMENTS



Recently, HKO and SCHSA also committed to: (a) develop a new version of HKO's Weather Information for Senior Citizens website (<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^f 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* website 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.

Figure 3.6 HKO's Weather Information for Senior Citizens website with ideas and suggestions from the elderly volunteers of SCHSA incorporated.



Figure 3.7 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.



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

CASE STUDY 3C

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

Authors: 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, the United Republic of 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 were 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 the United Republic of 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.

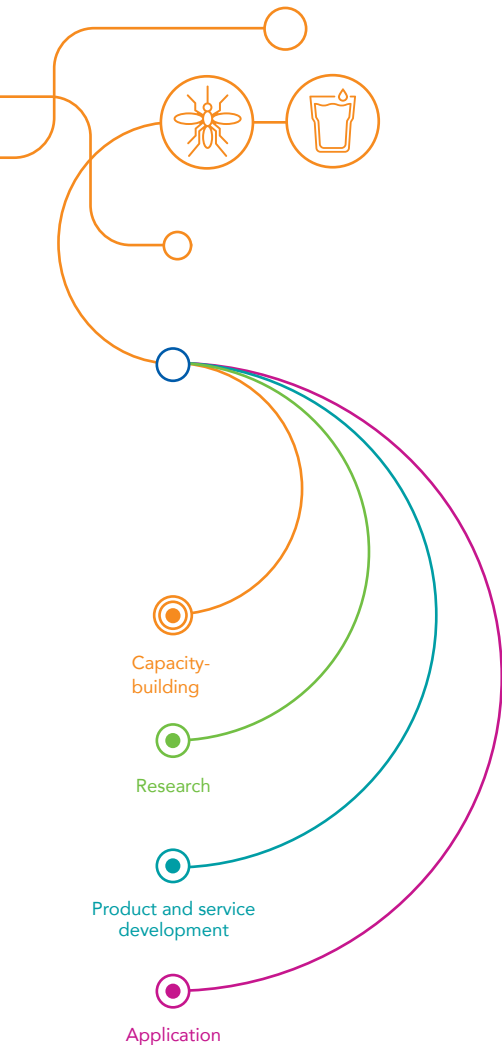
In East Africa, once-consistent rainfall patterns are shifting, and this could have significant implications for disease, creating more larval habitats for mosquitoes, washing pathogens into water sources and disrupting sanitation.

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 the United Republic of Tanzania, projects were undertaken in the 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 and 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 Figure 3.7 for further information.

Figure 3.8 Activities and structures of climate-based disease anticipation approaches.

| | SETTING | |
|----------------------------|---|---|
| | KENYA | UNITED REPUBLIC OF TANZANIA |
| ONGOING ACTIVITIES | Create awareness of hygiene, conduct hazard review. | Monitor forecast 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. | Hold volunteer meeting about rainfall forecasts prior to advent of rainy season, clean local environment, distribute treated bednets and water purifiers, conduct sanitation campaigns. |
| PEAK SEASON ACTIVITIES | Open water channels and ponds, review disaster response activities. | Check that treated bednets are hung, people with symptoms are going to the clinic, conduct 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. |



Figure 3.9 Silas Liech, a Kenya Red Cross Society volunteer, and eight-month-old Daren Onunga. Photo credit: IFRC.

ACKNOWLEDGEMENTS



LESSONS AND BENEFITS

The project significantly increased community-level risk reduction behaviour in project locations. This included hygiene activities as well as participation in the construction of latrines in Kenya, for example. Lessons learned are focused in three areas, starting with 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 project demonstrated 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.

3 REFERENCES

CIPHA TRAINING NETWORK

1. Lowe R, Mantilla G and Mendiola L. Final Report: Summer Institute on Climate Information for Public Health, International Research Institute for Climate and Society, The Earth Institute at Columbia University Palisades, 2011. New York, 10964, USA. Available at: http://iri.columbia.edu/docs/publications/SI2011Report_web.pdf. (Accessed 1 Oct 2017).
2. Cibrelus, L and Mantilla, G. Climate Information for Public Health: A Curriculum for Best Practices. 2010. Available at: <https://academiccommons.columbia.edu/catalog/ac:130711>. (Accessed 30 Oct 2017)
3. del Corral, J et al. Climate information for public health: the role of the IRI climate data library in an integrated knowledge system. *Geospatial Health* 2012 Vol 6(3). S15-S24.
4. Lowe R et al. Dengue outlook for the World Cup in Brazil: an early warning model framework driven by real-time seasonal climate forecasts. *Lancet Infectious Diseases* 2014. doi: 10.1016/S1473-3099(14)70781-9
5. Mantilla G et al. Capacity development through the sharing of climate information with diverse user communities. *Earth Perspectives* 2014 Vol 1:21.

HONG KONG

6. Yip KM; Leung YK and Yeung KH. Long-term Trend in Thermal Index and its Impact on Mortality in Hong Kong International Conference on Climate Change, Hong Kong, China, 29-31 May 2007.
7. Goggins WB et al. Associations between mortality and meteorological and pollutant variables during the cool season in two Asian cities with sub-tropical climates: Hong Kong and Taipei, *Environmental Health* 2013 Vol 12. P 59.
8. Chan YY et al. Hospital admission as a function of temperature, other weather phenomena and pollution levels in an urban setting in China, *Bulletin of the World Health Organization* 2013 Vol 91. Pp 576–584.
9. Mok, HY and Leung B. The impact of cold and hot weather on senior citizens in Hong Kong, *Hong Kong Meteorological Society Bulletin* 2011. Vol 19.
10. Wong HT et al. The influence of weather on health-related help-seeking behavior of senior citizens in Hong Kong, *Int. J. Biometeorol* 2014. doi: 10.1007/s00484-014-0831-7

EAST AFRICA

11. Coughlan de Perez E. et al. Managing risks in a changing climate: Red Cross operations in East Africa and Southeast Asia. *Climate and Development* 2015 Vol 7.
12. Kolstad EW and Johansson KA. Uncertainties Associated with Quantifying Climate Change Impacts on Human Health: A Case Study for Diarrhea. *Environ Health Perspect* 2011 Vol 119. Pp 299–305.

3

Enabling environment

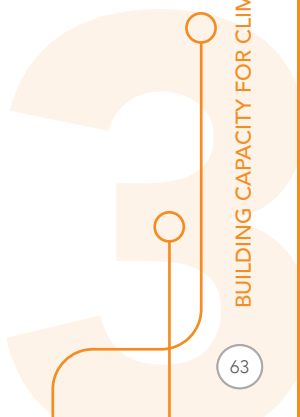
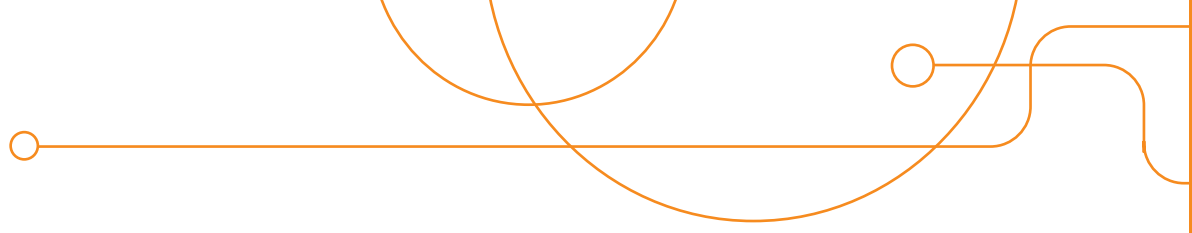
Capacity-building

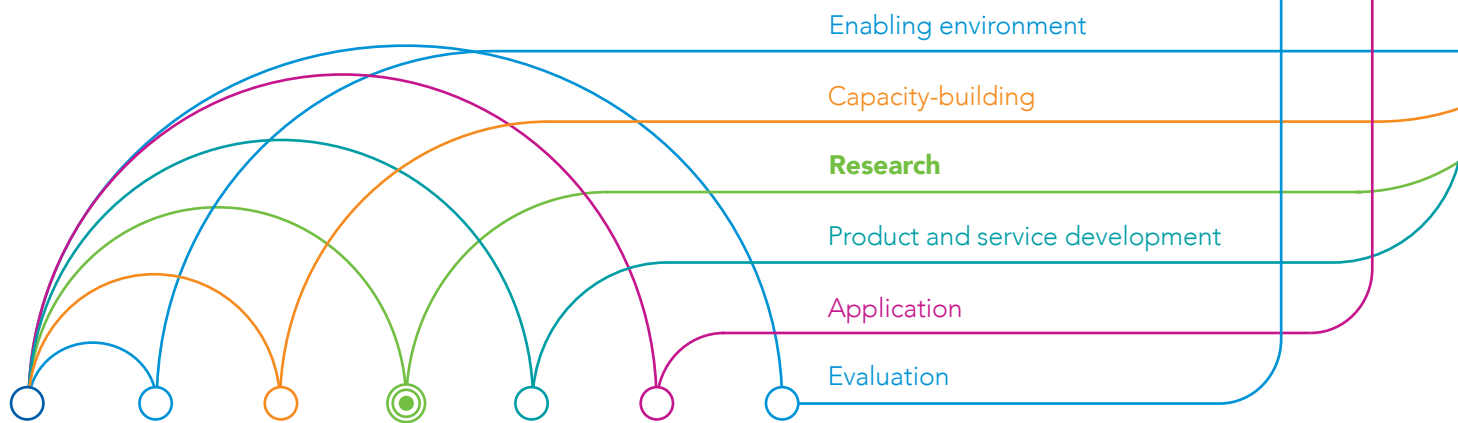
Research

Product and service development

Application

Evaluation





CHAPTER 4

4

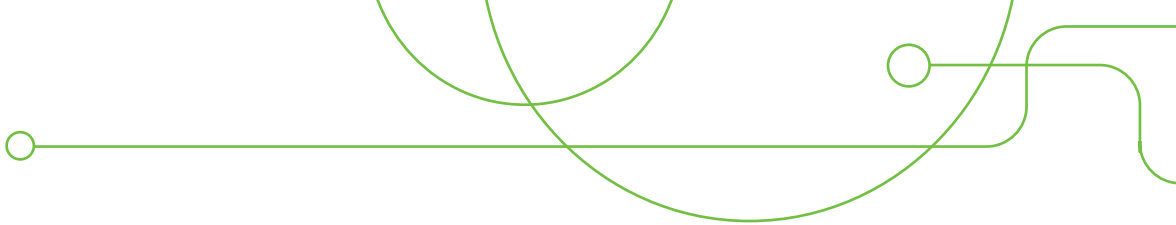
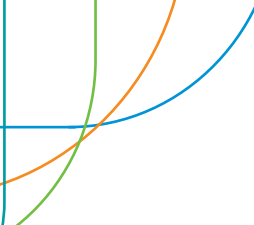
RESEARCH TO INFORM CLIMATE SERVICES

GOAL: Generate evidence on the needs for climate services for health, and produce 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 establishes 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.

Figure 4.1 Statisticians entering data into the database for further processing and analysis. Turkmenistan. Photo credit: World Bank.





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 stakeholder coordination and information-sharing mechanisms; as well as cost-efficiency assessments.

IMPORTANCE OF RESEARCH FOR EFFECTIVE CLIMATE SERVICES

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. These approaches allow for timely feedback on progress and user-specifications, and testing of prototypes before the service is rolled out on a larger scale. They help 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 (4A, 4B and 4C) 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 (4A) 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 climate knowledge needs, upon which future decision-tools and adaptation measures can be developed. The second case study from Brazil (4B) 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 (4C), 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 4D, 4E and 4F 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 through a range of available software and models. 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 covered a range of quantitative analyses to identify the relevant variables which drive dengue transmission in order 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 4G and 4H are examples of operations research undertaken to make sure climate services are appropriately tailored and communicated to reach the intended audiences, and make an impact. The case study 4G, CcTalk!, tested a methodology for designing and evaluating the best ways to communicate climate knowledge and motivate protective behavior in Austria, and the final case study (4H) provided evidence of the usefulness of climate information to inform ambulance emergency service planning in London.

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

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

CONTEXT

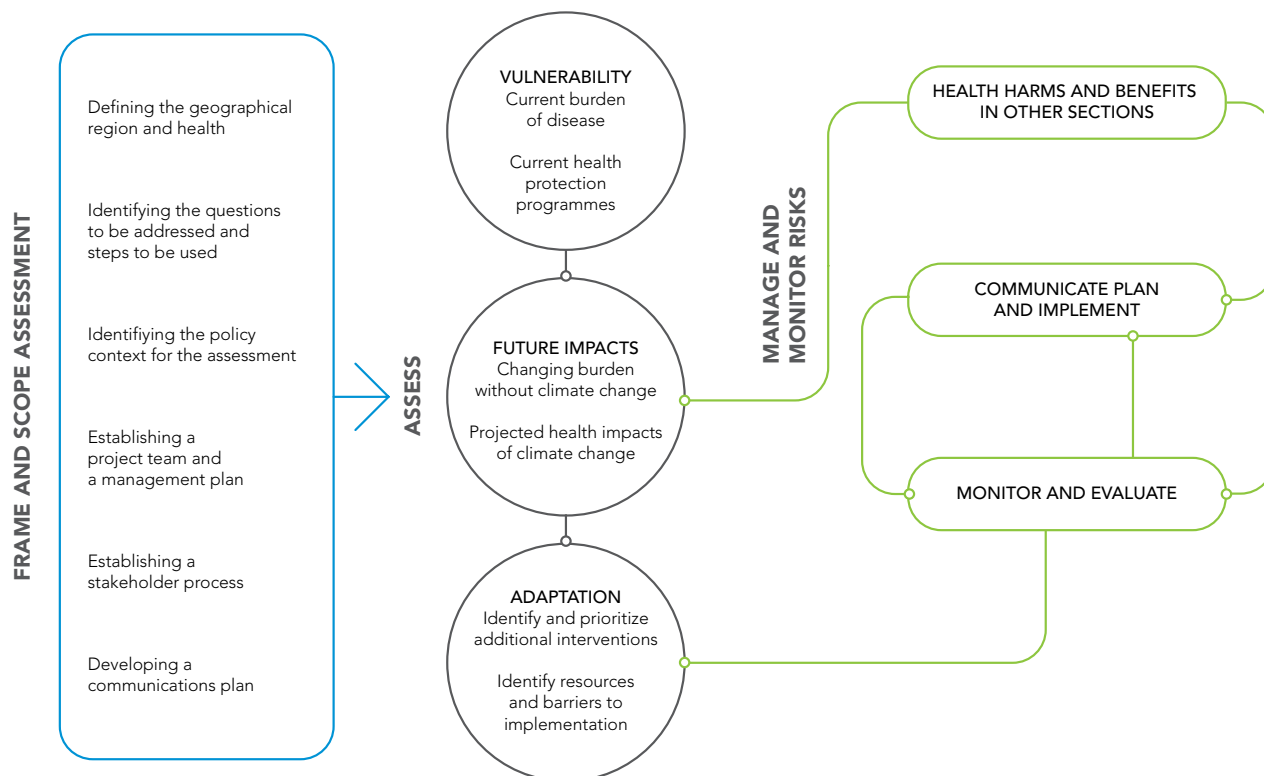
In Bhutan, climate change is expected to lead to an average temperature increase of ~ 0.8°C - 1.0°C by 2010-2039, and ~ 2.0°C - 2.4°C by 2040 - 2069, as well as a progressive and steady increase in precipitation, which has been on the rise since 1980. Higher precipitation increases are expected during 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 diarrhoeal 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 4.2 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 lowlands, which due to their specific microclimates will each experience a diverse range of climate change impacts. Furthermore, multiple sources of information were used to complement official statistics, such as national and district scale statistics, firsthand observations of risk factors, and interviews with health workers and communities.

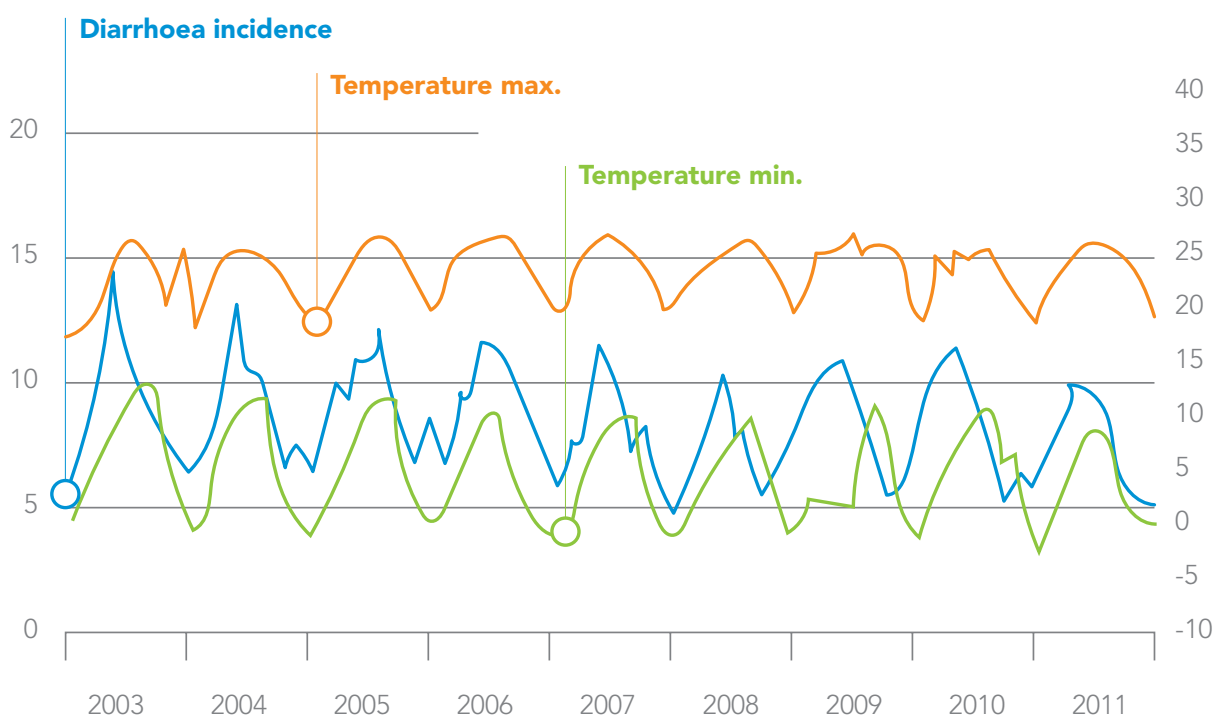
The assessment explored the climate influence on risk factors for diarrhoea, such as levels of access to improved water and sanitation infrastructure. Since 1997, the coverage of water and sanitation has been over 70%, reaching 96% in 2011, with 55% of households having access to improved latrines. However, 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 diarrhoeal 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 4A

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. When reality and reporting do not align, the vulnerability of both communities and the health system can increase, resulting in a range of deteriorating conditions that can lead to disease outbreaks.

Research

Figure 4.3 Trends of total diarrhoeal incidence and temperature (degree C) 2003 to 2011.



ACKNOWLEDGEMENTS

This work was conducted under the auspices of the Piloting Climate Change Adaptation to Protect Human Health, which is a joint WHO/UNDP project funded by the Global Environment Facility (GEF).



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 diarrhoeal 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 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 priorities. Finally, disease surveillance systems should be strengthened (including on-going data collection, validation, databases, analysis and reporting).

Figure 4.4 Unimproved community latrine.





Research

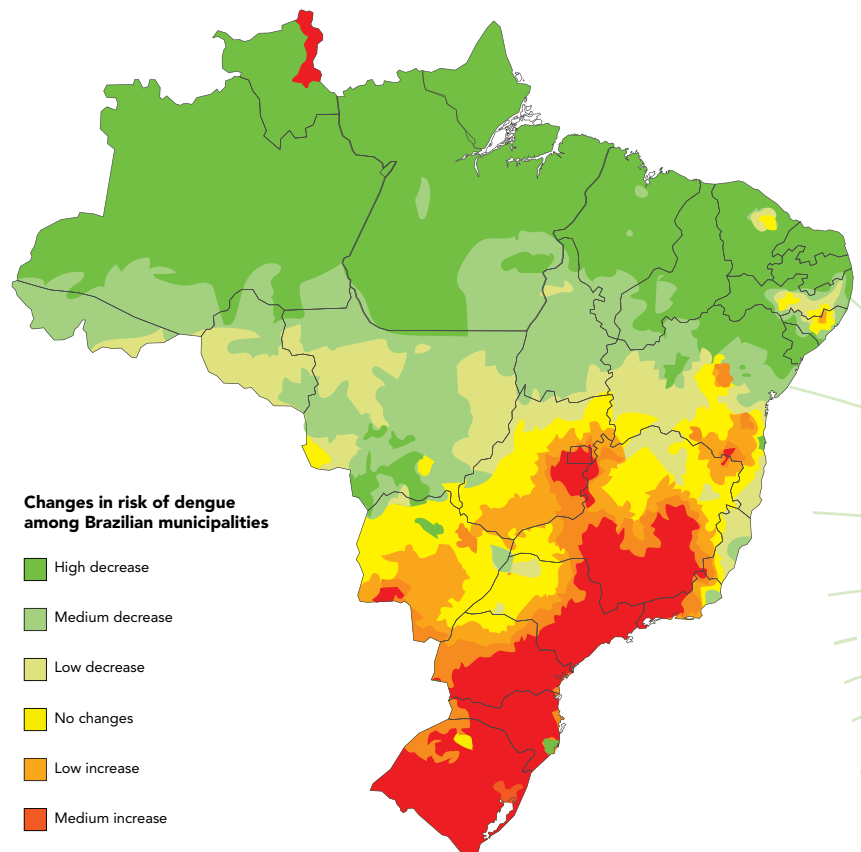
UNDERSTANDING THE SENSITIVITY OF DENGUE TO CLIMATE AND URBAN RISK FACTORS IN MINAS GERAIS STATE, BRAZIL

Authors: M. da Consolação Magalhães Cunha, J. Marques Pessanha, W. Teixeira Caiaffa (Observatory for Urban Health, Belo Horizonte, School of Medicine, Federal University of Minas Gerais, Brazil).

CONTEXT

This study was motivated by the complex dengue epidemic that has continued in the Brazilian 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 Centre for Health Development's Observatory for Urban Health at the Kobe Centre in Japan, which is implemented in partnership with local, regional and country-level health authorities.

Figure 4.5 Thematic map, rainfall versus epidemics.



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 the Southeast Region of Brazil, from 2001 to 2014. Based on a proposed theoretical model (4), reported cases of dengue were geocoded by county and macro region. Data on rainfall, altitude and temperature were obtained from the National Meteorological Institute, a government agency managing weather and climate information 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: 1) Weather (comprising rainfall in millimeters and temperature by degrees of Celcius, obtained from the national meteorological service INMET); 2) Geographic (altitude in meters; and 3) Demographic (urban population density by inhabitants within urban areas).

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 ($\beta=15.41$).

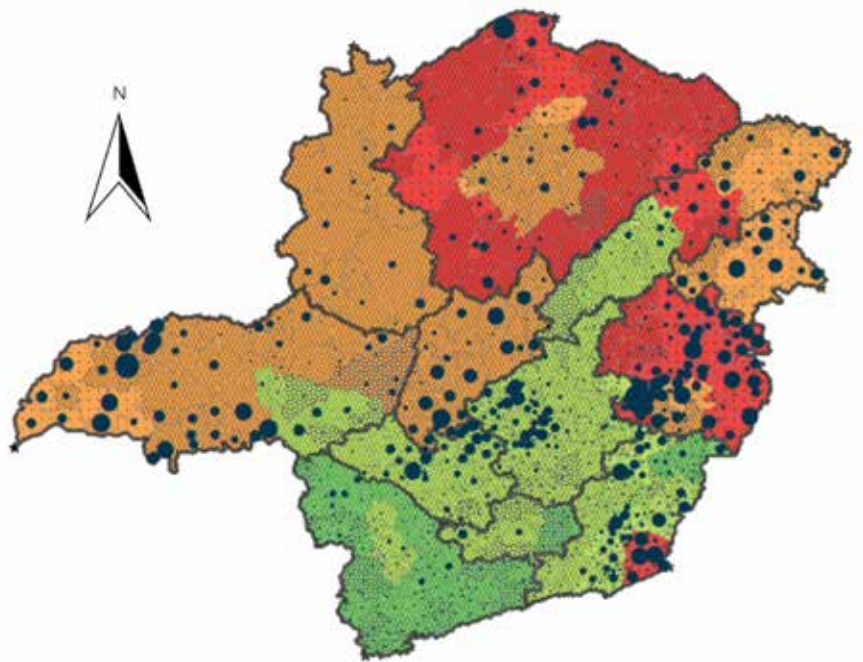
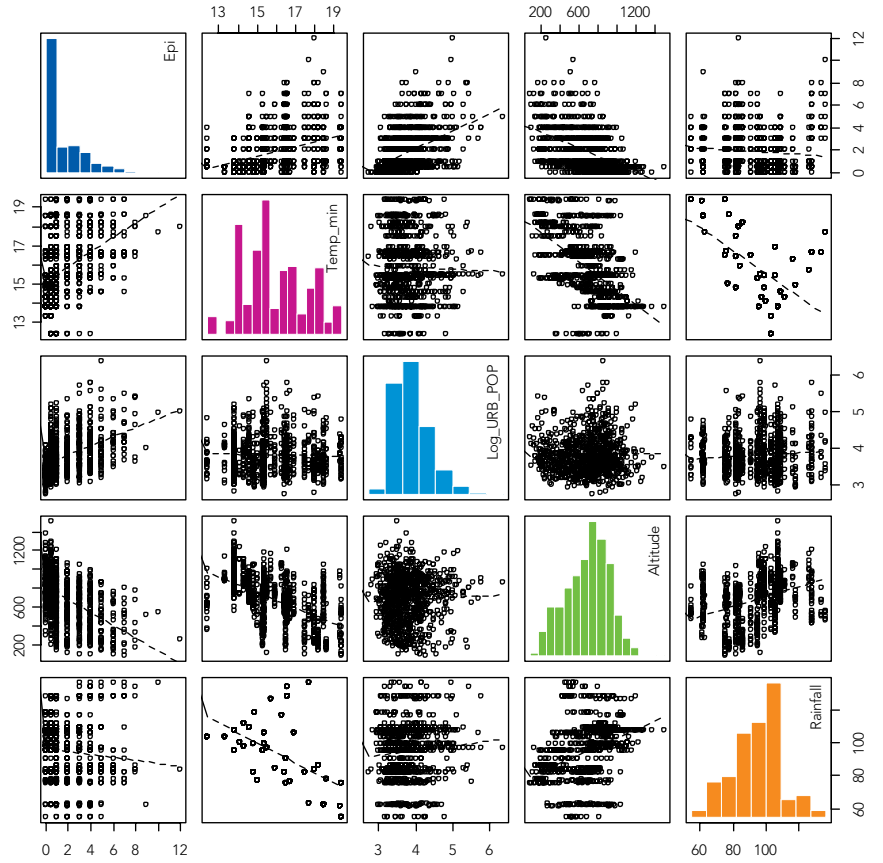
In the second phase of the study, geographic information systems (GISs) were used to compare climate averages to dengue incidence rates in macro-regions and municipalities (5). The results show an overlapping of high incidence rates of dengue with hot and densely populated regions (Figure 4.4; Figure 4.5).

CASE STUDY 4B



Research

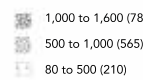
Figure 4.6 Scatter matrix showing associations between epidemiological data, minimum temperature, urban population, altitude and rainfall (top); Thematic map showing temperature, altitude and number of epidemic years (bottom).



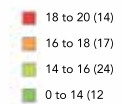
Epidemics years by county
Jul/2001 - Jun/2014



Altitude in meters
Counties of Minas Gerais State



Minimum temperature average
Minas Gerais State Regions



ACKNOWLEDGEMENTS



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 it has 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 (6), and the special climatic conditions and changes in urban areas (such as increases in the minimum annual temperature in cities over recent years and the well-documented urban ‘heat-island’ effect), systematic integrated monitoring is needed 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 (7) have high potential to contribute to the mitigation of risk of dengue transmission associated with climate change (4). The lack of intersectoral coordination, and of 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.



CASE STUDY 4C

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

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

CONTEXT

Communicable diseases, such as diarrhoea, hepatitis A, leptospirosis, dengue and respiratory infections, and non communicable diseases, such as hypertensive disorders, cerebrovascular and chronic respiratory diseases affect Argentina, Uruguay and Brazil and are sensitive to the influence of temperature, rainfall and extreme weather events. In order to increase evidence on the impact of climate on these diseases in Buenos Aires, Montevideo, Salto and Manaus, a project entitled 'Climate variability and its potential impacts on health' was elaborated and approved by the regional "Training Institute on Climate and Health"⁹ in Piriápolis (Uruguay).

NEW APPROACHES

Extreme meteorological events (such as heat and cold waves, floods and droughts) were analysed from 1981 to 2010 and, particularly, their relationship with impacts on public health between 2005 and 2010. The categorization of cold and heat waves was conducted by calculating the 10th and 90th percentiles 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 10th and 90th monthly percentiles were calculated and accumulated on a weekly basis.

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.

In Uruguay, the disease 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 hospital's 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 (8).

ACKNOWLEDGEMENTS



Ministério da Saúde

FIOCRUZ

Fundação Oswaldo Cruz



Ministerio de
Salud
Presidencia de la Nación



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

Hepatitis A was studied in Buenos Aires, Manaus and Montevideo. In Manaus, a similar linkage with climate as for diarrhoea was observed. In Montevideo, Hepatitis A was studied in relation to heat waves. An increase in the number of cases during severe heat waves was observed. In Buenos Aires, no association between Hepatitis A and heat waves was observed.

Bronchiolitis (in children less than two years old) and pneumonia 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 increased cold waves severity. In Buenos Aires, the peak of bronchiolitis cases in children less than two years old and in influenza-like disease in the general population, was observed to coincide with a cold wave in 2007.

Dengue and leptospirosis were studied in Manaus, while in Buenos Aires only leptospirosis was studied. The number of dengue cases in Manaus increased in all age groups, especially among children less than 14 years of age, as the rainfall increased. Leptospirosis was analysed in relation to rainfall. Like dengue, the number of cases of leptospirosis increased to the greatest number during the highest rainfall months in Manaus. In Buenos Aires, no association between leptospirosis and extreme rainfall events was observed.

BENEFITS AND LESSONS

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 easily accessible by 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.

The findings presented here contribute 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. However, it was difficult to homogenize health data due to 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.

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

Author: 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 database.

NEW APPROACHES

The first activity was to transform asynchronous climatological and epidemiological years to epidemiological 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 (such as 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 seasonal malaria prevention system.

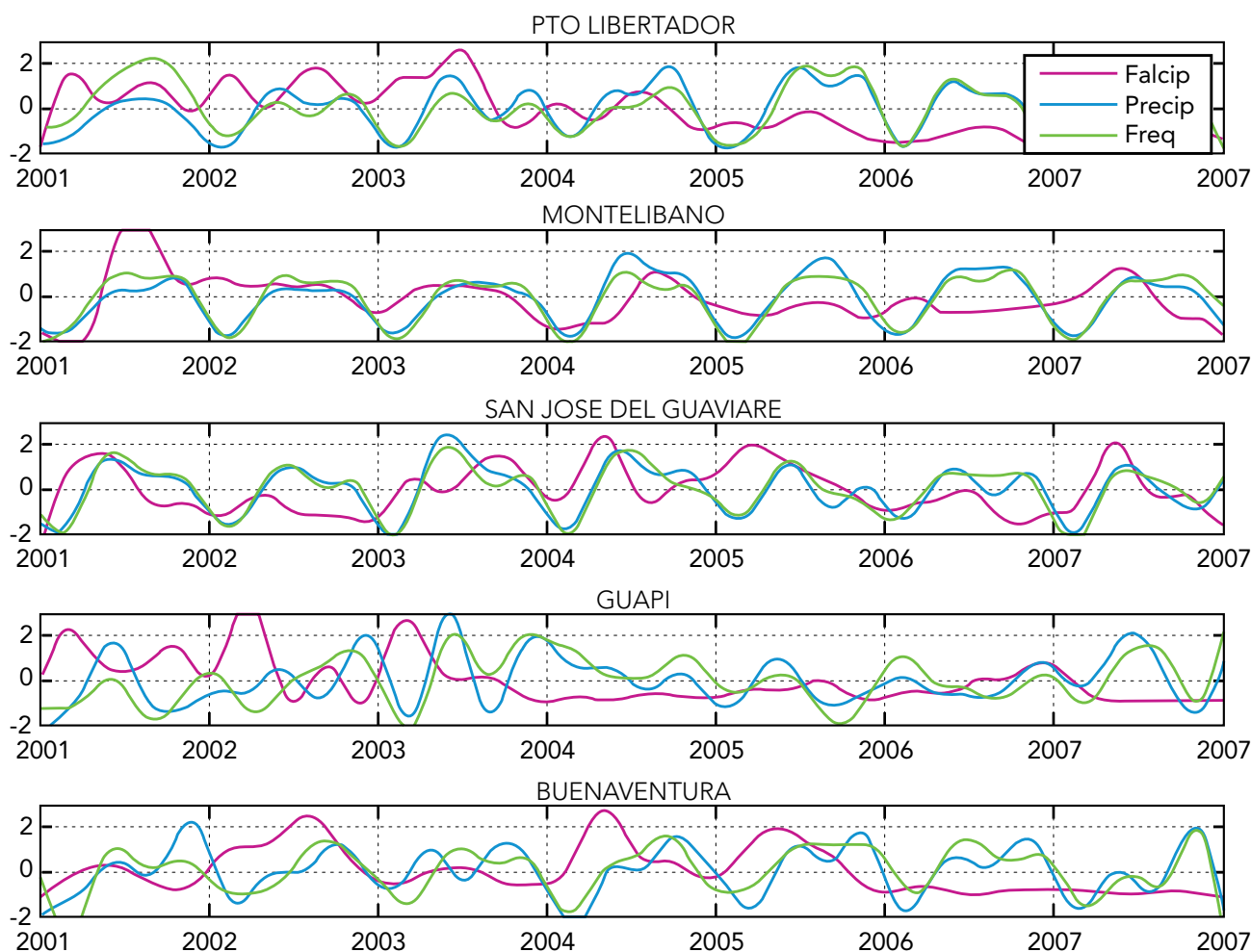
Various groups were convened to review work and evaluate progress in the first phase of the model development. Exploratory research was also undertaken to understand the status of technological and scientific tools in the field of malaria globally (such as databases, specialized software, and transmission models) 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 the 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 (9).

The variable effects can be seen in Figure 4.6, 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.

Research

Figure 4.7 Comparison between the series of *Plasmodium falciparum* and standardized rainfall (2001 to 2008).



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.



BENEFITS AND LESSONS

Available health time series data in Colombia are very short, preventing robust statistical analysis from being conducted. As a result, it is difficult to determine the disease seasonality, epidemic behaviour or correlation with climate data series.

Similarly, the study showed 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 a cumbersome process. 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 study was interrupted mid-way because of the overall project completion, and staff turnover prevented continuation. The initial climate and malaria/dengue model was not used due to lack of institutional capacity (10).

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

Authors: T. Morris, K. Thomas (Office of the Chief Medical Officer of Health, Alberta Health); B. Friesen (Alberta Health Services); P. Pytlak, R. Wright (Agrometeorology Applications and Modelling Section, Alberta Agriculture and Forestry); D. Henderson (Health and Air Quality Forecast Services, Meteorological Service of Canada, Environment and Climate Change Canada); D. Kulak (Prediction Services Directorate, Meteorological Service of Canada, Environment and Climate Change Canada); S. Dolan (Climate Change and Innovation Bureau, Health Canada).

CONTEXT

Climate change is anticipated to increase the frequency and intensity of extreme heat events in northern latitudes, including in Canada (11-13). Such heat events can lead to increases in hospital admissions, morbidity and premature mortality, particularly among the most vulnerable groups (14, 15). The western Canadian province of Alberta had relatively little experience with severe heat waves of long duration. In 2012, consistent with Alberta's climate change adaptation framework (16), 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. The first was to test the effectiveness of the proposed thresholds and associated responses (see Figure 4.7). 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 in the ministry of health. The second goal was to promote awareness among key decision-makers and the general public through a targeted communication initiative. The third goal was to 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 ministries of health so that they could be notified when thresholds were exceeded (see Figure 4.8).

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

Figure 4.8 Criteria to trigger different levels of heat warnings.

| DESCRIPTION | CRITERIA |
|--|---|
| <p>Heat warning</p> <p>MSC provides early notification to ministries of health 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 ministry of health monitors the local situation and adjusts the public health response.</p> | <p>When the weather forecast is for two or more consecutive days above the 95th percentile of maximum and minimum temperatures.</p> |
| <p>Extended heat warning</p> <p>MSC maintains the heat warning, notifies the ministries of health and provides guidance on severity, duration and geography of the event.</p> <p>The local ministry of health may contact municipalities, vulnerable population organizations to implement response measures.</p> <p>The local ministry of health 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 for three consecutive days and are forecast to continue.</p> |

CASE STUDY 4E

Figure 4.9 Screen view of the Alberta HWIS real-time weather monitoring website.



(Source: www.weatherdata.ca/health)

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.



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 heat information system. 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, such as the McMaster University Extreme Heat Events website 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 allowed for historical analyses to develop meteorological thresholds. AF had unique technical expertise. Having local ministries of health champion the project helped create credibility and encouraged other local organizations to participate. The genuine passion and goodwill exhibited from agencies working on the project contributed to the successful development and execution of the pilot within its two-year time frame.

Figure 4.10 Alberta Health Service's Online Heat Warning Information Portal.

The image is a screenshot of the Alberta Health Services website's "Heat Warning Information" page. At the top, there are logos for "Alberta Health Services" and "Healthy Alberta, Healthy Communities Together", along with the "811 Health Link" logo. A navigation menu includes "ABOUT AHS", "PHD HEALTHCARE", "INFORMATION FOR", "CAREERS", "NEWS", and "AHS IN MY ZONE". The main heading is "Heat Warning Information". The page is divided into several sections: "When a Heat Warning is in Effect:" with a list of precautions; "Monitor for symptoms of heat stroke, including:" with a list of symptoms; "While awaiting medical attention:" with a list of actions; "Heat Warnings:" with information on how to receive alerts; and "Learn more about Heat on:" with a link to "MyHealthAlberta".



Research

Product and 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. This caused estimated losses of about US\$ 880 million in 2010 (17), with approximately one-quarter comprising direct costs, and the remainder as 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. Its climate variability makes Brazil an interesting setting for this 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 (18): 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, $d^{(t-1)}$). 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 deposit of eggs (although large amounts of rain may have the reverse effect). The risk model for dengue is:

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

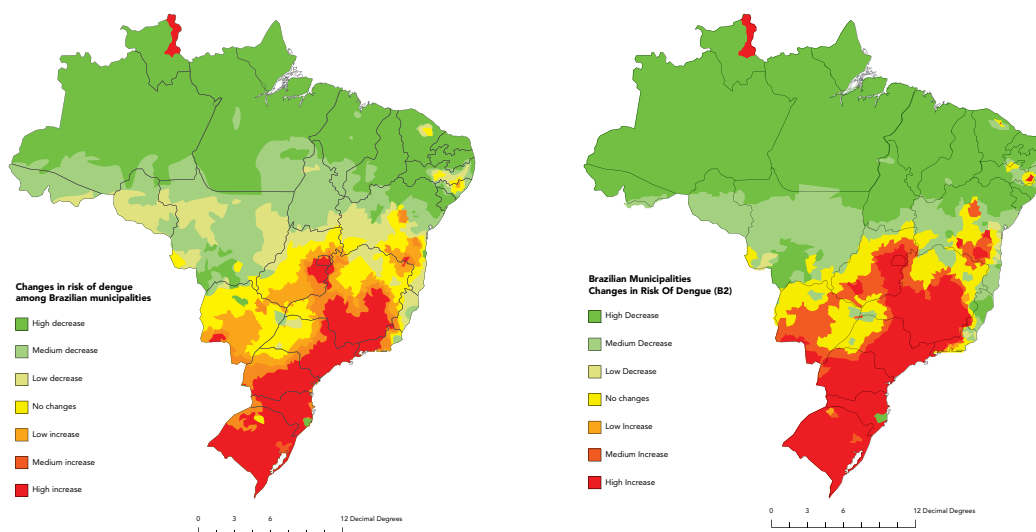
where i, j identifies Brazilian municipalities. The function can be estimated using count data models (19).

The period analysed was 2010 and data sources were: SINAN (dengue notifications); National Demographic Census (socio-demographic variables); National Treasury (local investments in health); Brazilian Ministry of Health (health information); US National Aeronautics and Space Administration (NASA) and IRI Data Library (Normalized Differenced Vegetation Index); National Meteorology Institute (monthly historical climate measures: 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 and 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 4.10):

Figure 4.11 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%.

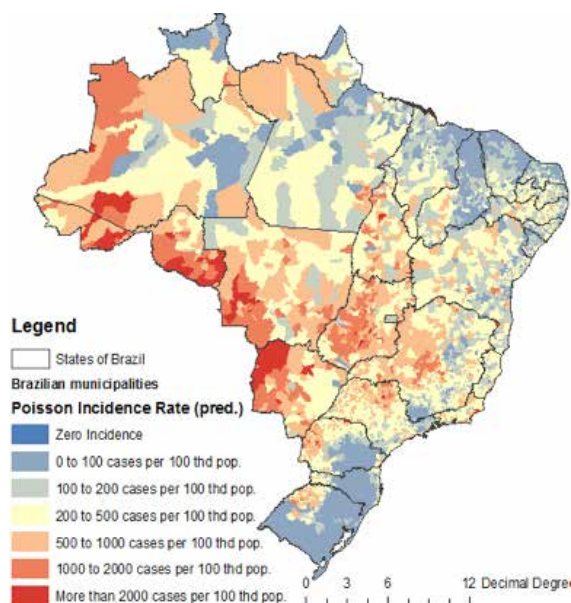


The 3-month predictions from the Instituto Nacional de Meteorologia (INMET) and Instituto Nacional de Pesquisas Espaciais (INPE) could also be used to forecast dengue cases for the next season. The use of precise climate data must be emphasized in order to obtain accurate forecasts. Figure 4.11 shows the model as used to identify the spatial vulnerability index for dengue, based on socioeconomic conditions and average climate in Brazil.

ACKNOWLEDGEMENTS



Figure 4.12 Dengue vulnerability ratio among Brazilian municipalities. predicted by the Poisson model, 2010.



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

Authors: T. 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

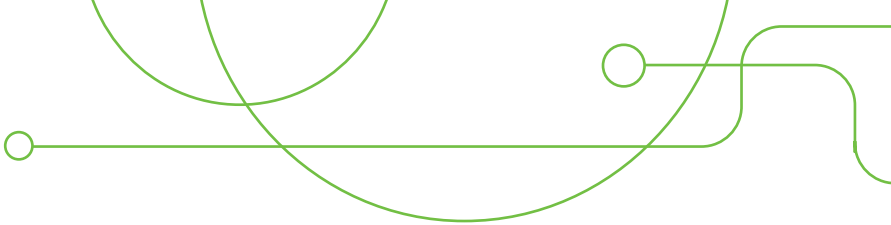
Due to climate change, excessive heat and heat waves are a growing threat to public health, in particularly to the elderly. The most widely documented policy for reducing heat vulnerabilities to date is the adoption of heat warnings and air quality alert systems to trigger emergency responses (20). Nevertheless, the evidence for their positive impact is limited and the most vulnerable groups are not being adequately reached (21). 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.

NEW APPROACHES

We designed and applied an efficient five-step-methodology (22):

1. Target group selection: Via a multi-criteria assessment (including criteria such as expected negative climate change impacts on the group and 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 (such as 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.
 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.

CASE STUDY 4G

Figure 4.13 Screenshots from animated CcTalk!-videos to convey basic information on the heat and health topic in an entertaining, emotionalizing and thereby motivating manner.



ACKNOWLEDGEMENTS

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

REKONSTRUKTION FÜR
UMWELT & GESELLSCHAFT **umweltbundesamt**[®]

PlanSinn.at
Planung & Kommunikation

DR. GROTHMANN
Training & Beratung

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 (23) and on psychological methods for designing behaviour change interventions (24). 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 (25) and interventions regarding health risks of heat waves (26).

The five-step methodology has proven effective to produce communication formats that can motivate protective behaviour during heat extremes. The methodology can be generalized to other activities where awareness, competence or behaviour can 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.

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 modeling, it will be possible to use real-time ambulance response data to feedback timely emergency warnings (27). 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 (28). In 2012/13 there were 2.95 million Category A (CatA - life threatening) incidents with a response rate (such as 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 8 000 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 5 000 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 3 000 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

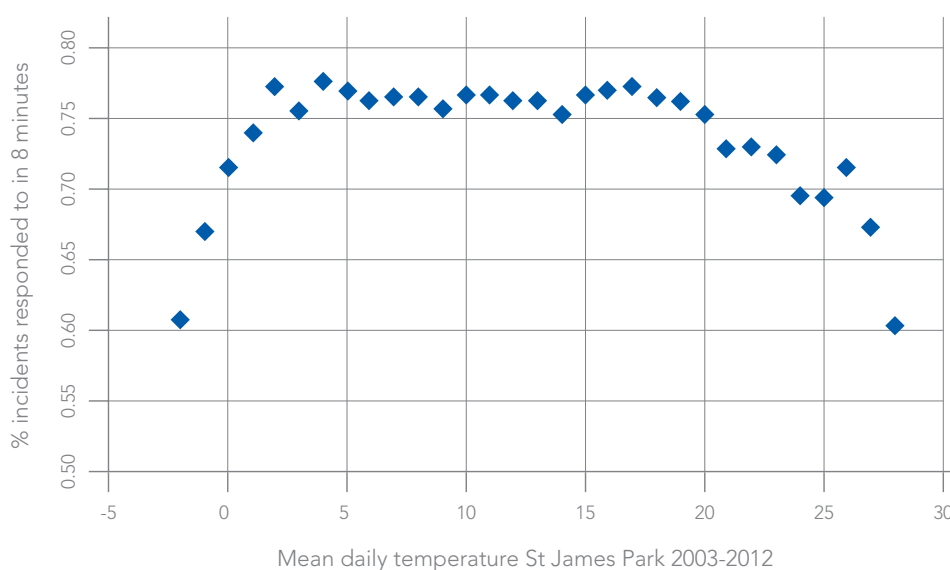
Daily data was obtained from the London Ambulance Service for 2003–2012, including the number of responded calls, the number of CatA calls, the % of responses within 8 minutes (target 75%) and illness codes. This data was then compared to mean daily temperature data from St James Park (SJP) in London, 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.

Research

Figure 4.13 shows a snapshot of the results obtained (which are discussed in detail elsewhere (29–31)). 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°C and below 2°C. More research is required to identify which illnesses increase beyond these thresholds. Figure 4.13 shows that, on average, performance drops off more quickly as the mean temperature drops below 2°C compared to the reduction in performance when the temperature rises above 20°C. 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. Both warm and cold weather 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 4.14 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
England

REFERENCES

Enabling environment

Capacity-building

Research

Product and service development

Application

Evaluation

BHUTAN

1. World Health Organization. Protecting health from climate change: vulnerability and adaptation assessment. World Health Organization 2013. Available at: <http://www.who.int/globalchange/publications/vulnerability-adaptation/en/> (Accessed 23 Oct 2017).

BRAZIL

2. Brasil Ministério da Saúde. Programa Nacional de Controle da Dengue (PNCD). In Ministério da Saúde, Fundação Nacional de Saúde, Fun asa, Brasília – DF 2002 (Portuguese), P 1-32.
3. Brasil Ministério da Saúde. Mudanças climáticas e ambientais e seus efeitos na saúde: cenários e incertezas para o Brasil /BRASIL. Ministério da Saúde; Organização Pan-Americana da Saúde. – Brasília: Organização Pan-Americana da Saúde (Portuguese), 2008.
4. World Health Organisation/PAHO. Dengue in an urban setting: vulnerability assessments and forecasts of the impact of climate change on health in the City of Belo Horizonte, Minas Gerais, Brazil. Technical Report. 2014.
5. Instituto Brasileiro de Geografia E Estatística. Censo Demográfico de 2010.
6. Vianello RL, Pessanha JEM and Sedyama GC. Ciclo Anual de Ocorrência dos Vetores da Dengue em Belo Horizonte e suas Relações com as Variáveis Meteorológicas. XIV Congresso Brasileiro de Meteorologia, Florianópolis, 2006 (Portuguese).
7. Assis WL. O sistema clima urbano do município de Belo Horizonte na perspectiva temporo-espacial. Instituto de Geociências. Universidade Federal de Minas Gerais 2010 (Portuguese).

FOUR MAJOR SOUTH AMERICAN CITIES

8. Orti A. La apertura y el enfoque cualitativo o estructural: la entrevista abierta semidirectiva y la discusión de grupo. En: El análisis de la realidad social, métodos y técnicas de investigación. Compiladores: Fernando Pourtois JP, y Desmet H. Epistemología e instrumentación en ciencias humanas 1992. Barcelona: Herder (Spanish).

COLOMBIA

9. M.B. Hoshenand A.P. Morse. A model structure for estimating malaria risk.
10. Practical Guide for in vivo Antimalarial Drug-Efficacy Studies.in the Americas. PAHO Disease Prevention and Control (PAHO/AD/DPC).

ALBERTA, CANADA

11. Lemmen D et al. From impacts to adaptation: Canada in a changing climate. Government of Canada, Ottawa, 2007.
12. Tingley MP and Huybers P. Recent temperatures extremes at high northern latitudes unprecedented in the past 600 years. *Nature* 2013 Vol 496. Pp 201-205.
13. I.P.o.C.C. (IPCC). Climate Change 2013: The physical science basis. Working group 1 contribution to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, 2013, Cambridge, United Kingdom and New York, NY, USA.
14. Seguin J. Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity. Government of Canada, Ottawa, 2008.
15. Lavigne E et al. Extreme ambient temperatures and cardiorespiratory emergency room visits: assessing risk by comorbid health conditions in a time series study. *Environmental Health* 2014 Vol13. P 5.
16. Alberta Environment and Sustainable Resource Development. Climate Change Adaptation Framework Manual. Government of Alberta, Edmonton, 2010 Vol 4.

BRAZIL

17. Shepard DS et al. Economic Impact of Dengue Illness in the Americas. *American Journal of Tropical Medicine and Hygiene* 2011 Vol 84. Pp 200-207.
18. Barcellos C et al. Mudanças climáticas e ambientais e as doenças infecciosas: cenários e incertezas para o Brasil. 2009.
19. Lowe R. et al. Spatio-temporal modelling of climate-sensitive disease risk: Towards an early warning system for dengue in Brazil. *Computers and Geosciences* 2010 Vol 37(3). Pp 371-381.

AUSTRIA

20. Harlan SL and Ruddell DM. Climate change and health in cities: impacts of heat and air pollution and potential co-benefits from mitigation and adaptation. *Current Opinion in Environmental Sustainability* 2011 Vol 3(3). Pp 126-134.
21. Bassil KL and Cole DC. Effectiveness of Public Health Interventions in Reducing Morbidity and Mortality during Heat Episodes: a Structured Review. *International Journal of Environmental Research and Public Health* 2010 Vol 7. Pp 991-1001. doi:10.3390/ijerph7030991
22. Grothmann T et al. A Five-Steps Methodology to Design Communication Formats That Can Contribute to Behavior Change: The Example of Communication for Health-Protective Behavior Among Elderly During Heat Waves. *SAGE open* 2017. Pp 1-15. doi: 10.1177/2158244017692014.

Enabling
environment

Capacity-
building

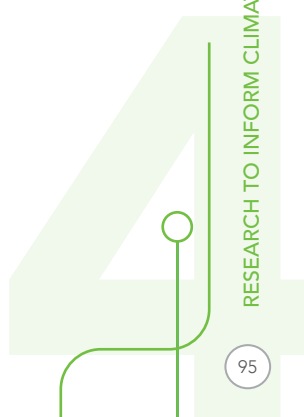
Research

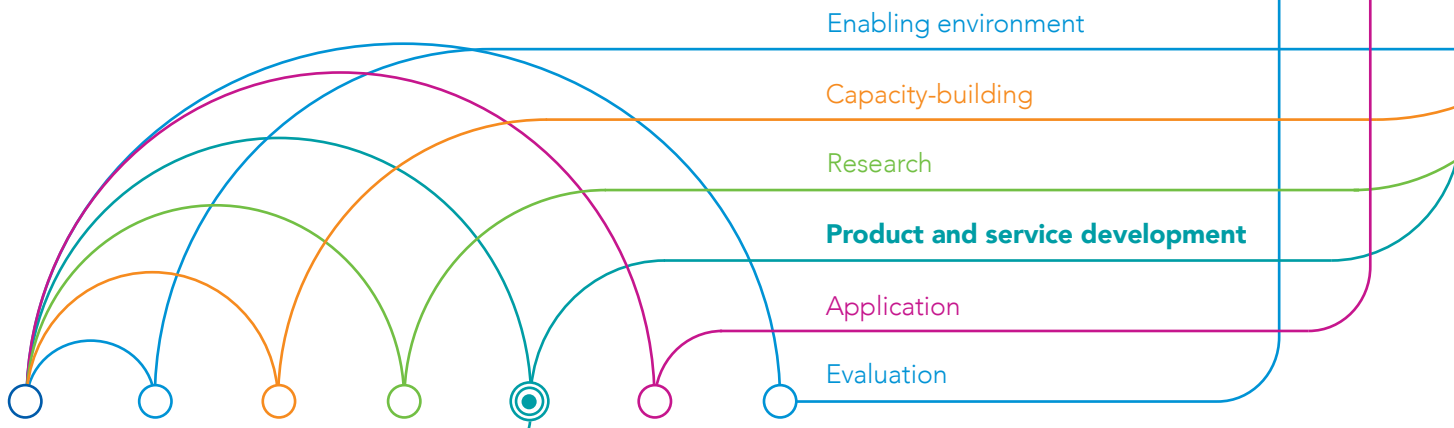
Product and service
development

Application

Evaluation

23. Prentice-Dunn S, McMath BF and Cramer RJ. Protection motivation theory and stages of change in sun protective behaviour. *Journal of Health Psychology* 2009 Vol 14. Pp 297-305.
 24. Abrahamse, W and Matthies E. Informational strategies to promote pro-environmental behaviours: Changing knowledge, awareness, and attitudes. In Steg L, van den Berg AE, and de Groot JIM (Eds.), *Environmental Psychology: An Introduction* (pp. 223-232). 2012. West Sussex, England: Wiley-Blackwell.
 25. Wirth V, Prutsch A and Grothmann T. Communicating Climate Change Adaptation – State of the Art and Lessons Learned from Ten OECD Countries. *GAIA* 2014 Vol 23(1). Pp 30-39.
 26. WHO – World Health Organization. *Protecting health from climate change: Global research priorities*. 2009. Geneva, Switzerland: World Health Organization.
- LONDON
27. Elliot AJ et al. Monitoring the effect of air pollution episodes on health care consultations and ambulance call-outs in England during March/ April 2014: A retrospective observational analysis, *23/6 Environmental Pollution* 2016 Vol 214. Pp. 903-911.
 28. HSCIC. *Health and Social Care Information Centre: Ambulance Services, England 2012-13*. 2013.
 29. Thornes JE (2013) Predicting Demand through Climate Data, *Ambulance Today*, 2013 Vol 10(4). Pp 39-41.
 30. Thornes JE, Fisher PA, Rayment-Bishop T and Smith C. Ambulance Call-outs and Response Times in Birmingham and the Impact of Extreme Weather and Climate Change, *Emergency Medicine Journal* 2014 Vol 31. Pp 220-228.
 31. Thornes JE. *The Impact of Extreme Weather and Climate Change on Ambulance Incidents and Response Times in London, Pilot Report for the London Ambulance Service*, Public Health England 2014.





CHAPTER 5

5

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

GOAL: 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 of 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 5.1) and present characteristic advantages and challenges (figure 5.2):

Figure 5.1
Common health tailored climate products

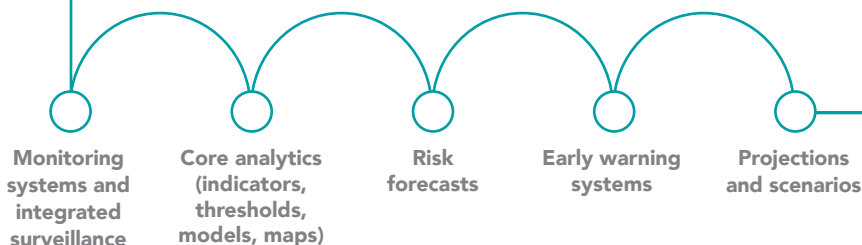


Figure 5.2 Advantages and challenges of the common health-tailored climate products.

| Categories of tailored products | Example advantages | Example challenges |
|--|--|---|
| MONITORING SYSTEMS AND INTEGRATED SURVEILLANCE | <p>Provide comprehensive and real time detection of health risks.</p> <p>Serve to trigger response plans.</p> <p>Facilitate data sharing and access for relevant stakeholders.</p> <p>Provide the basis for development of all other product categories.</p> | <p>Poor data quality, availability and interoperability across systems.</p> <p>Establishment of data sharing agreements between stakeholders.</p> <p>Effective links between monitoring activities and response plans.</p> |
| CORE ANALYTICS | <p>Enable dynamic characterization of health risks across space and time.</p> <p>Facilitate identification of vulnerable populations.</p> | <p>Lack of analytical capacity to calculate thresholds and develop risk models.</p> <p>Lack of fundamental research to inform the development of key analytics.</p> <p>Absence of standard indicator definitions.</p> <p>Limited availability of geo-coded information.</p> |
| RISK FORECASTS | <p>Anticipate the likelihood of when and where health impacts may occur.</p> <p>Provide extended lead time for preparedness.</p> | <p>Varied level of skill in weather and climate predictions across regions and seasons.</p> <p>Lack of sufficiently reliable and long data sets.</p> <p>Poor mechanistic understanding of health risk dynamics.</p> |
| EARLY WARNING SYSTEMS (EWS) | <p>Create awareness of prevention and preparedness needs and opportunities.</p> <p>Provide authoritative and continuous source of information to guide risk management.</p> | <p>Dependencies on quality of all the above product categories.</p> <p>Limited availability of robust thresholds to trigger warnings.</p> <p>Reliance on weather and climate forecasts with limited predictive ability.</p> <p>High levels of institutional commitment and capacity to sustain the EWS and respond to warnings.</p> |
| PROJECTIONS AND SCENARIOS | <p>Enable foresight of future risks and alternative futures to inform mid- and long-term decision making.</p> | <p>High levels of uncertainty in climate projections.</p> |

IMPORTANCE OF PRODUCT DEVELOPMENT AND DELIVERY FOR EFFECTIVE CLIMATE SERVICES

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 developing applied services.

Both an enabling environment and sufficient capacity play a crucial role in ensuring the access, applicability and suitability of the climate products and service developed. Research findings are key to informing 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.

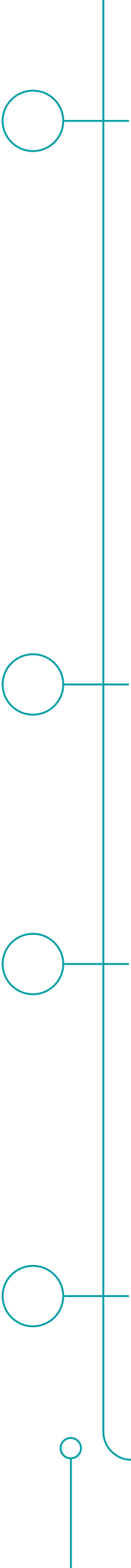
COMMON HEALTH-TAILORED PRODUCTS AND SERVICES

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:

Monitoring systems and integrated surveillance are foundational elements for most climate products and services, necessary to collect, compare, and manage data. Technical data and software requirements vary according to the respective goals of each initiative. Data quality, availability and compatibility are common challenges, and innovative data collection or data preparation techniques are frequently needed to enhance, transform or blend data to be usable.

For example, to compensate for the lack of, poor quality, or poor coverage of climate and environmental observation and monitoring systems, techniques that blend local meteorological or environmental observations with remotely-sensed data are often used. Similarly, national health surveillance systems can be strengthened by integrating data sourced from sentinel sites, early disease detection or community-based disease surveillance systems in order to generate comprehensive datasets. 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.

Monitoring and integrated surveillance systems combine relevant health, climate and other socioeconomic data and 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.). To ensure these systems can support health decision inputs from the public health community, spatial and temporal data compatibility are essential. 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.



Core analytics including indicators, thresholds, models and maps are generated from descriptive and statistical analyses. 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 hazard 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).

Risk models and maps help describe and illustrate the spatial and temporal dimensions of climate-related health risks to population health. 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.

Risk forecasts can be used to anticipate when and where climate conditions may increase the likelihood for health impacts to occur. These risks can be estimated by integrating forecasts of weather, climate and other relevant conditions at different timescales into mathematical or statistical disease transmission or incidence models. The risk management of diverse health hazards may require weather and climate forecasts with different lead times. For example, initiatives addressing community heat-related health risks may use local weather forecasts with lead times of several days to anticipate heat stress risks for specific populations. Long-term climate projections can help anticipate the number of extreme hot days populations may be exposed to in the future.

Early warning systems use risk forecasting and thresholds to alert health professionals as well as the public of rapid-onset emergencies such as extreme weather or disease outbreaks. They are important to provide communities and professionals additional lead time for preparing and responding to the event. Hazard and exposure thresholds are set at different levels of estimated risks to trigger appropriate actions. Communication strategies within these systems ensure the proper dissemination of warnings to health decision-makers, emergency response teams, communities and especially to vulnerable populations. 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.

Projections and scenarios are risk models that generate projections of health risks up to several decades into the future, and are 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.

A–D

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

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

5C: EPIDEMIA: integrating climate information and disease surveillance for malaria epidemic forecasting in Ethiopia

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

E/F/G

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

5F: MalaClim: climate-based suitability mapping to inform vector control programmes in the Solomon Islands

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

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.

Monitoring systems and integrated surveillance

The first four case studies (5A–D), take different approaches to enhancing the surveillance of health risks and conditions. The first (5A) illustrates the potential of using a community-based surveillance system to complete partial national health data records in Ecuador. The second, also in Ecuador (5B), is about an integrated dengue vector–virus microclimate surveillance system that produces high-resolution risk information as the basis for improving seasonal dengue early warnings. The epidemiological–climate data repository that is managed by a research team uses a secure cloud-based server to store and share information with partners. In Ethiopia, the third case study (5C) is about software developed to link environmental and epidemiological databases in order to forecast and rapidly detect 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 1–25 kilometre spatial resolutions. Case study 5D explains 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.

Core analytics

Case studies (5E–G) illustrate the development of climate-informed indicators, risk modeling and mapping for airborne pollen and the suitability of transmission of vector-borne diseases. Case study 5E from Hungary is a particularly good example of the research required to identify and use climate-specific indicators to monitor and forecast pollen conditions. In the Solomon Islands, case study 5F describes how malaria transmission suitability maps were produced at the provincial level based on an environmental risk score, a composite measurement of in-situ and remotely sensed environmental, population-based, and entomological indicators. 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 updates of the environmental risk score provides further indication of high risk areas during transmission season. In Uganda (5G), 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. 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 targets and trains traditional healers and outreach workers to identify and refer plague patients.

H/I/J

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

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

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

Risk forecasts

Case studies (5H-J) illustrate examples of climate-informed health risk forecasts for hazardous air quality, as well as dengue and malaria transmission. In Manitoba, Canada, case study 5H shows how climate and atmospheric conditions are used to monitor, forecast and communicate wildfire smoke risks to the public and disaster management 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 to alert citizens at risk of hazardous smoke inhalation. In the second case study (5I), a malaria early warning system in Uganda uses seasonal forecasts to drive a dynamic malaria model. Validation shows the system produces skillful 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 (5J) 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.

K/L

5K: SUPREME: an integrated heat health warning system for Quebec

5L: 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 (5K), 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 (5L), 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 a broad-based risk communication campaign using modern communication technologies (e.g. electronic display screens, mobile text or instant messaging groups).

M/N/O

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

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

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

Projections and scenarios

Finally, three case studies provide examples of decision tools using future climate projections to generate scenarios of health risks. In the first (5M), an interactive, web-based mapping and decision support tool constructs the future probability of simulated transmission intensity, prevalence and 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 projections of vulnerability and susceptibility throughout eastern sub-Saharan Africa. Case study 5N details a risk framework that was developed to generate climate-related risk projections for food- and water-borne diseases in Canada in diverse time frames up to 2100. It allows for the evaluation of different adaptation options by enabling their inclusion in the projection models. The final case study (5O) from the United States describes how complex climate model projections were interpreted to project the number of future extreme hot days at a meaningful geographic unit for public health surveillance.

MONITORING SYSTEMS AND INTEGRATED SURVEILLANCE

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

Authors: J. Palacios (Department of Meteorological Studies and Research, National Institute of Meteorology and Hydrology Quito, Ecuador); W. Cevallos (Biomedical Center, Central University of Ecuador Quito, Ecuador); M. Zapata (Department of Biophysics, Central University of Ecuador Quito, Ecuador); J. Cartagena (National Laboratory of Water and Sediment Quality, National Institute of Meteorology and Hydrology Quito, Ecuador); A. Von Hildebrand (World Health Organization, Ecuador).

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 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 Southern Oscillation (1,2).

NEW APPROACHES

The diarrhoeal diseases information was obtained from data taken from a passive surveillance system grouping data from 12 ministry of health public health centres scattered in the study area, covering the period 2008–2012. Diarrhoeal diseases 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 socio-organizational activities. Their 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, a Catholic nongovernmental organization with close ties to local health authorities, the ministry of health 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 WMO.

Enabling environment

Capacity-building

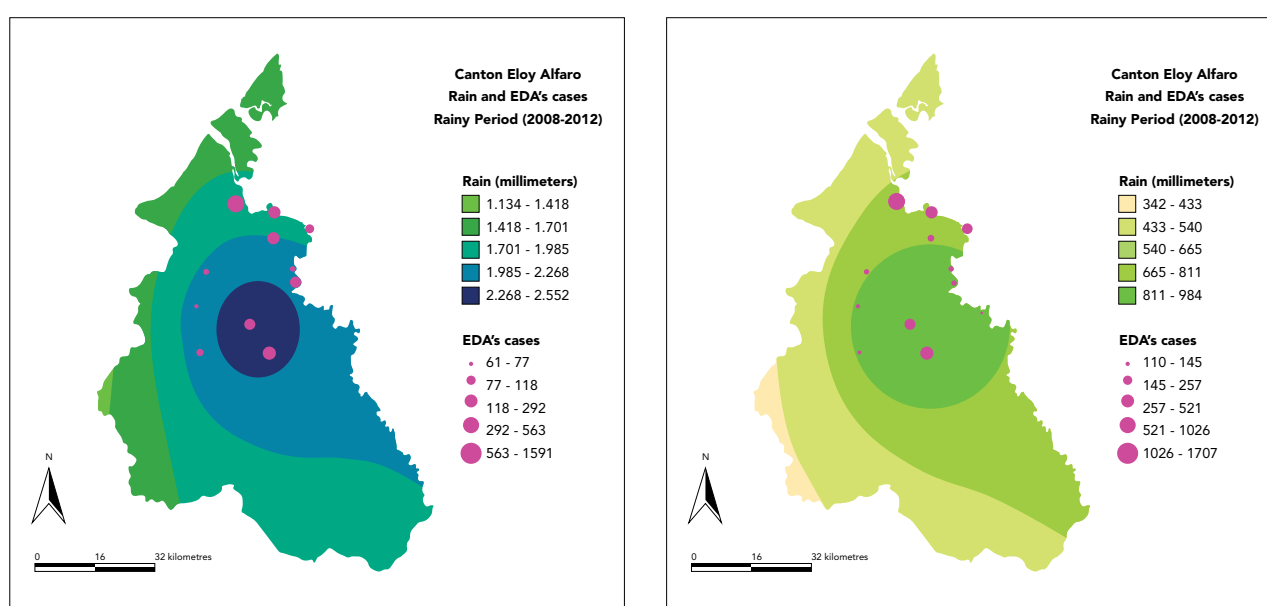
Research

Product and service development

Application

The method of principal component analysis and correlation was used for data analysis and it helped establish that the number of diarrhoeal disease cases reported during the dry period is larger than those cases reported during the rainy season (3). This information was shared with the local authorities and nongovernmental organizations to undertake actions to improve drinking water quality (such as proposing chlorination at various points along the piped distribution systems and distributing chlorine tablets for use by households) and with the ministry of health to include factors linking climate and health in national health policies (4). Climate information is now being provided on 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 5.3 Influence of climatic seasonality on diarrhoeal disease.



ACKNOWLEDGEMENTS



The total numbers of diarrhoeal disease reported in the 12 health centres during 2008-2012 varied between 61-1591 cases in the rainy season, and 110-1707 cases in the dry season. This indicates that diarrhoeal diseases are more prevalent during the dry season (51.3 cases per 1 000 inhabitants) than in the rainy season (47.8 cases per 1 000 inhabitants) (5–11).

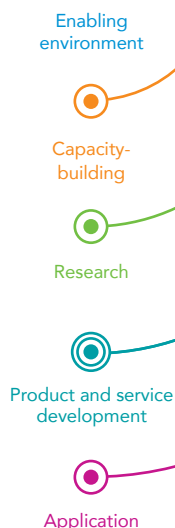
BENEFITS AND LESSONS

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 the 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.

MONITORING SYSTEMS AND INTEGRATED SURVEILLANCE

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

Authors: M. Borbor-Cordova (Facultad de Ingenieria Maritima, Ciencias Oceanicas y Recursos Naturales, Escuela Superior Politécnica del Litoral Guayaquil, Ecuador); E. Beltran (Facultad de Medicina, Universidad Técnica de Machala, Machala, Ecuador); The Ministry of Health, Machala, Ecuador); W. Cardenas (Facultad de Ciencias de la Vida, Escuela Superior Politécnica del Litoral, Guayaquil, Ecuador); T. Endy, C. King, M. Polhemus, A. Stewart-Ibarra (Center for Global Health and Translational Science, State University of New York Upstate Medical University, Syracuse, NY, USA); J.L. Finkelstein (Division of Nutritional Sciences, Cornell University, Ithaca, NY, USA); St. John's Research Institute, Bangalore, India); R. Leon (Universidad San Francisco de Quito, Laboratorio de Entomología Médica, Quito, Ecuador); A.G. Munoz (NOAA/ Geophysical Fluid Dynamics Laboratory, Princeton University; International Research Institute for Climate and Society, Columbia University, NY, USA); R. Mejía (Instituto Nacional de Hidrología y Meteorología del Ecuador, Guayaquil, Ecuador); G. Recalde Coronel (Facultad de Ingenieria Maritima, Ciencias Oceanicas y Recursos Naturales, Escuela Superior Politécnica del Litoral, Guayaquil, Ecuador); Department of Earth and Planetary Sciences, The Johns Hopkins University, MD, USA); S. Ryan (Department of Geography, and Emerging Pathogens Institute, University of Florida, Gainesville, FL, USA).

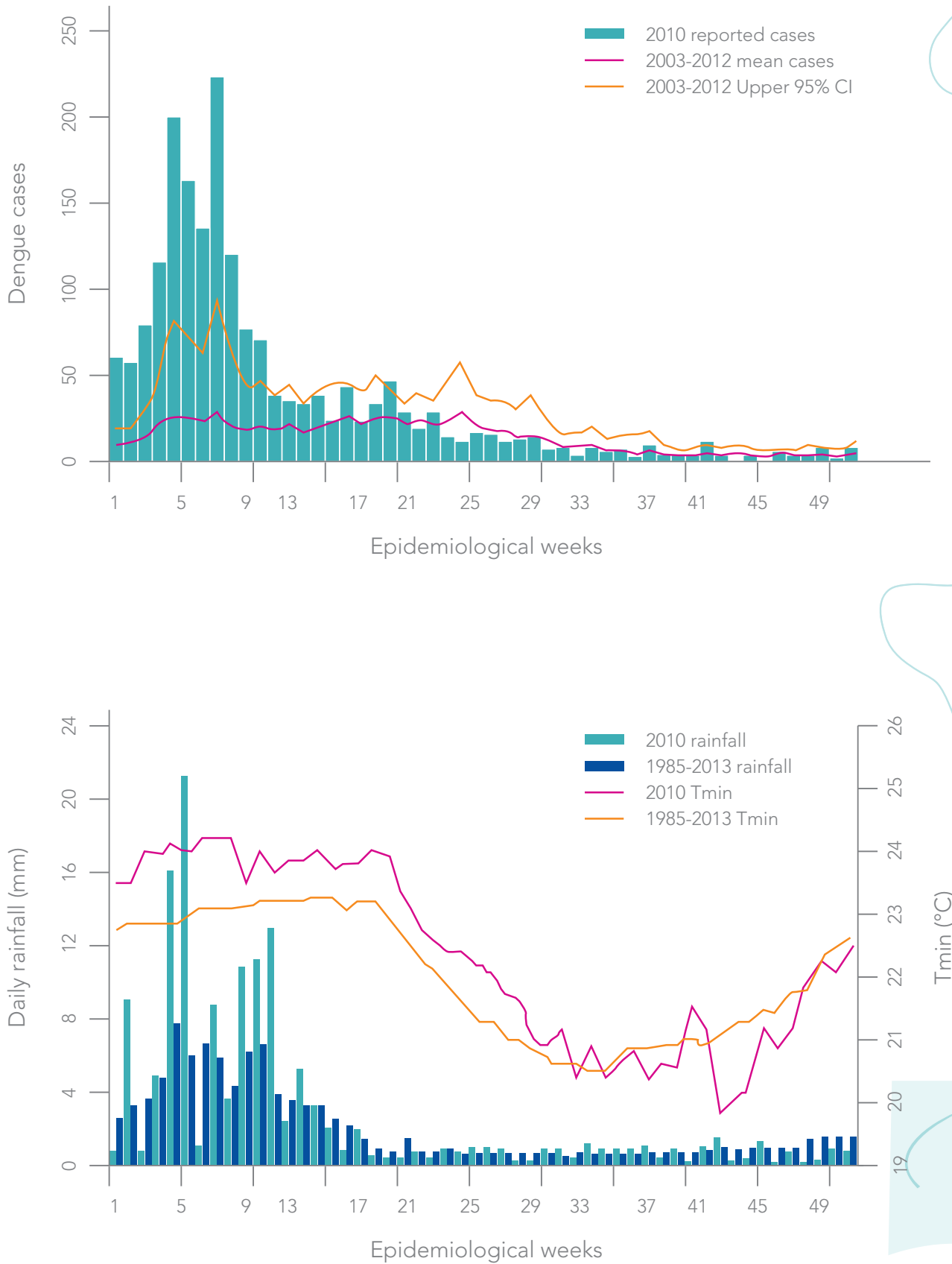


CONTEXT

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 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 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 5.4). That year, over 17 000 cases of dengue were reported in the country, with more than 2 000 cases in Machala, resulting in a local incidence rate more than three times the baseline rate from 2003 to 2009 (12). The epidemic rapidly surpassed the capacity of local public health services, highlighting the need for alternative prevention and control strategies.

Figure 5.4 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 (12).



CASE STUDY 5B



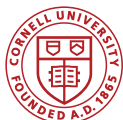
NEW APPROACHES

Initial collaborative research efforts led by INAMHI and partners indicated the potential to develop a dengue early warning system. 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, local climate, the virus serotypes in circulation and mosquito abundance (13). The research team identified key local climatic conditions that likely triggered outbreaks, as observed in 2010 (12). Studies also showed that dengue risk was associated with social vulnerability factors such as housing conditions, demographics, risk perceptions and knowledge (12, 14). 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 (15). 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 (16).

Figure 5.5 Active surveillance of lab-validated dengue cases and *Aedes aegypti* 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.



ACKNOWLEDGEMENTS



In 2013, the team gained additional support from the Global Emerging Infections Surveillance and Response System to establish an integrated vector-virus microclimate surveillance system (Figure 5.5). This comprehensive surveillance system is generating fine-scale spatio-temporal 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 (Stewart-Ibarra 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 early warning system 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.

MONITORING SYSTEMS AND INTEGRATED SURVEILLANCE

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

Authors: M. Wimberly (South Dakota State University, Brookings SD, USA); T. Gebrehiwot (Amhara Regional Health Bureau, Bahir Dar, Ethiopia); M. Bishaw (GAMBY College of Medical Science, Bahir Dar, Ethiopia); W. Yalew (College of Medical and Health Sciences, Bahir Dar University, Bahir Dar, Ethiopia); A. Mihretie (Health, Development, and Anti-Malaria Association, Addis Ababa, Ethiopia).

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 (17, 18). 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 (19, 20). 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 (21).

Figure 5.6 Conceptual diagram of information flow through the EPIDEMIA system (Merkord et al. 2017).

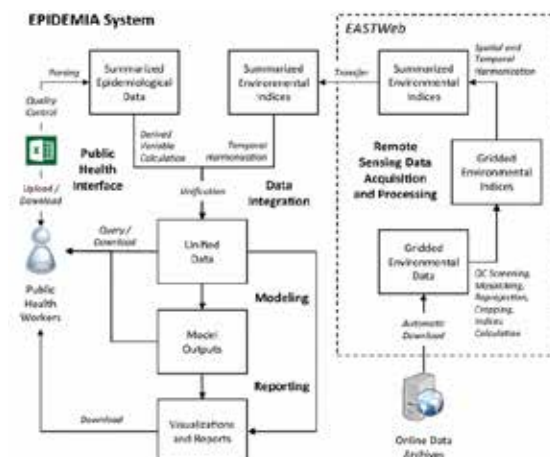
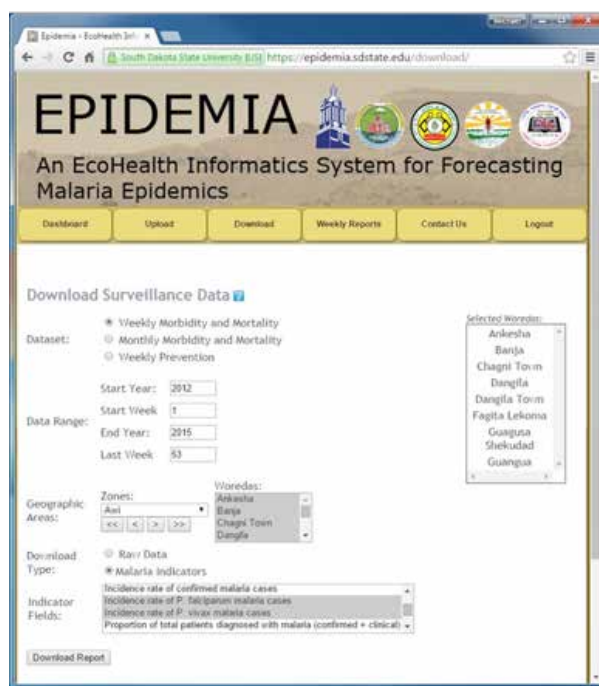
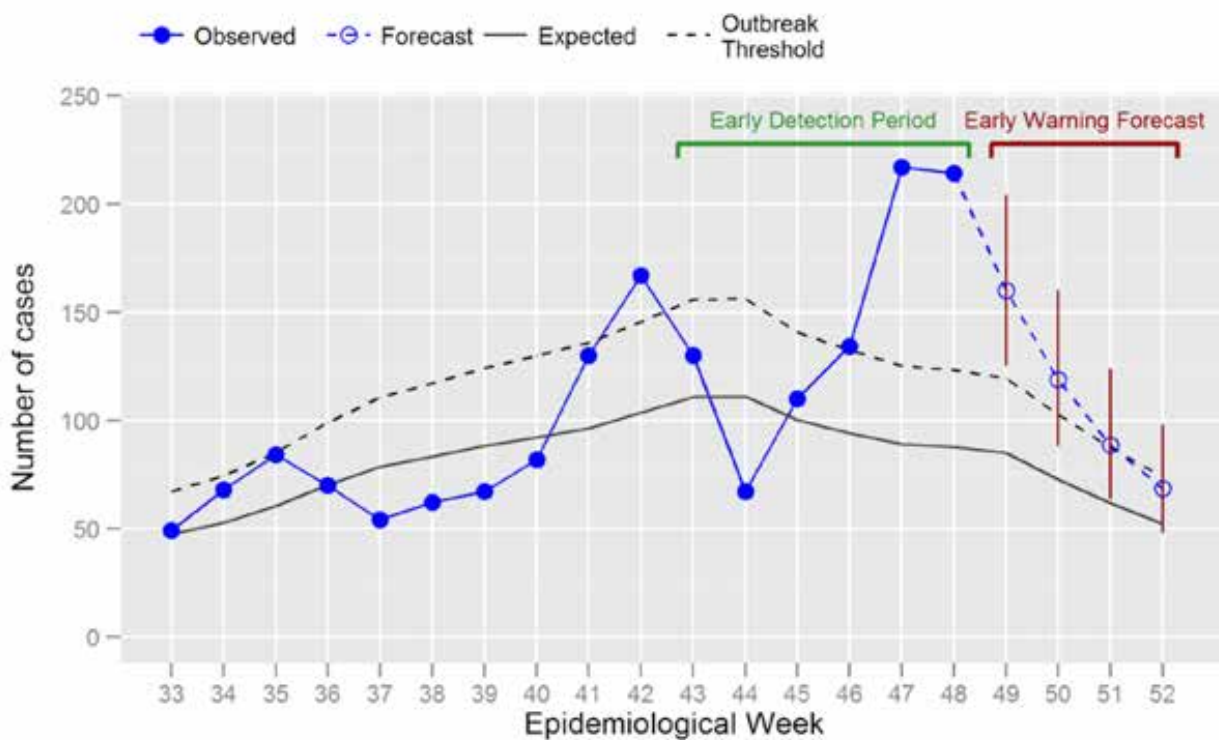


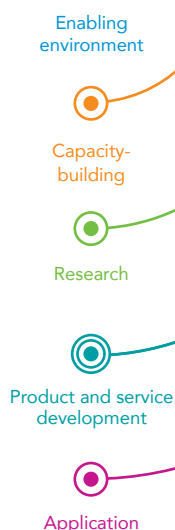
Figure 5.7 EPIDEMIA public health interface and an example malaria forecasting chart from a weekly report produced on epidemiological week 48 in 2015.



Epidemiological Week 48, 2015



CASE STUDY 5C



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 kilometres). 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.



Figure 5.8 Irrigation ditches provide breeding sites for malaria vectors. Photo credit: M. Wimberly/2009.



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.

MONITORING SYSTEMS AND 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 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 (22). 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 (23).

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. (24), 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.

Enabling environment

Research

Product and service development

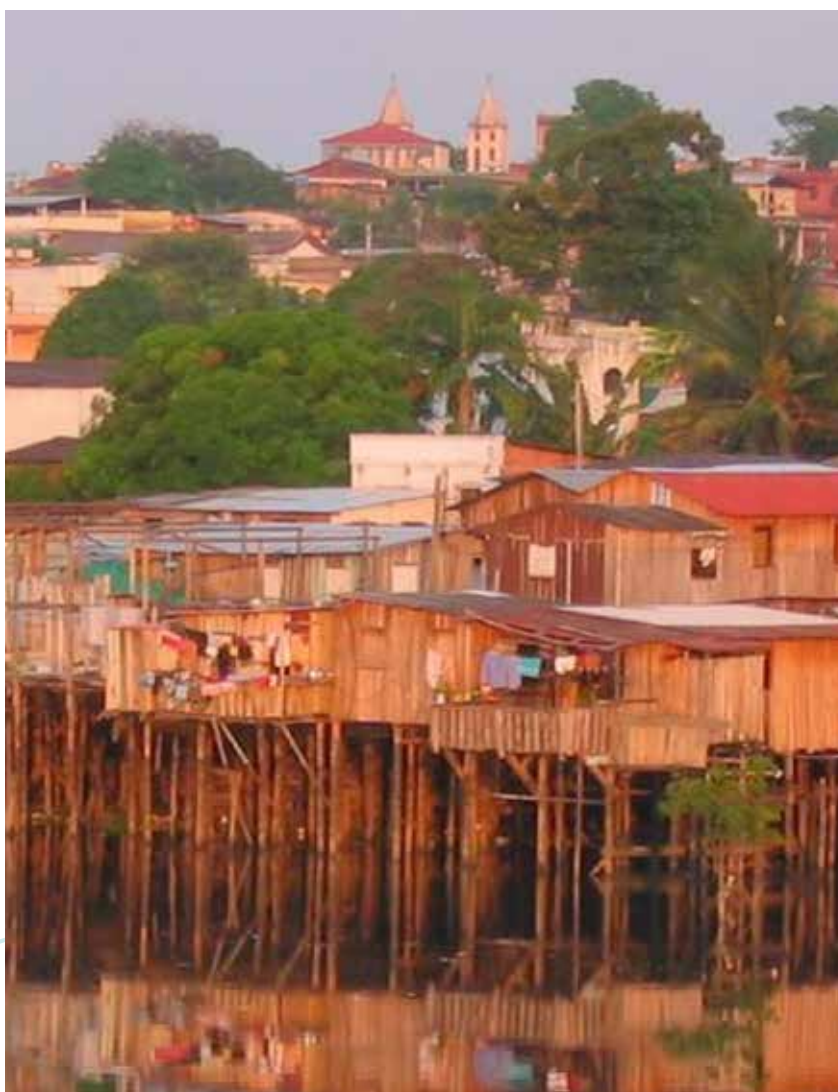
Application

NEW APPROACHES

The objective of the Brazilian Observatory of Climate and Health (www.climasaude.icict.fiocruz.br) is to collect, organize and disseminate environmental, sociodemographic, climate, population and health data, with the aim of constructing 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.

Figure 5.9 Houses built on stilts (*palafitas*) along the Negro River (Manaus, Brazil).



CASE STUDY 5D

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. 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 the form of media news, scientific papers as well as online climate and health data (25). The diagram in Figure 5.10 shows the structure of the system.

Figure 5.10 Data loading model for sentinel sites.

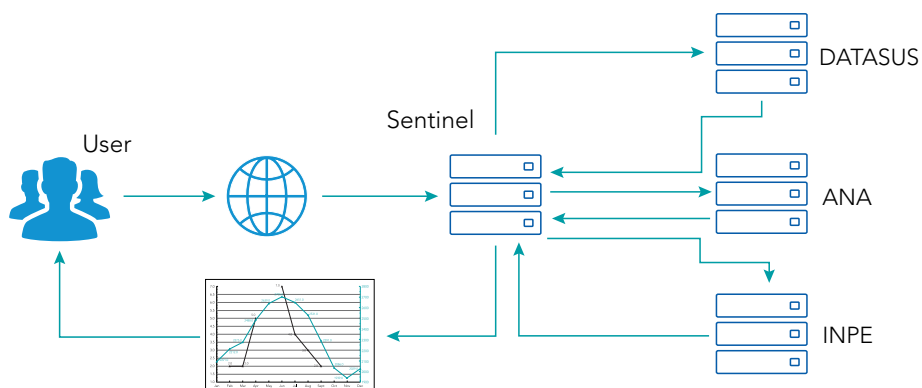
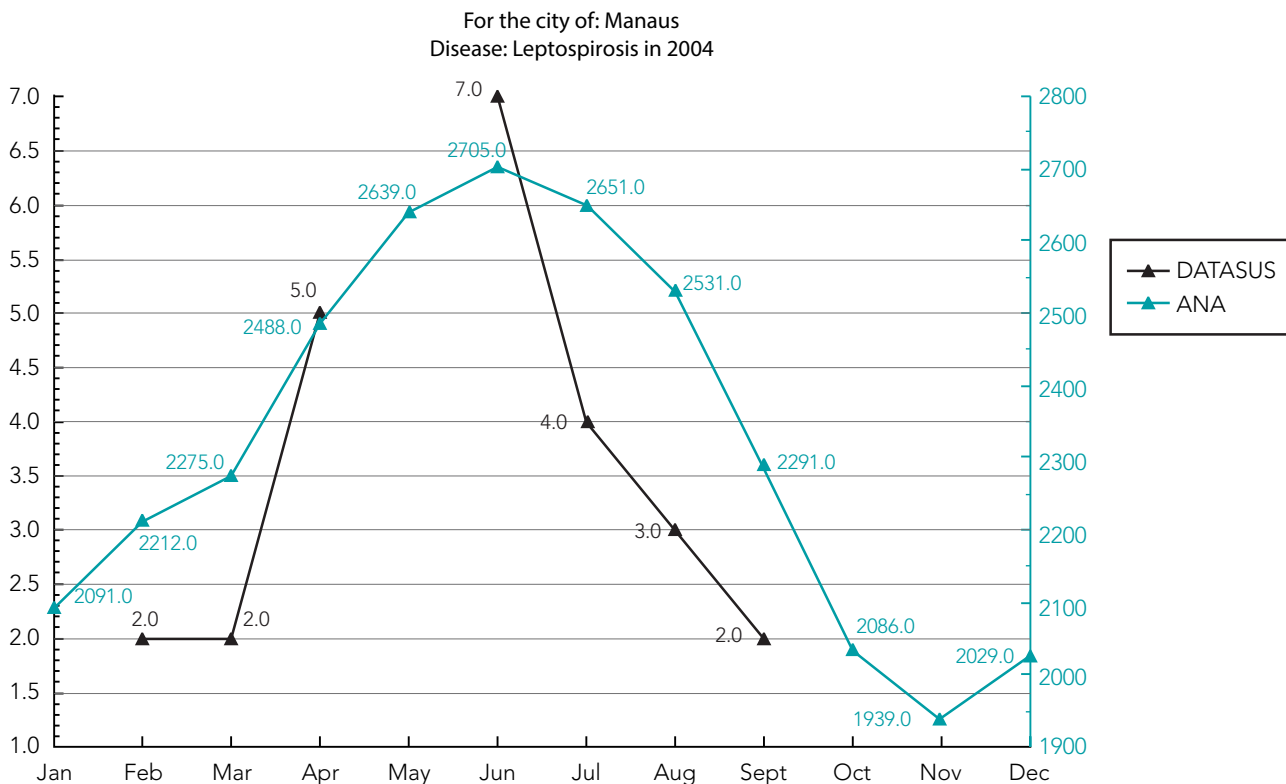
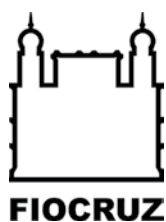


Figure 5.11 shows the graph resulting from a user query. It demonstrates the dynamics of the variables of the climate (i.e. level of the Negro River) and health (i.e. hospital admissions due to leptospirosis) over time. In the months of May to July, the river reaches its annual maximum level, which is immediately followed by an increase in the number of cases of leptospirosis.

Figure 5.11 Dynamic graph of river water level and leptospirosis incidence.



ACKNOWLEDGEMENTS



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 (25). The persistence of low-cost traditional houses built on stilts, known locally as palafitas (Figure 5.9), 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.

CORE ANALYTICS

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

Authors: J. Bobvos, A. Páldy, B. Fazekas, G. Mátyóki, D. Magyar (National Institute of Environmental Health, Budapest, Hungary); A. Egorov, D. Dalbokova, C. Gapp (WHO European Centre for Environment and Health, Bonn office).

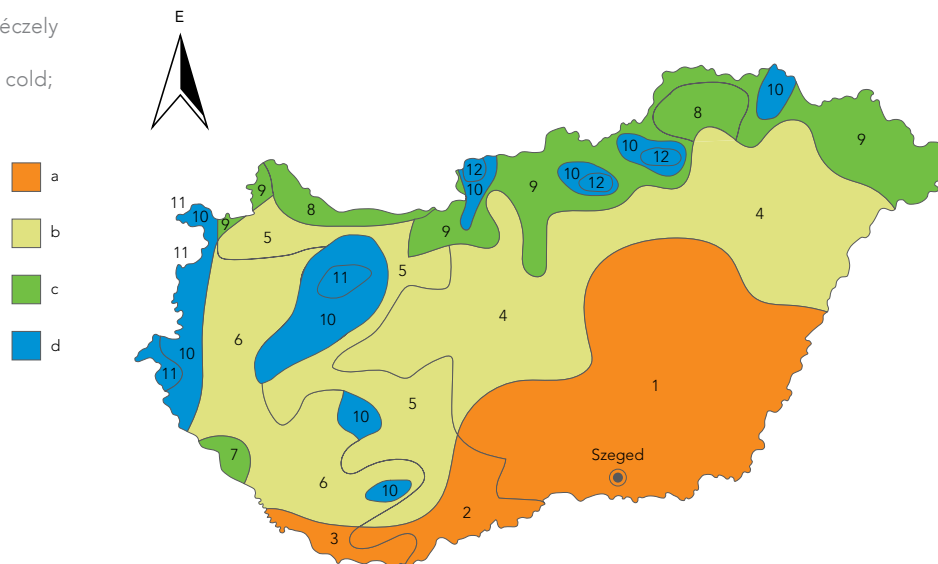
CONTEXT

The 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (26) 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 European Union strategy on adaptation to climate change (27) 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 (28) stated that warmer conditions generally favour the production and release of airborne allergens. Progressively increasing temperatures may modify the global pollen load (29). 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, with the contribution of Member States, has developed climate-related indicators as part of the Climate Change, Environment and Health Action Plan and Information System (CEHAPIS) project. Four allergen plants were selected as indicators: alder (*Alnus* sp.); birch (*Betula* sp.); grasses (*sp.*); ragweed (*Ambrosia* sp.). These provoke high sensitization rates, have fairly broad geographical and temporal coverage in the European flowering season (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 kilometres of the monitoring stations should be noted for weighting purposes.

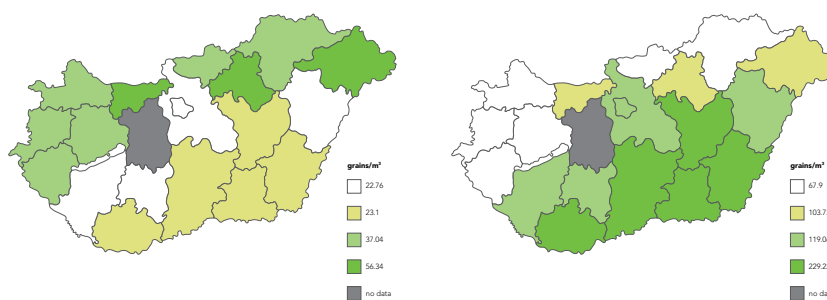
Figure 5.12 Climatic regions by Péczely (23) in Hungary: (a: warm and dry; b: moderately warm; c: moderately cold; d: cold and wet).



A software tool has been elaborated with the contribution of the National Public Health Institute (NPHI) (30). The software enables calculation of the start and end, duration (days), and severity of the pollen period (annual sum and daily maximum of pollen grains (grains/m³) 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 (≥ 30 grains/m³); (ii) average exposure to the pollen (grains/m³); (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 5.12 shows the climatic regions within Hungary (31); Figure 5.13 displays the effect of weather variability on the population-weighted pollen exposure.

Figure 5.13 Ragweed: population-weighted average pollen concentration (grains per cubic meter). Left: extreme dry summer 2007. Right: extreme wet summer 2010.



ACKNOWLEDGEMENTS



BENEFITS AND LESSONS

NPHI uses this software to communicate results for the healthcare 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 NPHI plans to disseminate the software at the international level, and to make it freely downloadable from its website.



CORE ANALYTICS

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 Disease Control Programme (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 southwestern Pacific countries still live in malaria high-incidence areas (32), despite an improvement of malaria programmes and a huge decrease in 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 (33).

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 accounting for environmental factors and a rainfall-based malaria outlook for the next malaria season.

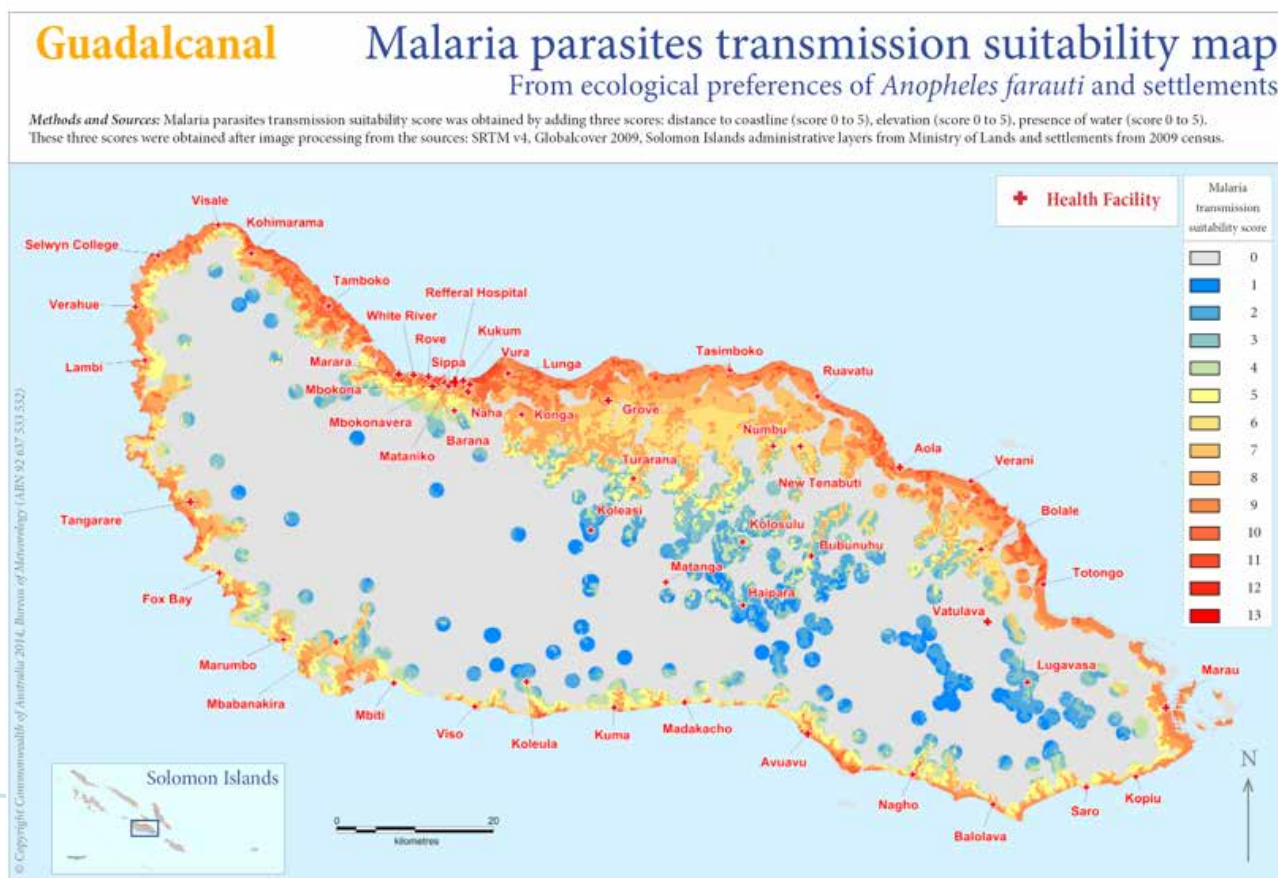
The MalaClim project is part of the Climate and Oceans Support Program in the Pacific (COSPPac), a programme funded by Australian Aid and run by the Australian Bureau of Meteorology in partnership with several Solomon Islands government ministries.

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 (34) tends to stay in coastal regions and at low elevations. From previous entomological studies (35) 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 Niño years, which are typically drier than normal (36), 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 Programme.

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, allow for adjustments to be made to these actions as the malaria outlook becomes clearer. These actions can include: community awareness, diagnostics tools and treatments allocations and expanding vector control measures.

Figure 5.14 Malaria parasite transmission suitability map based on the ecological preferences of the main mosquito vector and the location of human settlements.



CASE STUDY 5F



Enabling environment

Capacity-building

Research

Product and service development

Application

Figure 5.15 Health clinic in Guadalcanal: pregnant women and children under the age of five are still the population most affected by malaria.



Figure 5.16 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 national malaria control authority, and regular meetings are conducted between SIMS and NVBDCP. The parasite transmission suitability maps and GIS for all nine provinces was very successful and monthly rainfall outlooks for 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.



CORE ANALYTICS

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, R. 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

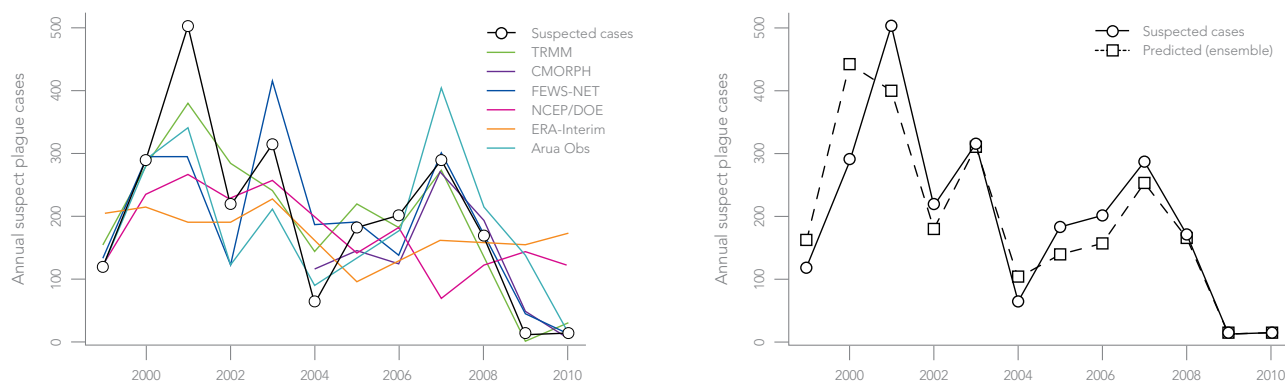
The West Nile region in northwestern Uganda is a focal point for human plague, which peaks in boreal autumn and is spread by fleas that infest rodent hosts (37,38). The U.S. Centers for Disease Control and Prevention (CDC) is partnering with the National Center for Atmospheric Research (NCAR) to quantitatively 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 (39). The dataset was subsequently employed to develop a spatial risk model for human plague occurrence in the West Nile region above 1300 metres (40) that improved upon a previous model (41) 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)(41). 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.



Figure 5.17 Left panel: modelled (colour) 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

The CDC and NCAR pilot programme enrolled and trained traditional healers in the regions of West Nile above 1 300 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 5.18). 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 5.18 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); 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

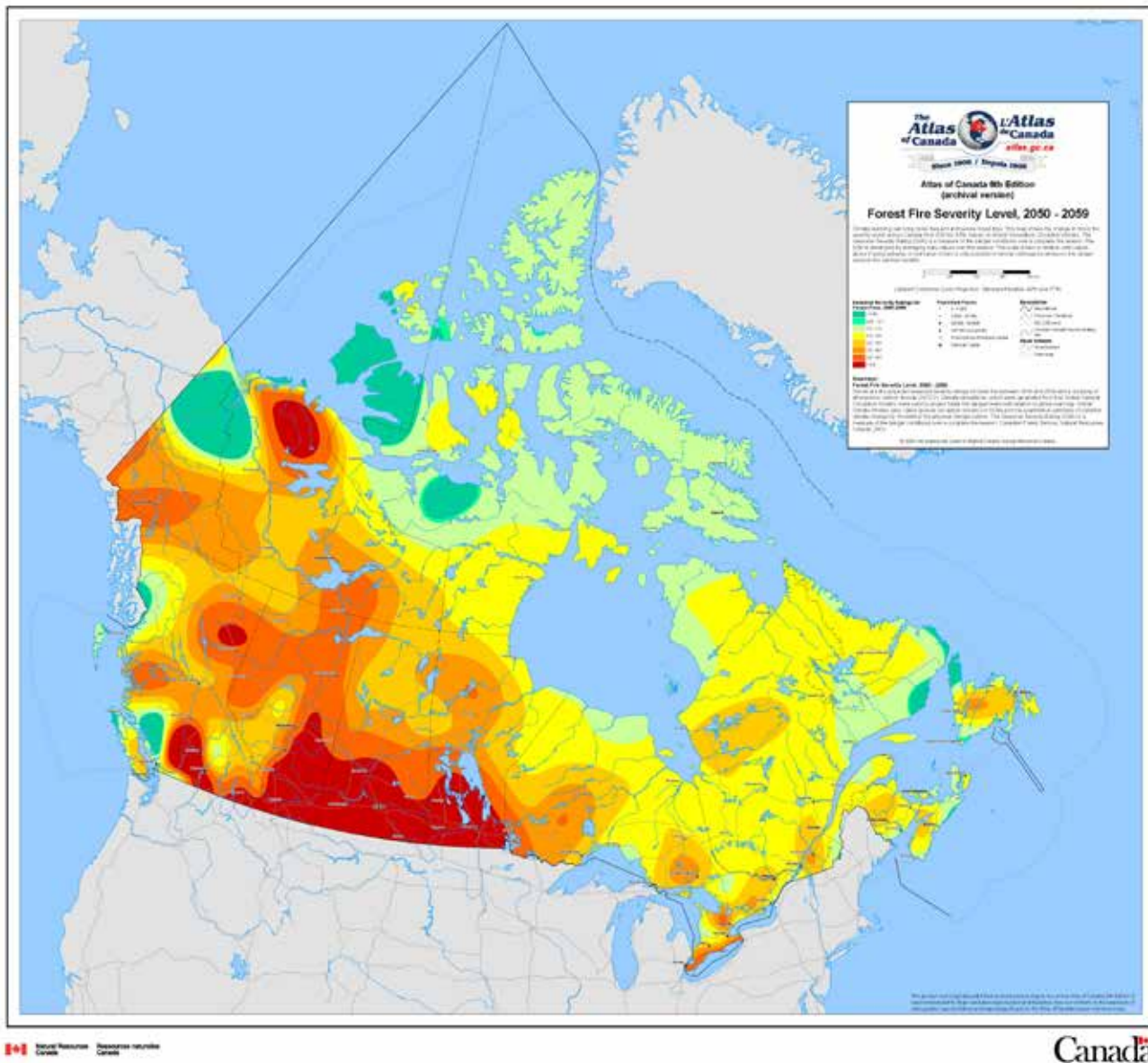
Air quality is a significant public health issue in many Canadian communities and will be impacted by wildland fires that are expected to increase with climate change (42). Wildland fires are a common occurrence across Canada where forests cover more than 50% of the country's landmass. In a changing 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 (43). Figure 5.20 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 (Figure 5.19). Some individuals are more vulnerable, such as children, seniors, people with pre-existing heart or lung conditions and people geographically, culturally or socially isolated (44).

Figure 5.19 Direct and indirect health impacts from wildland fires (Adapted from 45 and 46).

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

Figure 5.20 Change in forest fire severity levels across Canada from 2050 to 2059.



CASE STUDY 5H

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 (47). 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, called the 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 5.21). 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, such as 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 (48). 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 (49), 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 (50). 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.

Enabling environment

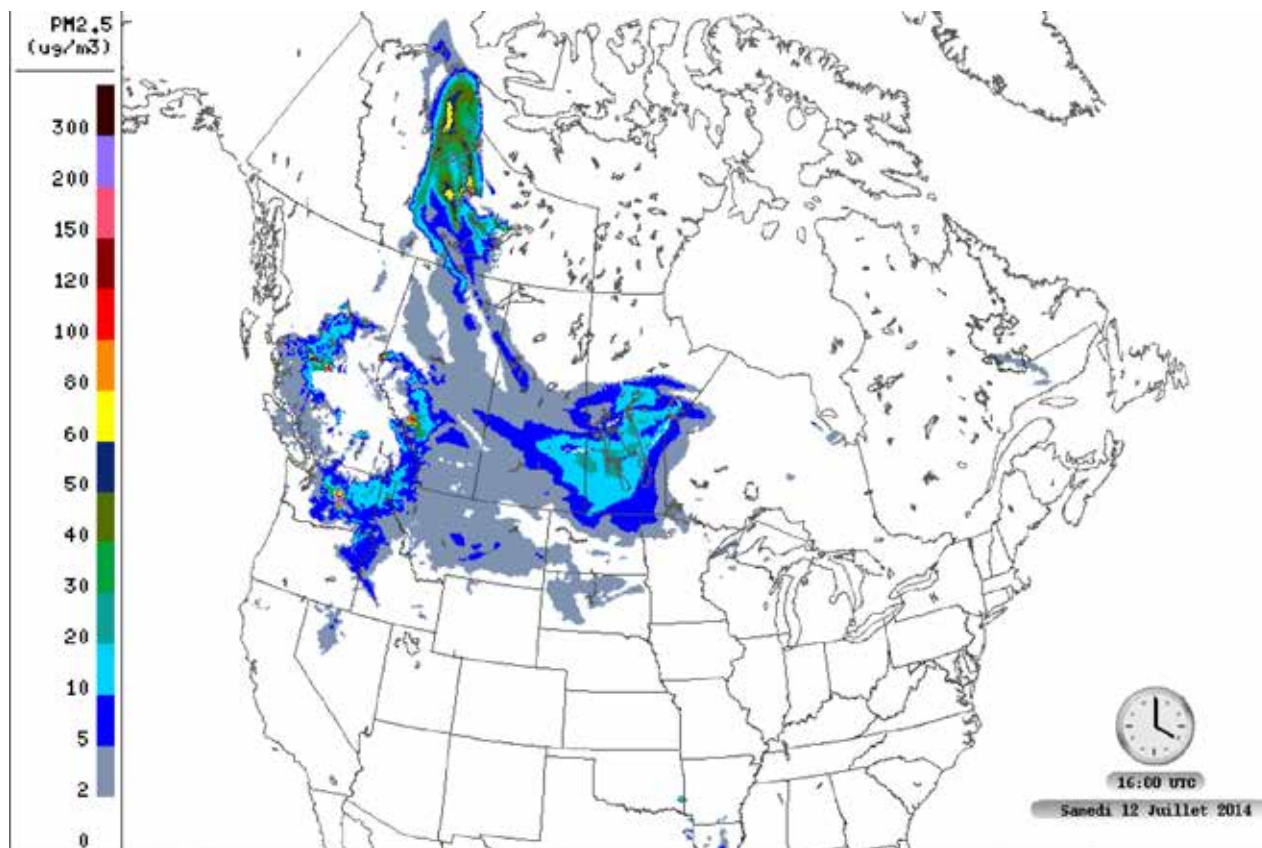
Research

Product and service development

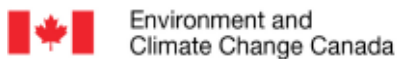
Application

Evaluation

Figure 5.21 Sample firework output of wildfire emission contributions to total forecasted PM 2.5 micrograms per cubic metre in western Canada on July 12, 2014. Environment and Climate Change Canada, 2014.



ACKNOWLEDGEMENTS



BENEFITS AND LESSONS

The BlueSky and Firework forecasting systems assist ODM officials to 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 operating picture that supports decision-making. Continued implementation of this system is expected to reduce health risks to Manitobans from wildland fire smoke events.



Enabling environment

Product and service development

Evaluation

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 (51), malaria still imposes a significant health and socioeconomic burden in over 100 countries (52). Every year about 10 million cases and 43 000 deaths occur in Uganda (53), which ranks third for malaria-related mortality in Africa (53). Nearly 50% of all outpatient visits and 35% of hospital admission are malaria-related (54). 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 (55). Rainfall regulates the production of mosquito breeding sites (56). 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 (57) 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 (58). 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.

Figure 5.22 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.

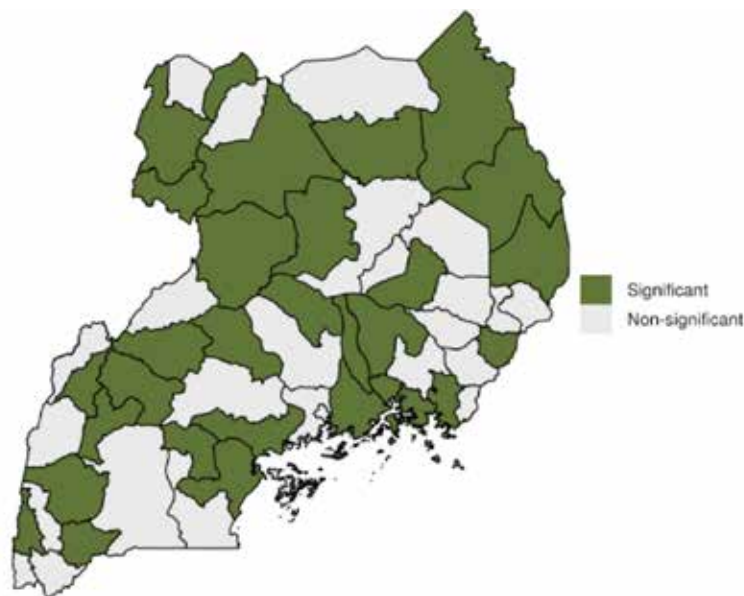


Figure 5.22 presents the areas where the malaria forecasts were skilful (in green) four months ahead, as evaluated against monitored malaria incidence. Statistically significant correlations (Spearman rho range: 0.3 - 0.8) were observed in areas considered of 'very low' and 'low' transmission such as 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) (59) for estimating the economic value of meteorological forecasts.

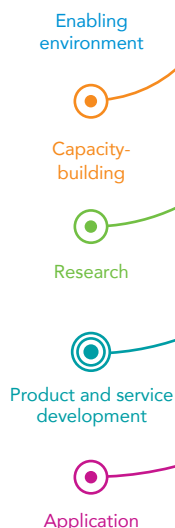
Despite considerable evidence that climate information could increase advance warnings, MEWS based on climate monitoring or forecasting have not been widely adopted in operational environments to assist planning anywhere in Africa. Decisions concerning drug distribution and interventions are still mostly 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.



Republic of Uganda, Ministry of Health



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 important health determinant. 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 of the different susceptibilities and vulnerabilities of different populations .

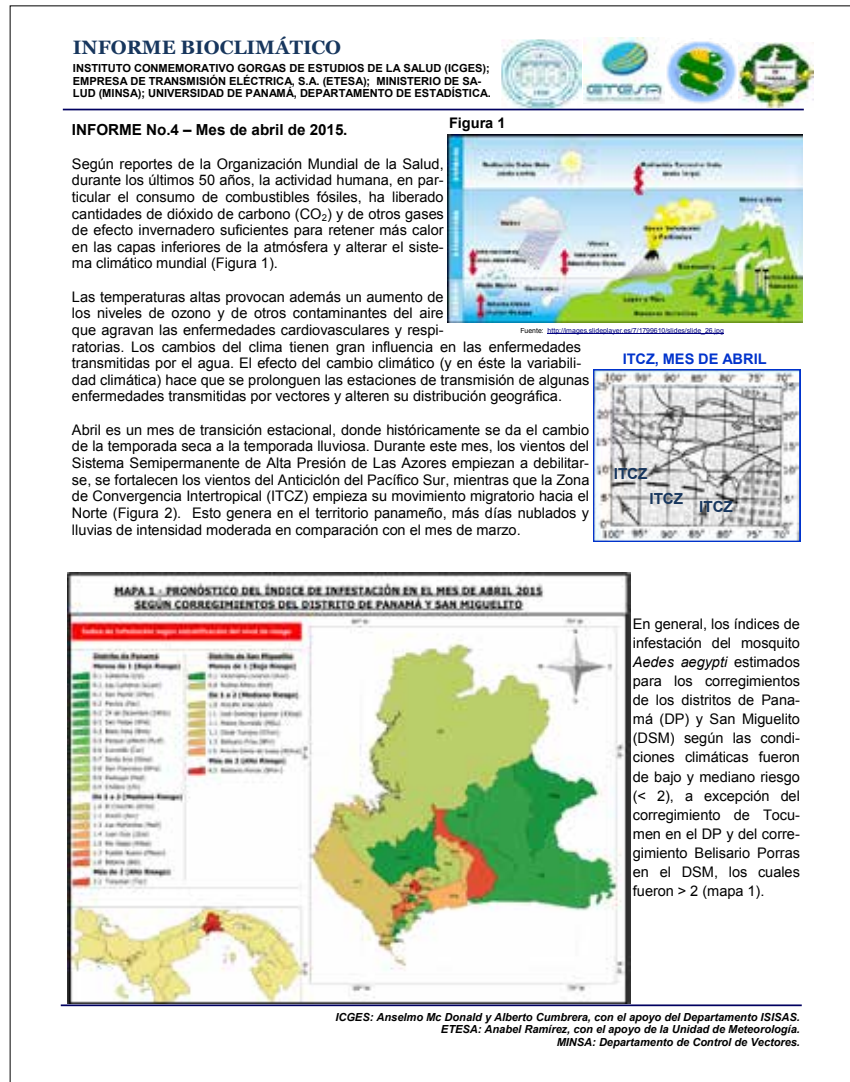
Climatic conditions can influence the transmission dynamics of communicable vector-borne diseases, water-borne diseases (60) and even of some noncommunicable diseases (61).

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 – one with the Cuban Institute of Meteorology (INSMET) for its experience in climate and health, and the other with the Panamanian Electric Transmission Company (ETESA), responsible for the administration of meteorological information in Panama.

On 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). The groups were trained in health-specific statistical methods (primarily time-series analysis), GIS and climate information management systems to ensure equal levels of capacity were attained across team members.

Figure 5.23 Monthly bio-climatic bulletin, Panama.



The main goal of the Panama Climate and Health Groups is to generate scientific evidence on climate impacts of specific diseases at the national level. This information serves as a technical asset for the ministry of health to make decisions and develop public health interventions.

With dengue 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 infestation of the mosquito *Aedes aegypti*, the vector that transmits the disease. The model was used to estimate the infection rate two months ahead to help the district of Panama, the capital of the country, plan for vector surveillance and control.

CASE STUDY 5J



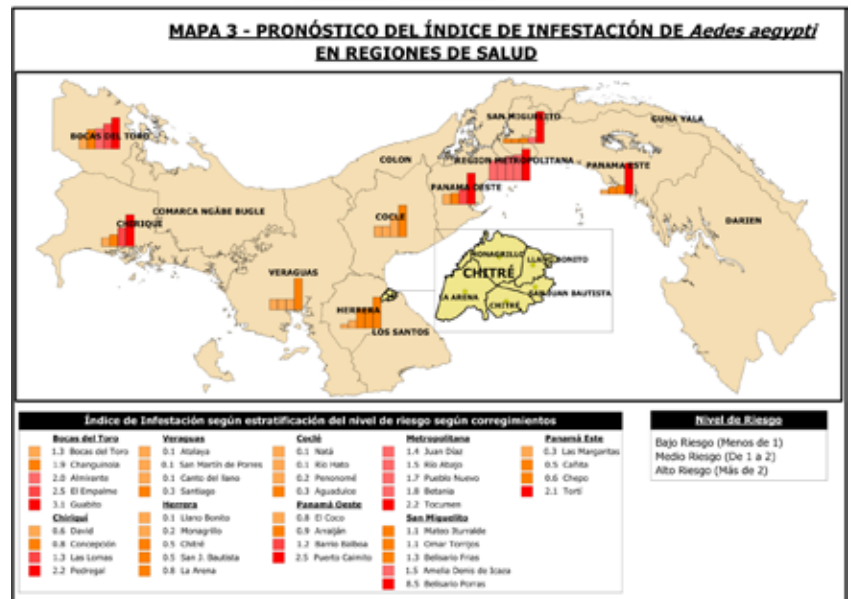
BENEFITS AND LESSONS

Based on this validated model, the GMIHS and the ETESA now publish the monthly *Bio-climatic Bulletin*. It describes the current influence of climate on health, and specifically the model predictions of indexes of vector infestation, and maps of the geographic distribution of vectors. This bulletin is sent to all relevant decision-making actors (such as the ministry of health, city mayor, academics, environmental authorities and researchers) to provide evidence and up-to-date information that can be used as the basis for disease control efforts.

Since 2011, the group has been progressively investigating the availability of data in other areas of the country, with the aim of extending the use of this climate and health product to different districts in nine of the 14 health regions (62).

In addition, the Department of Hydrometeorology of ETESA has actively participated in the project to provide meteorological data; the Ministry of Health Department of Vector Control has provided entomological data, and the School of Statistics of the University of Panama has provided technical expertise.

Figure 5.24 Forecasts of the *Aedes aegypti* infestation index, extracted from the *Bio-climatic Bulletin*, April 2015.



ACKNOWLEDGEMENTS



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 endorsed 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 with planning health promotion and disease prevention strategies. We also hope to extend this information to the community level via social media and conduct knowledge. Attitudes and practices studies can identify community groups with high-risk behaviours that can be targeted by community health promotion and prevention activities.

This project has demonstrated the importance of forming multidisciplinary and intersectorial research teams, and developing community participation that increases awareness of protective and high-risk behaviours.

Resources and efforts from several institutions were brought together with the health sector for the first time, enabling a regional network to collaborate in Central America and elsewhere to address vector-borne diseases through climate change and health initiatives.

EARLY WARNING SYSTEMS

SUPREME: AN INTEGRATED HEAT HEALTH WARNING SYSTEM FOR QUEBEC

Authors: P. Gosselin (Institut National de Santé Publique du Québec, Québec, QC, Canada); R. Bustinza (Institut National de Santé Publique du Québec, Québec, QC, Canada); S. Jeffers (Environment and Climate Change Canada, Meteorological Service of Canada, Montreal, QC, Canada); P. Gachon (Centre pour l'étude et la simulation du climat à l'échelle régionale: ESCER, Université du Québec à Montréal, Montréal, QC, Canada); L. Bussièrès (Environment and Climate Change Canada, Meteorological Service of Canada, Montreal, QC, Canada); D. Gosselin (Environment and Climate Change Canada, Meteorological Service of Canada, Montreal, QC, Canada); P. Martin (Environment and Climate Change Canada, Meteorological Service of Canada, Montreal, QC, Canada); S. Labrecque (Environment and Climate Change Canada, Meteorological Service of Canada, Montreal, QC, Canada).

CONTEXT

The southern and central regions of Québec can experience heat waves that are responsible for a substantial increase in human death and morbidity over urban and suburban areas (63). By 2050, significant growth in summer temperatures is very likely (64), along with a probable increase in the occurrence and severity of heat waves. The rapidly ageing 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 (65) 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.

Enabling environment

Capacity-building

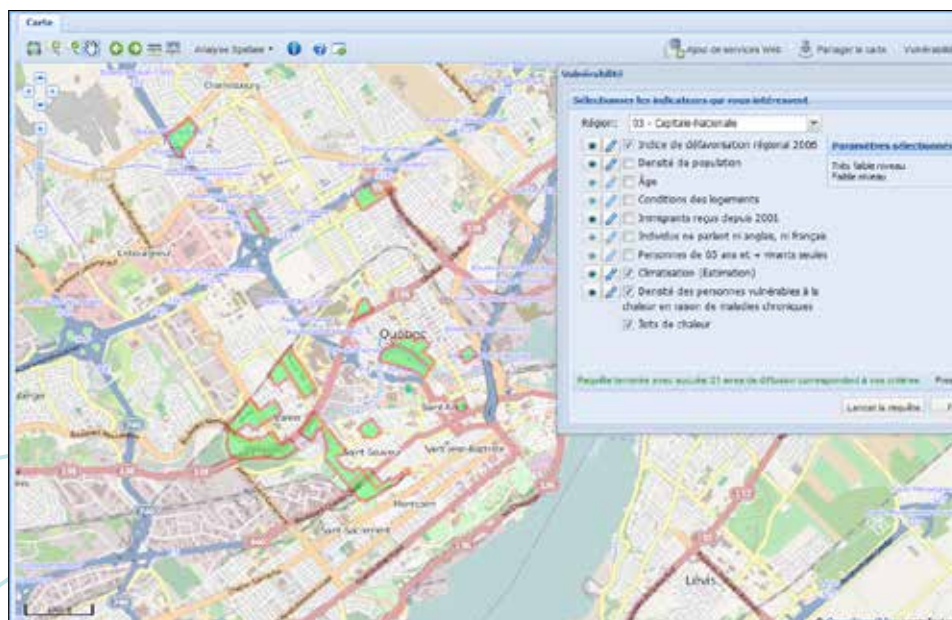
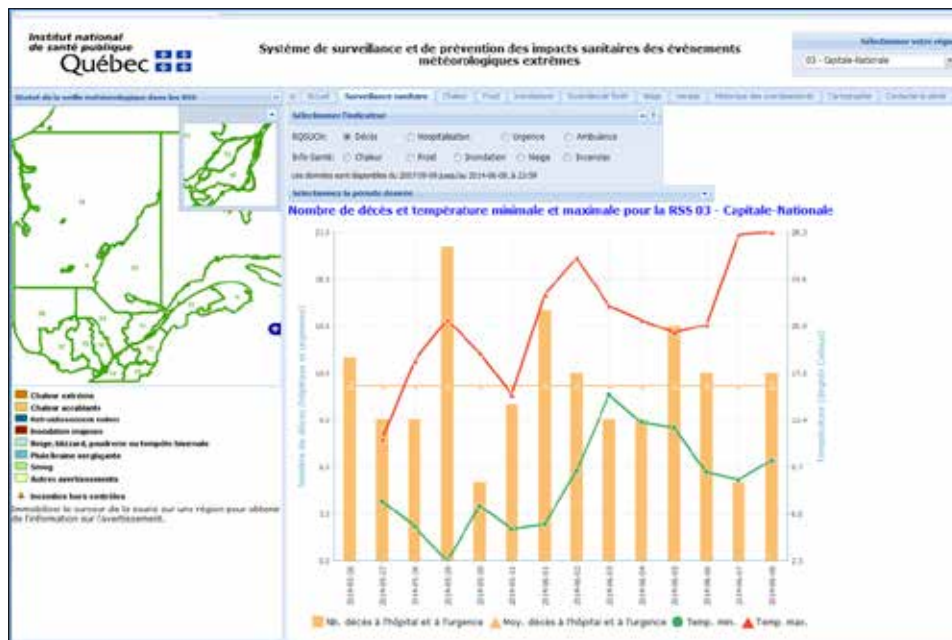
Research

Product and service development

Application

In Québec, SUPREME (Figure 5.25) 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 led to an intense collaboration between the INSPQ and the MSC that has endured.

Figure 5.25 Upper: Home page for the SUPREME system surveillance component. 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 5K



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.

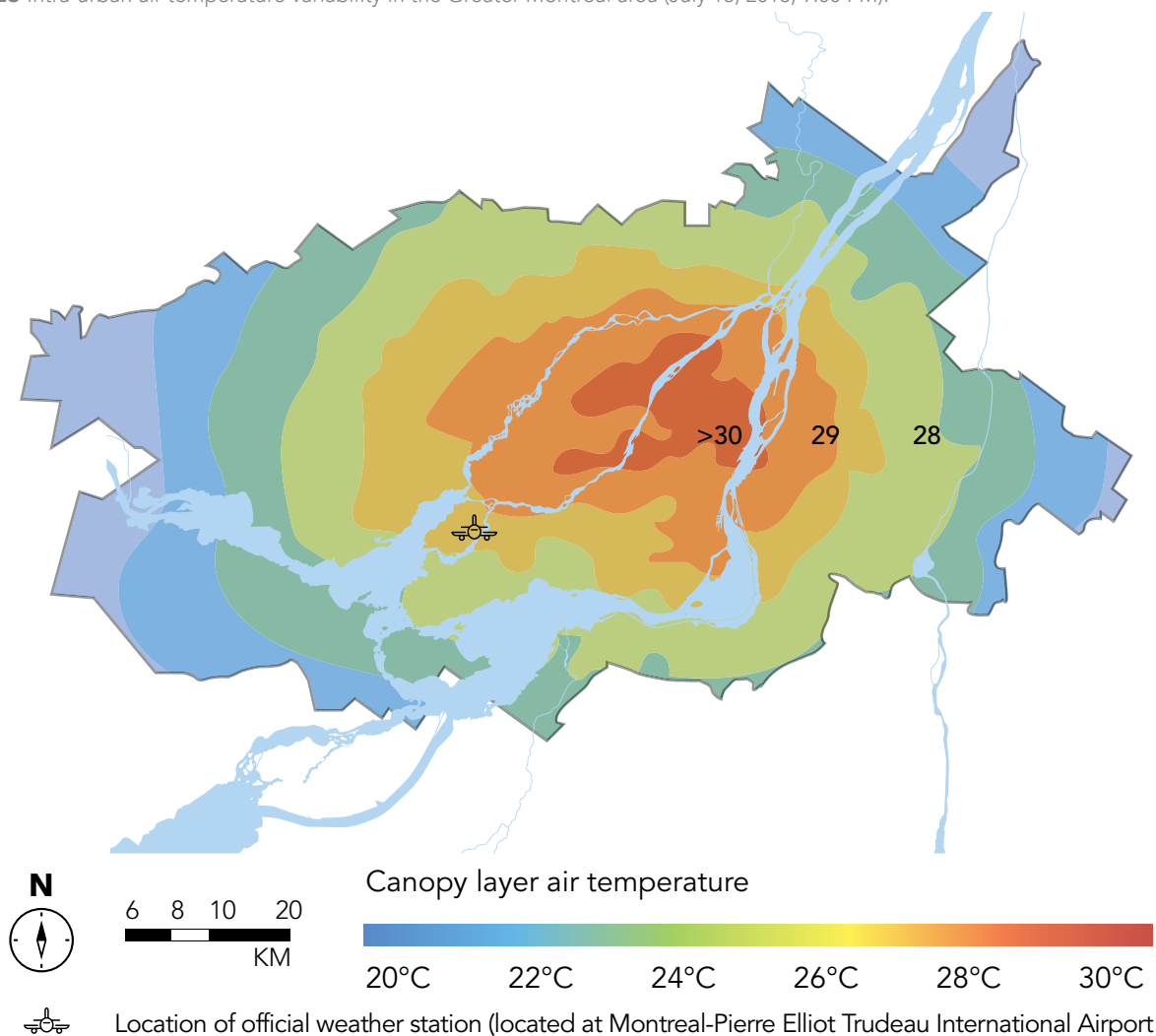
In metropolitan areas, regional health agencies base their heat alert thresholds and mortality/morbidity statistics on official weather stations, mostly located at airports, which are protected from urban influence. With environmental characteristics of residential areas significantly different from those found at airports, urban meteorological monitoring has now demonstrated that heat alert thresholds can be reached in certain localized areas (see Figure 5.26) before being observed at those official stations (66).

Such meteorological measurement campaigns – such as 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.

Figure 5.26 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 Québec, 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, and to serve as a climate service for health application. This capacity-building initiative was part of a 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

Authors: Y. Li, Y. Jin, Y. Cheng, C. Li and Z. Wu (Institute of Environmental Health and Related Product Safety, China CDC); C. Peng, S. Yu and D. Fang (Shenzhen CDC); Y. Xu, X. Chen and Q. Wang (Jiangsu Provincial CDC); G. Cui, C. Yang and L. Lan (Harbin CDC); S. Luo and Y. Wang (Chongqing CDC); M. Jin (Qijiang District CDC of Chongqing).

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 (67–69). 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 workplan, implementation and progress of the project.

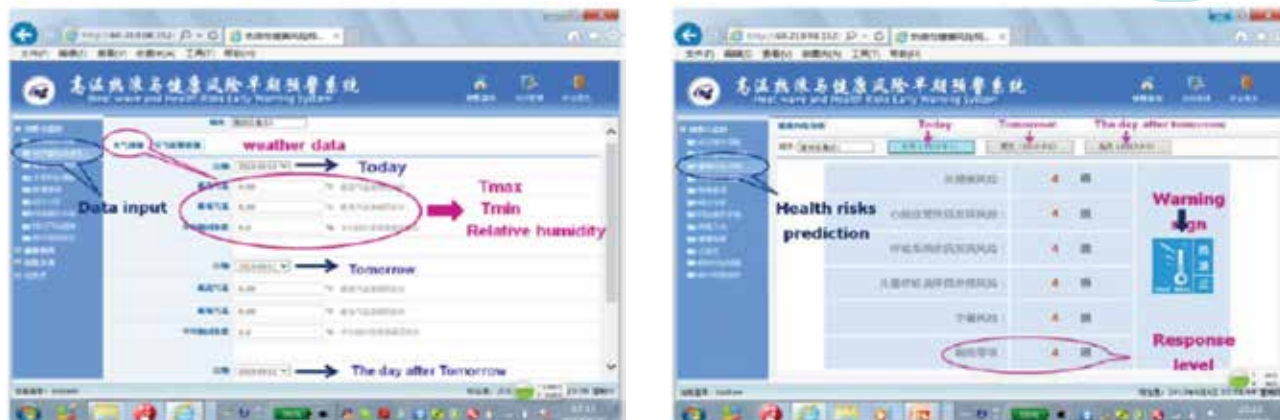
The project was piloted in four cities: Harbin, Nanjing, Shenzhen and Chongqing, located in different climate zones within China.

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 (PM₁₀, SO₂, NO₂). 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.
- **Risk models** were used to develop and pilot the heat wave early warning system in the selected communities. The system includes data input, the health risk models, and communication modules 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.

Figure 5.27 Heat Early Warning System online platform. a) data input module; b) heat risk prediction tool.



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 Centers for Disease Control (CDC), Shenzhen CDC, Harbin CDC and Chongqing CDC made equal contributions to this work.



The early warning system was implemented through the local centres for disease control 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 groups, 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 students 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, and health risk information issuing and health education, were evaluated by experts in different fields of statistics, health, meteorology, environmental protection, and health education through expert evaluation meetings.

BENEFITS AND LESSONS

The early warning system 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.

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

Authors: S. Kienberger, L. Morper-Busch, M. Hagenlocher (Z_GIS, University of Salzburg, Austria); A. Morse (Department of Geography and Planning, University of Liverpool, UK); A. Tompkins (Earth System Physics, ICTP, Italy); D. Taylor (Department of Geography, NUS, Singapore).

CONTEXT

Global climate change is projected to have geographically varied and potentially substantial negative effects on health (70), with sub-Saharan Africa particularly vulnerable (71). Malaria remains one of the world's most devastating infectious diseases, with both the malaria vector and pathogen affected by climatic conditions (72). Prevailing levels of social vulnerability are increasingly recognized as additionally critical determinants of impact (73). Recent reports call for vulnerability and risk to be at the centre of future assessments of climate change impacts, and for increased research on effective decision-support systems.

The European Union-funded HEALTHY FUTURES (74) research project was designed to address these assessments. Completed at the end of 2014, 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) countries.



Enabling environment

Capacity-building

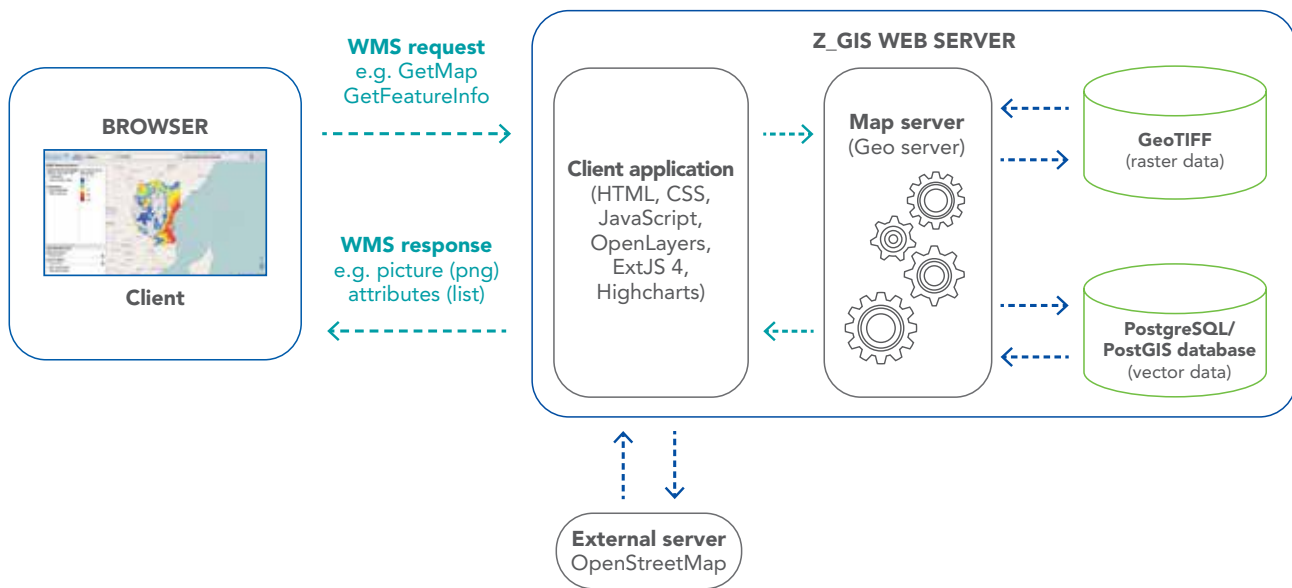
Research

Product and service development

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 5.28). Currently, the 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 the HEALTHY FUTURES Atlas in supporting decisions over 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.

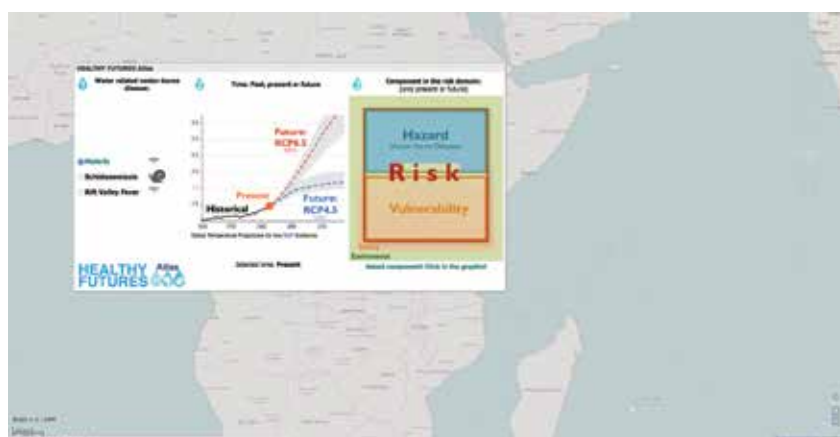
Figure 5.28 HEALTHY FUTURES Atlas WebGIS architecture.



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 the 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: 1) infectious diseases targeted by the HEALTHY FUTURES project; 2) time, allowing comparisons of current conditions with a range of future projections, while also allowing access to information on historical outbreaks; and 3) different components of risk, in accordance with the Intergovernmental Panel on Climate Change (IPCC) AR5 (Figure 5.29).

CASE STUDY 5M

Figure 5.29 Screen-shot of introduction window of the HEALTHY FUTURES Atlas.



The 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 (75). The projected climatic conditions drive two state-of-the-art dynamic malaria transmission models (LMM and VECTRI) (78) 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 5.30). 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 5.30 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.

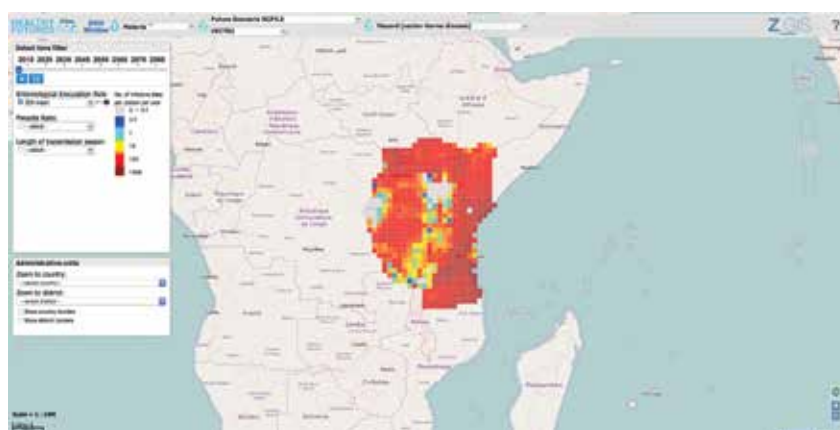
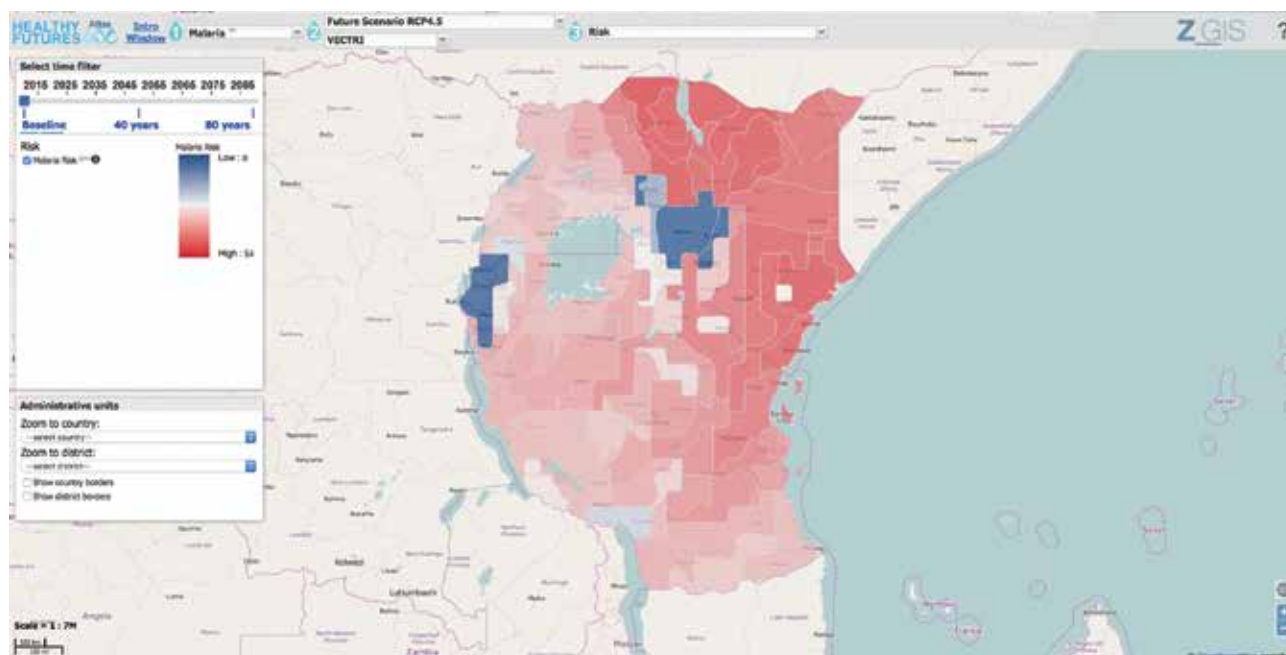


Figure 5.31 Screen shot of projected malaria risk under high-estimate of projected climate change (scenario RCP8.5) for period 2045–2055. Underlying EIR hazard projected according to VECTRI model; index of social-vulnerability determined through discussions with experts. National and health district boundaries shown for EAC countries.



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/>).



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, the 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, the 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 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, and 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, the HEALTHY FUTURES Atlas adds value to outputs from Group on Earth Observation (GEO), Copernicus and Global Monitoring for Environment and Security 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 levels like the Eastern African Community, as both climate change and infectious diseases are transboundary challenges.

CASE STUDY 5N

PROJECTIONS AND SCENARIOS

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

Authors: B. Smith (Public Health Risk Sciences Division, National Microbiology Laboratory, Public Health Agency of Canada); T. Ruthman, E. Sparling, H. Auld, N. Comer (Risk Sciences International, Canada); I. Young, A. Lammerding, A. Fazil (Public Health Risk Sciences Division, National Microbiology Laboratory, Public Health Agency of Canada).

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 (78). Risk modelling tools are needed to project the impacts of weather, climate and climate change on human health, and to assess the effectiveness of potential adaptation responses (79).

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 (80). 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 5.31). 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 Figure 5.33.



Research

Product and service development

Application

Figure 5.32 Key components of the risk and adaptation modelling framework.

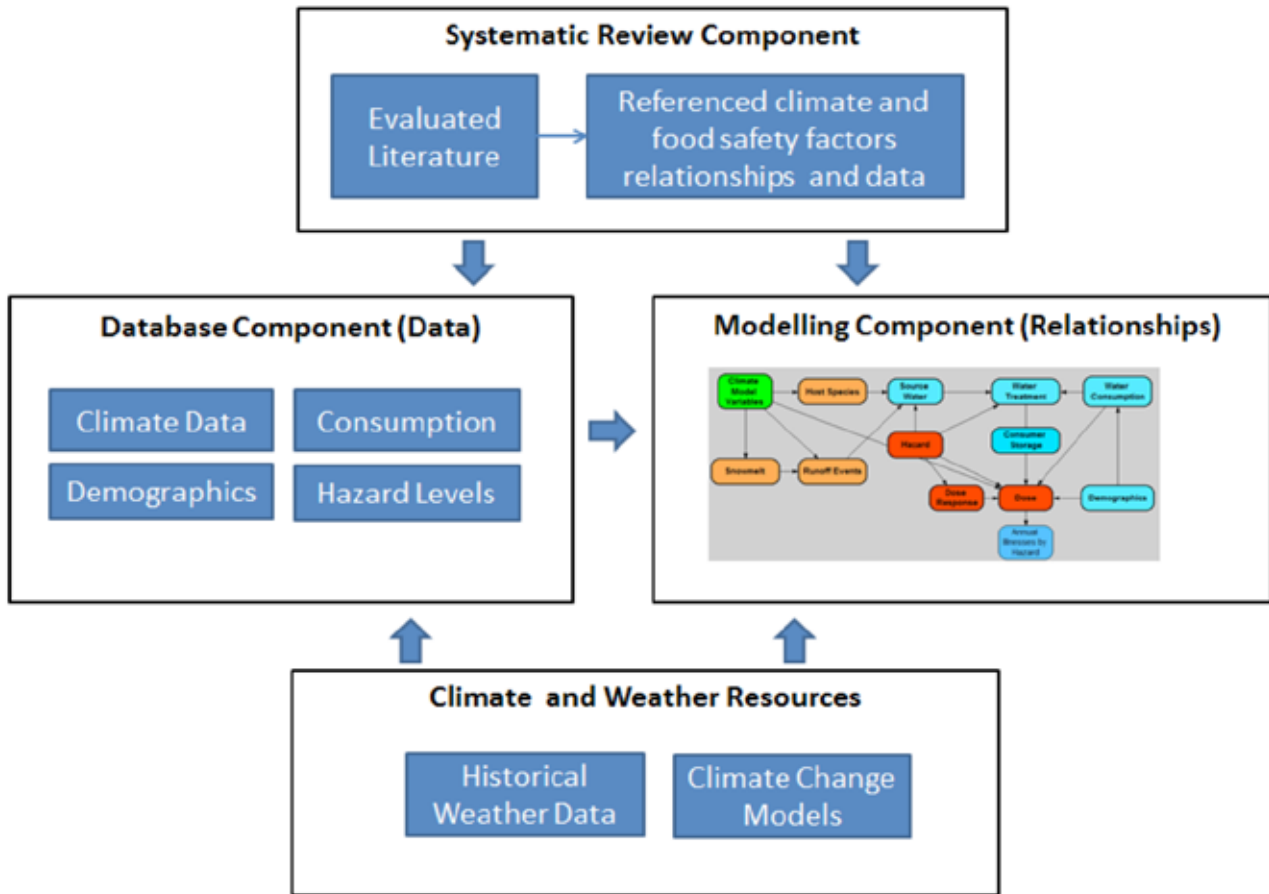


Figure 5.33 Summary of case studies developed using the risk modelling framework to project the impacts of climate change on food and water safety.

| 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 5N

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 (81), and the World Climate Research Programme (82). Meteorological and climate information varied for each risk model (Figure 5.33), 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.

Figure 5.34 Pacific Coast oyster farming. Photo credit: Tara Schmidt.



Product and service development

Application

Research

ACKNOWLEDGEMENTS



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 climate changes. 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 working together to develop 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 alternative climate scenarios.

PROJECTIONS AND SCENARIOS

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. Lubber (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 (83). 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 14 kilometres) 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

Capacity-
building

Research

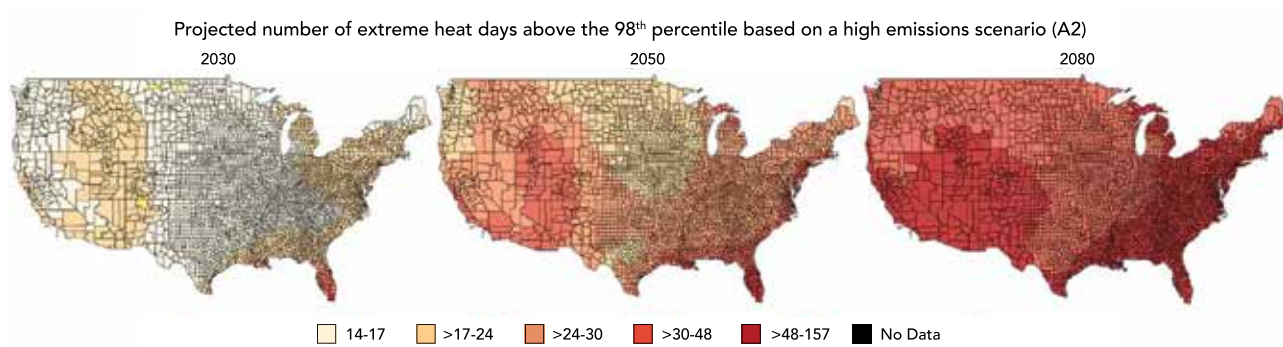
Product and service
development

Application

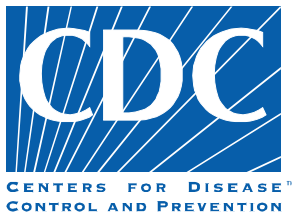
Since a meaningful geographic unit of resolution relevant for public health surveillance in the US is a 'county', information in the gridded output was converted to conform to county boundaries.

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 (84). 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 5.35 for 2030, 2050 and 2080.

Figure 5.35 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 the CDC are currently using this information to prepare for future vulnerabilities from extreme heat in respective jurisdictions (85). The spatial scale relevant to public health decision-making should be considered when transforming the climate data for use by public health practitioners.

REFERENCES

ECUADOR

1. Cardenas R et al. Impact of climate variability in the occurrence of leishmaniasis in north-eastern Colombia. *Am. J. Trop. Med. Hyg.* 2006. Vol 75(2). Pp. 273-277.
2. Carlton E et al. Heavy Rainfall Events and Diarrhea Incidence: The Role of Social and Environmental Factors. *Am. J. Epidemiol.* 2014. Vol 179(3). Pp 344-352. doi: 10.1093/aje/kwt279
3. Bhavnani D et al. Impact of Rainfall on Diarrhoeal Disease Risk Associated with Unimproved Water and Sanitation. *Am J Trop Med Hyg* 2014 Vol 90(4). Pp 705-711.
4. Montero J. Evaluación externa final del proyecto: Intervención en epidemiología comunitaria para el control y vigilancia de la morbi-mortalidad evitable en San Lorenzo y Eloy Alfaro. Centro de Epidemiología Comunitaria y Medicina Tropical. 2012. (Spanish) Available at: http://www.cooperacionspanola.es/sites/default/files/8.evaluacion-ccomet_esmeraldas_ecuador1.pdf (Accessed 30 Oct 2017).
5. Moya R. Climates of Ecuador. National Institute of Meteorology and Hydrology 2006. Ecuador.
6. Palacios J. Supit. Periods of Rain Start and End in Ecuador. Institute of National Meteorology and Hydrology 1989. Ecuador.
7. Schafrick N et al. Spatial Clustering of *Aedes aegypti* Breeding Container Related to Characteristic in Coastal Ecuador. *American Society of Tropical Medicine and Hygiene* 2013. doi: 10.4269 / ajtmh.12-0485.
8. Terradez M. Principal Component Analysis. Secretary of State for Education and Universities 2010. Spain.
9. Tsai C et al. Exploring the spatial and temporal relationships between mosquito population dynamics and dengue outbreaks based on climatic factors. *Stoch Environ Res Risk Assess* 2012 Vol 26(5). Pp 671-680 doi: 10.1007 / s00477-011-0527z.
10. Villa S et al. Seasonal mortality from diarrhoea among Mexican children. *Bulletin of the World Health Organization* 1999 Vol 77(5). Pp. 375-380.
11. Wolf D et al. Analysis of aggressiveness and concentration of rainfall in Venezuela plains region. *Bioagro* 2010 Vol 22(3). Pp.169-176.
12. Stewart-Ibarra AM et al. Spatiotemporal clustering, climate periodicity, and social-ecological risk factors for dengue during an outbreak in Machala, Ecuador, in 2010. *BMC Infect Dis* 2014 Vol 14. P 610.
13. Stewart Ibarra AM and Lowe R. Climate and non-climate drivers of dengue epidemics in southern coastal Ecuador. *Am J Trop Med Hyg* 2013 Vol 88. Pp 971-981.

Enabling environment

Capacity-building

Research

Product and service development

Application

Evaluation

ECUADOR

14. Stewart-Ibarra AM et al. Dengue Vector Dynamics (*Aedes aegypti*) Influenced by Climate and Social Factors in Ecuador: Implications for Targeted Control. PLOS ONE 2013 Vol 8: e78263.
15. Recalde-Coronel GC, Barnston AG and Muñoz ÁG. Predictability of December-April Rainfall in Coastal and Andean Ecuador. J Appl Meteorol Climatol 2014.
16. Muñoz ÁG et al. An Environmental Watch System for the Andean Countries: El Observatorio Andino. Bull Am Meteorol Soc 2010 Vol 91. Pp 1645–1652.

ETHIOPIA

17. Midekisa A, Senay GB and Wimberly MC. Multisensor earth observations to characterize wetlands and malaria epidemiology in Ethiopia. Water Resources Research 2014 Vol 50. Pp 8791-8806.
18. Midekisa A et al. Remote sensing-based time series models for malaria early warning in the highlands of Ethiopia. Malaria Journal 2012 Vol 11. P 165.
19. Wimberly MC et al. A computer system for forecasting malaria epidemic risk using remotely-sensed environmental data. Proceedings of the 2012 International Congress on Environmental Modelling and Software, Leipzig, Germany, July 1-5.
20. Wimberly, MC et al. Spatial synchrony of malaria outbreaks in a highland region of Ethiopia. Tropical Medicine & International Health 2012 Vol 17. Pp 1192-1201.
21. Wimberly, MC et al. EPIDEMIA – An EcoHealth informatics system for integrated forecasting of malaria epidemics. Proceedings of the 2014 International Congress on Environmental Modelling and Software, San Diego, CA, June 15-19, 2014.

BRAZIL

22. McMichael AJ, Woodruff RE, Hales S. Climate change and human health: present and future risks. The Lancet, 367 (9513), p.859, 2006 doi: [http://dx.doi.org/10.1016/S0140-6736\(06\)68079-3](http://dx.doi.org/10.1016/S0140-6736(06)68079-3)
23. Corvalan, C.; Hales, S.; McMichael, A. Ecosystems and Human Well-Being: Health Synthesis. Millennium Ecosystem Assessment; World Health Organization: Geneva, Switzerland, 2005. Available at: <https://www.millenniumassessment.org/documents/document.356.aspx.pdf> (Accessed 5 Oct 2017).
24. Vera C et al. Needs Assessment for Climate Information on Decadal Timescales and Longer. Procedia Environmental Sciences Vol 1, Edited for the World Meteorological Organization by M.V.K. Sivakumar MVK, Nyenzi BS and Tyagi A. 2010. Pp 275-286.
25. Silva DRX, Variabilidade climática, vulnerabilidade ambiental e saúde: os níveis do rio Negro e as doenças relacionadas à água em Manaus. 2014, Thesis, ID: tes-5949. <http://pesquisa.bvsalud.org/enfermeria/resource/pt/tes-5949> (Accessed 5 Oct 2017).

Enabling environment

Capacity-building

Research

Product and service development

Application

Evaluation

HUNGARY

26. Confalonieri U et al. Human health. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to: Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, eds). 2007. New York: Cambridge University Press, Pp 391-431.
27. Commission of the European Communities. *White Paper Adapting to climate change: Towards a European framework for action*. 2009. Brussels. 147 final.
28. Field CB et al. *Climate change 2014: impacts, adaptation, and vulnerability. Volume I: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press 2014. Cambridge and New York.
29. Ariano R et al. Possible role of climate changes in variations in pollen seasons and allergic sensitizations during 27 years. *Ann Allergy Asthma Immunol*. 2010 Vol 104(3). Pp 2012-222.
30. Bobvos J et al. A statistical software to calculate climate specific pollen indicator: P.E.A.S. 2014. *Pollen exposure analyser software (Version 1.6)* (Hungarian). Available at: <http://oki.antsz.hu> (Accessed 23 Oct 2017).
31. Péczely, Gy. *Climatology (Hungarian)* Nemzeti Tankönyvkiadó (National Schoolbook Publisher) 1998. Budapest, Hungary.

SOLOMON ISLANDS

32. World Health Organization et al. *World malaria report 2013*.
33. Feachem RG et al. Call to action: priorities for malaria elimination. *The Lancet* 2010 Vol 376 (9752). Pp 1517–1521.
34. Russell T et al. Successful malaria elimination strategies require interventions that target changing vector behaviours. *Malaria Journal* 2013 Vol 12(1). P 56.
35. Bugoro H et al. Influence of environmental factors on the abundance of *Anopheles farauti* larvae in large brackish water streams in Northern Guadalcanal, Solomon Islands. *Malaria Journal* 2011 Vol 10(1). P 262.
36. Australia, Bureau of Meteorology, CSIRO (Australia) ICCAI (ICCAI), Pacific Climate Change Science Program (PCCSP), Australian Agency for International Development. *Climate change in the Pacific: scientific assessment and new research*. 2011. Collingwood, Vic., CSIRO Pub.

UGANDA

37. Eisen RJ et al. Assessing human risk of exposure to plague bacteria in northwestern Uganda based on remotely sensed predictors. *Am. J. Trop. Med. Hyg.* 2010 Vol 82. Pp 904-911.
38. Eisen RJ et al. Flea diversity as an element for persistence of plague bacteria in an east African plague focus. *PLoS ONE* 2012 Vol 7: e35598, doi:10.1371/journal.pone.0035598.
39. Monaghan AJ et al. A regional climatology of West Nile, Uganda, to support human plague modeling. *J. Appl. Meteor. Climatol.* 2012 Vol 51. Pp 1201-1221.

- 40. MacMillan K et al. Climate predictors of the spatial distribution of human plague cases in the West Nile region of Uganda. *Am. J. Trop. Med. Hyg.* 2012 Vol 86. Pp 514-523.
- 41. Moore SM et al. Improvement of disease prediction and modeling through the use of meteorological ensembles: Human plague in Uganda. *PLoS ONE* 2012 Vol 7. doi:10.1371/journal.pone.0044431.

CANADA

- 42. Warren FJ. and Lemmen DS. Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation. Climate Change Impacts and Adaptation Division, Natural Resources Canada. 2014. Available at: <http://www.nrcan.gc.ca/environment/impacts-adaptation/assessments/10029> (Accessed 1 Oct 2017)
- 43. Wotton BM, Nock CA and Flannigan MD. Forest Fire Occurrence and Climate Change in Canada; *International Journal of Wildland Fire* 2010 Vol 19(3). Pp. 253–271.
- 44. IPCC. Climate Change 2014. Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Field CB et al. eds). Cambridge University Press 2014. Cambridge, United Kingdom and New York, NY, USA.
- 45. Berry P et al. Chapter 7. Human Health. In Warren FJ and Lemmen DS eds: Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation. Climate Change Impacts and Adaptation Division, Natural Resources Canada. 2014. Available at: http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2014/pdf/Chapter7-Human-Health_Eng.pdf (Accessed 1 Oct 2017).
- 46. Finlay, SE et al. Health Impacts of Wildland Fires. *PLOS Current Disasters* 2012 Vol 1. doi: 10.1371/4f959951cce2c.
- 47. Manitoba Health. Wildland fire smoke and air quality health index year end report. Internal report prepared for Health Canada. 2013.
- 48. Environment Canada. Air Quality Health Index. 2014. Available at: <http://www.ec.gc.ca/cas-aqhi/> (Accessed 1 Oct 2017).
- 49. Pavlovic R et al. The FireWork Air Quality Forecast System with Near-Real-Time Biomass Burning Emissions: Recent Developments and Evaluation of Performance for the 2015 North American Wildfire Season. *Journal of the Air & Waste Management Association* (2016) Vol 66(9). Pp 819-41. doi: 10.1080/10962247.2016.1158214
- 50. Yao J, Brauer M and Henderson SB. Evaluation of a wildfire smoke forecasting system as a tool for public health protection. *Environmental Health Perspectives (Online)* 2013 Vol 121(10). P 1142.

Enabling environment

Capacity-building

Research

Product and service development

Application

Evaluation

UGANDA

51. Gething PW et al. Climate change and the global malaria recession. *Nature* 2010 Vol 465. Pp 342-345.
52. WHO. World Malaria Report. 2013. Geneva, Switzerland: World Health Organization.
53. Uganda Bureau of Statistics and ICF International. Uganda Demographic and Health Survey 2011. 2012. Kampala, Uganda: UBOS and Calverton, Maryland: ICF International Inc.
54. Yeka A et al. Malaria in Uganda: Challenges to control on the long road to elimination: I. Epidemiology and current control efforts. *Acta Tropica* 2012 Vol 121. Pp 184-195.
55. Mordecai EA et al. Optimal temperature for malaria transmission is dramatically lower than previously predicted. *Ecology letters* 2013 Vol 16. Pp 22-30.
56. Paaijmans KP et al. Unexpected high losses of *Anopheles gambiae* larvae due to rainfall. *PLoS ONE* 2007 Vol 2: e1146.
57. Tompkins AM and Ermert V. A regional-scale, high resolution dynamical malaria model that accounts for population density, climate and surface hydrology. *Malaria Journal* 2013 Vol 12. P 65.
58. Smith T et al. Relationships of malaria morbidity with exposure to *Plasmodium falciparum* in young children in a highly endemic area. *American Journal of Tropical Medicine and Hygiene* 1998 Vol 59. Pp 252–257.
59. Richardson DS. Skill and relative economic value of the ECMWF ensemble prediction system. *Quarterly Journal of the Royal Meteorological Society* 2000 Vol 126(563). Pp 649-667.

PANAMA

60. Hewitt, CD. The Impact on Human Health of Climate and Climate Change: Research in the ENSEMBLES Project from Seasonal to Centennial Timescales. In: Thomson MC, Garcia-Herrera R and Beniston M. *Seasonal Forecasts, Climatic Change and Human Health*. Springer 2008. Pp 5-29.
61. International Diabetes Federation. *Diabetes and Climate Change*. June 2012. Available at: <https://ncdalliance.org/sites/default/files/rfiles/IDF%20Diabetes%20and%20Climate%20Change%20Policy%20Report.pdf> (Accessed 5 Oct 2017).
62. Bio-climate Bulletin. Gorgas Memorial Institute for Health Studies (ICGES). Available at: <https://www.hidromet.com.pa/> (Accessed 5 Oct 2017).

QUEBEC

63. Chebana F et al. A general and flexible methodology to define thresholds for heat health watch and warning systems, applied to the province of Québec (Canada). *International Journal of Biometeorology* 2013 Vol 57(4). Pp 631-44.
64. Eum HI, Gachon P and Laprise R. Developing a likely climate scenario from multiple regional climate model simulations with an optimal weighting factor, *Climate Dynamics* 2014 Vol 43. Pp.11-35.

- 65. Toutant S et al. An open source Web application for the surveillance and prevention of the impacts on public health of extreme meteorological events: the SUPREME system. *International Journal of Health Geographics* 2011 Vol 10. P 39. doi:10.1186/1476-072X-10-39.
- 66. Martin P, Baudouin Y and Gachon P. An alternative method to characterize the Surface Urban Heat Island. *Int J Biometeorol* 2015 Vol 59. P 849. doi: <https://doi.org/10.1007/s00484-014-0902-9>

CHINA

- 67. Oudin D, Forsberg B and Rockl J. Heat wave impact on morbidity and mortality in the elderly population: A review of recent studies. *Maturitas* 2011 Vol 69. Pp. 99-105.
- 68. Yonghong L et al. Association between high temperature and mortality in metropolitan areas of four cities in various climatic zones in China: a time-series study. *Environmental Health* 2014 Vol 13. Pp. 65-74.
- 69. D'Ippoliti D et al. The impact of heat waves on mortality in 9 European cities: results from the EuroHEAT project. *Environ Health* 2010 Vol 9. P 37.

EASTERN AFRICA

- 70. WHO. Ed: Hales S et al. Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s. 2014 ISBN 978 92 4 150769 1. Available at: http://apps.who.int/iris/bitstream/10665/134014/1/9789241507691_eng.pdf (Accessed 1 Oct 2017).
- 71. McMichael AJ, Montgomery H and Costello A. Health risks, present and future, from global climate change. *British Medical Journal* 2012 Vol 344: e1359.
- 72. Siraj, AS et al. Altitudinal Changes in Malaria Incidence in Highlands of Ethiopia and Colombia. *Science* (2014) Vol 343. Pp 1154-1158.
- 73. Smith KR et al. Human health: impacts, adaptation and co-benefits. In: IPCC WGII AR5, 2014. Chapter 11.
- 74. Healthy Futures Atlas. Available at: <http://www.healthyfutures.eu/> (Accessed 1 Oct 2017).
- 75. Meinshausen M. et al. The RCP greenhouse gas concentrations and their extensions from 1765 to 2300. *Climatic Change* 2011 Vol 109. Pp 213-241.
- 76. Hoshen, MB and Morse AP. A weather-driven model of malaria transmission. *Malaria Journal* 2004 Vol 3: Article # 32.
- 77. Tompkins, A.M. and Ermert, V. (2013) A regional-scale, high resolution dynamical malaria model that accounts for population density, climate and surface hydrology. *Malaria Journal*, 12: Article # 65

Enabling environment

Capacity-building

Research

Product and service development

Application

Evaluation

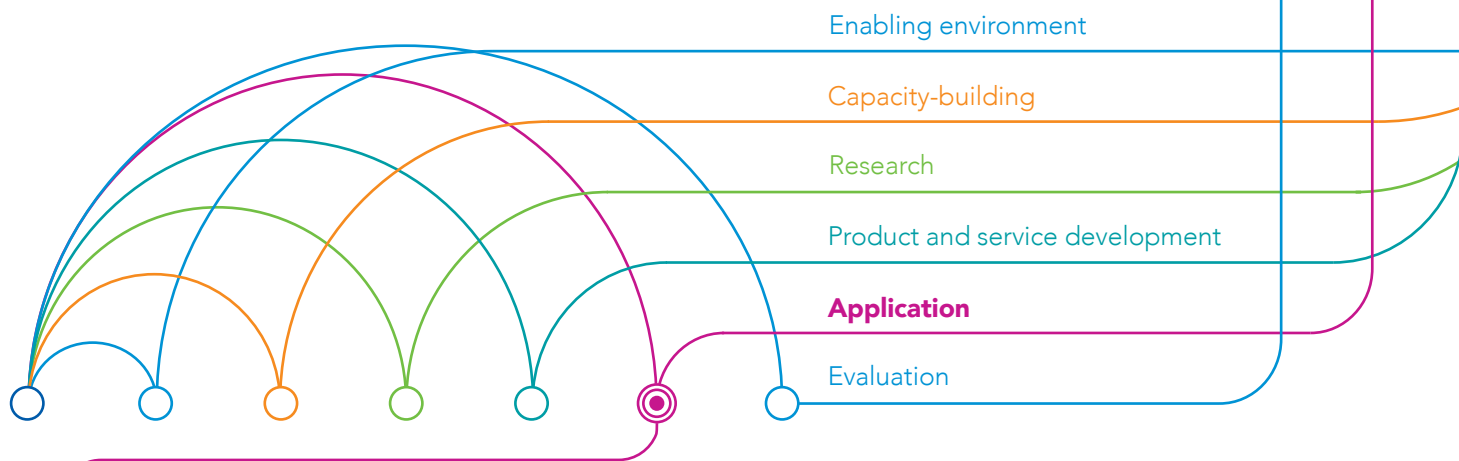
CANADA

- 78. Charron D et al. Human health in a changing climate: A Canadian assessment of vulnerabilities and adaptive capacity. Health Canada 2010, Ottawa, Canada.
- 79. Ebi K. Healthy people 2100: Modeling population health impacts of climate change. Climatic Change 2005 Vol 88. Pp 5-19.
- 80. Smith BA et al. A risk modelling framework to evaluate the impacts of climate change and adaptation on food and water safety. Food Research International 2015. Vol 68. Pp 78-85.
- 81. McKenney DW et al. Customized spatial climate models for North America. Bulletin of the American Meteorological Society 2011 Vol 92. Pp 1611-1622.
- 82. World Climate Research Programme. CMIP5 Phase 5 <https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip5> (Accessed 5 Oct 2017).

UNITED STATES

- 83. White-Newsome, JL et al., Survey of County-Level Heat Preparedness and Response to the 2011 Summer Heat in 30 U.S. States. Environ Health Perspect. doi:10.1289/ehp.1306693
- 84. CDC, Tracking Environmental Health Data for Public Health Decision-Making. Available at: <http://www.cdc.gov/nceh/tracking/> (Accessed 1 Oct 2017).
- 85. Wisconsin Climate and Health Program. Understanding the Link Between Climate and Health. Available at: <http://www.dhs.wisconsin.gov/publications/P0/P00709.pdf> (Accessed 1 Oct 2017).





CHAPTER 6

6

APPLYING CLIMATE KNOWLEDGE TO PRACTICE

GOAL: Apply 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 to 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 is commonly used to enhance health decision tools, through the use of 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.

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 producing quality, reliable, usable, suitable and responsive information, the climate knowledge generated must be relevant, accessible, credible and sustainable over time. Projects that do not meet these criteria often result in unused or unsustainable products and wasted resources.



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 that establish the value of the climate service and increase its acceptance.
- 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 promoting available resources.
- Encouraging open discussion and feedback opportunities on climate products and services to increase understanding, ownership, and facilitating agreement on the essential climate service features, ensuring optimal fit-for-purpose and added value to health decision needs.
- Communicating local evidence of climate and weather impacts on community health, and highlighting 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 of 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 disease 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

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 the United Republic of Tanzania. The national malaria programme 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).

CONTEXT

More than 7 million people live in the rapidly urbanizing city of Ahmedabad, located in the state of Gujarat in Western India. Heat waves have already proven to be dangerous in the city, leading to heat stress, heat stroke and heat-related illnesses. Climate change is creating higher daily peak temperatures and longer, more frequent and intense heat waves. 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-resilient (1).

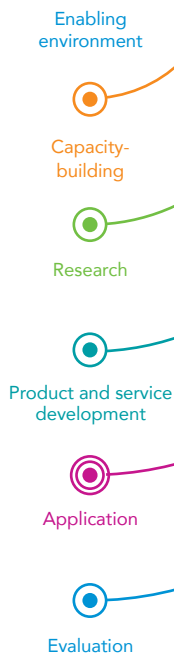


Figure 6.2 Ahmedabad survey respondents, 2011. Photo credit: Kathy Tran/Gulrez Azhar.



NEW APPROACHES

A coalition of academic, health and environmental groups partnered with the AMC in 2011 to create an early warning system and heat preparedness plan as a roadmap to save lives during dangerous heat waves (2). In collaboration with the Ahmedabad Municipal Corporation, the Ahmedabad Heat and Climate Study Group consists of Natural Resources Defense Council; Indian Institute of Public Health, Gandhinagar; Emory University; and Icahn School of Medicine at Mount Sinai, in New York City. Dr Peter Webster and Dr Violeta Toma of Georgia Institute of Technology provided the long-term temperature forecasts for the Ahmedabad health early warning system. The project was supported in part by the Climate and Development Knowledge Network.

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 to impending heat waves, along with formal communication channels to disseminate these warnings.

The team work to improve heat disaster response planning at the local level by developing an interagency heat action plan, including longer-term forecasting, which would 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 early warning system 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. Training helped medical professionals better diagnose and treat cases, and reduce mortality and morbidity with standard surveillance protocols (2). Advanced warnings helped 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 (3, 4, 5). 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. 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 6A



BENEFITS AND LESSONS

The team developed an innovative seven-day temperature forecast with international experts that complements IMD's forecast. During the hot season, the forecast is sent daily to the lead officer, providing robust forecast and weather warnings, that help to accurately determine when to declare a heat alert and initiate the inter-agency response. As a result, the local IMD has increased its capacity to provide the 5-7 day forecast to the AMC and several other cities.

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 surveys 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 better prepared for heat waves (5)¹. Over 10 cities in key 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, Odisha and Telangana. The National Disaster Management Authority has added information on heat waves to its website and the IMD has adapted its temperatures and heat wave forecasts, in addition to strengthening inter-agency communication. IMD now provides a five-day forecast to more than 100 cities around India to increase cities' capacity to warn citizens and respond to impending heat waves.

Figure 6.3 Ahmedabad residents during community survey, 2011.
Photo credit: Kathy Tran/Gulrez Azhar.



Figure 6.4 Local resident reads advertisement in Gujarati with tips on how to stay cool during extreme heat events. Photo credit: Nehmat Kaur.

ACKNOWLEDGEMENTS





Enabling environment

Product and service development

Application

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

Authors: A. Sena, C. Barcellos, C. Freitas (Oswaldo Cruz Foundation - FIOCRUZ); 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 (6, 7). 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 (8–13).

Between 1960 and 2013, 612 drought events resulted in 2.19 million deaths and 2.14 billion affected persons globally (14). In Brazil, disaster notifications are issued by municipalities, and between 1991 and 2010, there were close to 17 000 drought events recorded in 2 944 municipalities, making it the most frequent disaster by type. Of the 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 2 475 registered deaths, roughly 10%, were drought related (15). 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.

Figure 6.5 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. Therefore, it tends to attract less attention than acute emergencies, which has adverse 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. 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. This framework is adapted for drought management, emphasizing the concept of adaptation (16). The steps are shown in Figure 6.6, with examples of community participation.

CASE STUDY 6B



Enabling environment

Product and service development

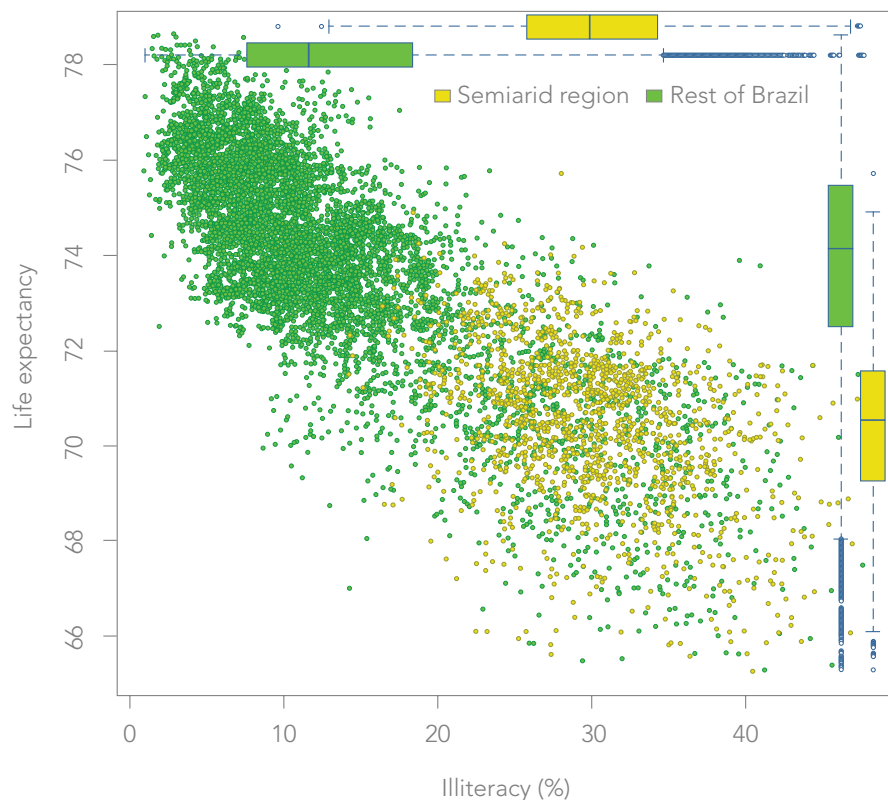
Application

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 of deaths (17).

Local governance and complete community participation are necessary for successful and sustainable actions (18). 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 (19). 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.

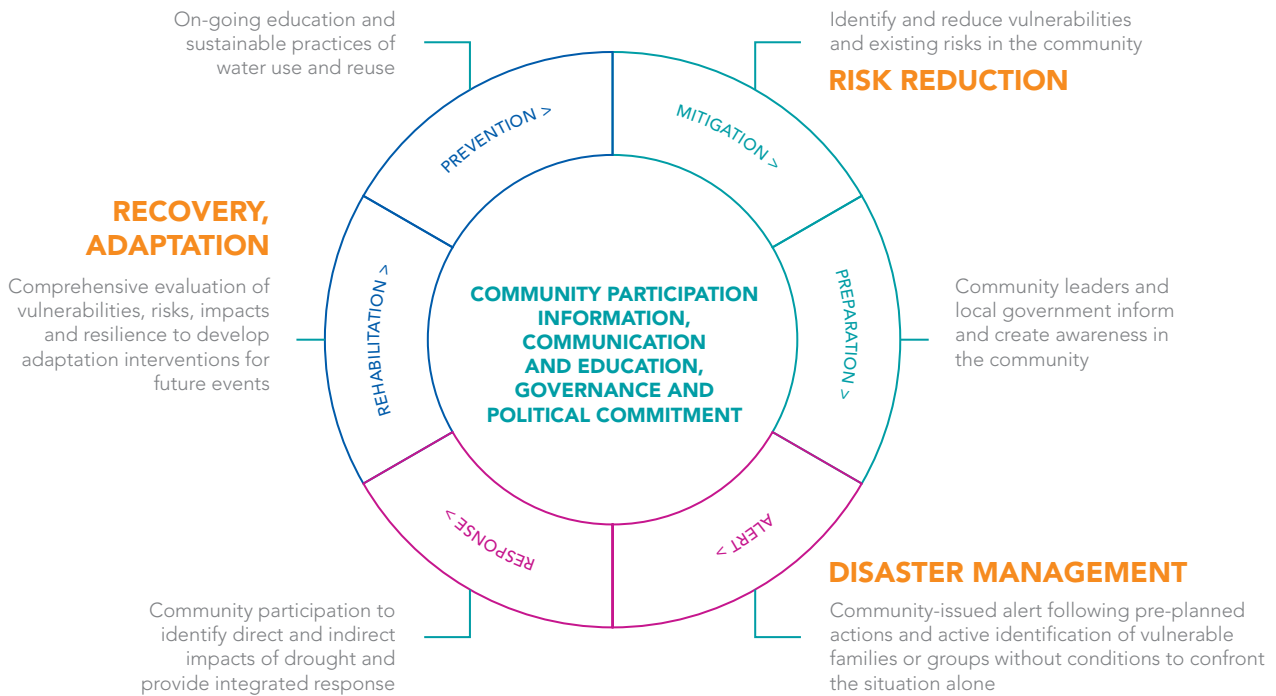
Figure 6.6 Inequalities between 1 133 municipalities in the semiarid region and 4 432 municipalities in the rest of Brazil: illiteracy (%) and life expectancy (2010).



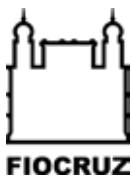
The health sector also has a key role promoting awareness of health risks and the social and environmental vulnerabilities of specific areas and communities, and to finding mechanisms to increase the resilience of local communities and local government health services. The health sector needs to ensure 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.

For further information on this case study, refer to Sena et al (20).

Figure 6.7 Adapted disaster risk reduction framework, highlighting community participation.



ACKNOWLEDGEMENTS



EARLY WARNING SYSTEMS TO GUIDE INFECTIOUS DISEASE 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 (21).

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 6.7) (22). 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 (22). 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 (23). 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 (23). 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 (23). 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 European Union structural funds for these intervention entry points.

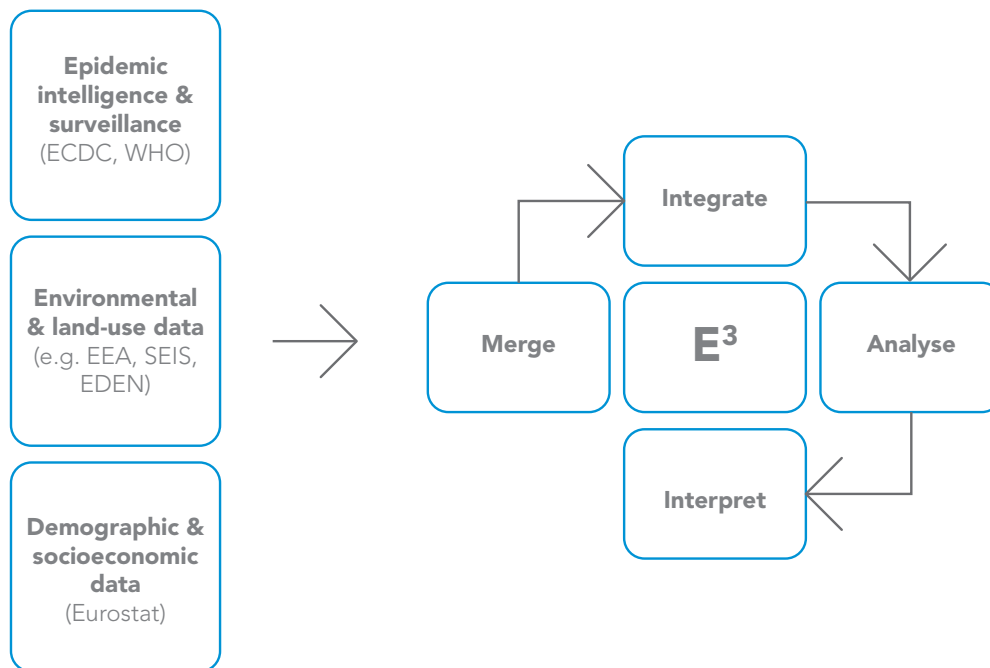


Enabling environment

Capacity-building

Product and service development

Figure 6.8 The European Environment and Epidemiology (E3) Network.



The E3 Geoportal also operates a tool for the real-time assessment of the environmental suitability of the *Vibrio* species 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 (24). 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* species. that can drive the emergence of infections. The tool provides short-term forecasts, present and past environmental suitability for these *Vibrio* species. 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 southeastern Europe. Temperature deviations from a 30-year average have been proven to be associated with these outbreaks (25). Drivers of subsequent outbreaks were computed through multivariate logistic regression models and included in prediction models (26). 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 (26).

To assist public health decision-making in Europe, several workshops have been held with Member State representatives to train them on the E3 functions.

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 (21).

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, Sergio Rene Salgado (*USAID/President's Malaria Initiative*); Madeleine Thomson (*International Research Institute for Climate and Society*).

Enabling environment

Capacity-building

Research

Product and service development

Application

Evaluation

CONTEXT

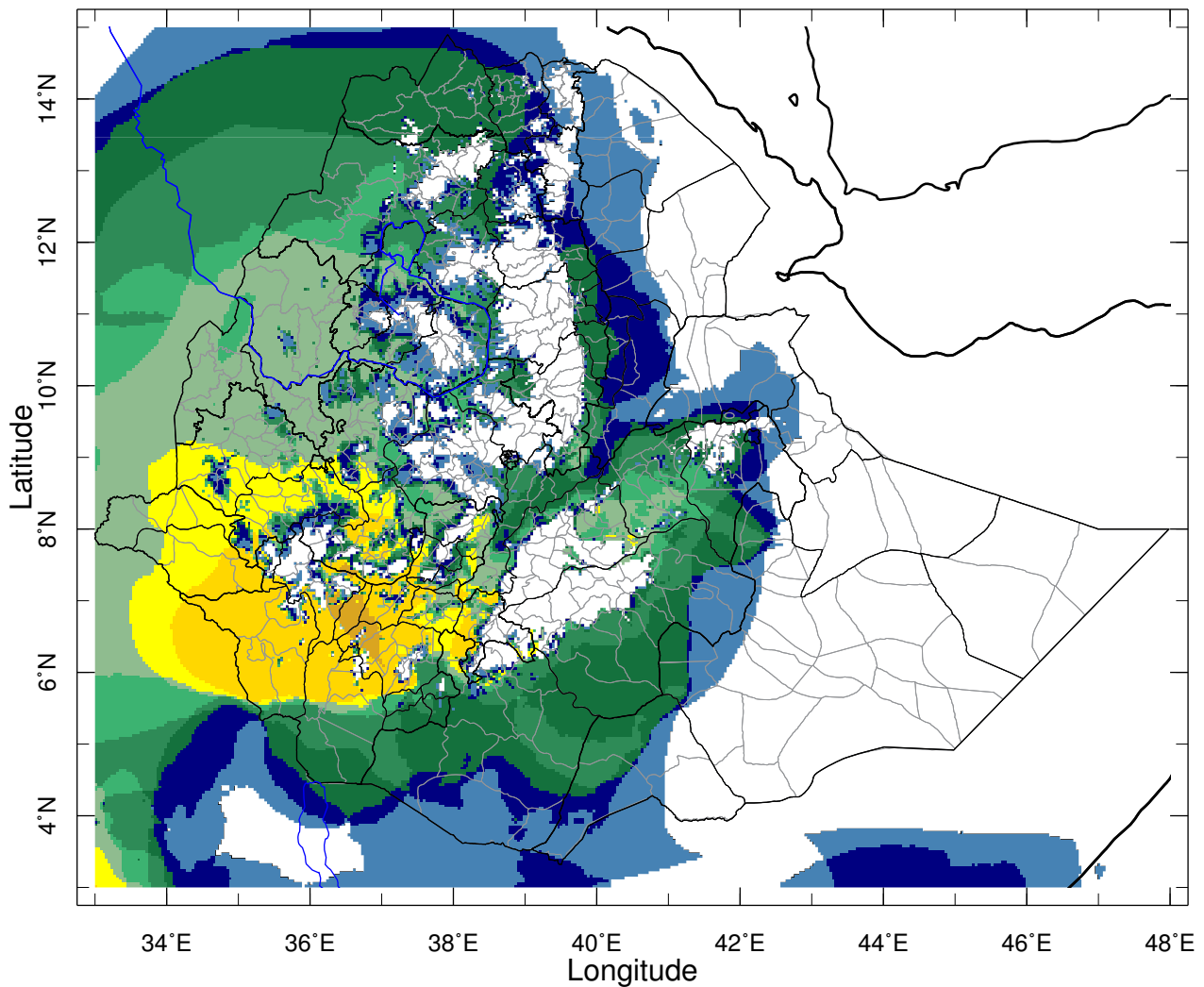
National malaria control programmes and national meteorological agencies in East Africa are pioneering new decision-support tools and partnerships to address the historical impact of climate on malaria transmission and to better prepare for the future (29). This case study highlights, in particular, 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 Partnership and the US President's Malaria Initiative (PMI). Lessons learned from incorporating climate data into malaria impact assessments (27), and other aspects of malaria planning (28), 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 (30).

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. 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).

Figure 6.9 Number of months suitable for malaria transmission, computed based on the suitability of climatological condition. Suitability is defined as the coincidence of precipitation accumulation greater than 80 mm, mean temperature between 18°C and 32°C, and relative humidity greater than 60%.



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 6D



Historically well-understood malaria stratification may be changing, however, due to recent climate trends (see Figure 6.9). Thus high-quality climate services are more crucial and in demand than ever (32). 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 (28). 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 6.10 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

Authors: P. Yaka (Direction Générale de la Météorologie, Ouagadougou - Burkina Faso); W. Thiaw (Climate Prediction Center/National Centers for Environmental Prediction/NOAA); B. Sultan (Laboratory of Ocean and Climate Science: Experimentation and Numerical Approach, Paris - France); F. Tarbangdo (Direction Générale de la Protection Sanitaire, Ministry of Health, Ouagadougou - Burkina Faso).

CONTEXT

Meningococcal meningitis (MCM) is a contagious infection disease caused by the bacteria *Neisseria meningitis*. 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 carriers 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 (35).

Enabling environment

Capacity-building

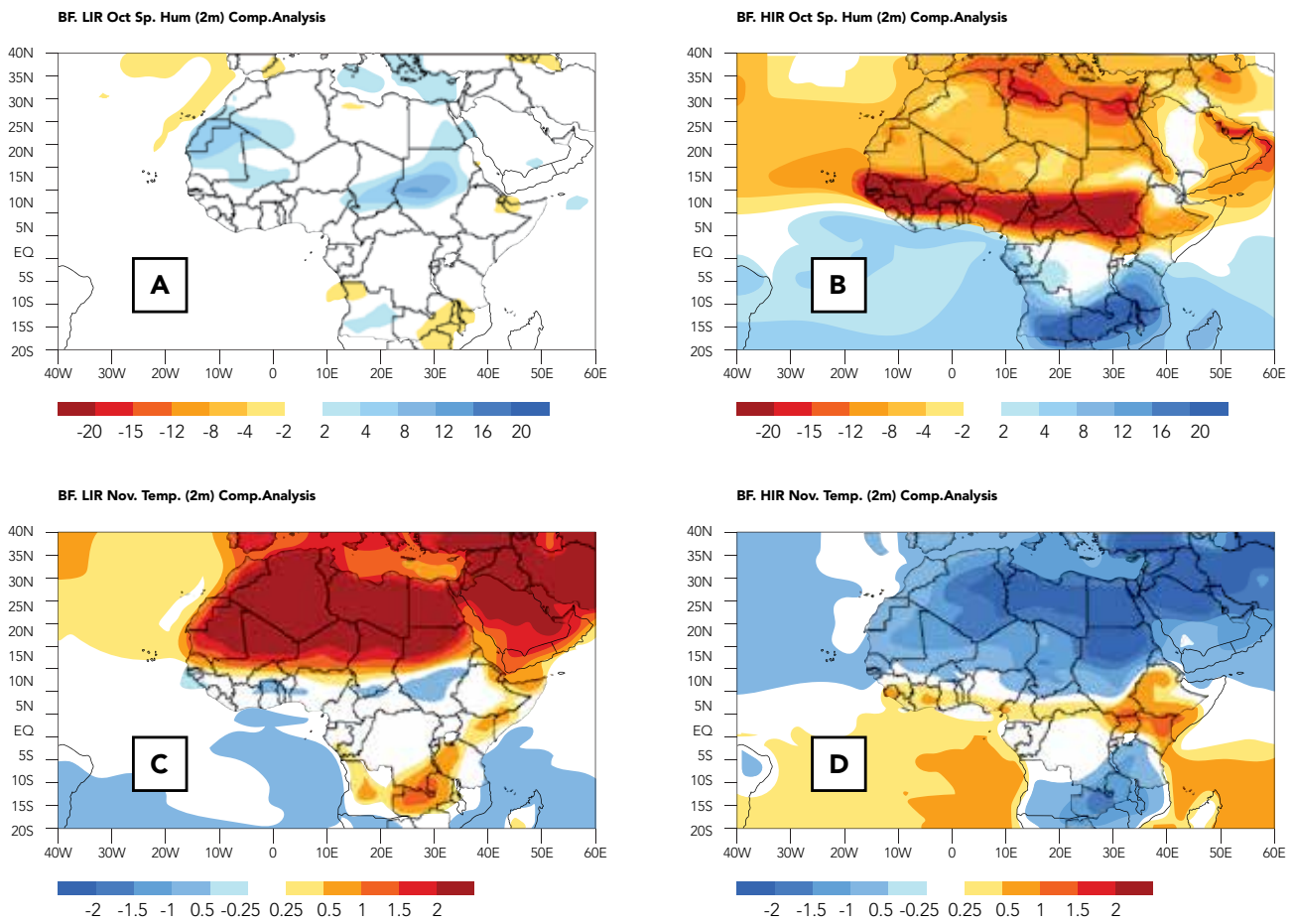
Research

Product and service development

Application

Evaluation

Figure 6.11 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 6E



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 (35). 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 (36).

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 (35). 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.

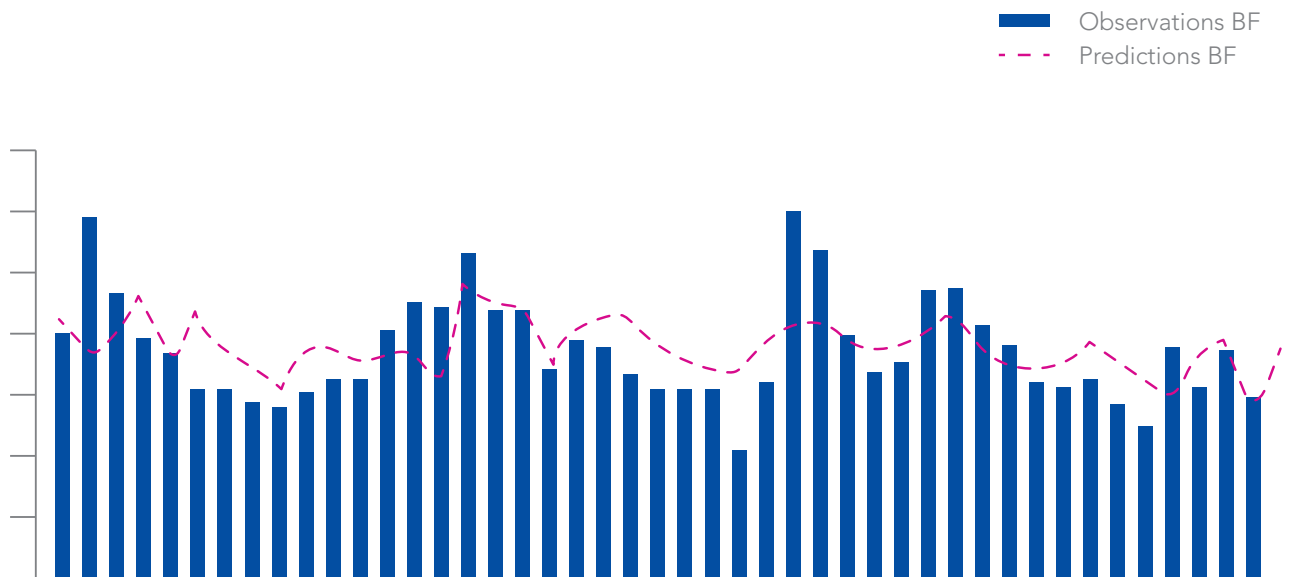
Figure 6.12 A child in Burkina Faso received the recently approved meningitis vaccine. Photo credit: WHO/Barry Rodrigue.



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 (36).

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. This is done through education, fundraising for vaccines, and putting staff and health equipment in place in case of MCM upsurge.

Figure 6.13 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

Authors: R. Lowe (Institut Català de Ciències del Clima, Spain); X. Rodó (Institut Català de Ciències del Clima/Institució Catalana de Recerca i Estudis Avançats, Spain); C. Barcellos, M. S. Carvalho (Oswaldo Cruz Foundation, Brazil); C. Coelho (Centro de Previsão de Tempo e Estudos Climáticos, Brazil); T.C. Bailey, T. Jupp, D.B. Stephenson (University of Exeter, UK); G.E. Coelho (Ministry of Health, Brazil); R. Graham (Met Office, UK); W. Ramalho (University of Brasilia, Brazil).

CONTEXT

Brazil has reported more cases of dengue fever than any other country this century (37), 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 (38–40) as part of the Leverhulme network project EUROBRISA (41) (led by the University of Exeter and the Brazilian Centre for Weather Forecast and Climate Studies, CPTEC)^j, which explored how European seasonal climate forecasts could be better exploited to improve climate resilience in South America (42). In collaboration with European and Brazilian climate services, universities and the Brazilian Climate and Health Observatory, data from different sources and spatial/temporal scales (such as dengue, climate, cartographic, demographic and socioeconomic) were 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.

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

Figure 6.14 Diagram showing the lead-time gained through a probabilistic dengue forecast driven by climate forecast and current dengue risks. Temperature forecast were produced by the empirical model described in (Coelho et al). Rainfall forecast were produced by the multi-model 3-monh average (March, April, May) precipitation forecast from the EUROBRISA integrated system. Current dengue cases were obtained from the Ministry of Health Brazil.

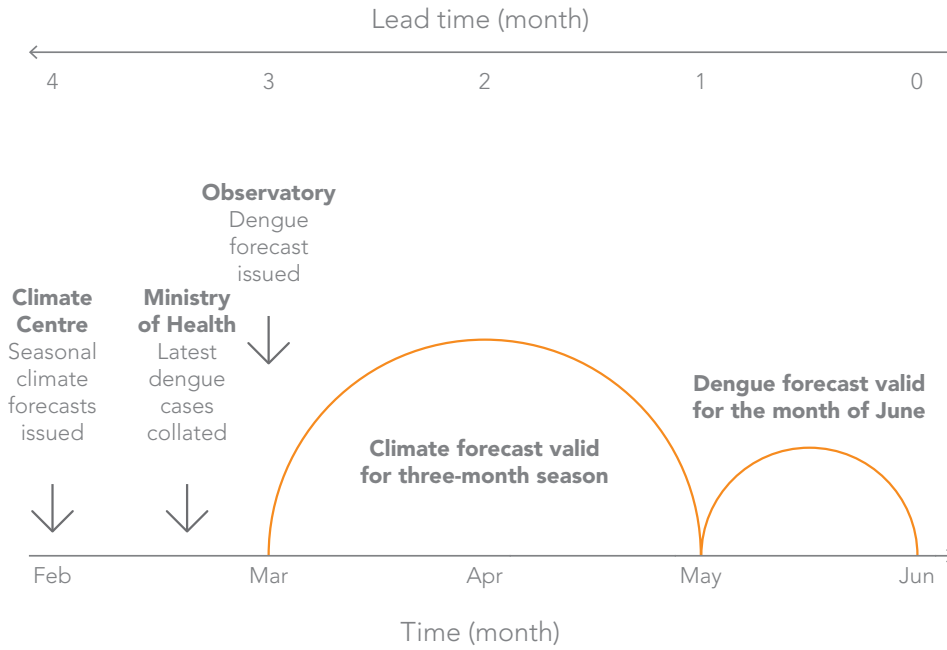
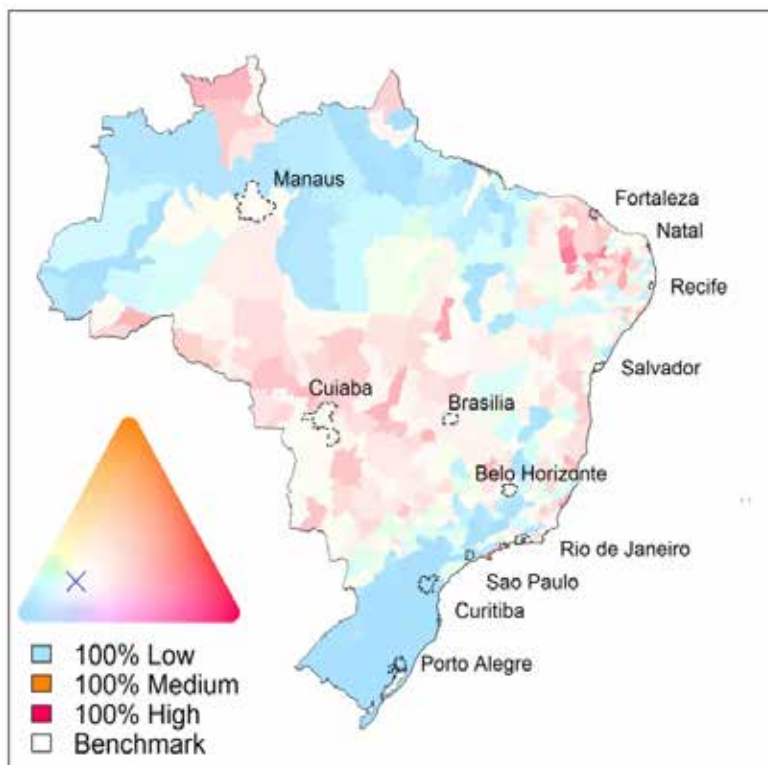


Figure 6.15 Probabilistic dengue risk forecast for Brazil, June, 2014. The continuous colour palette (ternary phase diagram, see Jupp et al.) conveys the probabilities assigned to low-risk, medium-risk, and high-risk dengue categories. The greater the colour saturation, the more certain is the forecast of a particular outcome. Category boundaries are defined as 100 cases per 100 000 inhabitants and 300 cases per 100 000 inhabitants. 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 6F



Enabling environment

Capacity-building

Research

Product and service development

Application

Evaluation

Data Collection and Management

Indicators and Thresholds

Risk Models and Maps

Forecasts

Warnings

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 (43). 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 6.13) and effectively present model results into an understandable format for stakeholders (Figure 6.14).

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 northeastern cities of Natal, Fortaleza and Recife (44). 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.

Figure 6.16 Cheering crowd during a football match. Photo credit: World Cup Portal - Government Brazil.

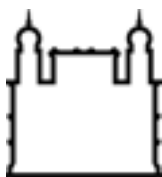


ACKNOWLEDGEMENTS

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 CNPq and Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro. The dynamic ensemble forecast data were kindly provided by European Centre for Medium-Range Weather Forecasts as part of the EUROBRISA licence agreement.



Ministério da
Saúde



FIOCRUZ

BENEFITS AND LESSONS

This timely dengue early warning assisted the ministry of health and local authorities to implement 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 (45), reported by the UK National Health Service (NHS) (46) and published by more than 18 international press outlets, including the BBC (47). 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 (48). Overall reported dengue cases for 2014 were much lower than the previous year (49), 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 (49).

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 (50), in collaboration with the Brazilian Institute for Space Research (INPE).

REFERENCES

INDIA

1. Azhar GS et al. Heat-Related Mortality in India: Excess All-Cause Mortality Associated with the 2010 Ahmedabad Heat Wave. *PLoS ONE* 2014 Vol 9(3): e91831.
2. Shah T et al. Inside Story: Addressing heat-related health risks in urban India: Ahmedabad's Heat Action Plan. *Climate and Development Knowledge Network* 2014. Available at: www.cdkn.org/resource/addressing-heat-related-risks-india (Accessed 1 Oct 2017).
3. Tran K et al. A cross-sectional, randomized cluster sample survey of household vulnerability to extreme heat among slum dwellers in Ahmedabad, India. *Int J Environ Res Public Health* 2013 Vol 10. Pp 2–3.
4. Kakkad K et al. Neonates in Ahmedabad, India, during the 2010 Heat Wave: A Climate Change Adaptation Study. *Journal of Environmental and Public Health* Vol 2014, Article ID 946875.
5. Knowlton K et al. Development and Implementation of South Asia's First Heat-Health Action Plan in Ahmedabad. *Int J Environ Res Public Health* 2014 Vol 11(4). Pp 3473-3492.

BRAZIL

6. Corvalan C, Hales S and McMichael A. *Ecosystems and Human Well-Being: Health Synthesis*. Millennium Ecosystem Assessment; World Health Organization: Geneva, Switzerland, 2005. Available at: www.millenniumassessment.org/documents/document.357.aspx.pdf (Accessed 1 Oct 2017).
7. *Atlas of Health and Climate*; World Health Organization and World Meteorological Organization: Geneva, Switzerland, 2012.
8. Mazyck PR. Drought and health. *Am. J. Public Health Nations Health* 1931 Vol 21. Pp 1198–1202. doi:10.2105/AJPH.21.11.1198.
9. Stanke C et al. Health effects of drought: A systematic review of the evidence. *PLoS Curr. Disasters* 2013. doi:10.1371/currents.dis.7a2cee9e980f91ad7697b570bcc4b004.
10. WMO. *Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes*; World Meteorological Organization: Geneva, Switzerland, 2014. Pp. 1970–2012.
11. McMichael AJ. Drought, drying and mental health: Lessons from recent experiences for future risk-lessening policies. *Aust. J. Rural Health* 2011 Vol 19. Pp 227–228.
12. O'Brien LV et al. Drought as a mental health exposure. *Environ. Res.* 2014 Vol 131. Pp 181–187.
13. Smith L et al. Drought impacts on children's respiratory health in the Brazilian Amazon. *Sci. Rep.* 2014. doi:10.1038/srep03726.
14. EM-DAT. *The OFDA/CRED International Disaster Database*. Université Catholique de Louvain, Brussels, Belgium. Available at: www.emdat.be (Accessed 1 Oct 2017).

Enabling environment

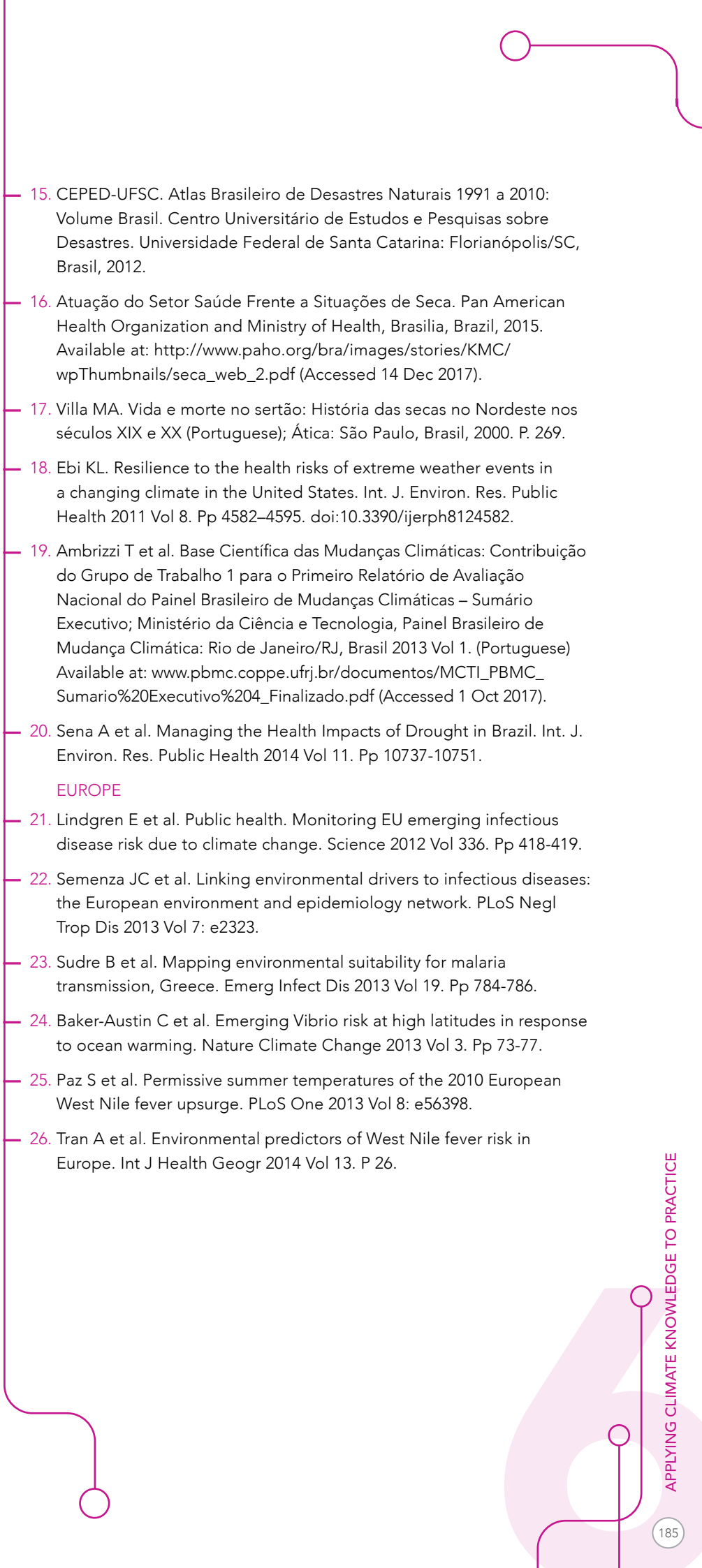
Capacity-building

Research

Product and service development

Application

Evaluation

- 
15. CEPED-UFSC. Atlas Brasileiro de Desastres Naturais 1991 a 2010: Volume Brasil. Centro Universitário de Estudos e Pesquisas sobre Desastres. Universidade Federal de Santa Catarina: Florianópolis/SC, Brasil, 2012.
 16. Atuação do Setor Saúde Frente a Situações de Seca. Pan American Health Organization and Ministry of Health, Brasília, Brazil, 2015. Available at: http://www.paho.org/bra/images/stories/KMC/wpThumbnails/seca_web_2.pdf (Accessed 14 Dec 2017).
 17. Villa MA. Vida e morte no sertão: História das secas no Nordeste nos séculos XIX e XX (Portuguese); Ática: São Paulo, Brasil, 2000. P. 269.
 18. Ebi KL. Resilience to the health risks of extreme weather events in a changing climate in the United States. *Int. J. Environ. Res. Public Health* 2011 Vol 8. Pp 4582–4595. doi:10.3390/ijerph8124582.
 19. Ambrizzi T et al. Base Científica das Mudanças Climáticas: Contribuição do Grupo de Trabalho 1 para o Primeiro Relatório de Avaliação Nacional do Painel Brasileiro de Mudanças Climáticas – Sumário Executivo; Ministério da Ciência e Tecnologia, Painel Brasileiro de Mudança Climática: Rio de Janeiro/RJ, Brasil 2013 Vol 1. (Portuguese) Available at: www.pbmc.coppe.ufrj.br/documentos/MCTI_PBMC_Sumario%20Executivo%204_Finalizado.pdf (Accessed 1 Oct 2017).
 20. Sena A et al. Managing the Health Impacts of Drought in Brazil. *Int. J. Environ. Res. Public Health* 2014 Vol 11. Pp 10737-10751.

EUROPE

21. Lindgren E et al. Public health. Monitoring EU emerging infectious disease risk due to climate change. *Science* 2012 Vol 336. Pp 418-419.
22. Semenza JC et al. Linking environmental drivers to infectious diseases: the European environment and epidemiology network. *PLoS Negl Trop Dis* 2013 Vol 7: e2323.
23. Sudre B et al. Mapping environmental suitability for malaria transmission, Greece. *Emerg Infect Dis* 2013 Vol 19. Pp 784-786.
24. Baker-Austin C et al. Emerging *Vibrio* risk at high latitudes in response to ocean warming. *Nature Climate Change* 2013 Vol 3. Pp 73-77.
25. Paz S et al. Permissive summer temperatures of the 2010 European West Nile fever upsurge. *PLoS One* 2013 Vol 8: e56398.
26. Tran A et al. Environmental predictors of West Nile fever risk in Europe. *Int J Health Geogr* 2014 Vol 13. P 26.

Enabling environment

Capacity-building

Research

Product and service development

Application

Evaluation

EAST AFRICA

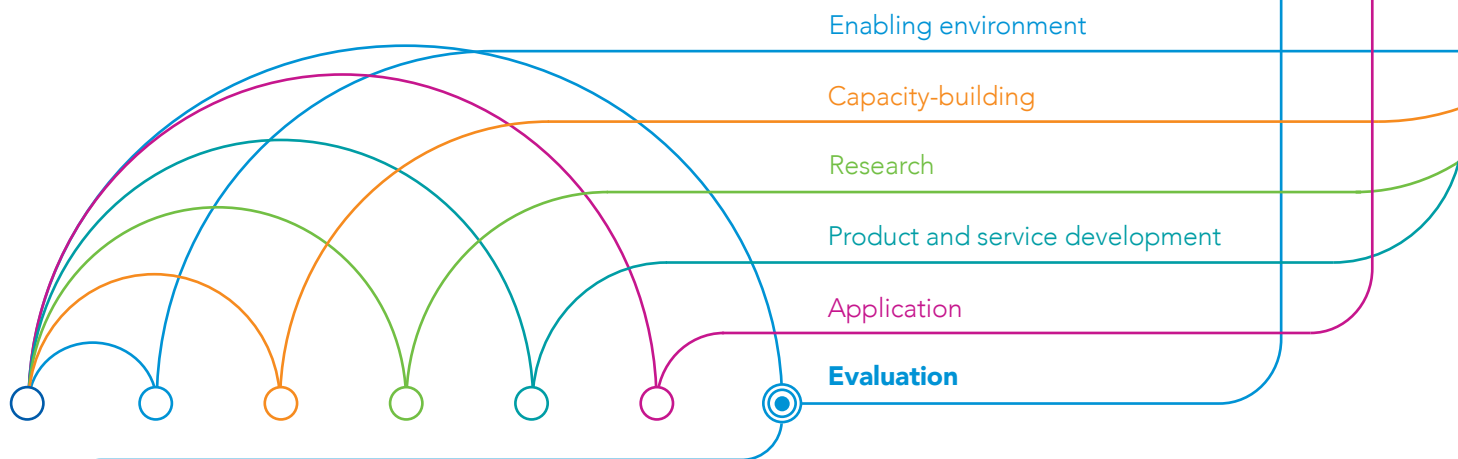
- 27. Dinku T et al. Leveraging the Climate for Improved Malaria Control in Tanzania. IEEE 2014. Available at: <https://earthzine.org/2014/02/15/leveraging-the-climate-for-improved-malaria-control-in-tanzania/>
- 28. Lyon B. Seasonal Drought in the Greater Horn of Africa and its Recent Increase During the March-May Long Rains. J. Climate 2014 Vol 27. Pp 7953–7975. doi: <https://doi.org/10.1175/JCLI-D-13-00459.1>
- 29. Platzer B et al. Strengthening National Climate Data and Information for National Decision-Making in Africa: An Executive Briefing and Consultation with National Collaborators from Ethiopia and Tanzania. Roll Back Malaria Partnership Report 2014. Geneva, Switzerland.
- 30. Thomson MC et al. President's Malaria Initiative - USAID Report: Development of Climate Analysis Section for the President's Malaria Initiative Impact Evaluation: Reports for Ethiopia and Tanzania. IRI 2012. Palisades, New York.
- 31. Lyon B. and DeWitt DG. A Recent and Abrupt Decline in the East African Long Rains. Geophysical Research Letters 2012 Vol 39.
- 32. Thomson MC et al. Africa Needs Climate Data to Fight Disease. Nature 2011 Vol 471. Pp 440-442.

WEST AFRICA

- 33. Dinku T et al. Improving Availability, Access and Use of Climate Information. World Meteorological Organization Bulletin 2011 Vol 60 (2). Pp 1-7.
- 34. Ghebreyesus TA et al. Public Health and Weather Services – Climate Information for the Health Sector. World Meteorological Organization Bulletin 2008 Vol 57(4). Pp 256-261.
- 35. Yaka P. et al. Relationships between climate and year-to-year variability in meningitis outbreaks: A case study in Burkina Faso and Niger. International Journal of Health Geographics 2008 Vol 7. doi: 10.1186/1476-072X-7-34.
- 36. Yaka, P. Report Title, Visiting scientist report, African Desk/CPC/NCEP, Washington, DC, USA, 1 August – 31 November 2010.

BRAZIL

37. Teixeira MG et al. Dengue: twenty-five years since re-emergence in Brazil. *Cad. Saúde Pública* 2009 Vol 25. Pp 7–18.
38. Lowe R et al. Spatio-temporal modelling of climate-sensitive disease risk: Towards an early warning system for dengue in Brazil. *Computers and Geosciences* 2011 Vol 37(3). Pp 371–381.
39. Jupp TE et al. On the visualization, verification and recalibration of ternary probabilistic forecasts. *Phil Trans R Soc A* 2012 Vol 370. Pp 1100–1120.
40. Lowe R et al. The development of an early warning system for climate-sensitive disease risk with a focus on dengue epidemics in Southeast Brazil. *Statistics in Medicine* 2013 Vol 32(5). Pp 864–883.
41. Leverhulme network project: EURO-Brazilian Initiative for Improving South American Seasonal Forecasts (EUROBRISA). Oct 2006 - Dec 2009. Available at: <http://eurobrisa.cptec.inpe.br>
42. Coelho CAS et al. Toward an integrated seasonal forecasting system for South America. *J. Climate* 2006 Vol 19. Pp 3704–3721.
43. FIFA 2014 World Cup in Brazil. Available at: <http://www.fifa.com/worldcup/archive/brazil2014/index.html> (Accessed 1 Oct 2017)
44. Lowe R et al. Dengue outlook for the World Cup in Brazil: an early warning model framework driven by real-time seasonal climate forecasts. *Lancet Infectious Diseases* 2014. doi: 10.1016/S1473-3099(14)70781-9.
45. ECDC. Risk Assessment Brazil 2014 FIFA World Cup, 12 June – 13 July 2014. Available at: <https://ecdc.europa.eu/sites/portal/files/media/en/publications/Publications/world-cup-Brazil-mass-gathering-risk-assessment-28-may-2014.pdf>
46. NHS Choices (2014) Scientists predict dengue risk for Brazil World Cup. Available at: <https://www.nhs.uk/news/medical-practice/scientists-predict-dengue-risk-for-brazil-world-cup/>
47. BBC News Health (2014) Brazil 2014: World Cup dengue fever risk predicted. Available at: <http://www.bbc.com/news/health-27441789>. (Accessed 1 Oct 2017).
48. Barcellos C and Lowe R. Dengue and the World Football Cup: A Matter of Timing. *PLOS Neglected Tropical Diseases* 2014 Vol 8(7): e3022.
49. Ministry of Health, Brazil, *Epidemiological Bulletin*, 2014 Vol 45(17). Pp 1–6.
50. Brazilian Climate and Health Observatory. Available at: http://www.climasaude.icict.fiocruz.br/index.php?pag=tc_ve (Accessed 1 Oct 2017).



CHAPTER 7

7

EVALUATION AND FEEDBACK TO IMPROVE HEALTH DECISION SUPPORT

GOAL: 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 (such as its credibility, availability, reliability, usability, usefulness, suitability, responsiveness, sustainability and accessibility);
- effectiveness to have positive health impacts (such as 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 FOR EFFECTIVE CLIMATE SERVICES

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.

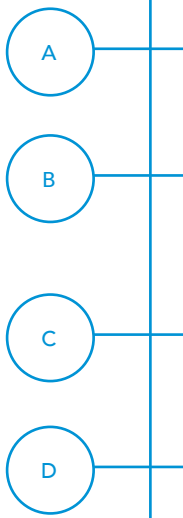
The final case study (7D) evaluated how warnings issued in Germany on health risk of UV radiation, extreme heat, pollen and ozone conditions help individuals and families make behaviour changes that can prevent negative health consequences.

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, 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.



Evaluation

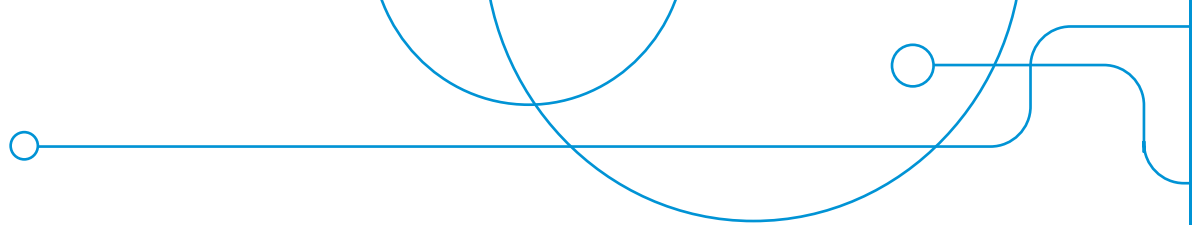
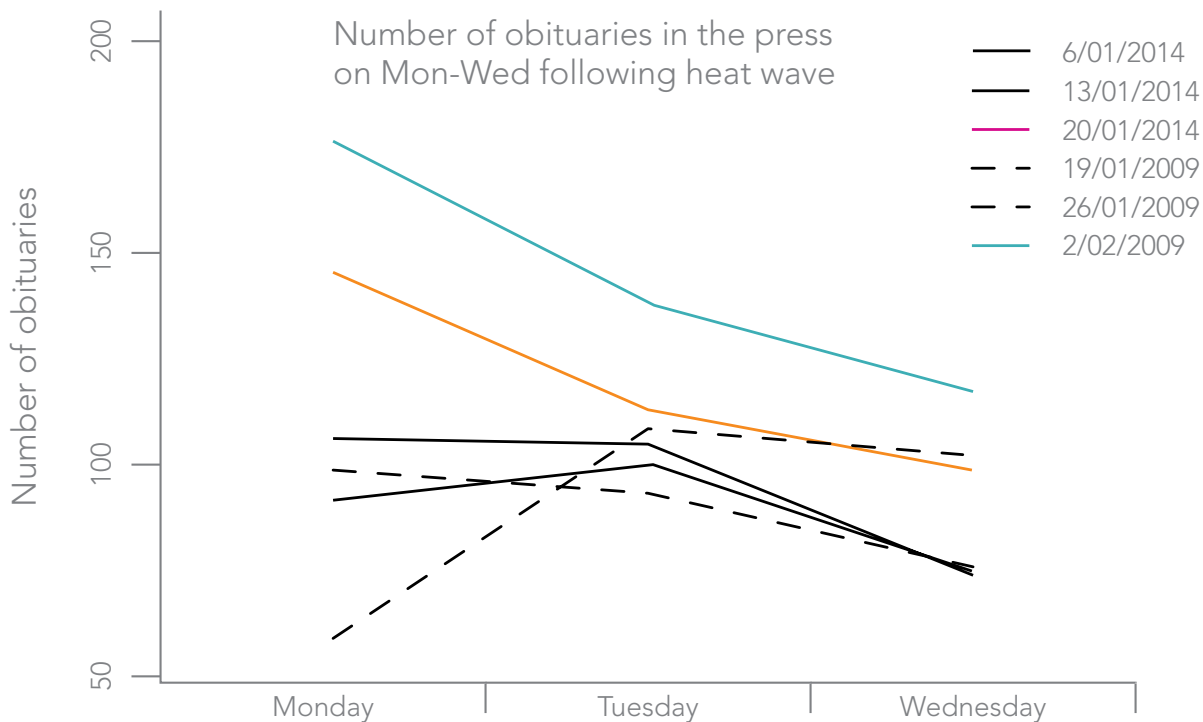


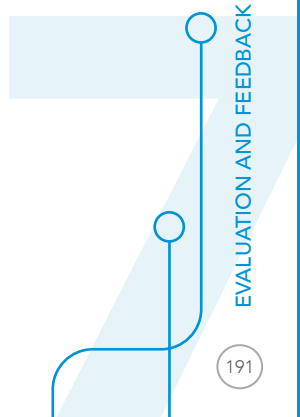
Figure 7.1 Number of post-heat wave obituaries in the press, 2009 and 2014.



ACKNOWLEDGEMENTS



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).



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 prediction models to forecast short- and medium-range extreme temperatures, and an early warning system (Meteolerta) has been implemented in cooperation with European EUMETNET 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.

Research

Evaluation

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.



CASE STUDY 7B

Research

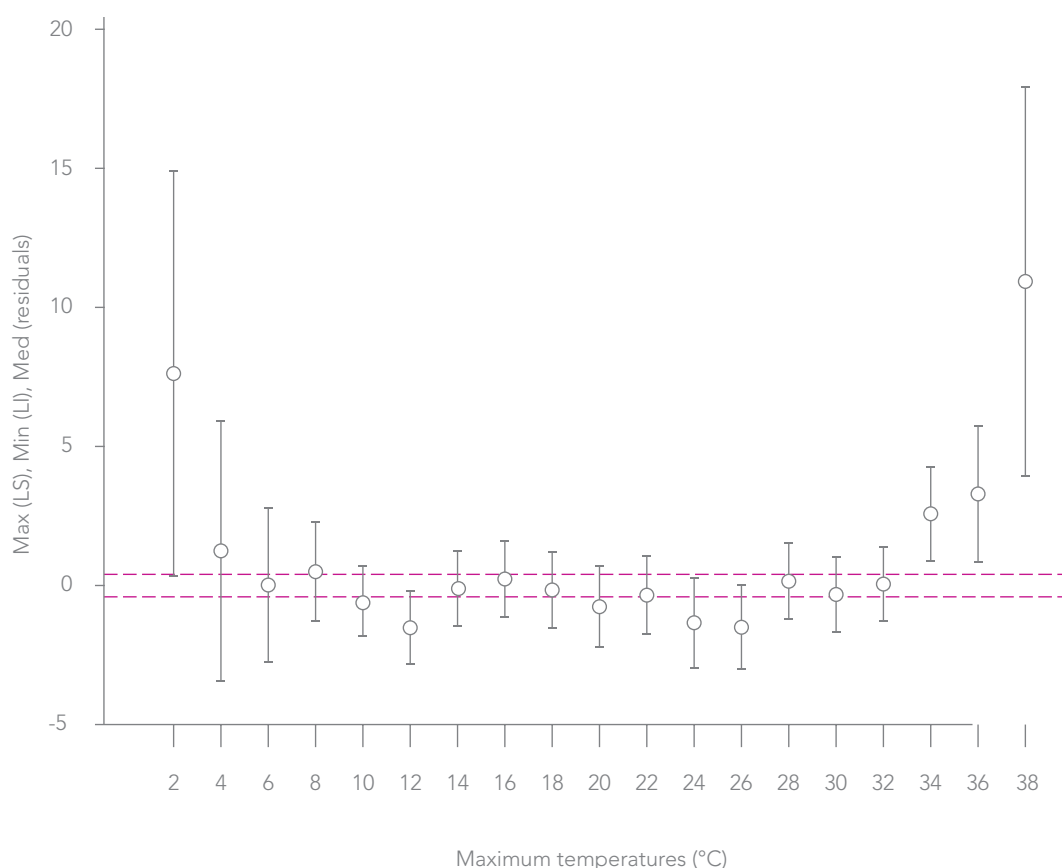
Evaluation

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, resulting in an attributable risk (AR) of 6.55% (95%CI: 4.36–8.72) excess heat-related mortality for each extra temperature degree amounting to 1150 (95%CI: 764–1524) extra deaths. If, however, the analysis were repeated by setting the threshold at 36.5°C, then the AR would be 20.7% (95%CI: 7.57–33.24). This threshold was exceeded on 41 occasions resulting in an associated mortality of 371 (95%CI: 136–596) deaths. Hence, the avoidable mortality in response to a change in the prevention plan activation threshold would be 779 people (95% CI: 628–928).

Figure 7.3 Weather station in Madrid-Retiro used to collect temperature data for the study.



Figure 7.4 Scatter plot of daily maximum temperature and mortality residuals, for a given heat-wave definition.



ACKNOWLEDGEMENTS



BENEFITS AND LESSONS

The use of updated climate data to determine prevention plan trigger temperatures could significantly reduce heat-related mortality and produce significant cost-savings. Our calculations suggest that over the period 2001-2009, 86 (95% CI: 70-103) deaths could have been averted. Assuming each death results in an average reduction of life expectancy of 1 year and that each year of life lost equals €90 000 (13), this would have resulted in an annual economic benefit of €7.7 million (95% CI: €6.3–9.3 million), calculated based on 2013 values.

The national health authorities have been informed and have welcomed the results of the study.



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

Author: WHO Ethiopia Country Office

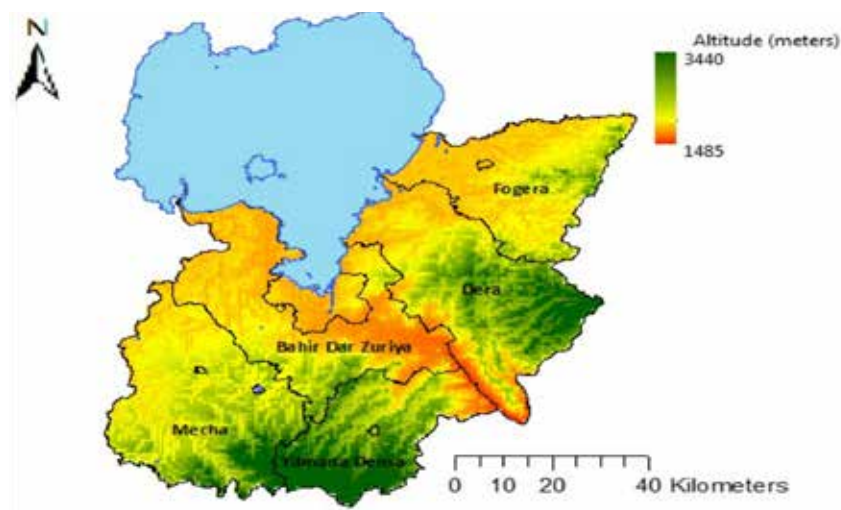
CONTEXT

Climate change and variability are the main drivers of several infectious and non-infectious diseases that are of great public health importance. Malaria is a 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. However, 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 highland areas prone to malaria. This epidemic 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 association's focuses has been climate and health. In 2008, HDAMA established 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 aimed at improving malaria epidemic early warning through coordination and collaborative efforts between the health and climate communities.

Figure 7.5 Elevation map of the project sites in Bahir Dar area, 2013.
Photo credit: WHO Ethiopia.



Evaluation

ACKNOWLEDGEMENTS



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 worked together to integrate and analyse it. However, these efforts were hampered by a lack of user-friendly tools for the prediction and early warning of probable epidemics at regional and district levels.

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 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 using checklists was only provided two times during the project implementation. Lack of close follow-up and regular supportive supervision has had a negative effect on project implementation and in solving problems at the field level.

Before considering scaling-up to a national level or to other climate-sensitive diseases, the forecasting and early warning system need to be better developed, and institutional arrangements and coordination mechanisms reorganized for effective implementation of the project. The promising PHEM 95% reporting completeness at district level will be essential for district level malaria risk mapping.

CASE STUDY 7D

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

Authors: M. Capellaro, P. Sadre Dadras, P. Kahn (Konzeption & Evaluation kommunikativer Maßnahmen, Hamburg, Germany); D. Sturm (HBF – Unabhängiges Institut für hausärztliche Bildung und Forschung Dr Sturm GmbH, Hohenstein-Ernstthal, Germany); U. Reis, C. Cholmakov-Bodechtel, M. Schmid (Kantar Health GmbH, München, Germany).

Research

Evaluation

CONTEXT

In Germany, there are national systems that provide information and early warnings for climate change and related environmental health risks, such as ultraviolet (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.

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.

Figure 7.6 Ragweed concentration forecast for 9 September 2017.



The following methods were used for the evaluation:

- A comprehensive search of the German environmental webportal (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 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.
- Physician and nursing services/facilities were requested to complete an online questionnaire.
- An extensive, representative poll of the population was carried out in the summer of 2013. Four thousand 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 (Figure 7.7).

Figure 7.7 Assignment of poll 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 7D

BENEFITS AND LESSONS

The use of institutionalized information^k 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 documented 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 (such as 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. Pollen forecasts were heard of or read by 86.8% of those polled, but the UV index reached only 29.5%. Lying in between were heat health warnings (71.0% reach) and ozone forecasts/warnings (54.2% reach). Awareness of warnings and forecasts most often come through television, radio, newspapers or magazines, or the Internet.^l Mass media primarily informed about heat, but neither uniformly nor reliably. The number of subscribers to the newsletters of the information systems was 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.

^k 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.

^l The websites of the DWD and UBA were excluded from this question.

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^m and the degree of personal involvementⁿ 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%)^o 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.

^m 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!"

ⁿ 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.

^o 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.

REFERENCES

Enabling Environment

Capacity-building

Research

Product and service development

Application

Evaluation

AUSTRALIA

1. Nicholls N et al. A simple heat alert system for Melbourne, Australia. *Int J. Biometeorology* 2008. doi:10.1007/s00484-007-0132-5.
2. Loughnan M, Nicholls N, and Tapper N. Mortality-temperature thresholds for ten major population centres in rural Victoria, Australia. *Health and Place* 2010 Vol 16. Pp 1287-1290.
3. Loughnan M, Nicholls N, and Tapper N. The effects of summer temperature, age and socioeconomic circumstance on acute myocardial infarction admissions in Melbourne, Australia. *International Journal of Health Geographics* 2010 Vol 9. P 41.
4. Loughnan M, Nicholls N and Tapper N. When the heat is on: threshold temperatures for Acute Myocardial Infarction admissions to hospital in Melbourne, Australia. *Applied Geography* 2010 Vol 30. Pp 63-69.
5. Victoria State Government. Extreme heat and heat waves. (n.a.) Available at: <http://www.health.vic.gov.au/environment/heatwaves-alert.htm> (Accessed 1 Oct 2017).
6. The Conversation. A change in the weather no-one predicted: forecasters are getting it right. 2011. Available at: <https://theconversation.com/a-change-in-the-weather-no-one-predictedforecasters-are-getting-it-right-752> (Accessed 1 Oct 2017).
7. The Conversation. Record heat waves not just a lot of hot air. 2011. Available at: <https://theconversation.com/record-heatwaves-not-just-a-lot-of-hot-air-1335> (Accessed 1 Oct 2017).

SPAIN

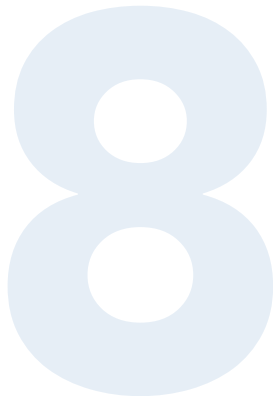
8. Ministeriode Sanidad, Servicios Socialese Igualdad. Plan Nacional de Acciones Preventivas por Altas Temperaturas. 2014. Available at: http://www.msssi.gob.es/ciudadanos/saludAmbLaboral/planAltasTemp/2014/Plan_nacional_actuaciones_preventivas.htm. (Accessed 1 Oct 2017) (Spanish).
9. Tong S, Wang XY and Barnett AG. Assessment of heat-related health impacts in Brisbane, Australia: comparison of different heatwave definitions. *PLoS One* 2010 Vol 8: e12155. doi:10.1371/journal.pone.0012155.
10. Linares C et al. The time trend temperature-mortality as a factor of uncertainty analysis of impacts of future heat waves. *Environ Health Perspect* 2014. doi:org/10.1289/ehp.1306670
11. Montero JC et al. Comparison between two methods of defining heat waves: a retrospective study in Castile-La Mancha (Spain). *Sci Total Environ* 2010 Vol 408. Pp1544–50. doi:10.1016/j.scitotenv.2010.01.013
12. Díaz J et al. Heat waves in Madrid 1986–1997: effects on the health of the elderly. *Int Arch Occup Environ Health* 2002 Vol 75. Pp 163-70.
13. De Ayala A and Spadaro JV. Economic Costs of Health Impacts. Report for the European Commission, 2014. ENV.2010.1.2.3-2, Project No.265325.

ETHIOPIA

- 14. WHO Ethiopia country office. Documenting Lessons learned from the Implementation of Climate and Health Project by the Health Development and Anti Malaria Association in Ethiopia. 2014.

GERMANY

- 15. Capellaro M et al. Evaluation of Information Systems Relevant to Climate Change and Health Volume 1: Adaptation to Climate Change: Evaluation of Existing National Information Systems (UV-Index, Heat Warning System, Airborne Pollen and Ozone Forecasts) from a Public Health Perspective – How to Reach Vulnerable Populations. Environmental Research of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. 2015. Available at: https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/ug_07_2015_evaluation_of_information_systems_volume_1_0.pdf (Accessed 1 Oct 2017).
- 16. Capellaro M et al. Evaluation of Information Systems Relevant to Climate Change and Health Volume 2: Adaption to Climate Change: Strategy for Provision of Health Care in Case of Extreme Weather Event. Environmental Research of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety 2015. Available at: https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/ug_08_2015_evaluation_of_information_systems_volume_2.pdf (German) (Accessed 1 Oct 2017).



SOLUTIONS TO COMMON CLIMATE SERVICE CHALLENGES

Learning from the insights, tools and experiences of the global community of practice is extremely valuable to scaling up climate services for health, in the current absence of sufficient formal evaluations of climate service performance, process development and impacts. Review of the current case studies identified project teams frequently had to overcome five common challenges:

1. Working with available data to develop fit-for-purpose products and services;
2. Drawing upon and developing sufficient foundational capacities to support climate services;
3. Generating adequate demand and endorsement to mainstream climate service application;
4. Securing and sustaining sufficient financial and human resources;
5. Communicating climate information and risks effectively.

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:

WORKING WITH AVAILABLE DATA TO DEVELOP FIT-FOR-PURPOSE PRODUCTS AND SERVICES

- Unaligned data collection spatial scales (climate data is collected at localized weather stations, health data is collected aggregated at different administrative levels).
- Gaps and inaccuracies in climate data due to poor coverage and quality of observation networks.
- Global climate products unable to provide quality data for all locations and climate variables.
- Unaligned data collection frequency (health data typically collected at weekly or monthly frequencies; climate data at hourly, daily frequency).
- User unfriendly data formats.
- Inconsistencies across data from different sources.

Fit-for-purpose products and services start with matching information to the spatial and temporal scales of decision-making. A range of challenges commonly arise while identifying, collecting, cleaning and preparing climate and health data to be interoperable and appropriate to the spatial and temporal time scales of decisions that need to be made. Spatial alignment is a challenge. Health decisions are most often made at the local level, such as the district or county level, down to specific point locations of health facilities and villages. However, climate observations are collected at specific stations which may and may not correspond to those locations and reflect the actual climate and weather conditions in the health catchment area; or data may be aggregated at broader spatial scales which can mask specific microclimates or conditions that are important to understand disease transmission. Spatial gaps and inaccuracies are often found in national climate data reflecting the status of the observational network. Global climate products can 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. Climate data should have both national coverage and local relevance to be useful for health research or planning.

Temporal alignment can also be a challenge. Environmental and climate global products are often disseminated at 10 day (dekadal) or monthly timescales. While the monthly time scale is a common time unit used in health decision-making, weekly data is preferred for epidemiological surveillance. Monthly averages for example may be of little use to understanding diseases that can be triggered in a matter of days. Hence, adjustments and transformations of climate observations often need to be made for it to be compatible to understanding the specific disease transmission or health risk conditions. The lack of customized data collection and formatting methods to meet the specific service needs was a key constraint for some projects. The mismatch of data collected from various sources, and the complexity of some data formats and archiving methods can often render existing data unusable and incompatible which block further advances to developing decision tools.

- Poor and discontinued access to climate observations.

Furthermore, access to the daily or hourly observational climate data which is most often required for establishing associations between climate conditions and health outcomes, remains limited by data dissemination policies of the national meteorological agencies in many countries. This occurs when authorities view observational data either as highly sensitive, an economic asset, or fail to understand the importance of daily values to developing climate services. As a consequence, data owners are often reluctant to provide raw observational data unless a clear value is shown for doing so and the conditions of data use are clearly documented. Where clear data exchange protocols have not been established, the regular and continuous access to observational climate data for risk monitoring and climate services can be interrupted or discontinued by personnel turn over, administrative changes that lead to changes in employees' responsibilities and roles, or policy changes.

- Produce consistent and integrated datasets containing health and climate data in the same time and spatial scales.

SOLUTIONS

Some projects created new integrated datasets and systems that transform health and climate data to common time and spatial scales, thereby resolving data mismatches 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 E3 geoportal and the International Research Institute for Climate and Society (IRI) Data Library, can be used to resample climate and health data to common time and space scales.

CHALLENGE 2:

DRAWING UPON AND DEVELOPING SUFFICIENT FOUNDATIONAL CAPACITIES TO SUPPORT CLIMATE SERVICES

- Limited capacity of both Meteorological Services and Health partners.

- Inability of core observation and surveillance systems to produce quality data at adequate scales.

- Lack of appropriate ICT infrastructure.

- Scientific limitations to the reliability of core climate products and services.

- Lack of human understanding of the limitation of climate products and services and health surveillance systems.

A range of core infrastructure, institutional, and human capacities are needed pre-requisites to co-produce and support tailored climate products and services. In many countries, limited capacity of both the National Meteorological and Hydrological Service and health partners hinders the technical feasibility of developing fit-for-purpose products, and readiness to apply climate-informed decision tools and products. Experience has shown that availability and access to specific resources and capacities strongly influences the potential to develop viable and relevant climate-informed decision products and service.

Teams often reported being unable to meet project goals or develop a skilful product. Authors cited insufficient readiness and foundational prerequisites to develop climate services such as: inability of core information systems to produce adequate data (such as poor availability, quality, homogeneity and good spatial and temporal resolution, as well as coverage of data at local and regional level); lack of information communication technology infrastructure, such as internet access or sufficiently robust data management systems and analysis tools; scientific limitations of core products and services (such as inadequate forecast skill to be used for local decision-making); lack of understanding about the limitations across institutions; and lack of human capacity and experience to propose solutions to overcome these shortfalls.

Weak underlying capacity of core observational and data management systems (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, inadequate data management systems, are commonly cited challenges to identifying and developing technically feasible and reliable analytical and forecast products. Data quality issues can also arise due to data collection, handling and storage methodologies. Understanding how data collection errors occur is critical to understanding how they might be removed. Within the health and climate communities, standard protocols exist that can help clean the data, which usually requires expert knowledge and awareness of appropriate methodologies.

- Assess process requirements and readiness.
- Policy advocacy and strong documentation for investment in surveillance systems and observations.
- Use community-based surveillance to complement national health records.
- Understand how data is collected.
- Have appropriate expectations.
- Develop, test and improve products and services.
- Establish partnerships with experience project teams.
- Seek mentorship and establish technology transfer mechanism.
- Facilitate access to relevant global climate data products.
- Take advantage of on-line data-management and analysis systems.
- Explore suitable software and web-based applications.

SOLUTIONS

A complete assessment of process requirements and readiness is important to judge the viability of an idea, and identify all of the necessary steps, data, people, and institutional and infrastructural support which will be required. The quality and reliability of a product will particularly depend on the quality of the original available data.

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 the National Meteorological and Hydrological Service 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, such as blending local and global climate products, and community-based surveillance with other sources of health information.

Cleaning and understanding the climate and health data is critical. Certain temporal data resolutions, (such as monthly or annual data) may mask data gaps or outliers that should be understood. In order to identify such issues, it is important to understand how data is collected and go back to the origin of the data wherever possible. 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).

Pilot programmes have proven crucial as a means to develop, test and improve products and services, facilitating the identification of data or analytical 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 experienced project teams 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 weakness in climate observation systems.

Involving regional and international partners can also facilitate access to relevant global climate data products, which can sometimes be downscaled to provide relevant local information. In addition, cloud-based servers or data-management systems that are remotely hosted have allowed local teams to access more robust data and data management software, avoid data losses and more effectively collaborate with international partners. 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.

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:

GENERATING ADEQUATE DEMAND AND ENDORSEMENT TO MAINSTREAM CLIMATE SERVICE APPLICATION

- Lack of experience using climate services and information as decision-making tools.
- Limited number of evaluations demonstrating the value and cost-benefit.
- Poor involvement of either health or climate authorities and lack of sufficient in-country coordination.
- Products and services developed that inadequately respond to operational health decision needs.

The difficulty of mainstreaming climate services as a consistent resource for health decision-making tools was a commonly cited challenge. This is often due to health decision-makers being unfamiliar with using climate information for health planning, tending to mistrust and undervalue non-health related information, or not understanding the uncertainty associated with climate-based disease forecasts. The limited number of evaluations demonstrating the value and cost-benefit 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 is the poor involvement of either health or climate authorities in the service development process. When academia led, it was sometimes difficult to engage and identify key decision-makers or professionals in the health and climate sectors. Without their engagement, misunderstandings can occur, leading to underestimating the value of climate knowledge, a diminished willingness to share data and information, and a poor sense of ownership. This ultimately results in products that do not meet the operational needs and in an inadequate response.

The lack of sufficient in-country coordination at the national, sub-national and local levels sometimes threatened the application of the climate services.

SOLUTIONS

- Establish multi-sectorial and multidisciplinary groups.
- Use academia and nongovernmental institutions as mediators, translators and knowledge brokers when needed.
- Communicate and establish dialogue with local expert climate science experts.
- Establish bilateral agreements and memoranda of understanding.
- Comply with data access and use policies.

In many case studies, multi-sectoral and multidisciplinary groups were 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 ownership; 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. Furthermore, diverse partners from academia or nongovernmental institutions can often be very constructive as mediators, knowledge brokers, and translators.

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. Bilateral agreements and memoranda of understanding have been instrumental in facilitating access to data and defining respective roles and responsibilities in a mainstream 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 AND SUSTAINING SUFFICIENT FINANCIAL AND HUMAN RESOURCES

- Lack of sustained funding.
- Lack of human capacity.
- Lack of training opportunities.

Lack of sustained funding was a reported reason for the interruption of service provision, cancelled products or services, the inability to advance from product R&D to application, or the further tailoring or upgrading of products and services to maximize uptake. This particularly occurred in cases where the service was developed as part of an externally funded project. The lack of funding made it impossible to maintain the salaries of the trained personnel, train new human resources, support the continuous engagement of national or international experts and fund other running costs required to sustain the service. Similarly, insufficient access to training, and too few experienced and engaged staff to develop and use the product, slowed or hampered local progress.

SOLUTION

Research and evaluations are extremely important to generate adequate evidence, and to increase awareness about the value of tailored decision tools and climate services. In order to transition from project-based funding to leverage core budget resources (such as 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 could be 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.

- Conduct cost-effectiveness and cost-benefit evaluations.
- Demonstrate benefits for health service provision and saving lives.
- Document public appreciation and value.
- Build partnerships.
- Gain hands-on experience.
- Establish students and staff exchanges.
- Attend international training courses and seek placements and funding for masters and doctoral level studies.

The lack of local human resources is often tackled through building partnerships, either locally or internationally to supplement and diversify the available skills and experience needed. Many case studies involved multiple institutions, which often include international experts from a range of disciplines who provide access to required technical expertise. Hands-on experience working with experts is often the best way to build capacity; climate and health seminars and workshops, and specific analytical skill-based trainings were shown to be beneficial. Other approaches to capacity-building include longer student and staff exchanges, attending international training courses, and seeking placements and funding for masters and doctoral level studies.

CHALLENGE 5:

COMMUNICATING CLIMATE INFORMATION AND RISKS EFFECTIVELY

- Poor understanding of uncertainty.

- Lack of awareness on climate driven health risks.

Communicating uncertainty to decision-makers, clearly presenting interpretations of statistical or technical analyses, and explaining climate-driven health risks to non-technical audiences were frequently reported challenges. Some public warning systems were reportedly not used when local communities did not understand the risk warnings, value or trust the information, or have adequate information about the actions they should take when a warning was issued. 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.

SOLUTION

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 social media, 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 in communicating messages on the presence or absence of disease risks, such as 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 was appropriate and that messages were 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 health data in ways that help communities better understand and contextualize risks. Furthermore, the effective use of data visualization in the form of well-designed maps, graphs, infographics and other figures can help information users and communities navigate and interpret complex information more easily.

- Better understand the local risk perceptions.

- Use modern communication technologies.

- Partner with local and global media.

- Include community representatives in service development processes.

- Engage communities in more effective health prevention and promotion.

- Present information in a visual and clear manner.

9

BENEFITS OF CLIMATE SERVICES TO HEALTH POLICY AND PROGRAMMING

KEY BENEFITS

Provide a more comprehensive understanding of immediate, short- and long-term health risks

Enhance integrated disease surveillance and monitoring systems

Provide tactical information to improve health service design and delivery

Provide health early warning systems

Help to increase community risk awareness

Inform mid- and long-term health sector adaptation planning

Support the evaluation of climate-sensitive health services and interventions

The case study experiences from around the world demonstrate the many advantages and benefits of enhancing traditional health information and decision tools with climate knowledge. 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 and providing feedback to service providers on the measured value, effectiveness and utility of tailored climate products and services.

As a result of developing or using tailored climate services, most case studies reported stronger contacts and collaboration between the National Meteorological and Hydrological Service (NMHS) 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 NMHS but with the agricultural sector to reduce pollen exposure, and in Brazil, partnership with the national water agency was needed to integrate river level information with national health surveillance data to comprehensively monitor risks for water-borne diseases.

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 leads to high cross-border human mobility, the creation of a bi-national dengue surveillance network has promoted technical cooperation and is helping health authorities in both countries better understand and align control strategies on each side of the border in order to better manage disease risks.

Experience is showing that the use and application of tailored climate knowledge can:

PROVIDE A MORE COMPREHENSIVE UNDERSTANDING OF IMMEDIATE, SHORT- AND LONG-TERM HEALTH RISKS

Research and risk assessments can assist health professionals 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 prior to the World Cup, dengue research models and forecasts using climate information informed 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.

ENHANCE INTEGRATED DISEASE SURVEILLANCE AND MONITORING SYSTEMS

Climate-enhanced surveillance can improve the monitoring of climate conditions and climate-affected risk factors, and allow 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 European Environment and Epidemiology (E3) portal used in Europe tracks the environmental suitability of multiple diseases such as Vibrio cholera risk in the Baltic Sea, areas suitable for malaria transmission in Greece; and drivers of West Nile Virus in southeastern 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, the web-based processing and modelling system EPIDEMIA accelerates the rapid detection and forecasting of malaria epidemics.



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. Multiple projects demonstrate the strategic advantages, such as in London where analysis of the demand for emergency services in relation to heat and cold episodes demonstrates important fluctuations that inform management changes to improve emergency response services. In Hong Kong, climate information is used to design and provide highly tailored and personalized health care to the elderly during extreme heat episodes. In the Solomon Islands, customized rainfall outlooks used by the National Vector Control Programme improve planning of community awareness and vector control activities as well as more efficient allocation of diagnosis and treatment resources. 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.

PROVIDE HEALTH EARLY WARNING SYSTEMS

Timely advanced notice of dangerous weather and climate conditions can improve health emergency preparedness and response, save lives and reduce negative health impacts. 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 heat waves. A Heat Health Warning System 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, 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 allow the Office of Disaster Management to protect communities in harm's way from the adverse health effects of wildfire smoke.

HELP TO INCREASE COMMUNITY RISK AWARENESS

Awareness is the trigger to encouraging protective behaviours and increasing 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 eastern 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 utensil handling and pit latrine constructions, which were proven to reduce the level of community risk behaviours.

In Ecuador, diarrhoeal disease incidence data were transformed into 'life stories' (a compilation of the story behind a sentinel event) to help communities better understand and analyse the relation of diarrhoea in the community to rainfall and propose feasible solutions. In China, a heat wave warning system provides timely and tailored risk information to community health centres and triggers advisories and awareness to residents, especially vulnerable populations, via multiple means of communication (such as TV, mobile text, instant messaging groups and electronic display, newspapers and painting contests) to encourage and facilitate locally appropriate preventive actions.

INFORM MID- AND LONG-TERM HEALTH SECTOR ADAPTATION PLANNING

Climate projections can support health planners to imagine and understand future conditions. 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 future projections in the different climate zones in the country. In Canada, the risk modelling framework for food and water safety provided projections of potential climate impacts on food and water safety up to 2100 and incorporated diverse scenarios of adaptation options. This approach helps decision-makers compare and select the most realistic 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 Rift Valley fever at different time scales, along with a detailed analysis of long-term future disease risk. By providing the opportunity to disaggregate composite risk indicators, decision-makers can better understand the significance of individual risk factors, and decide where risk reduction investments may have the greatest protective value.

SUPPORT THE EVALUATION OF CLIMATE-SENSITIVE HEALTH SERVICES AND INTERVENTIONS

Climate services can be a critical asset to health professionals when evaluating the performance of health services and interventions that may be influenced by extreme weather, seasonal or inter-annual climate conditions. This benefit can be seen in Ethiopia where the influence of seasonal and long-term climate changes 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.

10

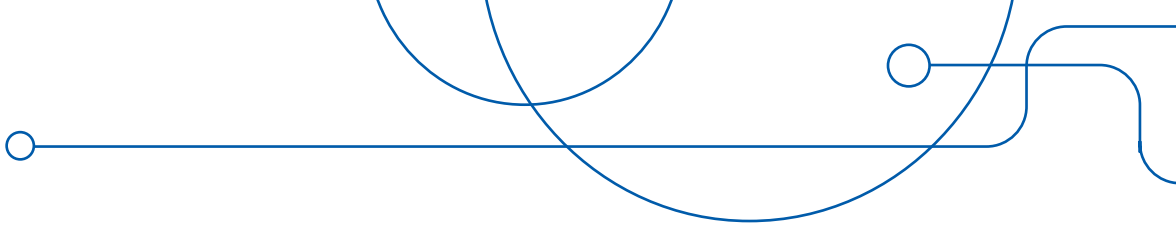
CONCLUSIONS: UNPACKING THE POTENTIAL OF CLIMATE SERVICES

This collection of pioneering experiences in applied climate and health science demonstrates that opportunities, expertise, techniques and good practices 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 that 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 that supports the development of appropriate tools. More effective communication with end-users and communities is also needed.

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 well as insufficient financial and human resources, are major obstacles. Tackling these challenges requires national and international partners from private and public sectors to come together and work with affected communities. Investments are needed to maintain and enhance both the global and national climate monitoring system, and the capacity of meteorological services to assist climate-sensitive sectors such as health to manage these climate risks.

Finally, a transformative approach to climate and health requires empowering many sectors to protect health. Climate services provide an excellent platform to encourage multistakeholder climate action, bringing together agents from sectors such as agriculture, disaster risk reduction, water management and energy. These sectors 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 collaboration between the National Meteorological and Hydrological Service 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
