2023 STATE OF CLIMATE SERVICES

HEALTH

WEATHER CLIMATE WATER

WORLD METEOROLOGICAL ORGANIZATION

GFCS
GLOBAL FRAMEWORK FOR CLIMATE SERVICES

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Key messages

Photo: Leo Wolfert

The world is warming at a faster rate than at any point in recorded history. Climate change undermines health determinants[1] and increases pressures on health systems, thereby threatening to reverse decades of progress to promote human health and well-being, particularly in the most vulnerable communities. The Intergovernmental Panel on Climate Change (IPCC) concludes, with very high confidence, that future health risks of injury, disease and death will increase due to more intense and frequent temperature extremes, cyclones, storms, floods, droughts and wildfires. It is anticipated that over 50% of the excess mortality resulting from climate change by the year 2050 will occur in Africa.[2]

Health protection is a priority in almost all countries and requires high-quality information to better inform decision-making. The majority of Nationally Determined Contributions (NDCs)[3] and National Adaptation Plans (NAPs)[4] prioritize the health sector. To systematically and effectively address the challenges presented by climate variability and change, the health sector needs to ensure that climate information and services inform national assessments and policies.

Climate information and services are fundamental for better understanding how and when health systems and population health can be impacted by climate extremes and a changing climate, and for managing climate-related risks. Tailored climate products and services can enhance the evidence and information available to health sector partners to detect, monitor, predict and manage climate-related health risks. Examples of where health sector partners are successfully using climate information and services are illustrated in the Case studies.

There is huge potential for enhancing the benefits of climate science and climate services for health. Despite examples of success, data shows that the health sector is underutilizing available climate knowledge and tools. At the same time, climate services need to be further enhanced to fully satisfy the health sector requirements. While 74% of National Meteorological and Hydrological Services (NMHSs) provide climate data to health actors, the uptake into mainstreamed health decision tools is limited, with just 23% of Ministries of Health having a health surveillance system that utilizes meteorological information to monitor climate-sensitive health risks. Data from WMO shows that only 31% of NMHSs provide climate services at a "full" or "advanced" level of capacity, where co-production and tailoring most often happen. This reflects a significant capacity gap to be filled in order to increase the role that NMHSs can play in supporting the health sector.

Extreme heat causes the greatest mortality of all extreme weather, yet heat warning services are provided to health decision makers in only half of the affected countries. Extreme heat services are expected to rapidly increase by 2027 under the United Nations Early Warnings for All initiative. The impacts of extreme heat and heatwaves are underestimated, as heat-related mortality could be 30 times higher than current estimates. Between 2000 and 2019, estimated deaths due to heat were approximately 489 000 per year, with a particularly high burden in Asia (45%) and Europe (36%).[5]

Every year poor air quality is responsible for millions of premature deaths and is the fourth biggest killer by health risk factor. Concerns relating to air quality, climate change and health are interlinked. Climate mitigation action leading to reducing air pollution can save lives. Despite this, only 2% of climate finance commitments made by international development funders in developing and emerging countries is explicitly aimed at tackling air pollution (in 2015–2021).[6]

There is insufficient investment to improve the capabilities of the health sector and related climate services to deploy research and integrated systems for effective climate adaptation and mitigation related decision-making. This leaves the health sector ill-prepared to safeguard the most vulnerable. Currently, just 0.2% of total bilateral and multilateral adaptation finance supports projects that identify health as the primary focus. There is insufficient investment for developing human resource and operational capacities and the systems needed to provide decision support for local adaptation and mitigation.[7]

To fully harness the potential of climate services for health, transformational change in institutional development and integration across the health and climate sectors are needed.

Photo: Xurzon

Photo: WMO/Muhammad Amjad Hossain

WMO has issued annual reports on the state of climate services since 2019 in order to provide scientifically based information to support climate adaptation and mitigation. This 2023 edition of the WMO *State of Climate Services* report focuses on health, one of the priorities of the Global Framework for Climate Services (GFCS) and a top priority for countries in their Nationally Determined Contributions. The interconnection between climate and health is undeniable and multifaceted. Climate change impacts a wide range of health factors, from heat-related illnesses to the spread of infectious diseases and air pollution-related health issues.

The onset of El Niño in 2023 will greatly increase the likelihood of breaking temperature records further, triggering more extreme heat in many parts of the world and in the ocean – and making the challenge of adaptation even greater.

Understanding and mitigating these risks requires concerted efforts on both the environmental and public health fronts, including transitioning to clean energy sources, improving health-care infrastructure and implementing climate adaptation measures to protect the most vulnerable populations. Addressing the climate-health nexus is essential for safeguarding the well-being of current and future generations.

As we highlight in this report, climate services and information are vital to saving lives and protecting livelihoods. There are many good examples included in the Case studies section, exploring how health sector partners are successfully using climate information and services to detect, monitor, predict and manage climate-related health risks.

Through the GFCS and the United Nations Early Warnings for All initiative, WMO and its partners want to realize the potential of climate information and early warning systems worldwide. The number of medium- or large-scale disaster events is projected to reach 560 per year – or 1.5 each day – by 2030.[8] Countries with limited early warning coverage have disaster mortality that is eight times higher than countries with substantial to comprehensive coverage.[9]

It is clear that by channelling investment and boosting collaboration, there is huge potential to go further and faster by enhancing the impact of climate science and services. This will allow health partners to receive the support they need at a time when unprecedented changes to our climate are having an increasingly greater impact.

Prof. Petteri Taalas
Secretary-General
WMO

Photo: Asantha Abeysooriya

About this report

In 2018, the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at the 24th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) called on WMO, through its Global Framework for Climate Services (GFCS), to regularly report on the state of climate services. WMO has issued annual reports on the state of climate services since 2019 in response to this United Nations request for more information on the adaptation needs of countries. The information provided helps countries, funding agencies and development partners to identify steps needed to address climate services gaps and needs, to inform more effective investment and to enhance adaptation and development outcomes.

The 2023 edition of the report describes the current state of climate services for health. It considers a range of data, peer-reviewed literature and reports, policy documents and case studies. The report is divided into seven sections. The first section presents the current and future challenges to protecting health and well-being from the impact of climate variability and change. The second section analyses countries' climate policy priorities in the Nationally Determined Contributions, and reflects on the demand for climate services to address health priorities. The third section describes the value that climate services bring to the health sector in achieving these policy goals. The fourth section reviews the status of climate services for health at global, regional and national levels, and the ability of such services to address two high-priority climate risks to health: extreme heat and hazardous air quality. Based on the analysis of the current status of climate services for health, the fourth section also identifies the needs, gaps and future actions required. The fifth section highlights the investment landscape of current funding for climate and health science and services. The report concludes with a series of next steps, recommendations (sixth section) and stories and case studies (seventh section).

Building on the established WMO *State of Climate Services* reports, this year's report is taking a new approach. Instead of solely relying on text and graphs, the 2023 report is introducing human-interest stories that resonate with and captivate audiences. Partnering with a creative agency, and with support from the Argentinian National Meteorological Service and WMO communications team, this is the first WMO flagship report to incorporate such storytelling.

Photo: Garten-gg

The challenge

The climate sustains life and people's health, but also poses important threats to well-being, through exposure to extreme weather and through its influence on life-sustaining ecosystems. The world is warming at a faster rate than at any point in recorded history. Climate change undermines health determinants and increases pressures on health systems, thereby threatening to reverse decades of progress to promote human health and well-being, particularly in the most vulnerable communities.[10]

"Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity", according to the World Health Organization (WHO).[11] The way in which "good health" is attained and protected is the result of economic, social, environmental, political and civic processes and systems, all of which are vulnerable to the changing climate The climate, exacerbated by climate change, poses systematic and serious threats to human health because it affects many of the social and environmental determinants of good health, such as clean and safe air, water and shelter, food security, economic opportunities, livelihoods, social status, healthy behaviours, culture, equity, and access to health care and social support structures.

Climate change is documented to be impacting human health in many complex ways,[12] including by leading to death, injury and illness from heat stress, the disruption of ecosystems and food systems, the increase in food-, vector- and waterborne diseases, and exposure to air pollution (Table 1). Direct injury, illness and death, and many forms of indirect effects of climate, such as deterioration of mental health and exacerbation of non-communicable diseases, also result from increasingly frequent and intense temperature extremes, cyclones, storms, floods, droughts and wildfires. Climate-related disruptions to ecosystems, resulting in cascading impacts on biodiversity, land use and mental health, are emerging concerns.

Table 1. Intergovernmental Panel on Climate Change (IPCC) observed and future risks to physical health due to climate change in all regions. The * indicate the confidence levels based on the strength and consistency of evidence as follows: **** = very high confidence; *** = high confidence; ** = medium confidence; * = low confidence.

Condition	Observed status	Diagnoses cited	IPCC WG II future assessment
Heat stress	Linked to mortality and morbidity *(8)*****	Heat illness	Increases *(13)*****
Foodborne and waterborne diseases *(8)*	Increased occurrence**** Increased regional risks of aquatic pathogens Increased occurrence of diarrhoeal disease linked to extreme temperature events or natural hazards	*Vibrio* spp.*** Cyanobacteria** Cholera**** Other gastrointestinal infections***	Increases in many regions *(13)**** Increases in schistosomiasis (Africa) *(13)****
Vector-borne diseases *(8)*	Increased occurrence** Increased range of expansion or increased reproduction of disease vectors***	Chikungunya (Americas, Asia, Europe)**/*** Tickborne encephalitis (Europe)** Lyme disease (North America,*** Europe**) Rift Valley fever (Africa) West Nile fever** (Europe, Asia, North America) Malaria (eastern and southern Africa)*** Dengue (globally)***	Expansion to higher latitudes and altitudes and increased duration of season of transmission*** 2.25 billion people across 4 regions newly at risk for dengue *(13)**** Increases in Lyme disease*** Increases in malaria across 3 regions***
Animal and human diseases such as zoonoses	Emerging in new areas *(8)****	Anthrax Tularaemia *(8)*****	Increasing emergence of novel zoonoses *(14)***

Condition	Observed status	Diagnoses cited	IPCC WG II future assessment
Air pollution (wildfire smoke, atmospheric dust, aeroallergens)	Increased exposure to wildfire smoke**** and pollen *(8)****	Cardiovascular and respiratory distress	Increases in respiratory disease from aeroallergens and ozone *(13)****
Food insecurity	Increased risks *(12)****	Malnutrition *(8)****	Increases in food insecurity *(15)**** Increases in undernutrition and dietrelated mortality and risks *(13)**** 10% increase in DALYs by 2050 for undernutrition and micronutrient deficiencies *(13)*** Increases in malnutrition through reduced nutritional quality, reduced access to balanced food, and inequality *(15)**** Increases in diet-related risk factors and related noncommunicable diseases globally *(13)* Increases in undernutrition, stunting and related childhood mortality, particularly in Africa and Asia *(13)**** 8–80 million people at risk of hunger by 2050, concentrated in sub-Saharan Africa, South Asia and Central America *(13)**** Increases in cardiovascular disease mortality; compared with the 1980s, this increase could be 69–134% by the 2080s *(13)****
Food safety	Increased risks in agriculture and fisheries *(16)**** Increased impacts on food safety *(8)****	Increased disease resulting from consumption of toxins or contaminants** (e.g. toxigenic fungi,**** POPs,** methyl mercury**) *(16)* Increased bacterial infections (*Salmonella, Campylobacter, Cryptosporidium*),** mycotoxins associated with cancer and stunting in children,*** and seafood contamination with marine toxins and pathogens***	Food safety compromised*** by toxigenic fungi, contamination, algal blooms,*** POPs, methyl mercury (15),** and increases in *Campylobacter*, *Escherichia coli* and *Salmonella (13)***
Insecure and inadequate WASH	Increased disease risk *(8)****	Waterborne and waterrelated diseases Malnutrition	Increases in water-related risks *(17)****

Note: DALYs = disability-adjusted life-years; POPs = persistent organic pollutants; WASH = water, sanitation and hygiene, WG = Working Group.

Source: Willetts, E.; Campbell-Lendrum, D. *Review of IPCC Evidence 2022: Climate Change, Health, and Well-being;* World Health Organization (WHO), 2022. https://www.who.int/publications/m/item/review-of-ipcc-evidence-2022--climate-change--health--and-well-being.

The IPCC's Sixth Assessment Report concluded that climate change is a multiplier of current health vulnerabilities, including food insecurity, limited access to safe water, and reduced access to improved sanitation, health care and education. Table 1 also highlights that climate change is predicted, with very high confidence, to increase global exposure to heat stress, and, with high confidence, to impact the transmission of infectious diseases and exposure to air pollution.

Detection and attribution studies show the increasing influence of anthropogenic climate change on weather extremes resulting in direct injuries and death. The situation is particularly acute in small island developing States (SIDS) and least developed countries (LDCs). Since 1970, SIDS have lost 153 billion US dollars (USD) due to weather-, climate- and water-related hazards – a significant amount given that the average gross domestic product (GDP) for SIDS is USD 13.7 billion. Meanwhile, 1.4 million people (70% of the total deaths) in LDCs lost their lives due to weather-, climate- and water-related hazards in the past fifty years.[13] In the last decade, the observed mortality as a result of floods, drought and storms is 15 times higher in countries ranked as "highly vulnerable" when compared to less vulnerable countries.[14]

As reported by the *Lancet* Countdown on Health and Climate Change,[15] extreme heat is having devastating impacts. Globally, in 2012–2021, adults over 65 years – an age group particularly vulnerable to the health impacts of extreme heat[16] – experienced 3.1 billion more person-days of heatwave annually (3.2 more days per person in 2021) than in baseline years (1986–2005).[17] Driven by the rising temperatures and the growing over-65 population, annual heat-related mortality in this age group increased by approximately 68% between 2017–2021, compared to 2000–2004. Worldwide, heat exposure also limits labour capacity and productivity, undermining the livelihoods and well-being of families.[18,19]

Climate change is exacerbating risks of food insecurity, as environmental impacts on food systems affect food availability, access and utilization, and ultimately health and nutrition.[20,21] In 2012–2021, 29% more global land area was affected by extreme drought for at least one month per year than in 1951–1960, threatening food security, water security and sanitation. The compounding impacts of droughts and heatwave days were associated with 98 million additional people reporting moderate to severe food insecurity in 2020 than annually in 1981–2010, in 103 countries analysed.[22]

The changing climatic conditions are also enhancing the transmission of many climatically sensitive infectious vector-, food- and waterborne diseases. For example, dengue is the world's fastest-spreading vector-borne disease.[23] The suitable climatic conditions (such as temperature and precipitation) that are optimal for the proliferation of the mosquito vectors responsible for the transmission of dengue increased by 11.5% for the *Aedes aegypti* vector and 12.0% for the *Aedes Albopictus* vector between 1951–1960 and 2012–2021. Meanwhile, the length of the malaria transmission season has increased in the highlands of the Americas (by 31.3%) and of Africa (by 13.8%) over this period, adding extra pressure to disease control efforts (Figure 1).

98 million more people with moderate to severe food insecurity in 2020 than in previous 30 years

Climate suitability of dengue transmission **rose by 12%** from 1951–1960 to 2012–2021

Climate suitability of malaria transmission increased in the highlands in the Americas and in Africa, by **31.3% and 13.8%** between 1951–1960 to 2012–2021

7 million deaths globally in 2020 due to air pollution

470 billion potential labour hours lost globally in 2021 due to heatwaves - a 37% increase from 1990–1999

USD669 billion potential loss on income in 2021

Elderly and children were **exposed to 3.2 more days of extreme heat per person** in 2021 than annually in previous 25 years

Heat-related deaths increased by 68% in 2017–2021 as compared to 2000–2004

Figure 1. Climate change impacts on health

Source: Based on data from Romanello, M.; Di Napoli, C.; Drummond, P. et al. The 2022 Report of the *Lancet* Countdown on Health and Climate Change: Health at the Mercy of Fossil Fuels. *The Lancet* **2022**, *400* (10363), 1619–54. https://doi.org/10.1016/S0140-6736(22)01540-9.

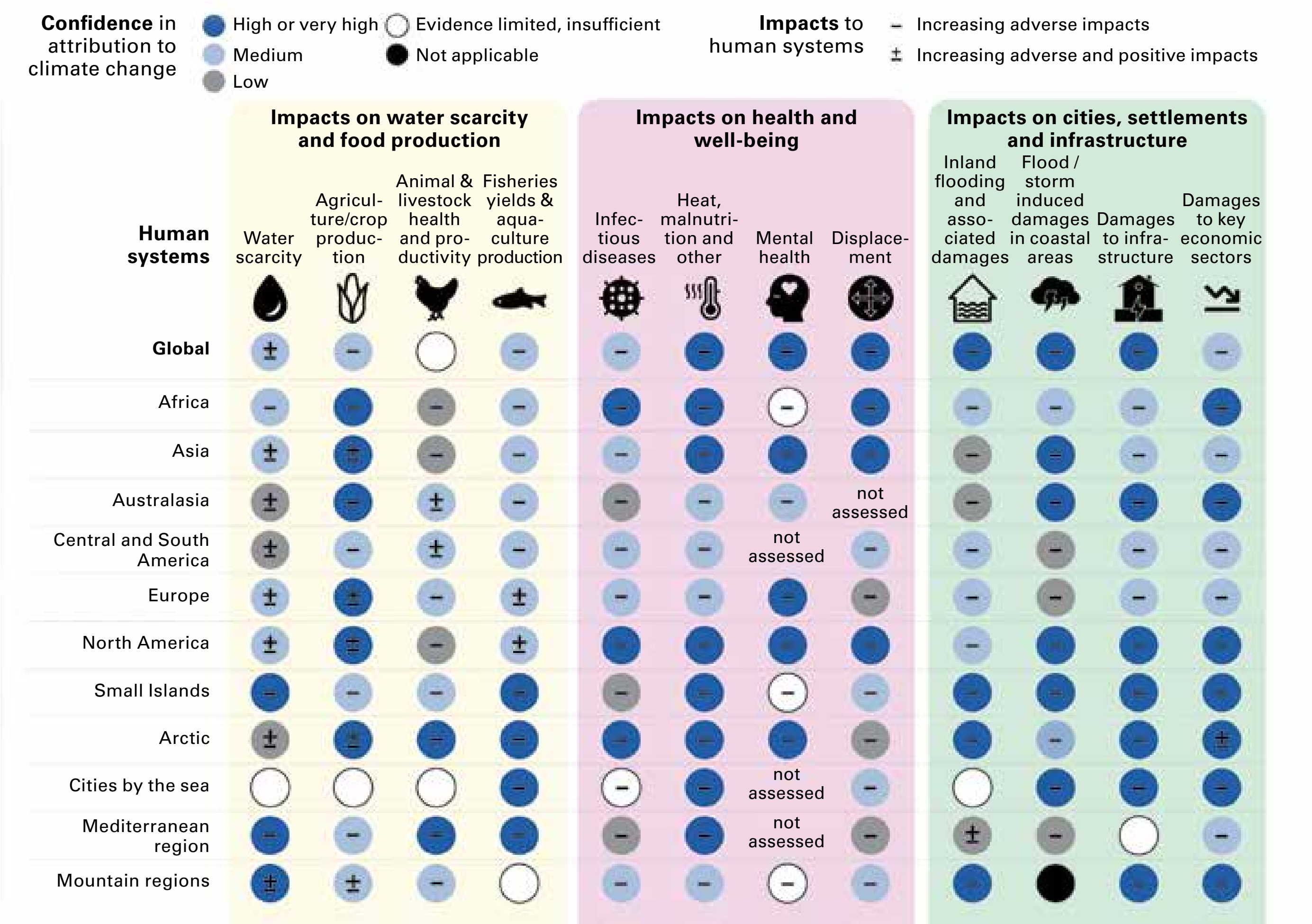


Figure 2. The need for a systems approach: observed impacts of climate change on human systems

Source: Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change;* Pörtner, H.-O.; Roberts, D. C.; Tignor, M. et al., Eds.; Cambridge University Press, Cambridge, UK and New York, USA, 2022. https://www.ipcc.ch/report/ar6/wg2/.

Figure 2 highlights that climate change is likely to present adverse and positive impacts on human systems and health in every world region. All of the human system impacts in Figure 2 either affect health directly or are determinants of health and well-being. The interdependency of many climate-affected systems, from agricultural food production to the built environment and water availability, will drive the degree of impact on human health. Some of the most significant challenges to health are in the nexus of water, food security and nutrition, the nexus of infectious diseases (food-, water-, vector- and airborne diseases) and the nexus of extreme weather and air quality, particularly in urban areas.

Health is one of the fundamental human rights of every human being without distinction of race, religion, political belief or economic or social condition.[24] The impacts of climate change threaten this right to health in unfair ways, because the impacts of climate and climate change are disproportionately felt by people experiencing higher, and often compounding, vulnerabilities and disadvantages, including women, children, ethnic minorities, Indigenous peoples, poor communities, migrants or displaced persons, older populations and those with underlying health conditions. Furthermore, as shown in Figure 3, highly vulnerable populations are not evenly distributed across regions, nor within countries. An even more inequitable future may lie ahead without targeted policy and adaptation efforts to protect the most vulnerable.

The IPCC projects, with very high confidence, future health risks of injury, disease and death as a result of more intense heatwaves and fire, and of food- and waterborne diseases. It is anticipated that over 50% of the excess mortality resulting from climate change by the year 2050 will occur in Africa.[25] Figure 4 provides a snapshot of the unequal risks that may be faced in 2050, such as projected mortality from heat, undernutrition and diarrhoea and projected population at risk of malaria, without adequate adaptation.

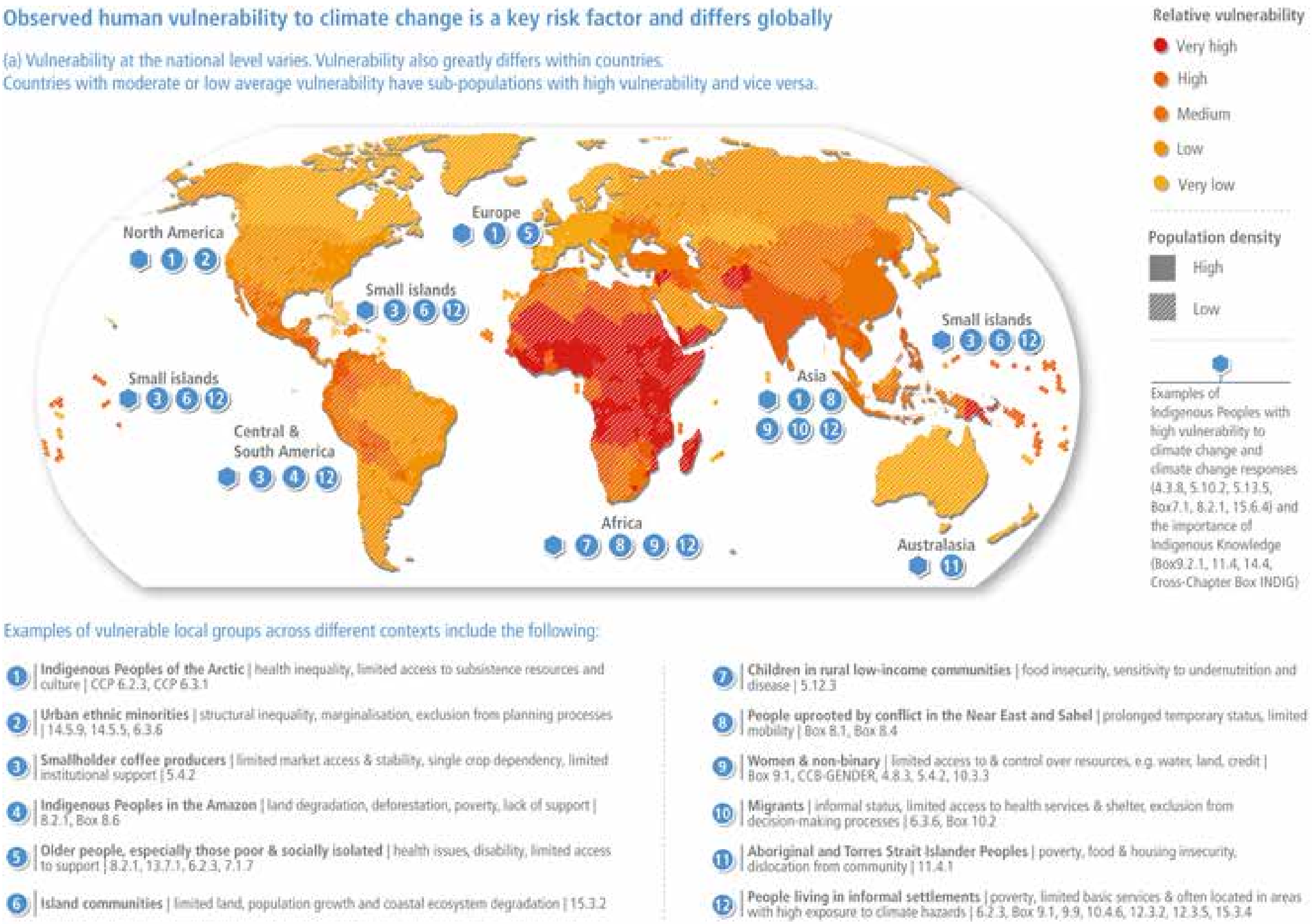


Figure 3. Global distribution of vulnerable people, with examples

Source: Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Pörtner, H.-O.; Roberts, D. C.; Tignor, M. et al., Eds.; Cambridge University Press, Cambridge, UK and New York, USA, 2022. https://www.ipcc.ch/report/ar6/wg2/.

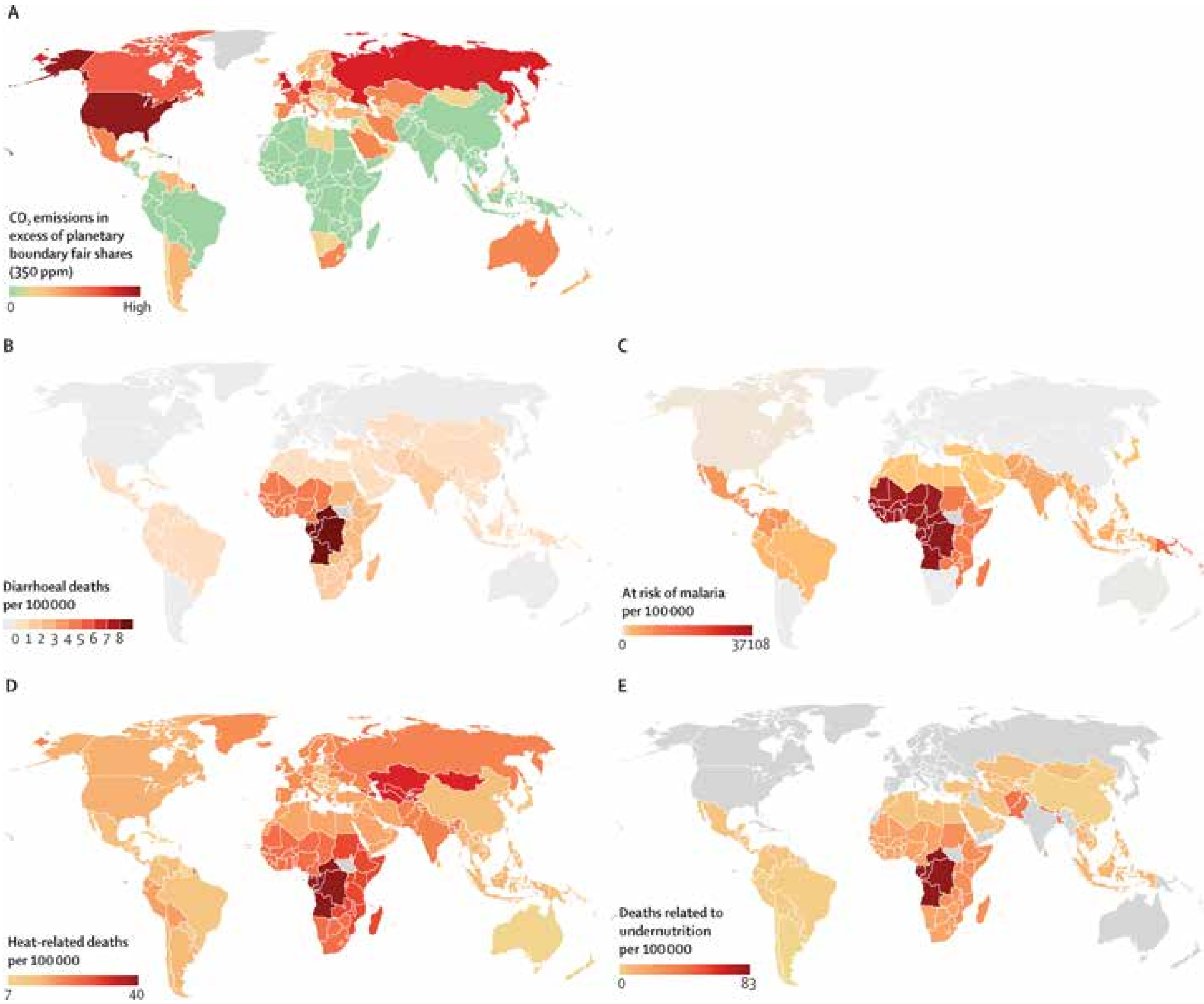


Figure 4. Health outcomes: CO_2 emissions (A) and projected climate change attributable mortality (B, C, D, E) in 2050 (ppm = parts per million)

Source: Deivanayagam, T. A.; English, S.; Hickel, J. et al. Envisioning Environmental Equity: Climate Change, Health, and Racial Justice. *The Lancet* **2023***, 402* (10395), 64–78. https://doi.org/10.1016/S0140-6736(23)00919-4.

Adaptation of health and health-supportive systems is urgently needed to prevent rapidly increasing health impacts of climate change. Insufficient preparedness and climate adaptation efforts expose vulnerable health systems to negative impacts of climate change-related health hazards.[26] Water and sanitation, hospitals and clinics, pharmaceutical and laboratory production to distribution pipelines, and ambulatory services are examples of health system functions that are at risk of disruption, damage or destruction from climate-related hazards such as flooding and extreme heat. In 2021, only 35% of low or medium Human Development Index (HDI) countries reported "high" to "very high" implementation status for health emergency management within the International Health Regulations monitoring.[27] Without enhanced risk prevention and preparedness in health and across the whole of society at the community level, the loss and damage to facilities and health services will prevent access to health care, lead to the loss of life, and hamper the ability of health systems to further manage the multifaceted risks to health from climate and climate change, such as extreme events and expanding infectious diseases.

With the health impacts of climate change rapidly increasing, accelerating health adaptation efforts is urgently needed. With each fraction of a degree of heating, these health risks will continue to increase. Accelerating efforts to limit global mean temperature rise to 1.5 °C is essential to keep climate change risks within the capacity of health-supporting systems to adapt.

The most effective measures to reduce vulnerability in the near term are programmes that improve public health today and consider the climatic conditions of the future.

Climate and health policy response

Health protection is a priority for climate policies in almost all countries and requires high-quality climate information to better inform decision-making.

Demand from policymakers for evidence and information about how the climate is changing and how it will impact society is rapidly rising. This is seen through an increasing focus on health within climate-related policies, such as Nationally Determined Contributions (NDC) reports to the United Nations Framework Convention on Climate Change (UNFCCC), National Adaptation Plans (NAPs), Health National Adaptation Plans (HNAPs), and disaster and emergency risk management policies. This is also seen through rapid growth in climate and health research, and policy and health system efforts to inform and enhance disease control programming, water and sanitation, social protection, energy, environmental protection policies – all of which support the transition to low-carbon, climate-resilient and sustainable health systems.

Based on a review of 193 NDC reports, the majority (91%) of NDCs[28] and all NAPs[29] referred to health. Close to a third (29%) of NDCs now allocate climate finance to health actions and/or plans. However, just 11% include unconditional finance targets for some or all of their health actions and/or plans.[30]

Figure 5 shows that the health sector is increasingly engaged in NDCs worldwide, especially in Africa. While many vulnerable countries had a high level of health engagement included in their NDC, the analysis does not determine whether the level of ambition is sufficient to address a country's health adaptation requirements.

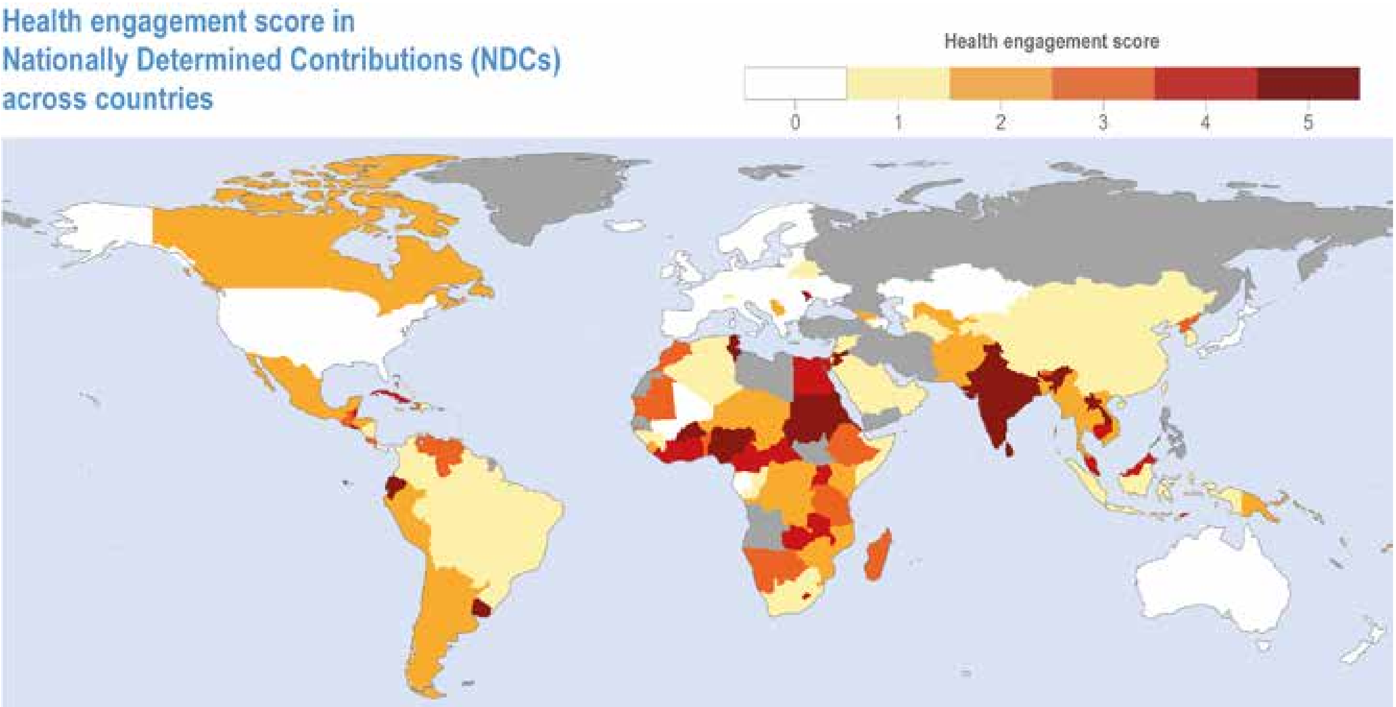


Figure 5. Health engagement score in NDCs, by country. The score is based on indicators measuring the specificity and detail of the references to health made within a nation's NDC

Note: No mention of any health-related term returned "0" on the scorecard. General mentions of health, the need for adaptation in the health sector, or co-benefits are entered as a "1" on the scorecard. Specific health impacts, adaptation needs, or co-benefits, such as concerning diseases or heat-related illness, scored a "2". Two or more particular mentions and detailed adaptation plans are entered at "3" on the scorecard. Detailed adaptation plans, combined with specificity elsewhere, received "4". NDCs containing a dedicated health section or subsection received a "5" on the scorecard. Grey indicates countries that are either not parties to the Paris Agreement or have not submitted an NDC as of January, 2020.

Source: Figure adapted from Dasandi, N.; Graham, H.; Lampard, P. et al. Engagement with Health in National Climate Change Commitments Under the Paris Agreement: A Global Mixed-methods Analysis of the Nationally Determined Contributions. *The Lancet Planetary Health* **2021***,* *5* (2), E93–E101. https://doi.org/10.1016/S2542-5196(20)30302-8.

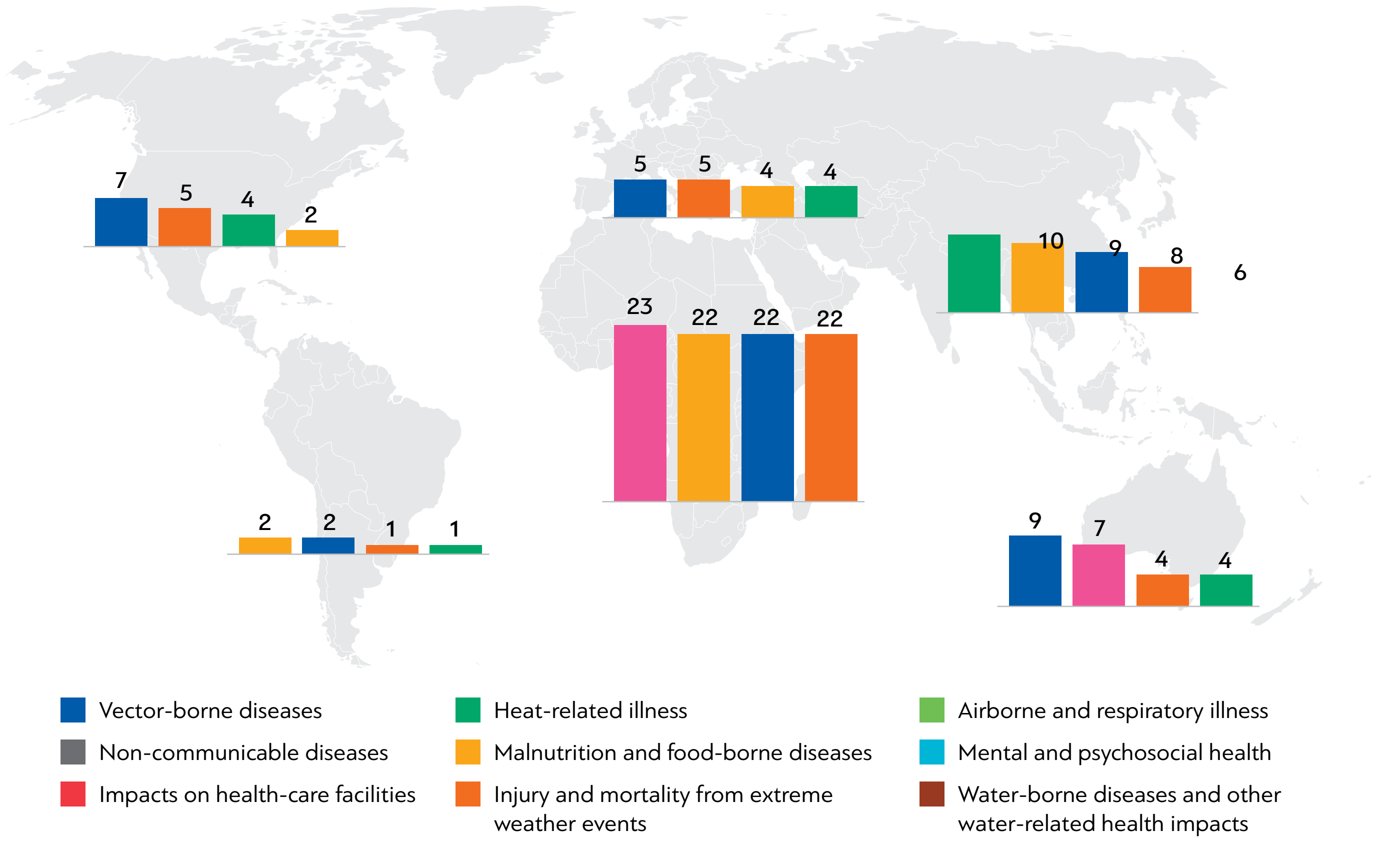


Figure 6. Number of NDCs that refer to climate-sensitive health risks or outcomes, by region

Note: Only the top four priorities are highlighted in the map.
Source: Readapted from WMO based on data from World Health Organization (WHO). *2023 WHO Review of Health in Nationally Determined Contributions and Long-term Strategies: Health at the Heart of the Paris Agreement*; WHO: Geneva, 2023. https://apps.who.int/iris/handle/10665/372276.

Figure 6 shows the regional distribution of priority health risks as mentioned in NDCs. Globally, 28% of NDCs prioritize vector-borne diseases, and 25% prioritize injury and mortality from extreme weather events.

This review of current NDCs highlights the progress made in integrating health and climate mitigation and adaptation, when compared with previously submitted NDCs. According to the World Health Organization (WHO):

> Compared with previous rounds of national climate plans, many climate and health targets have improved their evidence base, level of quality, scope, and financing. Most national climate plans now recognize climate change is a threat to human wellbeing and planetary health, while the benefits for human health arising from mitigation action are increasingly incorporated in climate targets.[31]

During the 26th United Nations Climate Change Conference (COP26), the health community reached an important milestone in bringing human health to the forefront of the climate change agenda. Despite the recognition of health in Article 4 of the UNFCCC, for the first time in the UNFCCC process a health programme was promoted in 2021. WHO launched the Alliance for Transformative Action on Climate and Health[32] (ATACH) which today brings together 70 countries that have made commitments at the Health Minister level to strengthen the climate resilience and/or reduce the greenhouse gas emissions associated with their health systems.

To help guide the health sector to systematically and effectively address the challenges presented by climate variability and change, WHO has developed the Operational Framework for Climate Resilient and Low Carbon Health Systems[33] (Figure 7) as the basis for developing Health Adaptation Plans and NDCs. Each area of the framework can be climate informed. The functions coloured in green require climate information and services to be able to inform the other functions, especially climate-informed programming, such as for vector control, water and sanitation or facilities, and health system preparedness for extreme weather.

Despite the recent growth in interest and policy engagement, there is still room for improvement in ensuring the health sector is fully aligned with national climate responses, and in utilizing climate information and services to seamlessly inform national assessments and policies.

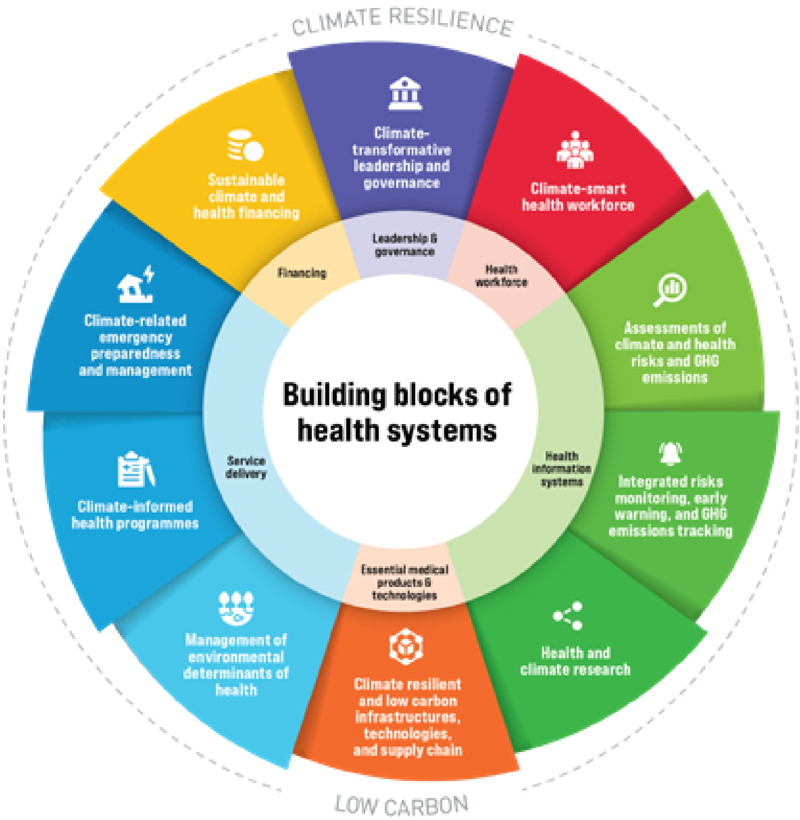


Figure 7. WHO Operational Framework for Climate Resilient Health Systems

Source: World Health Organization (WHO). *Operational Framework for Building Climate Resilient and Low Carbon Health Systems*; WHO: Geneva, 2023. (in press)

The value

Photo: Kraken images

Climate information enhances public health prevention strategies and preparedness to save lives, reduce health risks and impacts, and support countries' adaptation and mitigation efforts.

Due to increased weather-, climate- and water-related health hazards, the health sector will increasingly need reliable and robust information services to strengthen its resilience to climate change and variability. Integrated and applied climate products, services and systems that are robust and tailored can enhance the evidence and information available to health partners to detect, monitor, predict and mitigate climate-related health risks.

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.[34] Climate services are a vehicle through which climate and other types of information can be tailored to appropriately inform sectoral decision makers.

WHAT ARE CLIMATE SERVICES FOR HEALTH?

Climate services for health are "the entire iterative process of collaboration between relevant multi and trans-disciplinary partners to identify, generate and build capacity to access, develop, deliver, and use relevant and reliable climate knowledge to enhance health decisions".[35] These services take many forms, but all have common characteristics and the common goal to produce integrated and actionable climate information, stemming from a well-grounded holistic perspective of past, present or future states of climate-related risks to society.[36]

Climate information and services are a foundational element for understanding and monitoring the influence of a changing climate on population health and health systems. They allow decision makers to have foresight and plan ahead to inform policy and practice that can be protective months, seasons and years ahead. Climate services can improve the communication of climate-related risks to health professionals, identify those populations that are most vulnerable, predict when and where climate-associated health risks may be greatest, and support the effective design and targeting of interventions.[37] Climate services are indispensable for risk assessment, emergency preparedness, early warning and programmatic interventions to protect the health of the public. They are also an integral part of disaster risk reduction, intended to minimize the impact of climate hazards on public health and society at large, by enhancing health early warning systems, disease prevention and control efforts, heatwave and air quality management, climate change adaptation, anticipatory governance structures and health education. Climate services contribute to empowering individuals, and building climate-resilient health systems and healthy communities.

Example benefits of climate services for health:

- In **Kenya**, humanitarian organizations are better able to quantify the risk of anticipated drought thanks to improved forecasting, increased drought monitoring and the sharing of information. A 2022 survey by Kenya Red Cross indicated that all of the rehabilitated water facilities remained functional throughout the drought period despite the increased dependence on them as a source of clean and cheaper water for household use, while drought impacts started peaking. See Case study No. 3.
- In **Europe**, a mobile app has been developed to provide information on risks of heatwaves in urban environments. In 2022, 1 000 Athenians and visitors used the app to cope with heat and air pollution. See Case study No. 13. Meanwhile, real-time observations of aeroallergens are revolutionizing the information available to users of the app – and improving the health of millions of European allergy patients. See Case study No. 14.
- Enhanced integrated risk monitoring and climate-informed early warning systems have helped people in **Fiji** to better prepare and respond to climatic changes, reducing morbidity and mortality from climate-sensitive diseases. See Case study No. 12.
- The 2006 heatwave in **France** resulted in 2 065 excess deaths, which is significantly lower than what was expected – namely, approximately 4 400 fewer deaths. This was attributed to increased awareness, preventive measures and the presence of a warning system.[38]

Climate information opportunities

Climate information has the potential to inform a wide range of health decisions through an improved understanding of the following:[39]

Mechanisms of disease transmission:	Spatial risk:	Seasonal risk:	Sub-seasonal and year-to-year changes in risk:	Trends in risk:	Assessment of the impacts of interventions:
to help identify new opportunities for intervention	to help identify populations at risk for better targeting of interventions	to inform the timing of routine interventions	to identify when changes in epidemic risk are likely to occur, so as to initiate appropriate prevention and response strategies	to identify long-term drivers of disease occurrence (including shifts in the climate) to plan for and support future prevention and response strategies	to remove the role of climate if it interferes with the proper assessment of interventions

HOW THE HEALTH SECTOR USES CLIMATE INFORMATION

The health sector is comprised of many actors at different levels, who work in partnership. These include Ministries of Health; public health agencies; public and private pharmaceutical and laboratory service providers; research teams and academia; non-governmental organizations (NGOs); public and private health-care providers; insurance and social protection schemes; and development banks, multilateral organizations, bilateral donors, philanthropic donors and funding mechanisms.

Health functions that can benefit from being informed by weather and climate information include[40] vulnerability analysis, risk assessment and proactive all-hazards risk reduction; disease control strategies; health policy and regulations; disease monitoring and surveillance; financial and human resource allocation; pharmaceutical, health, pesticide and vaccine supply flow; and health infrastructure siting and maintenance.

Public health and health protective functions in other sectors include water, sanitation and hygiene infrastructure and services, disaster and emergency services, land use and urban planning, and food security.

"Good health" is a common outcome for other sectors which provide clean water, sufficient and safe housing and transport, food security, access to energy and social services. Protecting health requires coordinated science, policy and action across many sectors and levels of governance. The interdependency and role of other sectors in health was demonstrated by the need for all sectors to help prevent and control the COVID-19 pandemic. The impact on other sectors, from meteorology to transport, was also evident when workers were sick and unable to maintain functions.

THE NEED TO INTEGRATE CLIMATE INFORMATION INTO KEY HEALTH SYSTEM FUNCTIONS IS MORE CRUCIAL THAN EVER

To effectively use and benefit from climate services, health sector partners need appropriate data, computing and analytical capabilities, methods, tools and models, training, institutional architectures and appropriate governance, and funding for health research.

Exposure monitoring, assessment, early warning systems and basic diagnostics can support a range of health decision applications. For example, historic climate observations can support epidemiological trend and regression analysis to understand associations of climate and health, set risk thresholds and inform disease control plans.[41] Weather monitoring and nowcasting products that deliver real-time weather conditions can guide emergency interventions, such as identifying flooded areas, potentially damaged health infrastructure or isolated communities, and can help in deciding on staff deployment or delivery of supplies.

This integration of climate knowledge starts with robust research, is built upon integrated and robust data systems and multidisciplinary training, and co-produced diagnostic and decision tools, including climate-informed early warning systems.

Climate services tailored for other sectors, such as agriculture, water and energy, make important indirect contributions to public health by helping safeguard life-sustaining food, water and energy resources. Applied climate science is an integral part of public policy in the context of climate change, providing essential future climate projections to inform long-term planning and evidence-based decision-making. Analysis of the potential health co-benefits of climate change adaptation and greenhouse gas (GHG) mitigation measures using climate sciences will support closer collaboration among health sector decision makers and those in other sectors. Expanding the use of climate services in the health sector has significant potential, especially for protecting vulnerable locations and populations at higher risk of adverse health impacts from climatic hazards.

Multidisciplinary partnerships and systems-based approaches are the foundation of climate services. Technical tools and products have limited impact unless they are demand driven, co-produced, and directly tied to solving problems of decision makers and practitioners.

ACCELERATING SUCCESSFUL PARTNERSHIPS WITH GOOD PRACTICES

Experience, gap analyses, expert opinion, evaluations and research findings on the application of climate science in the health sector all point to a convergent set of principles and approaches that can maximize practices and impact. Applied climate information products and services do not exist in isolation. This information joins a complex ecosystem of decision makers, localized challenges and contexts, diverse ranges of potentially useful information and misinformation, varied capacities and social considerations, all amidst a rapidly changing and dynamic climate risk context. These applied climate information products and services support evidence-based decision-making, enable proactive planning and contribute to the development of resilient health systems in the face of climate change.[42]

Good practices can support health and meteorological actors to work together more effectively to understand, adapt and mitigate the impacts of climate change in the health sector. Seven essential approaches have been identified through practice, as outlined in Figure 8, starting with making sure climate services are fit for purpose and respond to health needs.

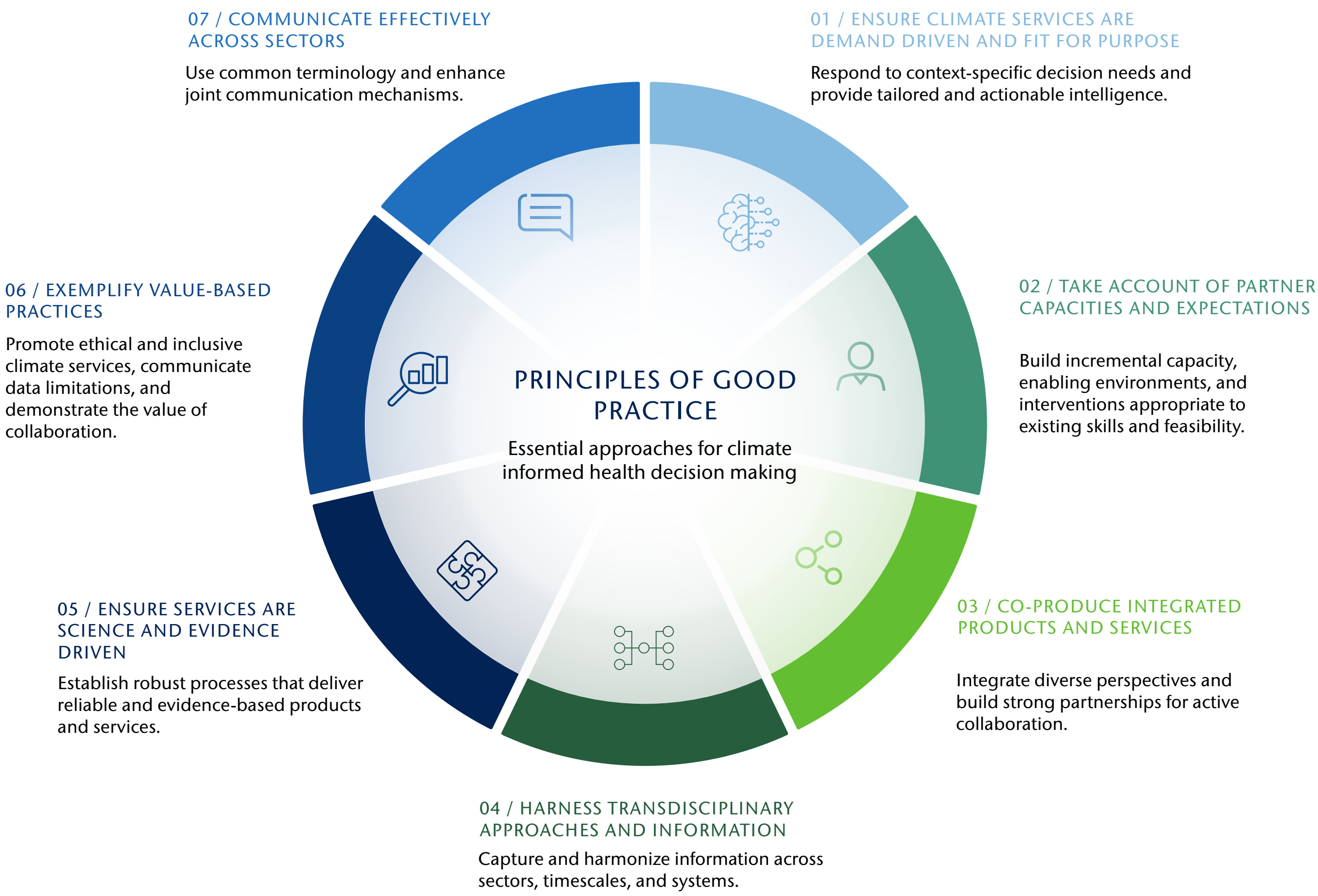


Figure 8. Principles of good practice for successful climate-informed health decision-making

Source: Shumake-Guillemot,J. ; von Borries, R.; Campbell-Lendrum, D. et al. Good Practices: Co-producing Integrated Climate, Environment and Health Services. *PLOS Climate* (in press).

Current status of climate services for health

Photo: Eric1513

There is huge potential for enhancing the benefits of climate science and climate services for people’s health and well-being.

The status of climate services for health is reviewed in three ways in the present report: by considering WHO and WMO monitoring data; by taking a deep dive into two thematic topics to see how climate information is used to manage the health risks of extreme heat and air quality; and finally, by considering commonalities and issues faced in a series of case studies exploring how climate services are being developed and used around the world to help support the health sector become more climate resilient and low carbon.

WMO monitors the capacity of NMHSs to provide both climate and weather service functionalities, according to defined technical criteria at “basic”, “essential”, “full” or “advanced” levels.[43] Since 2018 there has been ongoing growth in capacity for climate services, with most NMHSs now providing services at an “essential” level (Figure 9). See Data and methods section for more details.

For climate services, only 11% and 20% of NMHSs provide climate services at a “full” and “advanced” level of capacity respectively, where co-production and product tailoring most often happen (Figure 9). This reflects a significant capacity gap to be filled in order to increase the service capacity of NMHSs.

Weather services play a vital role in protecting public health by providing timely and accurate information that allows communities and individuals to prepare for and respond to weather-related risks which occur on a less than 30-day timescale. Based on the available data, only 20% of NMHSs provide weather services at a “full/advanced” level, while 31% provide those services at a “basic/essential” level (Figure 10).

Regional Climate Centres (RCCs) play an important role in supplementing national capacity, providing regional scale analytics and forecasting. The 16 designated WMO RCCs[44] and RCC-Networks provide health-relevant climate products and services, which can be used by NMHSs or directly by health partners. For example, the RCC-Caribbean and RCC-Beijing provide predictions of high-temperature days and RCC-Moscow provides sub-seasonal forecasts of the duration of cold and warm spells, and uses the Extreme Forecast Index to indicate the probability of the occurrence of heatwaves.

Figure 11 shows that most services provided are still not sector-tailored services. NMHSs’ self-reported level of service provision to the health sector is reported on a scale of 1–6, with 1 corresponding to “initial engagement” and 6 to “full engagement”, with socioeconomic benefits achieved and documented. The average score is 3.06 out of 6, corresponding to initial engagement and definition of needs (1–3), rather than provision of tailored products and services (4–6). From a regional perspective, the lowest levels of service for health are reported in Asia (2.3), Africa (2.7), and North and Central America and the Caribbean (2.7). This indicates that most relationships between government authorities for health and climate have nascent relationships and limited collaboration.

However, 74% of NMHSs indicate that they provide data services for the health sector, which reflects that the entry point for collaboration is often in the form of data-related services for the purposes of risk assessment and research (Figure 11).

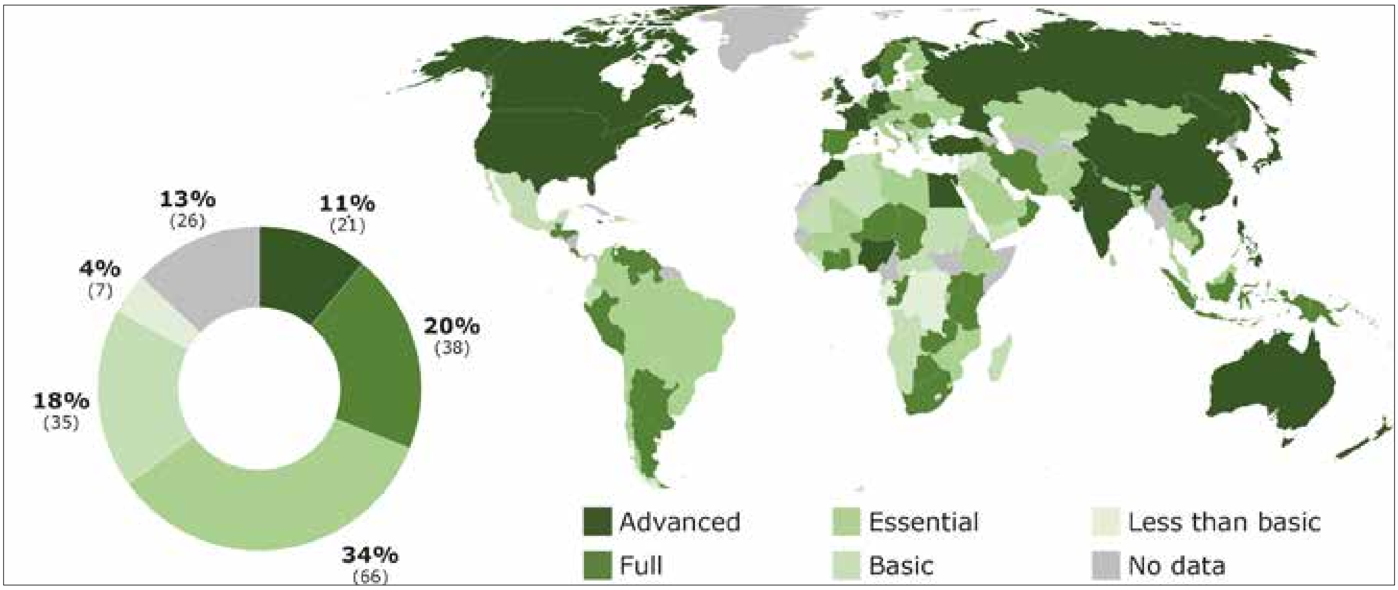


Figure 9. Overview of generalized climate services capacities (not sector specific)[45]

Note: Percentages in the pie chart are based on the 193 WMO Members, with absolute number in parentheses. The information in Figure 9 represents 14 Members whose data has been validated by international certified auditors. They are Botswana, Jamaica, Argentina, Nepal, United Republic of Tanzania, Lao People's Democratic Republic, Niue, Oman, Nigeria, Greece, Timor-Leste, Peru, Philippines and Croatia.

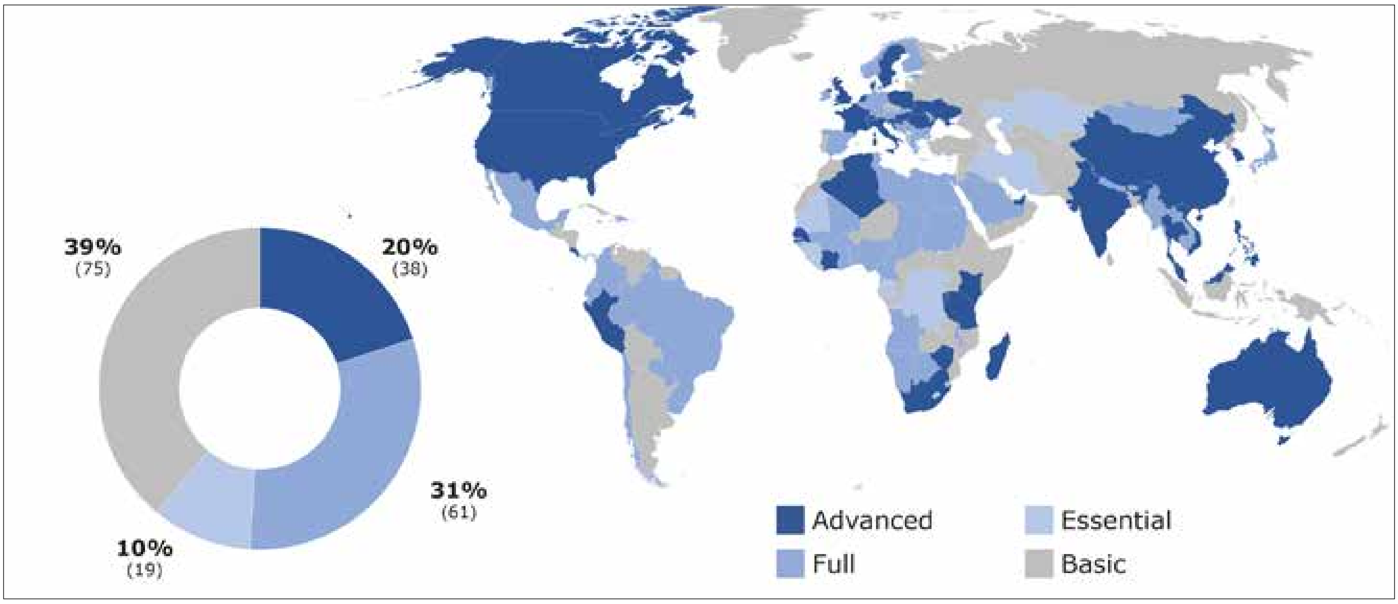


Figure 10. WMO Member weather services capacities calculated as a percentage of functions satisfied of NMHSs providing data, categorized as "less than basic" (0–33%), "basic/essential" (34–66%) and "full/advanced" categories (67–100%) of functions satisfied, respectively (not sector specific)

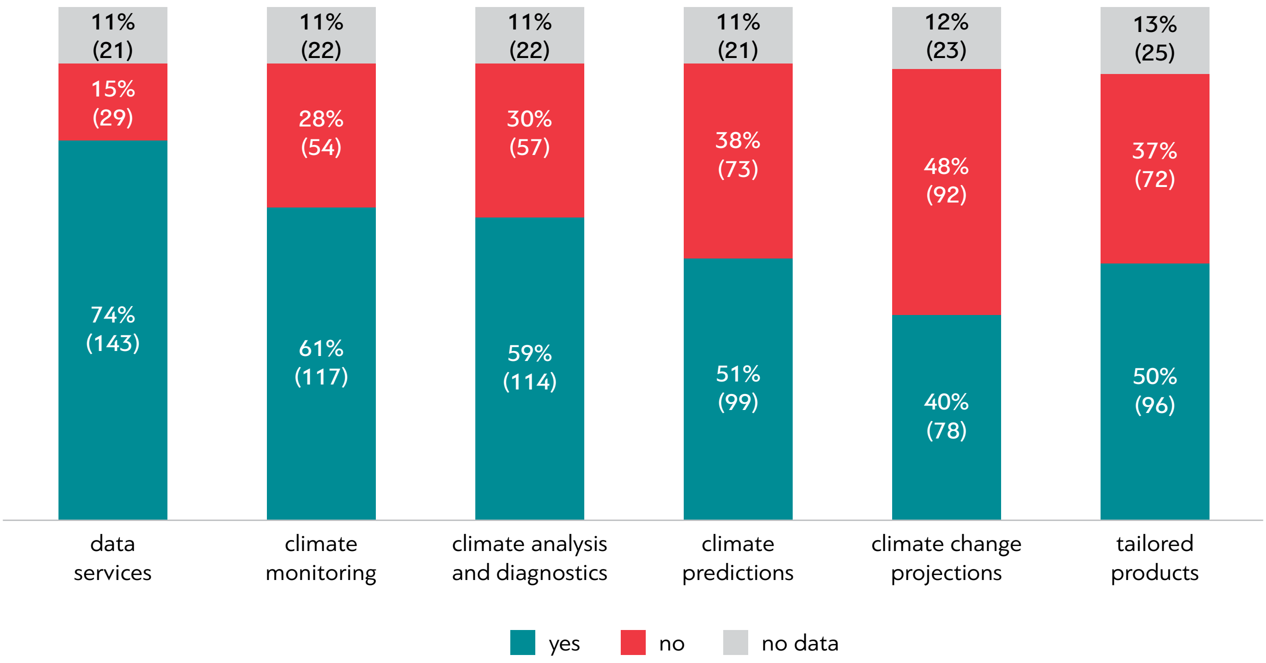


Figure 11. Breakdown of the diverse range of climate services provided by NMHS to the health sector globally[46]
Note: Percentages are based on the 193 WMO Members, with absolute numbers in parentheses.

Where climate services are available, access to climate information at the right resolution, in the right format and of sufficient quality, often remains a barrier. Although 74% of NMHSs report providing data services to the health sector, data from WHO show that only 14% of Members have a formalized agreement between the Ministry of Health and the NMHS to enable data sharing and collaboration, which are key for the creation and functionality of decision-making platforms, such as integrated climate and disease surveillance systems.[47]

Access to appropriate and usable climatic information remains a key constraint for many health partners to develop climate-informed decision-making tools. Limited availability and access to local observations results in climate data being sought from sources other than NMHSs, particularly remotely sensed data or global reanalysis products, in order to fill gaps in local in situ observations. The capacity and climate literacy of health partners to appropriately identify, use and analyse climate information remains generally low.

A dedicated web portal, www.climahealth.info, was launched jointly by WMO and WHO in 2022 to help improve climate literacy and accelerate access to relevant information for policymakers, practitioners, researchers, the media and students.

Available climate, weather, environmental science, and technology are currently underutilized in the way the health sector does business and makes programmatic and financial decisions.[48] Three indicators are used to assess the use of climate information by national health authorities: the conduct of climate change and health vulnerability and adaptation assessments; the presence of health surveillance systems that use meteorological data; and the presence of climate-informed warning systems.[49]

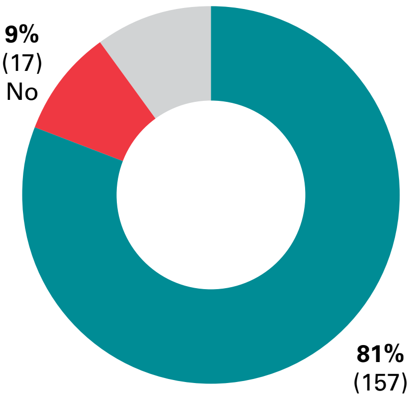
Firstly, many countries do not have the requisite information to plan effective health adaptation measures. The WHO survey of Ministries of Health in 2021 revealed that only 48 out of 95 countries have completed a climate change and health vulnerability and adaptation assessment. The conduct of these assessments requires localized historical and future climate information provided through climate services. Only nine of these assessments strongly influenced resource allocation.[50]

Secondly, health surveillance systems provide the analytical backbone to decision-making in the health sector, by providing observations and trends of disease incidence and health outcomes, as well as service delivery metrics. These data collection and analysis platforms play a critical role in early detection of health threats, monitoring the performance of health interventions, and informing public health policies, interventions and resource allocation. The seamless integration of climate information into these national data systems therefore serves as a core measurement of the use of climate information in the sector.

Despite 74% of NMHSs providing climate data, the uptake by Ministries of Health of such data to be used in surveillance systems is limited. Based on data from WHO, only 23% of Ministries of Health have a health surveillance system that uses meteorological information (Figure 12). These findings indicate considerable potential for increasing the use of climate services for the health sector by strengthening collaboration, data sharing, and integrated climate and health surveillance systems. This is true for health surveillance systems in all climate-sensitive health risk areas analysed, based on data from WHO (Figure 13).

Thirdly, based on data from WHO, only 26[51] countries reported having climate-informed heat-health early warning systems (HHEWS) in place for heat-related illness, and 24[52] countries reported having them in place for other extreme weather events. The data also show a strong income disparity: half of the very high Human Development Index (HDI) countries (n=26) had HHEWSs to monitor extreme weather events, compared with just 19% of low or medium HDI countries (n=31).[53] These data suggest that low HDI countries are proportionally less prepared to address extreme weather, because they lack early warning systems (EWS).

The status of these three indicators of "use" suggests that there is considerable potential for increasing the availability, access and use of climate information. Limitations in data availability and exchange policies, technology gaps, data quality, resolution and formatting, workforce skill and capacity, and collaboration all need to be addressed to enhance uptake.



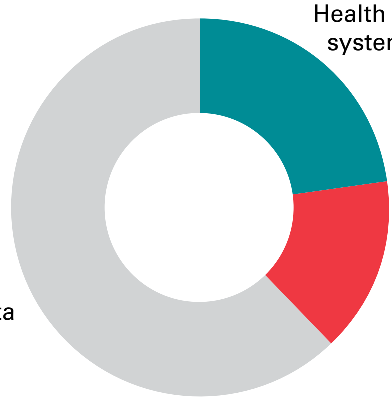


Figure 12. (Left) Percentage of NMHSs self-reporting provision of climate services for the health sector. (Right) Percentage of Ministries of Health self-reporting a health surveillance system that includes meteorological ("met") information.

Note: WHO data have been restructured to fit WMO regional classification. Percentages in Figure 12 are based on the 193 NMHSs, with absolute numbers in parentheses.

Source: (Left) WMO Climate Services Checklist data; (Right) World Health Organization (WHO). *2021 WHO Health and Climate Change Global Survey Report*. WHO: Geneva, 2021. https://www.who.int/publications/i/item/9789240038509.

It is clear from these data, that cooperation and coordination among the health and climate communities needs to be catalysed and cultivated in order to enhance the co-production of health-relevant climate science and services.[54] As a mechanism to encourage collaboration, WMO has requested NMHSs to nominate focal points as the first point of contact with the health sector. To date, NMHSs in 66 Members have designated focal points. However, very few of these focal points have training in health analytics or in how to support health-specific projects.

Case studies and the peer-reviewed literature also report that collaboration between the health and meteorological sectors for risk management decisions is limited,[55] that interpretation can be compromised without meteorological experts, and that this poses an impediment to policy and actions to protect health from climate risks.

Furthermore, to promote the upscaling of climate services for health, a focus on improving the underlying systems for science-based decision-making and the enabling environment through policy and governance enhancements is needed.[56]

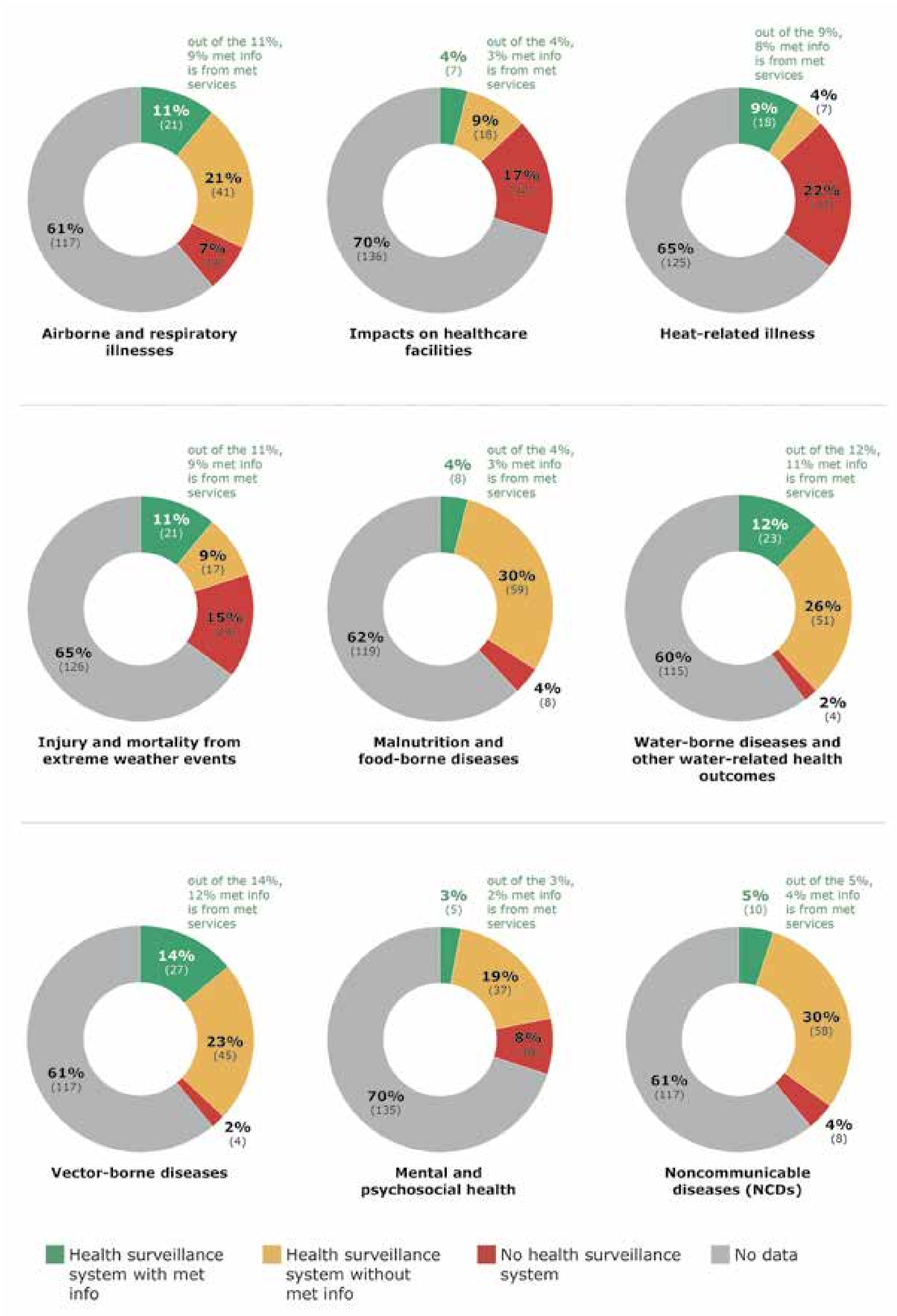


Figure 13. Detailed breakdown of the percentages of Ministries of Health reporting a health surveillance system for climate-sensitive health risks, which includes or excludes meteorological information

Note: Percentages in Figure 13 are based on the 193 NMHSs, with absolute numbers in parentheses.
Source: Based on data collected by WMO in 2022 and World Health Organization (WHO). *2021 WHO Health and Climate Change Global Survey Report*. WHO: Geneva, 2021. https://www.who.int/publications/i/item/9789240038509.

Barriers to co-producing and implementing climate services for health

The combination of information collected from the surveys and case studies reveals a range of common barriers to co-producing and implementing climate services for health, which need to be addressed to see progress in this field. These include barriers to collaboration and accessing data, insufficient human and institutional capacity, lack of uptake and application of information and services, research and knowledge gaps, availability and access to sufficient data, predictions and modelling products, financial sustainability, sufficient understanding and risk communication.

In particular:

1. The terms "Climate-informed decision tools" and "climate services" are used interchangeably by the health community. What are often referred to as a "climate services" are actually the partnerships and techniques used to enhance existing health sector decision tools and processes (for example, epidemiological studies, risk assessment, monitoring and surveillance, early warning and detection, public risk communications and emergency response planning) with information about the climate exposure at different timescales.
2. To the health community, weather and climate information are considered the same type of "exposure", expressed as a continuum. The strong distinction between climate and weather is not perceived by the health community, and the division made by the meteorological community is seen as a barrier to data and understanding. Appropriate epidemiological analysis requires risk assessment and planning across timescales, building on robust historical climatological records.
3. Climate services are co-developed by a broad range of partners and actors. Rarely are NMHSs the principal "providers of climate services", but rather play a role on a team to provide data, analysis and interpretation, computing capacity and subject matter expertise. The language of "users and providers" is in fact seen as a barrier to co-production and collaboration. Universities play a strong role in providing the research and analytical requirements needed to develop and test robust climate-informed health analytics and tools, which are often beyond the remit or capabilities of government authorities.
4. Multisectoral collaboration and transdisciplinary research is key for climate services because a mechanistic understanding of how climatic conditions impact health outcomes is necessary to develop tailored climate products and services, including a sound understanding of disease transmission and ecology, and human behaviour. Research and operational services cannot be divided, and seamless systems are needed to address health risks.
5. Health risks and impacts are dynamic, multidimensional and hyperlocal, so the spatial scale of information services is a paramount consideration. Many case studies are at the urban scale where populations are most heavily concentrated, and yet climate exposure information often does not match this resolution.
6. Very few NMHSs, regional climate centres, and regional specialized meteorological centres have dedicated capacity, training programmes and human resources to work with the health sector at a level to support climate and weather-related research and co-produce tailored products and services. Finding climate experts to collaborate with health partners on projects and research remains a challenge.
7. Access to sufficient local meteorological observations is a frequent limitation. The use of remote-sensing information is commonly sought to fill this data gap or access limitation, as well as provide a larger-scale perspective sometimes needed to understand patterns of disease transmission or environmental risk. However, remote-sensing data introduces additional limitations and capacity requirements.
8. Capacity challenges are fundamental and frequent because training of meteorologists and health professionals, including epidemiologists, in similar mental models, frameworks and techniques is rare. Staff and technicians with sufficient training to develop tailored climate information products and services are extremely limited in low- and middle-income countries (LMICs).
9. Collaboration is not always formalized through Memorandums of Understanding, working groups, staff exchanges and joint activities (for example, joint risk assessments, planning, exercises, operations, training and reviews) that help build capacity, relationships, common understanding and a more conducive partnership and enabling environment.
10. The demand for climate-informed health analytics and services underestimates the long-term investments needed to build robust and responsive decision support systems, integrated with, and responding to, policy and programmatic needs. Many case studies focus on building integrated surveillance systems, demonstrating that integrated climate and health data collection and processing systems are foundational to sustainable climate services for health.
11. Climate services are most often developed as analytical tools for decision makers, such as policy analysts or programme managers. Health workers across health systems, particularly at the local, operational levels, require climate information to assess, plan and deliver health services tailored to the local climate and public health risk contexts. Public-facing risk advisories or warnings can be derived but often take years to develop, prototype, quality control and refine for dissemination in a way that meets public risk communication standards and good practice.
12. Communicating climate risk to different target audiences is just as important as tailoring the information to their needs. This is particularly true between researchers and decision makers.
13. Systems for monitoring and evaluating the availability, access and use of climate science and services are almost non-existent. Very few case studies discuss evaluation of the products and services. However,

determining usefulness, uptake and precision of climate services is critical for building trust, confidence and mainstreaming this knowledge into decision-making.

A theory of change and next steps to address these challenges have been proposed in the WHO-WMO Implementation Plan for Integrated Climate and Health Science and Services[57] and highlighted in The way forward section.

Focus: Extreme heat

Extreme heat causes the greatest mortality of all extreme weather, yet heat warning services are provided to health decision makers in only half of the affected countries. Extreme heat services are expected to rapidly increase by 2027 under the United Nations Early Warnings for All initiative.

Deadly heatwaves and extreme heat affect all inhabited world regions. Half of the world's population has experienced record maximum temperatures in the last decade.[58] In 2022, the sixth warmest year on record for the Earth's surface, approximately 380 million people experienced their hottest single hourly temperature ever recorded.[59] July 2023, was the Earth's hottest month on record at the time of writing the present report.

For a large part of Europe, 2022 was the warmest year on record, with unseasonably high temperatures recorded throughout the year affecting much of the continent. The hot daytime and night-time extremes experienced in late spring and summer resulted in conditions that were hazardous for human health. Southern Europe experienced a record number of days with "very strong heat stress" during summer, consistent with an upward trend in the number of days with "strong" or "very strong heat stress" across Europe and a decreasing trend in the number of days with no heat stress.[60,61] These extreme heat conditions during the summer of 2022 have been estimated to have claimed over 60 000 excess deaths in 35 European countries.[62]

Over recent decades, singular and extended extreme heatwave events have resulted in a large number of casualties. The 2003 heatwave in western Europe resulted in the deaths of over 70 000 people. Other notable deadly events occurred in 2010 in the Russian Federation, in 2015 in India, in 2019–2020 in Australia, in 2021 in North America and in 2022 in China. While these mega-events take a large number of lives, cumulatively most heat-related deaths and injuries occur during the more frequent, less intense heatwaves which affect people due to occupational exposure, health impairment or age-related vulnerabilities. In 2023, Asia experienced record temperatures in Thailand, Myanmar, Lao People's Democratic Republic, Viet Nam, China, and south Asia.[63] The human toll of extreme heat is far higher than often reported, as insufficient reporting restricts the capacity to produce accurate mortality estimates at national and global levels, particularly in tropical and subtropical countries which experience chronic heat, as well as extremes.

Globally, the impact of extreme heat and heatwaves is heavily underestimated, with mortality potentially 30 times higher than previously suggested. Between 2000 and 2019, estimated deaths due to heat were approximately 489 000 per year, with a particularly high burden in Asia (45%) and Europe (36%).[64]

Heatwaves are among the most dangerous of natural hazards, but rarely receive adequate attention because heat attributable deaths and damages are not always immediately obvious. This is because registering of heat hazards is inconsistent, chronic heat exposure is deadly, official government heat impact monitoring and health surveillance systems are nascent, and even where available, data are often analysed, validated and reported on months after a heat season. These factors result in the immediate impacts of heat on human health being underappreciated and the perception of heat risks understated.

Climate change attribution studies play an important role in identifying when and how climate change is exacerbating extreme heat. Studies show that climate change exacerbated the severity of the 2003 European heatwave by increasing the risk of heat-related mortality in Paris by 70%,[65] where it is estimated that more than nine years of life were lost on average. More recently, studies estimated that climate change made the June 2021 heatwaves on the Pacific coast of the United States of America and Canada at least 150 times more likely.[66] In 2023, extreme heatwaves impacted several parts of the northern hemisphere, including Mexico and the south-west of the USA, southern Europe and China.[67] Studies show that without human-induced climate change, these heat events would have been extremely rare. In China, the heat of 2023 would have been about a 1 in 250-year event, while the occurrence of the maximum heat levels experienced in the USA/Mexico region and southern Europe would have been virtually impossible without human-induced climate change.

Research on extreme heat is important for understanding how extreme heat is triggering cascading impacts on fire, drought, storms, water resources, food insecurity and infrastructure, which affect multiple sectors or regions at once and can amplify the scale of other hazards.[68] For example, in India, concurrent heatwaves and droughts in 2002 and 2009 negatively impacted the agriculture, health and economic sectors and caused terrestrial water storage losses and electricity shortages.[69]

According to the IPCC, there is "high confidence" that Central and South America, southern Europe, southern and South-east Asia and Africa will be the most affected by climate change in terms of heat-related mortality by 2100, based on 1.5 °C, 2 °C and 3 °C increases in the global temperature.[70]

The IPCC also notes with "very high confidence" that significant impacts of heat are expected from the combination of future urban development and the more frequent occurrence of heatwaves, with more hot days and warm nights adding to heat stress in cities. Impact assessments and adaptation plans in cities require high spatial resolution climate projections along with models that represent urban processes, ensemble dynamical and statistical downscaling, and local-impact models.[71]

STATUS OF EXTREME HEAT SERVICES

In order to understand, monitor, predict and prepare for a warming world, the following are all critical: climatological records; hazard registration; seasonal, sub-seasonal and weather forecasts; research on the changing characteristics and dynamics of extreme heat; urban heat modelling; climate change attribution studies; vulnerability and impact research; and operational early warnings and impact advisories.

The IPCC states, with "high confidence", that Heat Action Plans and Heat Health Warning Systems (HHWS) represent key adaptation options to extreme heat.[72]

These interventions play a critical role in mitigating the health risks associated with extreme heat. While heat warning systems provide alerts when adverse temperatures are likely to impact on the health and well-being of the population, HHWSs go one step further in providing tailored decision support information. Heat health warnings are impact-based warnings underpinned by thresholds and other decision tools co-developed jointly by meteorologists and public health officials (such as epidemiologists, community health specialists, environmental health specialists and risk communicators). These warning systems alert decision makers to cumulative excess heat that presents significant risk to human health. Decision makers characterize the impact of extreme heat in their heat action plans through the combination of forecast heat intensity, known exposures, risk communication strategy and targeted interventions. These tools save lives, raise public awareness, enhance preparedness and improve response capabilities throughout the heat season.

Nevertheless, only 54% of NMHSs (104) have extreme heat warnings.[73] These NMHSs monitor, forecast and warn for extreme temperatures (78), provide thermal human heat budget information (9) and monitor, forecast and warn for heatwave intensity (2). In response to this rapidly emerging hazard, WMO recognizes the need for rapid development of extreme heat climate, monitoring, forecast and warning services, noting the valuable role NMHSs play in the provision of authoritative extreme heat services and warnings. Development of heatwave intensity climatologies and attribution studies are noted as key initiatives to support hazard awareness and impact-based services and warnings.

The applicability and feasibility of extreme heat warning systems varies across regions. As shown in Figure 14, current models for some areas of the world are skilful and can be used for early extreme heat warnings at both the short-term and seasonal scale (black), whereas other areas have either short-term skill (red) or seasonal skill (green).

WMO and its Members are taking steps to address these gaps and accelerate technical capabilities for extreme heat.[74] The diversity in existing extreme heat warning systems demonstrates a lack of consistent heatwave terminology and definitions, and varying levels of capacity for monitoring, research, prediction and services. In this regard, WMO is renewing *Heatwaves and Health: Guidance on Warning-System Development* (WMO-No. 1142),[75] and developing new resources, such as a Handbook of Extreme Heat Indicators and Indices, and training opportunities. These resources will develop an understanding of how extreme temperature, heat stress and heatwave intensity services provide benefits to local heat action plans. Such resources will also help promote harmonized good practices for the development of extreme heat impact-based forecast and warning services and for improved multidisciplinary dialogue and collaboration.

INVESTMENTS TO ADDRESS KNOWLEDGE GAPS: EXTREME HEAT AND MATERNAL AND CHILD HEALTH AND NUTRITION[76]

Major knowledge gaps exist regarding the impact of climate and extreme heat on health outcomes, as well as adaptation effectiveness. For example, there is a particularly large knowledge gap on the impact of chronic and extreme heat exposure on women and children in LMICs, because most of the existing research has been conducted in high-income, temperate countries, and often in relation to men of working age. This fundamental research into the impacts of extreme heat and the effectiveness of adaptation requires climate information services, and is a necessary basis for establishing thresholds of impact, monitoring and prediction. Further evidence on the effectiveness of adaptation interventions under a diverse range of climate- and location-specific scenarios is also urgently needed in order to inform protective policies and measures.

SOME PRIORITY RESEARCH TOPICS INCLUDE:

- Examination of the effects of chronic heat stress in LMICs, especially in vulnerable/underserved communities;
- Better understanding of the mechanistic relationships of multiple stressors and risk factors that could exacerbate the effects of heat stress, including prior undernutrition, food insecurity, indoor air quality and exposures;
- Streamlining and standardization of current use of impact indicators, especially for heat stress, effects on mental health and non-communicable diseases, and maternal and child health and nutrition;
- Document and study of the gender dimensions of climate risks and adverse outcomes, including effects across the lifespan of women (from childhood, through adolescence and pregnancy, to old age);
- Study of the effect of heat stress (and multipliers) on adverse pregnancy outcomes such as poor maternal health, perinatal mortality and small, vulnerable newborns;
- Design of early warning systems for extreme heat events in LMICs, specifically tailored to the needs of pregnant women and young children.

Extensive reviews of research needs in this area have been carried out.[77]

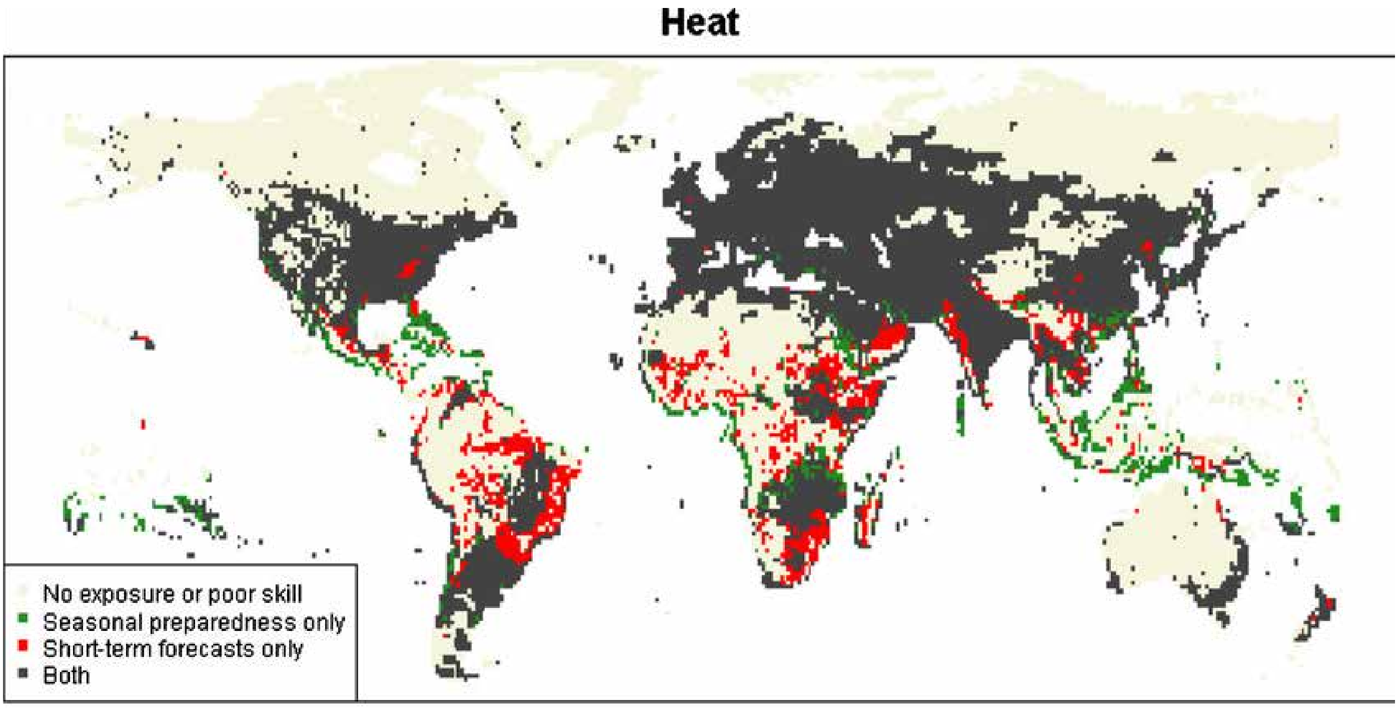


Figure 14. Modes of heatwave preparation. Black areas offer both skilful short-term and seasonality of heatwaves in either the NOAA or ECMWF models. Green areas are regions where only seasonality could be used for preparation. Red areas are regions where only skilful short-term forecasts can be used for preparation.

Note: NOAA = National Oceanic and Atmospheric Administration; ECMWF = European Centre for Medium-Range Weather Forecasts
Source: Coughlan de Perez, E.; van Aalst, M.; Bischiniotis, K. et al. Global Predictability of Temperature Extremes. *Environmental Research Letters* **2018**, *13* (5). DOI 10.1088/1748-9326/aab94a.

Focus: Air quality

Air quality, the fourth biggest killer by health risk factor, is closely interlinked with climate. Despite this, only 2% of climate finance commitments made by international development funders in developing and emerging countries explicitly aimed to tackle outdoor air pollution (in 2015–2021).[78]

Poor air quality is responsible for almost seven million premature deaths annually and a major health issue in all countries. Air pollution is the most dangerous environmental threat to human health, alongside climate change.[79,80] Emissions of pollutants into the air can result in changes to the climate. These pollutants, including greenhouse gases, are often referred to as climate forcers. Ozone in the atmosphere warms the climate, while different components of particulate matter (PM) can have either warming or cooling effects on the climate. For example, black carbon, a particulate pollutant from combustion, contributes to the warming of the Earth, while particulate sulfates cool the Earth's atmosphere. Changes in climate can result in impacts to local air quality. Atmospheric warming associated with climate change has the potential to increase ground-level ozone in many regions, which may present challenges for compliance with the ozone standards in the future. The impact of climate change on other air pollutants, such as particulate matter secondary production, is less certain, but research is underway to address these uncertainties. Furthermore, the increase of droughts connected with climate change can: amplify the occurrence of wildfires and sand and dust storms; advance the blooming of certain plants (associated with pollen); and amplify pollution by deteriorating the air quality.

Many of the drivers of air pollution, including the combustion of fossil fuels, contribute to overall greenhouse gas emissions. Actions and policies to improve air quality offer a win-win strategy for both climate and health, reducing the burden on health-care systems while contributing to the mitigation of climate change.

For example, phasing out fossil fuels can reduce the health risks associated with small particulate matter air pollution ($PM_{2.5}$) derived from fossil fuel combustion, which in 2020 was responsible for 1.2 million deaths.[81] Transitioning to clean public transport and active travel modes can help reduce road travel-derived air pollution (responsible for 497 000 deaths in 2020), and lead to increased physical activity and reduced burden of non-communicable disease. Sustainable, efficient and low-carbon food systems can reduce agricultural emissions, which contribute to about one third of global greenhouse gas emissions, 55% of which come from red meat and milk production.

In 2019, air pollution moved up from the fifth to the fourth place in the scale of leading risk factors for death globally, continuing to exceed the impacts of other widely recognized risk factors for chronic disease such as obesity and malnutrition.

Wildfires are increasing around the globe in frequency, severity and duration, contributing to poor air quality and heightening the need to understand the health effects of wildfire exposure. The risk of wildfires grows in extremely dry conditions (such as drought), heatwaves and during periods of high wind. With climate change leading to warmer temperatures and drier conditions in some places, and the increasing urbanization of rural areas, the fire season is starting earlier and ending later. Wildfire events are becoming more extreme in terms of acres burned, duration and intensity, and they can disrupt transportation, communications, water supply, and power and gas services. Wildfire smoke is a mixture of hazardous air pollutants, such $PM_{2.5}$, NO_2, ozone, aromatic hydrocarbons or lead. In addition to contaminating the air with toxic pollutants, wildfires also simultaneously impact the climate by releasing large quantities of carbon dioxide and other greenhouse gases into the atmosphere. The health impacts of wildfire smoke are noticed in both developed and developing countries, with several hotspots of wildfires occurrence in LMICs.[82] As a result, exposure to wildfire can further amplify health inequality.

Children are vulnerable to adverse health impacts from air pollution and extreme weather events brought about by climate change. Preventing adverse environmental exposure during the early life stages (for example, the prenatal stage) is critical to reduce the relevant burden of child mortality. Improving child health is a key target of Sustainable Development Goal (SDG) No. 3 (Ensure healthy lives and promote well-being for all at all ages). Therefore, quantifying the burden of child mortality and relevant adverse outcomes (such as stillbirths) attributable to air pollution and extreme weather can be useful to measure contribution from the delivery and uptake of climate services to SDG No. 3.

Strengthening and attaining global and national air quality standards can improve health benefits by reducing air pollution exposure. Mitigating climate change will have co-benefits in terms of air quality improvement and health.

STATUS OF AIR QUALITY MONITORING AND WARNING

Poor air quality affects populations in developing and developed countries without exception. However, the technological divide between developed and developing countries is evident, as the most robust monitoring and warning systems are in the USA, Canada and Europe. There are several cases of successful systems in Asia (China, Republic of Korea, Japan and Thailand), a few in Latin America (Argentina, Brazil and Mexico City), Australia and only one in Africa (Cape Town, South Africa).[83] Brazil's case stands out due to its exceptional fire monitoring system, developed by the Brazilian Space Research Institute (INPE).[84] However, it is important to acknowledge that the air quality monitoring system in Brazil has poor spatial coverage.[85]

Most of the existing systems focus on real-time air quality monitoring by collecting and analysing pollutant concentration measurements from ground stations. In regions with limited ground-level air quality observations, such as Africa, remotely sensed data are providing important information on local air quality conditions. Satellite observation is extremely useful for tropospheric ozone monitoring, which is done by the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the Japan Meteorological Agency (JMA), providing atmospheric composition information.

Air quality information is communicated mainly through web services. For example, the United States Environmental Protection Agency (EPA) provides an email alert service (EPA AIRNow) which is only available in the USA, and the Ministry of Environment, Conservation and Parks of Ontario, Canada, also provides email alerts. The EPA AIRNow notification service provides air quality information in real time to subscribers via email, mobile telephone or pager, allowing them to take steps to protect their health in critical situations. However, while satellites can quantify the integrated column of ozone from the surface to the tropopause, or even in the lowest 2–3 km of the atmosphere, they have almost no sensitivity to ozone at the surface where humans breathe. Therefore, satellites are not useful for estimating human exposure to ozone. The new Tropospheric Emissions: Monitoring of Pollution (TEMPO) instrument, onboard a geostationary satellite, is now operational, and it is expected to quantify ozone in the lowest 1–2 km of the atmosphere multiple times per day across North America (but again, its sensitivity at the surface will be limited). The TEMPO data will need to be ingested by air quality models to estimate the surface ozone concentrations.

The WMO Global Atmosphere Watch (GAW) programme focuses on building a single coordinated global understanding of atmospheric composition and air quality and its change. It also helps to improve the understanding of interactions between the atmosphere, the oceans and the biosphere. The GAW programme coordinates high-quality atmospheric composition observations across global to local scales to drive and impact high-quality science, while co-producing a new generation of research-enabled products and services. At present, GAW is coordinating researchers, data providers and final users for the implementation of services for air quality[86] and atmospheric composition (such as greenhouse gases, wildfires[87] and sand and dust storms).[88]

There is a growing ambition across many cities to reduce their greenhouse gas emissions. Since most anthropogenic emissions originate in urban areas, this is a key component of national and international mitigation efforts. Currently, cities rely on inventory-based methods to evaluate their emissions, typically estimating total city-wide CO_2 emissions for each source sector on an annual basis. While there is no compulsion to use specific methodologies, most cities follow a general set of guidelines to create city-wide inventories.[89] However, as efforts to mitigate emissions expand, the need for more detailed, timely emissions information at sub-national scales is growing. The WMO Integrated Global Greenhouse Gases Information System (IG^3IS)[90] *IG^3IS Urban Greenhouse Gas Emission Observation and Monitoring Good Research Practice Guidelines* detail the solutions available, categorizing them by three tiers of increasing sophistication: urban inventory and flux models, direct observational methods and data assimilation systems.[91] The possibility of applying these solutions and GHG monitoring infrastructure to provide air quality services opens new opportunities and will need to be further explored.

COPERNICUS ATMOSPHERE MONITORING SERVICE

Air quality is not only a local problem. It has very local aspects (for example, immediate proximity of a pollution source like an incinerator, petrol station or very busy road) but pollution is also transported from one location to another by wind patterns in the atmosphere. Observations, both from satellites and from the ground, can provide a snapshot of the air quality, but have no real predictive capability. The Copernicus Atmosphere Monitoring Service (CAMS) combines state-of-the-art computer models of the atmosphere, like the ones used for daily weather forecasts, with satellite and non-satellite observations, providing daily forecasts of the composition of the air worldwide.

CAMS provides operational daily analyses and forecasts of worldwide long-range transport of atmospheric pollutants (as well as the background air quality for the European domain) (Figure 15). These forecasts can be used as they are, but they also serve as input to a wide range of downstream services, such as national air quality forecasts, smartphone applications and policy tools. CAMS information on worldwide pollution and European air quality reaches over 200 million users.

Policymakers and authorities can decide to temporarily limit source pollutants to reduce the severity of an upcoming pollution event (for example, with mandatory factory closures or traffic restrictions). Individuals can voluntarily reduce their own emissions (for example, by using public transport) and reduce their personal exposure (for example, by avoiding exercising outside, or wearing masks).

To have a better overview of the quality of the air around us, CAMS provides hourly data on a global scale and, with higher spatial resolution over Europe, for the main regulated pollutants, including ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO) and fine particulate matter ($PM_{2.5}$ and PM_{10}). CAMS also provides data on pollen and UV index, which are also of prime importance for health, and monitors sand and dust and smoke plumes.

While using model-derived outputs, such as the CAMS database, holds value, it cannot replace the necessity for direct, physical surface air quality measurements. Integrating modelled products and surface measurements ensures the most robust air quality assessments and informed policy decisions.

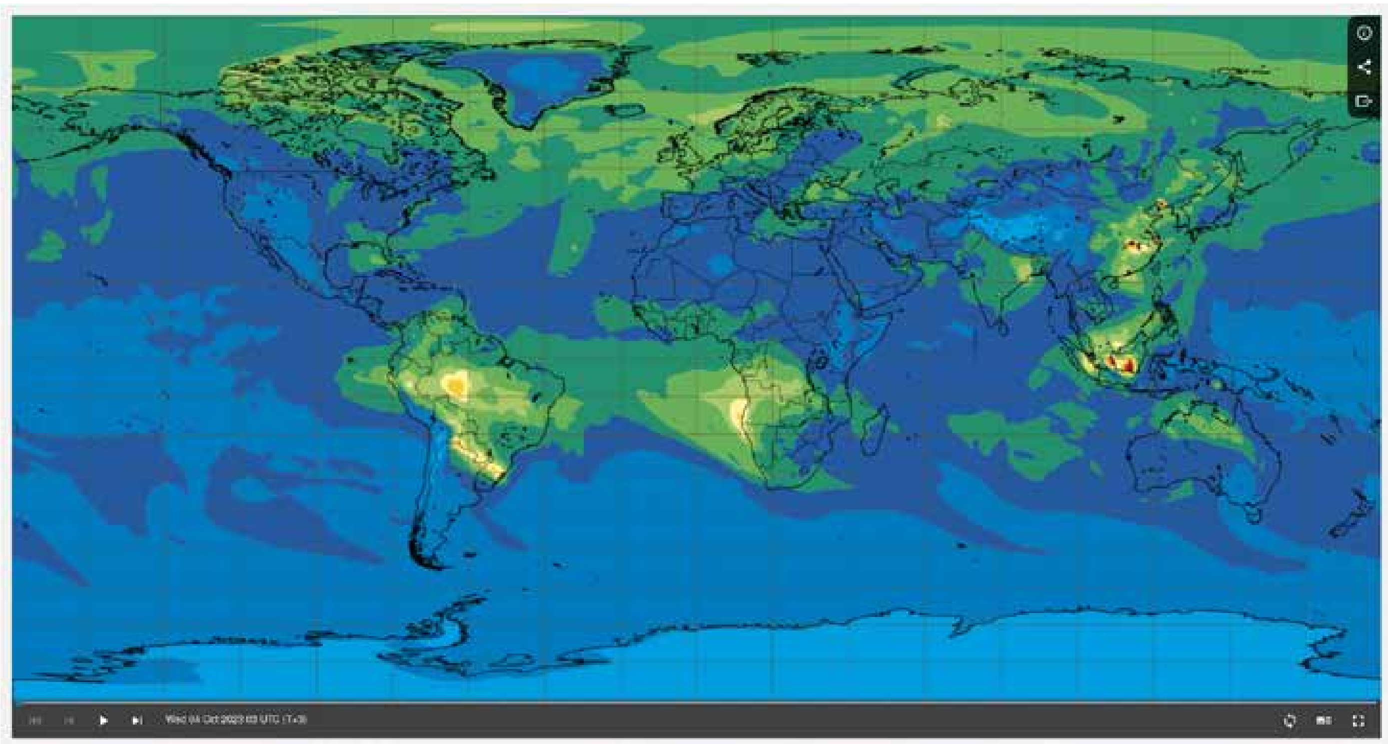


Figure 15. Carbon monoxide (CO) is a pollutant in the atmosphere produced by the burning of fossil fuels as well as wildfires and biomass burning. It has an average lifetime of several months and therefore clearly demonstrates long-range transport. The CAMS daily forecasts show how CO is distributed around the globe and how plumes from, for instance, wildfires are transported across continents by the prevailing winds.[92]

Investment

Photo: Towfiqu-barbhuiya-joqWSI9u

Insufficient investment in climate services leaves the health sector unprepared to protect the most vulnerable. Currently, just 0.2% of total bilateral and multilateral adaptation finance supports health-focused projects,[93] and a far lower proportion is dedicated to creating decision support systems to support these projects and policies.

Total global climate finance flows have steadily increased in the past decade, at a compound annual growth rate (CAGR) of 7%. In 2020, climate finance reached a record high USD 665 billion, driven primarily by investment growth in the renewable energy and transport sectors. Based on currently available information, preliminary estimates by Climate Policy Initiative suggest that 2021 climate finance flows amount to at least USD 850 billion (Figure 16).[94,95]

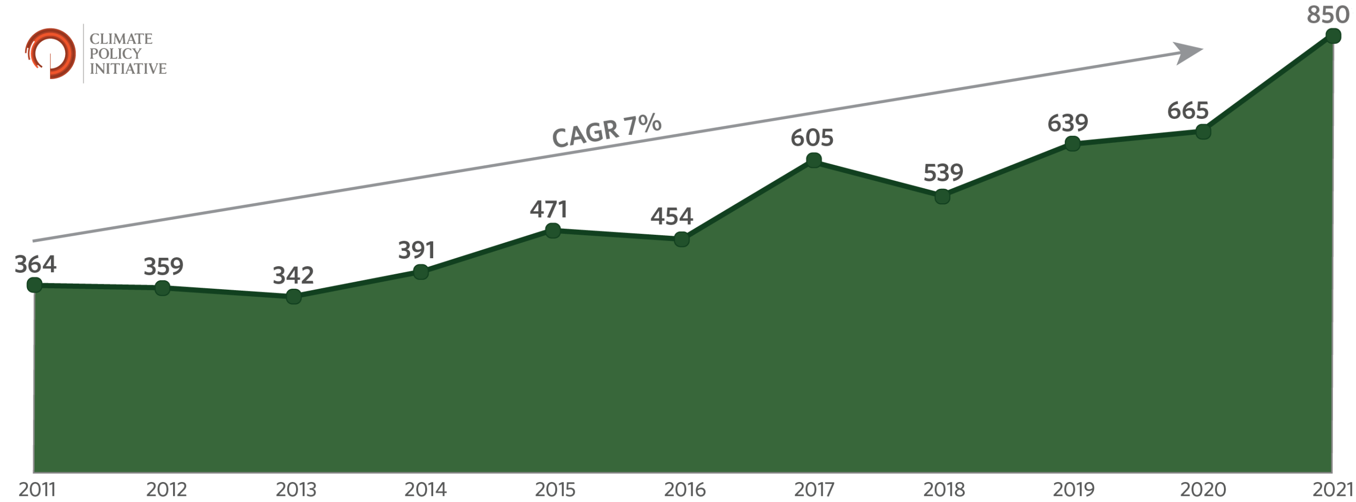


Figure 16. Global climate finance in 2011–2021 (USD billion, nominal)

Despite this positive trend, a rapid and sustained increase in climate finance and redirection of high-carbon finance is required to secure a climate-resilient, net zero future. It is estimated that at least USD 4.3 trillion in annual finance flows (a 20% year-on-year increase) will be needed by 2030 to avoid the worst impacts of climate change.[96]

While global finance for climate change mitigation is substantial, with an annual average of USD 571 billion in 2019/2020, finance specifically for adaptation is significantly lower, at USD 46 billion,[97] and most of this is directed towards the sectors of water management, agriculture and disaster risk management.[98,99]

Additional studies show that only 0.2% of the total bilateral and multilateral climate adaptation funding in 2009–2019 helped to fund projects specifically focused on health (or 0.5%, if only multilateral climate funding is considered). One study[100] finds that just under 5% of total climate adaptation funding is committed to health projects[101].

The 2021 WHO *Health and Climate Change Survey Report* documents that lack of access to finance is the most commonly reported constraint by countries in implementing their health adaptation plans for climate change.[102]

The limited attention and funding for health in climate change adaptation can be attributed to various factors. Health ministries face barriers in accessing climate finance, such as a lack of information and capacity to engage in climate change processes, which are often led by other ministries. Other barriers include challenges related to defining climate- and health-related outcomes, limited climate funding targeted at health system strengthening activities, lack of accreditation of health sector organizations in climate finance institutions, and deficient involvement of health stakeholders in climate finance and climate policy processes at the national and international level. LMICs face additional challenges due to insufficient domestic budgets in the health sector.[103]

To date, very few traditional health donors have encouraged or supported investments in interdisciplinary data systems and analytics, which would lead to applied climate science and services for health. This is in part because health financing often does not consider climate-related risks, or the climate data, research and services required to safeguard health infrastructure, services and interventions, pointing to the need to ensure that there is investment at the interface of health financing and climate and disaster risk reduction.

INVESTMENTS TO PROTECT SAFE AND HEALTHY AIR QUALITY ALSO PROTECT THE CLIMATE

Investments to improve air quality bring enormous benefits to human health, economic development, social justice and climate mitigation and adaptation goals. Since the sources of air pollution and climate change overlap substantially, joint action on air pollution and climate change can deliver more cost-effective, faster and fairer results with the same resources.

Between 2015 and 2021, international development funders[104] committed USD 11.6 billion to projects which simultaneously and explicitly aim to tackle outdoor air pollution and mitigate climate change. During the most recent five years for which data is available (2017–2021), almost all of this funding (95%) went to climate change mitigation projects, while adaptation and dual benefits projects[105] only attracted a total of USD 483 million (Figure 17). Transport and energy sector projects attracted the majority of funding, reflecting the positive impact interventions in these sectors can have on both improved outdoor air quality and climate change mitigation.

During the period 2015–2021, USD 5.4 billion went to transport-sector projects, mainly for the development of rail and public transportation systems which have a clear and immediate benefit in terms of outdoor air quality improvements in urban contexts. Energy projects – mainly for renewable power and heat generation plants replacing fossil fuels alternatives – attracted USD 2.9 billion over the same period.

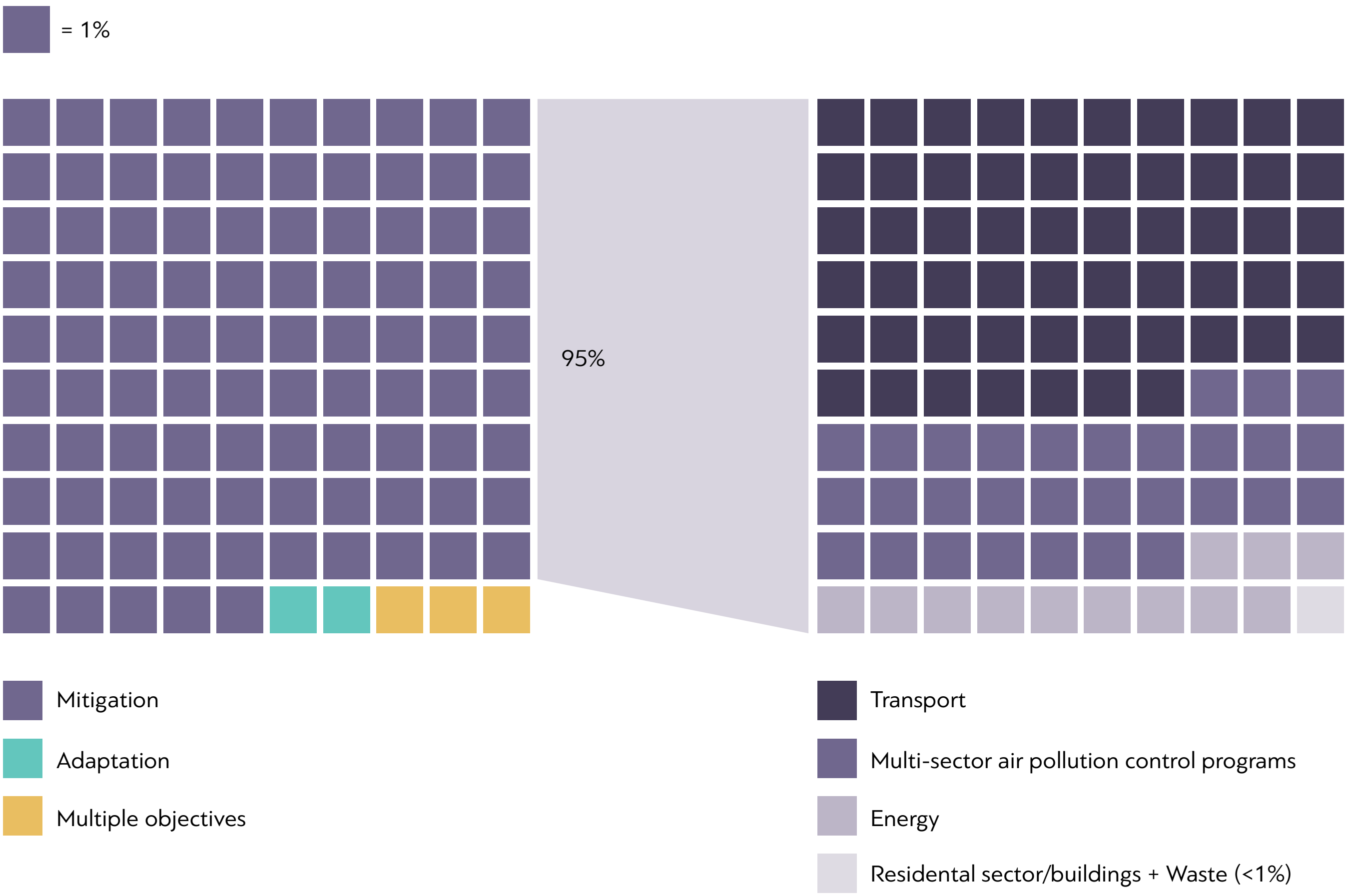


Figure 17. Proportion of outdoor air quality and climate funding by climate objective (left) and sector (right), 2017–2021

Source: Clean Air Fund (CAF) and Climate Policy Initiative (CPI). *The State of Global Air Quality Funding 2023.* https://www.climatepolicyinitiative.org/publication/the-state-of-global-air-quality-funding-2023/.

Over the period 2015–2021, only 2% of climate finance commitments made by international development funders in developing and emerging countries explicitly aimed at tackling outdoor air pollution. In other words, 98% of international public climate finance flows had no explicit outdoor air quality objectives, despite the clear links between improving air quality and climate action.

According to a recent study by Clean Air Fund and Climate Policy Initiative,[106] there is an under-reporting and underappreciation of the positive impact of climate finance on improving outdoor air quality and health benefits. In addition to the USD 11.6 billion committed during 2015–2021 by international development funders to explicitly tackle air pollution and climate change, another USD 66.6 billion invested in climate mitigation and adaptation projects also resulted in outdoor air quality co-benefits, even though outdoor air quality was not explicitly recognized as a funding objective.

By accounting for the health and development benefits gained from improved air quality in their climate finance strategy, funders can considerably increase the impact of their capital and reap multiple key benefits at once.

FINANCING THE HEALTH COMMITMENTS ON CLIMATE-RESILIENT AND LOW-CARBON HEALTH SYSTEMS

The WHO-led ATACH Working Group on Financing the Health Commitments on Climate Resilient and Low Carbon Health Systems (FIN-WG)[107] brings together diverse global stakeholders. This includes both health and climate financing mechanisms, as well as the donor community, to set targets and plans to maximize investments in health by applying a climate lens and integrating climate resilience and sustainability in health financing to ensure available funds are used as efficiently and equitably as possible.

The FIN-WG aims to contribute to the attainment of the overall mission of ATACH, namely "to realize the ambition set at COP26 to build climate resilient and sustainable health systems",[108] using the collective power of WHO Members and key stakeholders to identify opportunities and tackle existing barriers to accessing sustainable finance and resource mobilization, and support scaling-up of investments in climate and health. Resource mobilization refers to both funding and technical assistance that may be required by countries to be able to develop the plans and assessments included in their commitments. Financing will also be needed for countries to implement those plans.

Among the key tasks of the working group is to set a common framework of understanding in regard to climate and health investments and financing, which allows for a meaningful coordination and improvement of both the needs and opportunities for enhancing finance for climate-health.

Figure 18 shows the areas of investment centred around the domain of climate-health solutions based on countries' articulated needs and defined by WHO.[109]

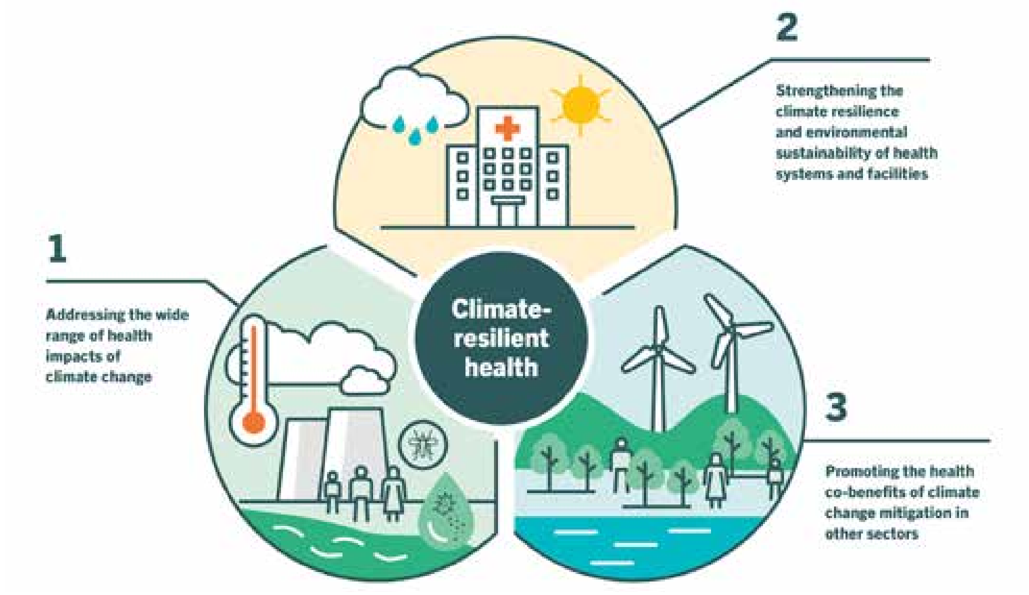


Figure 18. WHO framework for types of climate-health interventions

Source: World Health Organization (WHO). *WHO Country Support on Climate Change and Health - Visual Guide*; 2021.

SNAPSHOT: CLIMATE ADAPTATION AND RESEARCH INVESTMENTS MADE BY PARTNERS

Climate finance investments in health sector adaptation have been slower and more limited than other sectors. However, this trend is shifting. Investment examples include:[110]

AGENCE FRANÇAISE DE DÉVELOPPEMENT

The Agence Française de Développement (AFD) has invested over USD 184 million (170 million Euros (EUR)) in 31 projects to strengthen hydrometeorology and climate services in the most vulnerable countries in the world. The most significant amount of funding flows toward Africa, where USD 139 million (EUR 128 million) is being invested in hydrometeorological activities, followed by South-east Asia, where USD 46.5 million (EUR 43 million) has been invested. A sum of USD 20.5 million (EUR 19 million) has also been invested in projects to address health-related issues and promote overall health sector resilience to climate change.

CLIMATE RISK AND EARLY WARNING SYSTEMS

The Climate Risk and Early Warning Systems (CREWS) portfolio[111] includes eight regional and ten country projects, of which a total of USD 68 million has been invested to strengthen climate services and early warning information systems in 73 LDCs and SIDS. Africa dominates the portfolio with a total of USD 44 million, followed by Asia and the Pacific (USD 16 million) and the Caribbean (USD 8 million).

GREEN CLIMATE FUND

The Green Climate Fund (GCF) has invested USD 414.6 million in ten projects to strengthen hydrometeorology and climate services, with activities that have focused on health in the most vulnerable countries in the world. Among these investments, the most significant amount of funds flows toward the South-west Pacific, where approximately USD 53 million is being invested in hydrometeorological activities, followed by Africa, where approximately USD 14 million has been invested. In addition, more than USD 100 million is estimated to have been invested in these projects to address health-related issues and to promote overall health sector resilience to climate change.

In Antigua and Barbuda, GCF has approved a project that is currently under implementation to increase the climate resilience of 54 key public buildings (which represents one third of the country's total number of public buildings) and to create new shelters and bunkers for disaster preparedness and management. This is combined with strengthening the capacity of Antigua and Barbuda Meteorological Services to produce early warnings by delivering training workshops on how to collect, process and manage climate data generated by servers, and use it to develop early warning information products, including easily interpretable infographics.

GLOBAL ENVIRONMENTAL FACILITY

The Global Environmental Facility (GEF) has provided financing of more than USD 940 million for projects supporting health and climate information services. Out of these, nearly USD 850 million has been provided to projects which support climate information services. GEF has provided funding to six projects which support both climate information services and health, with an investment of nearly USD 44 million. In addition, GEF has also provided funding of USD 52 million for projects which include health, among other adaptation priorities.

CLIMATE AND HEALTH RESEARCH FUNDING

A 2016 study exposed that minuscule amounts of funding have been provided by Medical Research Councils worldwide to understand and address global climate change risks.[112] Limited research funding translates into limited capacity, training and experience of scientists with appropriate skills and mental models to conduct climate and health research. Experts have called for increased funding,[113] mechanisms to enable the quantification of the global impact of climate change,[114] more multiscale transdisciplinary research,[115] and data processing mechanisms.

There has been rapid growth in climate and health research in the past 15 years. WHO identified a sixfold increase from 2008, when 58 studies were published, to 2019, when 373 articles were released, with a year-to-year increase of 25% between 2018 and 2019.[116] However, major health research donors, such as the Wellcome Trust, consider that there are gaps in scientific understanding of the scale of the current and future effects of climate change on health, of the ways to protect the health of populations as the climate changes (adaptation), and of the potential benefits to health of actions that would reduce climate change (mitigation).[117]

Philanthropic and national research bodies are increasing available funding for fundamental and applied research to provide timely and useful insights on effectively protecting vulnerable populations and regions, for building climate-resilient health systems, and for promoting health system-related greenhouse gas emission reductions in a changing climate. Some examples include:

Belmont Forum

For over a decade, the Belmont Forum has served as a single point of entry for international funders to tackle global challenges jointly with researchers from across different countries and disciplines, and in consultation with local communities, policymakers, national governments and international organizations. Since 2017, the Belmont Forum has invested over USD 270 million (EUR 250 million) in international, transdisciplinary projects. The Belmont Forum has funded six multi-hazard early warning systems (MHEWS) projects, all of which fall within a One Health[118] theme.

Through the One Health approach, the research outputs of these projects have supported the development of MHEWS that predict climate change impacts on terrestrial, marine and fresh water biodiversity and ecosystems across nearly 20 countries. Furthermore, additional research on the human health-centric MHEWS projects has supported the development of a pre-season warning system for diarrheal diseases, vector-borne diseases, and an accessibility-based screening prediction platform for natural disasters across 13 countries. Projects, which have received investment of between USD 1.1–2.1 million (EUR 1–2 million) each, include:

Land2Sea,[119] a platform to predict the impacts on aquatic ecosystems and ecosystem services and socioeconomic and cultural impacts, through its application from policy to management; and ARCTIC-BIODIVER,[120] an early warning platform for ecological impacts of climate change that addresses the bio-economic models to integrate scenarios of biodiversity across trophic levels, considering the socioeconomics of ecosystem services provided by arctic fish. While such projects focus on the wider environment (including ecosystems), they are closely linked to and interdependent with human and animal health.

These successful projects exemplify "decision science" early warning platforms, linking climate and environmental information for health decision-making. Belmont Forum's commitment to decision science has brought together over 22 funding institutions to support research teams from over 120 countries to receive financial and technical support in the latest Collaborative Research Action.[121]

Wellcome Trust

Wellcome's investments in research for climate services for health reached USD 33.1 million (26.6 million pounds sterling (GBP)) in 2022–2023 and spanned investments in climate-sensitive infectious disease modelling, early warning systems, climate change impact projections and heat adaptation strategies. Services for climate-sensitive infectious diseases attracted 80% of the total investments. About 31% of the investments were made to host institutions based in Europe, mainly in Spain (15%), the United Kingdom of Great Britain and Northern Ireland (12%), and the Kingdom of the Netherlands and Cyprus (14%). Other investments were made to institutions in the USA (14%), Australia and New Zealand (24%), Mexico and Brazil (7%), Bangladesh and Malaysia (9%), South Africa (2%), and international governmental organizations (12%).

Investment in research on climate services for health is a major priority for Wellcome. This dedication underscores Wellcome's pursuit to understand the intricate interplay between climate and health, with a view to continually fostering the development of cutting-edge strategies and interventions that effectively safeguard the well-being of vulnerable populations.

In summary, the investments made in climate services for health have proven to be instrumental in fortifying the global response to the challenges posed by climate change on human health.

The commitment to research in climate services for health has sparked a surge in scientific exploration and collaboration. The rapid growth in climate and health research, as evidenced by the significant increase in studies over the past decade,[122] signifies a growing awareness of the critical need to understand and mitigate the impacts of climate change on health. Philanthropic efforts and international research bodies, such as the Belmont Forum and the Wellcome Trust, have played a pivotal role in funding interdisciplinary projects that bridge the gap between climate, environment and health. These successes underscore the global commitment to and promoting climate-resilient health systems in an ever-changing climate landscape.

However, despite these notable achievements, there remains a crucial need to better align health and climate finance and ensure that capacity and systems for adequate decision science is built. Bridging the gap between these two domains will be essential to further enhance our preparedness and response to the growing climate-related health challenges. By fostering greater collaboration and investment synergy between organizations, governments and research bodies, we can work towards a more resilient and healthier future for all, where climate services for health are not just individual project successes but a comprehensive and integrated approach to protecting global well-being. More work needs to be done to ensure that there is investment at the interface, and assessment of climate services for health along the causal chain, in order to know whether these are genuinely contributing to health.

Closing the funding gap for health in climate change adaptation requires increased attention, capacity support, sector integration and innovative financing mechanisms.

Photo: WMO/Muhammad Amdad Hossain

The way forward

To fully harness the potential of climate services for health, transformational change in institutional development and multisector integration are required in both the health and climate and meteorological sectors.

Adapting to the fast-changing and dynamic health risks which are being created or exacerbated by climate change demands transformative changes, targeted investments and coordinated approaches across sectors. In the wake of the global COVID-19 pandemic, all countries have experienced the social and economic losses and damages which can occur when the health of society is compromised. More must be done to prepare the health community for future shocks and pressures it may experience due to climate variability and the damaging effects of climate change.

Based on the findings in the present report, there is considerable potential to maximize the use of climate services for health. A multitude of strategies and investments to enable effective collaboration and co-production of services can support the health sector to be more resilient to climate variability, and to adapt to and mitigate climate change.

To build sufficient capacity to integrate skills, people, data and knowledge for enhanced and agile decision-making to protect health, there is an urgent need to move beyond pilot projects, toward investment in catalytic and systemic strategies to understand and address climate risks. This transformation needs to start with a paradigm change in the approaches used by both the health and hydrometeorological communities to build trust, address identified barriers and entrench good practices that can lead to success (Figure 19). Sustainable multisectoral coordination and policy mechanisms, along with scaled-up operational capabilities and mechanisms of NMHSs, RCCs and health partners are key to building skills and capacity for climate-informed research, risk assessments, surveillance, early warning and informed health policy and programming.

The achievement of long-term systemic support for climate-vulnerable populations will come as the result of a multifaceted investment plan to fully enable actors and mechanisms at the science-policy interface for climate, environment and health.

An Implementation Plan for Advancing Integrated Climate, Environment and Health Science and Services was endorsed by the World Meteorological Congress at its nineteenth session, in June 2023. This ten-year plan guides WMO, WHO, governments and other partners to identify strategic and priority actions that should be developed. It is organized according to three dimensions and uses a nexus approach to allow flexibility and tailoring as relevant to local and regional contexts. Six foundational support areas propose investments to lead transformational change in climate, weather, environment and health science, services and policy. These include:

- Policy and coordination;
- Capacity building;
- Communications;
- Research;
- Operational services;
- Monitoring, evaluation and learning.

Focus is also placed on four thematic grand challenges in response to multiple vulnerabilities of urban populations (for example, extreme heat and air pollution), the sensitivity of infectious diseases to climate, climate risks to food security and nutrition, and climate adaptation and mitigation needs within the health system itself.

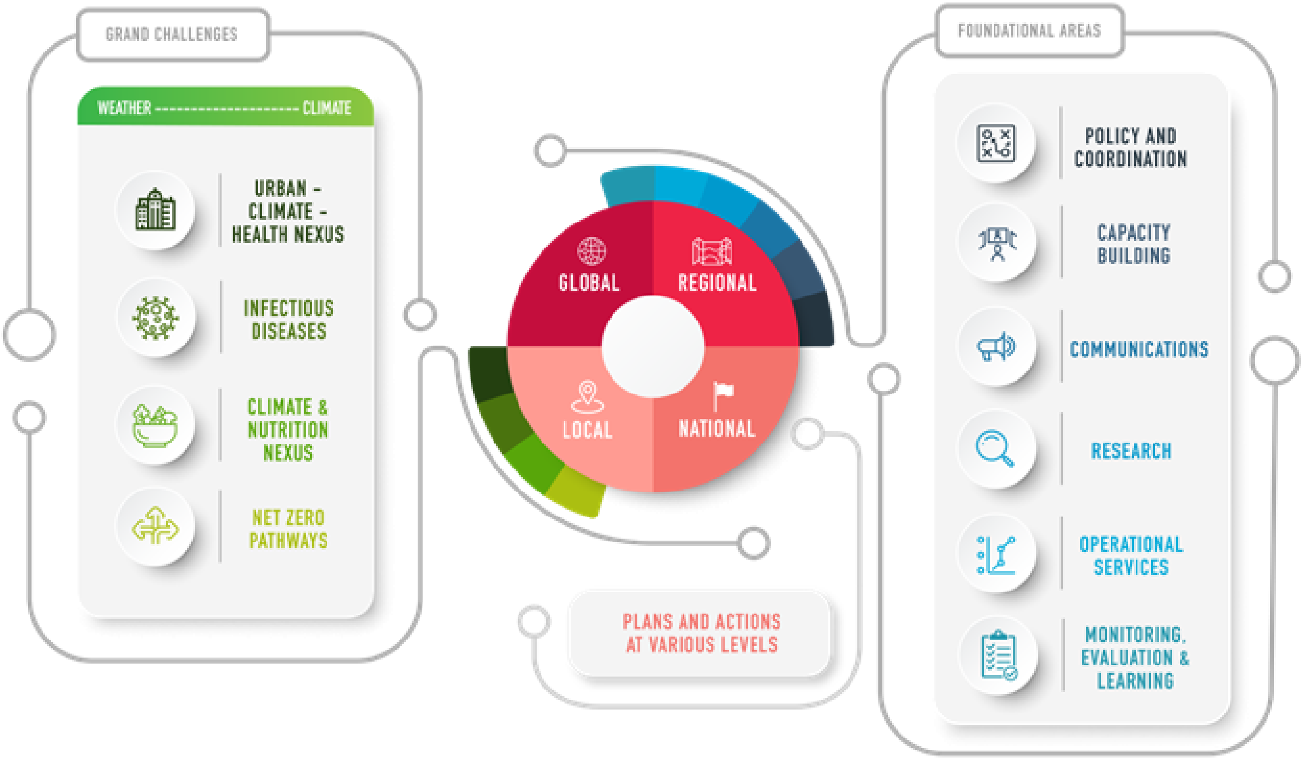


Figure 19. Framework for 2023–2033 Implementation Plan for Advancing Integrated Climate, Environment and Health Science and Services: https://climahealth.info/resource-library/who-wmo-implementation-plan-2023-2033/

Addressing the gaps in climate services for the health sector requires collaborative efforts between climate scientists, health professionals, policymakers and funding agencies. By prioritizing data availability, localization, integration, capacity building, effective design of the institutional and anticipatory governance dimensions, action-oriented approaches and sustainable funding, these gaps can be gradually addressed, leading to more effective climate services that protect and promote human health.

Currently, the health sector is often seen as operating sub-optimally in a silo from health-determining sectors like agriculture, water, energy and disaster risk management with regards to understanding climate-related health risks and co-developing and utilizing climate services. Transdisciplinary and integrated approaches, such as the NOAA One Health approach and multidisciplinary working groups (like those in Niger) can help break down sectoral barriers. Addressing the underlying challenges of data interoperability, climate literacy, and human resource and institutional and other capacities are fundamental goals of WMO and WHO to support their Members.[123]

Science, technology and information are clearly under-utilized in health sector decision-making. Frequently, there is a mismatch between availability and uptake of climate, weather and environmental services in public health. Mainstreaming tools and knowledge into health surveillance, investigations of outbreaks of diseases, climate change and health assessments, research and long-term planning and programmatic decision-making calls for significant capacity building of institutions and people and enabling environments to facilitate collaboration.

As a way forward, a number of strategic activities and mechanisms are critical to help reduce the health impacts of climate change, including:

- Enabling policy mandates for health and meteorological actors to collaborate and share data;
- Adopting interlinked and multisectoral policies and coordination mechanisms, at all operational and institutional levels;
- Raising awareness of the importance of climate information for climate adaptation and resilience, and of the technical requirements and investment gaps ;
- Assessing the readiness of partners to co-produce fit-for-purpose climate analytics and services and building projects based on capacities;
- Developing cadres of new professionals who have received transdisciplinary climate and health training and are institutionally enabled to work across a diverse range of partnerships;
- Improving climate literacy and transdisciplinary communication skills of meteorological, climate, environment and health actors, and the means of using innovative tools and platforms to communicate with the public;
- Setting up a systematic process to identify and respond to research gaps and knowledge priorities between and across health, climate and other sciences;
- Establishing data processing standards and support mechanisms which enable interoperable and quality-controlled pipelines of information to enhance decision

processes;

- Developing in-country capacities to improve local knowledge (including collection of epidemiological, climate and socioeconomic data), along with institutional interaction with policymakers;[124]
- Enhancing climate change impact and attribution science[125] and mechanisms to assess and monitor climate impacts on health;
- Improving monitoring and evaluation mechanisms of the performance, effectiveness and cost-effectiveness of climate services with respect to people's health and to health systems and connecting back to policy and system outcomes (to improve the quality of health vulnerability and adaptation assessments, integrated surveillance systems and climate-informed early warning systems).

Diverse financing approaches should be explored across the streams of climate, hydrometeorological services and health financing mechanisms. Enhanced coordination and involvement are necessary among different stakeholders including engaging philanthropic funders, private investors and financial mechanisms. Blended finance models that combine public and private funds can help attract investments while reducing risks. Integrating climate action into public-private partnerships within the health sector can also unlock financing opportunities.[126] For example, developing NAPs that prioritize health and include costed health interventions can be another means to help allocate resources effectively to the health sector. Mainstreaming climate adaptation and mitigation into national and health sector development plans, budgets and annual planning cycles can leverage existing budgets and facilitate access to bilateral and global finance.

The use of weather, climate and environmental knowledge underpins decision-making to strengthen health sector resilience to climate, to extreme weather and water events and to hazardous air quality. Strategic investment in climate services for health can support countries to make progress toward multiple United Nations SDG targets (including SDG No. 3 – Ensure healthy lives and promote well-being for all at all ages), health sector goals such as universal health care, as well as the Sendai Framework and the Paris Agreement.

WMO RECOMMENDATIONS TO MEMBERS' NMHSS TO SUPPORT HEALTH

At its nineteenth session, the World Meteorological Congress, through its Resolution 17 on the Implementation of Integrated Health Science and Services, suggested specific actions by NMHSs and other key actors. These include:[127]

- NMHSs, RSMCs and RCCs to enhance support to the health sector and continue to nominate and support the work of health sector focal points for health-related research and services;
- NMHSs to contribute to the implementation of integrated health science and services by sharing current capacities, expertise and experience; to strengthen research and operational mechanisms, including open sharing of meteorological and health data; to facilitate coordination and cooperation of their NMHSs and other relevant actors with the health community on matters of climate, weather, water and environmental health risks;
- The World Health Organization, Members and development and research partners to co-fund such arrangements and nominate health experts to the WMO Expert Network.

STORIES AND CASE STUDIES

Case studies provide a rich opportunity to learn what is working and where challenges remain (see section on Barriers to co-producing and implementing climate services for health). Nineteen case studies representing diverse thematic topics, world regions and application of climate science and services are outlined in this section, demonstrating the experience of partners in co-producing and using climate services for health.

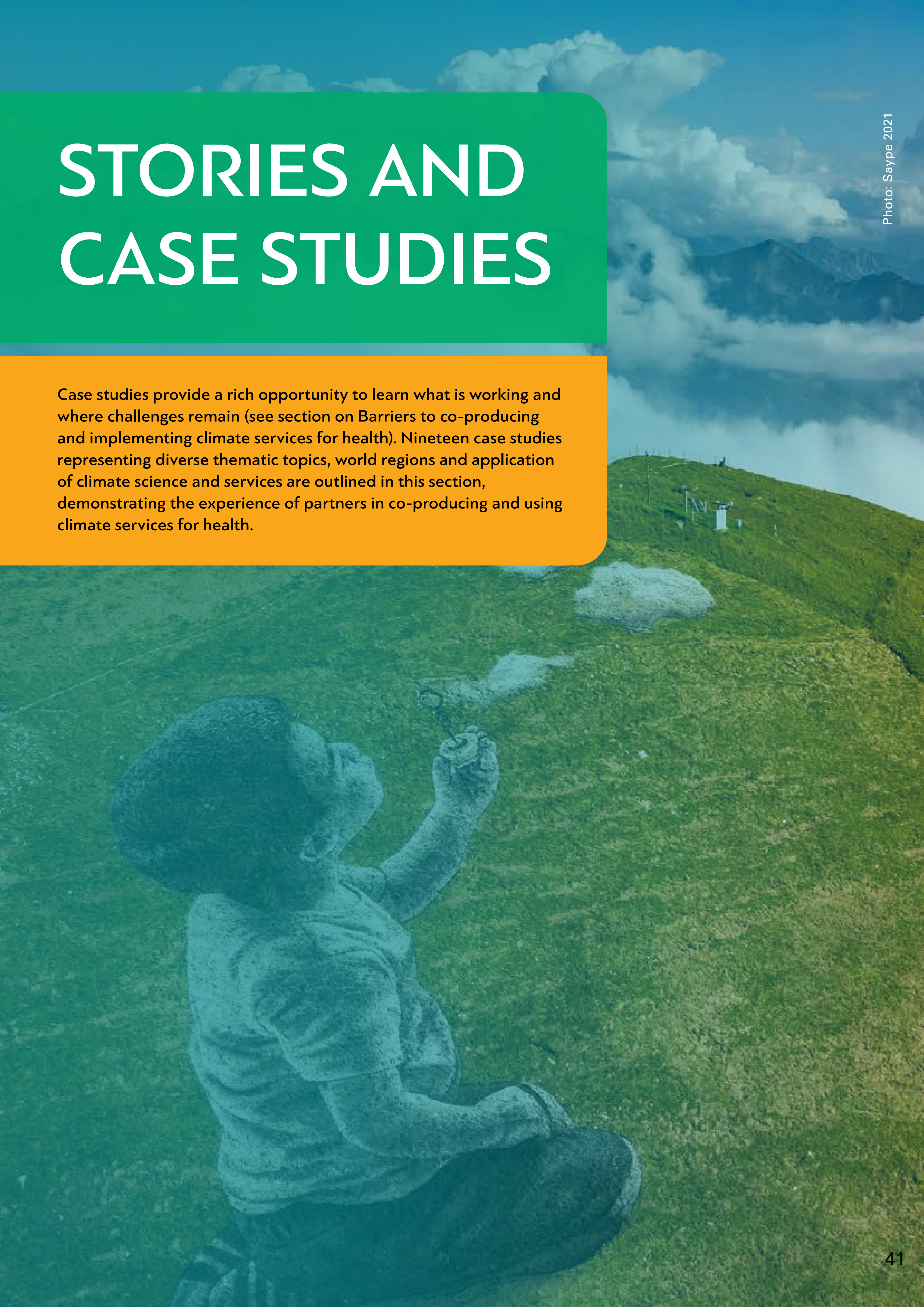


Photo: Saype 2021

STORY: COLLABORATION ACROSS THE CARIBBEAN PROVIDES CLIMATE AND HEALTH RISK REDUCTION

Home to beautiful, sandy beaches and bright, turquoise water, the Caribbean is among the most idyllic regions in the world.

Yet, the Caribbean has a challenge looming on its horizon: it is one of the most climate-sensitive and disaster-prone regions in the world, and these issues are anticipated only to worsen in coming years as climate change progresses. Caribbean small island developing States (SIDS) are among the most vulnerable to climate change despite contributing very little to climate change on the global scale. Rising sea levels pose a massive threat to SIDS, with large areas of coastline disappearing over the past decades. Mounting temperatures also increase heat-related health threats, and the Caribbean's tropical climate also puts the region at risk of other unique health issues, such as vector-borne and tropical diseases, which continue to grow in severity as climate change progresses. As such, Caribbean SIDS have a time-sensitive need to create climate-resilient health interventions.

Until 2017, there was no early warning climate system tailored for health providers. As a result, there was little integration of meteorological forecasting with easily digestible implications for the health sector. For example, publicly available weather forecasts might have issued alerts regarding anticipated droughts, but there was no standardized corresponding messaging about how such droughts would affect health risks or how the health sector should adapt to them.

However, that changed in 2017, when a three-organization partnership team trailblazed the way in facilitating collaboration among climate and health professionals in the region. That year, the Caribbean Institute for Meteorology and Hydrology (CIMH) partnered with the Caribbean Public Health Agency (CARPHA) and the Pan American Health Organization (PAHO) to co-produce a freely available quarterly *Health Climatic Bulletin* (HCB) for the Caribbean. Through the co-production of the bulletin, experts from both the climate and the health fields work together to disseminate messages detailing the anticipated effects of upcoming forecasted climate conditions on a range of health conditions. The HCB publishes early warning information on a wide array of the climate forecast's anticipated health risks, including threats related to well-being and mental health, vector-borne diseases, respiratory illnesses, non-communicable diseases, gastrointestinal illness and COVID-19. Each time a new issue of the bulletin is released, it is disseminated to Caribbean health ministries to promote early planning for upcoming health threats.

By providing health-tailored climate information three months in advance, the bulletin gives the health sector an opportunity to prepare for risk mitigation. For example, rainy periods create ideal breeding conditions for mosquitoes, which carry vector-borne diseases such as dengue, which is estimated to cost the Caribbean over USD 300 million annually.[128] Conversely, periods of drought exacerbate risks associated with asthma and bronchitis. The bulletin provides an easy platform to disseminate this information, which can be used to inform decision-making.

At the heart of the HCB team are some essential individuals, each of whom brings something unique to the partnership and makes the bulletin the product it is today: Dr Laura Lee Boodram, the Head of Vector-Borne Diseases at CARPHA; Dr Karen Polson, Advisor on Climate and Environmental Determinants of Health at PAHO; Audreyanna Thomas, a PAHO consultant and Coordinator of the large-scale, multi-year Climate Change and Health Project; and Dr Roché Mahon, Social Scientist and Dr Cédric J. Van Meerbeeck, Climatologist, both at the Caribbean Institute for Meteorology and Hydrology.

"Our organizations are driven by a common vision to provide climate early warning information for Caribbean health practitioners that serve Caribbean populations. We now have more than 5 years of co-development and co-delivery since May 2017 when we launched the bulletin and released the first issue", explained Dr Mahon. Dr Thomas added, "partnerships are about adding value. CIMH brings an added value, PAHO brings an added value, CARPHA brings an added value, and that's all recognized. The bulletin would not be what it is if one agency should do it alone."

The main reason why the partnership works is respect. When asked about advice for other regions or countries hoping to facilitate similar collaborations, Dr Polson said that "one of the key things is respecting persons as experts in their own field or own area and not trying to present yourself as an expert in an area that you're not. Respect is key, and so is a willingness to learn and to engage. I might have expertise in a particular technical area, but I don't know how to articulate it in a manner that's understandable to everybody."

Dr Boodram said that the intersectoral collaboration is the most rewarding part of her work. "It's the respect and the camaraderie that cements our meetings and what we produce. It's not just simply sitting down and authoring the bulletin, but it's establishing that partnership, it's setting the stage for the future work that we can do, and there's a certain level of trust in knowing that you have colleagues here that you can rely on to advance the work."

For Dr Van Meerbeeck, moving away from simply forecasting climate towards forecasting the implications of our climate on health outcomes, is crucial. "There are different approaches to what we call impact-based forecasting: either hazard-specific forecasting and monitoring, or sector-specific hazards forecasting and monitoring", he said, pointing to the *Health Climatic Bulletin* as a good example of a tool that can help with the latter.

It is hoped that within the next ten years, the bulletin will be heavily used to inform policy briefs and will become a "household document within the Caribbean. It is a product of which we can be proud", added Dr Polson.

See Case Study 11 for more details.

STORY: EXTREMA GLOBAL: BUILDING INTEGRATIVE NETWORKS FOR COOLER CITIES

The year is 2023, and Athens, Greece, is engulfed by a cataclysmic heatwave, with temperature highs reaching 43.4 °C.

Amidst the challenges posed by heatwaves, one element becomes abundantly clear: awareness and preparedness are essential to safeguarding citizens. Elissavet Bargianni, Chief Heat Officer for the City of Athens, emphasizes the significance of understanding vulnerability beyond its conventional boundaries. Factors such as age, socioeconomic status, and health conditions play pivotal roles in defining vulnerability to extreme heat. However, obtaining specific personal data remains a challenge.

Bargianni uses a two-pronged approach. Firstly, by making comprehensive information easily accessible to the public through a website, Athens can showcase its capacity to address heat-related issues, raise awareness (for example, of temperatures in different neighbourhoods, where to go to find cool spots and so forth) and empower individuals to seek assistance when it comes to staying cool and avoiding the risk of heat-related illness.

Secondly, Bargianni emphasizes the significance of eco-friendly city design, aiming to provide 70% of the population with access to green spaces. These areas not only provide relief from the heat but also bring valuable ecosystem benefits.

The EXTREMA Global app serves as a beacon of hope, coordinating awareness and empowering city authorities in Europe. With its multilanguage capabilities, constant updates, and expansion to cities like Milan, Paris and Rotterdam, EXTREMA Global has the potential to become a global tool for managing heatwaves. By utilizing data from various sources and creating user-friendly maps, policymakers can plan sustainable infrastructure and identify vulnerable areas within cities. Even during heatwaves, the app guides users to safe routes, considering the density of trees along the way. All of the information is dynamic and managed by a dashboard, so any change is immediately visible within the app for users.

Heatwaves present significant challenges that extend beyond their direct impact on the local tourism industry, as highlighted by Anna Vasila, Head of Sustainability and Industry Affairs at Athens International Airport. The scorching heat acts as a game changer, prompting tourists to explore alternative seasons rather than the traditional summer period. This shift in preferences not only affects the tourism seasonality but also has far-reaching implications in various other areas, including the city's preparedness to provide adequate infrastructure throughout the year. It also impacts the broader network of Greek destinations connected to the capital. The EXTREMA Global app therefore strives to help Athens become a year-round destination by making travel during the hot season safe for residents and tourists, demonstrating resilience in the face of climate change's influence.

"The app can guide you through selected destinations of the centre of Athens, while protecting you from extreme heat. It's part of our continuous attempt to enhance the customer experience to show them how they could potentially experience better routes while visiting the renowned sites of Athens", adds Vasila.

Throughout the terminals at Athens International Airport, the promotion of EXTREMA Global demonstrates a concrete commitment to prioritize the health and safety of tourists. By enabling visitors to independently experience the city and its attractions in a sustainable manner, the airport fosters resilience and showcases the city's dedication to providing a year-round destination despite the challenges posed by climate change.

Understanding and addressing the needs of cities is crucial to finding effective solutions. Instead of solely focusing on scientific perspectives, it is important to engage with local communities. "Smart communities are the key to building smart cities", emphasizes former Chief Resilience Officer Piero Pelizarro.

To overcome this barrier of understanding and addressing the needs of cities, Dr Eleni (Lenio) Myrivili, former Deputy Mayor of Athens, suggests that reframing the discourse on climate change to highlight its tangible impact on vulnerable individuals is needed. This approach allows programmes like EXTREMA to be tailored to community needs and foster empowerment through meaningful engagement.

As we navigate the realities of climate change, the message of resilience and hope becomes clear. Normalizing climate change discussions, integrating innovative tools like EXTREMA Global, and mainstreaming climate adaptation into everyday life are essential steps. By linking cities worldwide through integrative networks, we can collectively strive for a resilient future. While the path ahead may require years of innovation, coordination and negotiation, the transformative power of tools like EXTREMA Global provides real hope in our efforts to mitigate the consequences of anthropogenic climate change.

See Case study 13 for more details.

STORY: COLLABORATIVE MONITORING PROGRAMME PREDICTS, DETECTS, AND REPORTS POLLEN CONCENTRATIONS IN REAL TIME TO HELP ALLERGY SUFFERERS

A staggering 40% of Europeans are currently battling allergies, and the severity of seasonal allergies is intensifying, particularly for older patients or those with respiratory comorbidities like asthma. At the heart of this unseen battle is Prof. Dr Peter Schmid, a renowned allergist at the University Hospital of Zurich. As a dedicated member of the European Academy of Allergy and Clinical Immunology, he tirelessly navigates the frontline of this escalating health crisis, seeking to understand how our transforming world imprints upon human health.

Equally integral to this struggle is Roxane Guillod from the aha! Swiss Allergy Centre. Her role: to lend a voice to those suffering silently, to guide them through the bewildering maze of symptoms towards much-needed and innovative solutions.

It is an urgent matter, with allergies in Europe imposing an annual health cost ranging from EUR 50–150 billion, excluding societal costs and quality of life implications. Dr Schmid's patient demographic is vast, encompassing all ages, from children to the elderly. The incidence of allergies peaks in young adults, but older patients often bear a more severe symptom burden. His initial queries circle around the onset of symptoms, their association with different weather conditions, and seasonal variations. Engaging with patients forms the crux of both Dr Schmid's and Guillod's day-to-day operations. Dr Schmid asks them about when they started noticing symptoms and whether those symptoms change with different kinds of weather and the time of year.

This past year, the first pollen allergy was reported on 28 December, a testament to the increasingly early start of the season. The onset of allergies has typically occurred around the age range of 10 to 12 years, but now allergies are starting much earlier. Over the past five years, more concerned parents are asking about their very young children having allergies.

The societal repercussions of allergies are significant – severe allergy symptoms can prevent individuals from attending work or school. Even when they are able to, their productivity is compromised due to fatigue and decreased concentration, impeding their ability to participate in meetings or excel in exams. Their social lives are substantially curtailed; outdoor activities or exercise become daunting tasks. When pollen count surges, they must reduce their exposure to the outdoors and modify their ventilation practices indoors (such as window aeration). While not universally experienced, these debilitating symptoms profoundly affect life quality during the peak pollen bloom weeks. Even "mild" symptoms can pose serious threats when paired with conditions like asthma, leading to impaired breathing.

To face these growing challenges, MeteoSwiss and EUMETNET (a grouping of European National Meteorological Services) have partnered to develop a monitoring programme that predicts, detects and reports pollen concentrations in real time. This information is then fed to end users, including physicians, patients and allergy patient association workers via an online system and mobile app. Users can input information about which pollen sources they are allergic to, and receive a map of Switzerland showing the concentration of that particular pollen throughout the country.

These daily pollen-related forecasts have drastically improved allergy patients' management of their symptoms. Guillod uses the pollen service several times every day. The service not only informs her about pollen concentrations so that she and her team can give behavioural advice to patients who inquire about pollen data, but also helps her to generate an end-of-season report summarizing the year's trends and to communicate with the media. Patients are happy that they can access real-time data on pollen counts every day (even multiple times a day). Users of the app do not need to know much about pollen concentrations in terms of exact numbers, but they understand the implications just by seeing that the pollen count is red on the app. Nearly 18 000 people have used the app since January 2023, and 14 000 have enabled push notifications every week.

This monitoring service has also highlighted the impact of climate change on the prevalence of allergies in the population: "We have realized some flowers pollen earlier due to warmer temperatures", said Dr Schmid. "We also observed some pollen in areas where they had not appeared before."

See Case study 14 for more details.

Photo:Juanita Swart

CASE STUDY 1

Food security and shock response systems support social protection in Mauritania and the Sahel

CHALLENGE

The population of Mauritania suffers from multiple vulnerabilities caused by the superposition of security, social and economic crises that the region is experiencing. The effects of climate change, particularly drought events, exacerbate these vulnerabilities. Almost a third of the population lives below the poverty line and between 450 000 and 1 000 000 people are food insecure each year, particularly during the agricultural lean period.

APPROACH

Based on an early warning system (EWS) of drought conditions, a part of the Social Safety Net System Project II (SSNSP) helps the Mauritanian Government to implement cash transfer programmes in response to climatic shocks, mainly during the lean season and possibly also when floods and bushfires occur.

The project developed a predictive model to anticipate drought risk and food security needs during upcoming lean seasons. The model uses remote-sensing data (the Standardized Precipitation Index (SPI), Normalized Difference Vegetation Index (NDVI) and biomass, as well as historic household-level data from the Food Security Monitoring Survey (FSMS)) collected every six months in Mauritania.

The Elmaouna programme,[129] implemented by the Mauritanian Food Security Commission (CSA), provides direct support to poor and vulnerable populations in the event of a shock, in particular, drought (emergency transfer during the lean season), and upstream support before the impacts are felt when the EWS allows it. During the lean period, targeted households receive a cash transfer of 75% of the average food basket for four months which helps to eradicate hunger and malnutrition and increase resilience.

RESULT

The aim was for the CSA to deploy emergency aid within a very short time frame, based on data from the social register integrated with analyses from the Food Security Observatory (OSA, part of CSA).

The programme allowed households affected by hazards to become solvent, and thus prevented recourse to harmful adaptation measures (such as the sale of livestock at low prices, marriage of young girls and so forth). During the 2022 lean season, the Elmaouna shock response programme reached 69 074 food insecure households – 47 000 of which were supported through the project.

During the 2022 lean season, the Elmaouna shock response programme provided malnutrition prevention, treatment and assistance to 47 000 food insecure households.

PARTNERS

Mauritanian Government, World Bank, World Food Programme, Sahel Adaptive Social Protection Programme donors (Agence Française de Développement, Germany, UK)

Photo: Fabian Jones

CASE STUDY 2

Early warning system for extreme temperatures in Argentina

CHALLENGE

Extreme temperatures have serious and direct effects on public health. In the summer of 2013–2014 Argentina experienced record heatwaves and preventable deaths. This motivated additional studies of the impact of extreme heat on health, with the aim of developing a health impact-based warning system.

Two studies established the statistical relationship between the occurrence of extreme temperatures and the increase in mortality. The studies were carried out jointly by the Ministry of Health, the National Meteorological Service, the National University of Entre Ríos, the National University of La Matanza and the University of Buenos Aires.

Mortality was analysed by sex, age and cause of death, and results indicated that mortality increased significantly in both extreme hot and cold temperatures. The mortality risk during heatwaves increased in 13 of the 18 provinces analysed.[130] For extreme cold temperatures, risk of death significantly increased in the week following a cold day in 10 of the 21 cities analysed, while cold waves were associated with an increased risk of death in the following two weeks in 10 cities.[131] Based on the evidence of extreme temperature episodes in Argentina driving increased negative health outcomes, an early warning system (EWS) for extreme temperatures was deemed necessary to reduce preventable deaths.

APPROACH

The objective of the EWS for extreme temperatures is to enable the population, the health system and civil protection organizations to take the appropriate prevention, mitigation and response measures at each alert level.

Development of the EWS occurred in several phases. Firstly, an EWS for Heatwaves and Health was developed and tested in two cities.[132] Subsequently, in 2017 and based on the results of a study,[133] the alert thresholds were adapted.

Finally, in 2021, the EWS began to cover the entire national territory (sub-divided into 168 fixed regions) and was renamed the EWS for Extreme Heat Temperatures.[134] In the same way, the EWS for Extreme Cold Temperatures was created.[135] The system issues alerts at different levels (yellow, orange and red). The alert thresholds were established based on the 90th percentile for heat (and the 10th percentile for extreme cold) of each city.

RESULT

During the warm period from October 2021 to March 2022, 987 daily alerts were issued for extreme heat (615 yellow, 205 orange and 167 red). Likewise, during the EWS for Extreme Cold Temperatures test period, from 9 June to 20 September 2021, 239 daily alerts were issued for extreme cold (197 yellow, 37 orange and 5 red). The alerts were communicated to health and civil protection agencies at the national level, as well as to the general population through different media. An evaluation of the effectiveness of the system is planned. Under this system the weather alerts are issued by the Argentinian National Meteorological Service, and the Ministry of Health issues recommendations for health care.

LIMITATIONS AND LESSONS LEARNED

The Early Warning System for Extreme Temperatures (SAT-TE in Spanish) has climatic thresholds for which the significant increase in mortality was evaluated epidemiologically. Two studies established the statistical relationship between the occurrence of extreme temperatures and the increase in mortality. However, future studies could evaluate the temperature at which mortality increases significantly, both for extreme cold and extreme heat.

The main actions carried out are preventive, with little development of those aimed at mitigation and response. There is still a long way to go to complete the system, including improving the criteria for issuing alerts so that they contemplate different scenarios, such as power cuts or water shortages, among others.

During the warm period from October 2021 to March 2022, 987 daily alerts were issued for extreme heat.

PARTNERS

Ministry of Health of Argentina

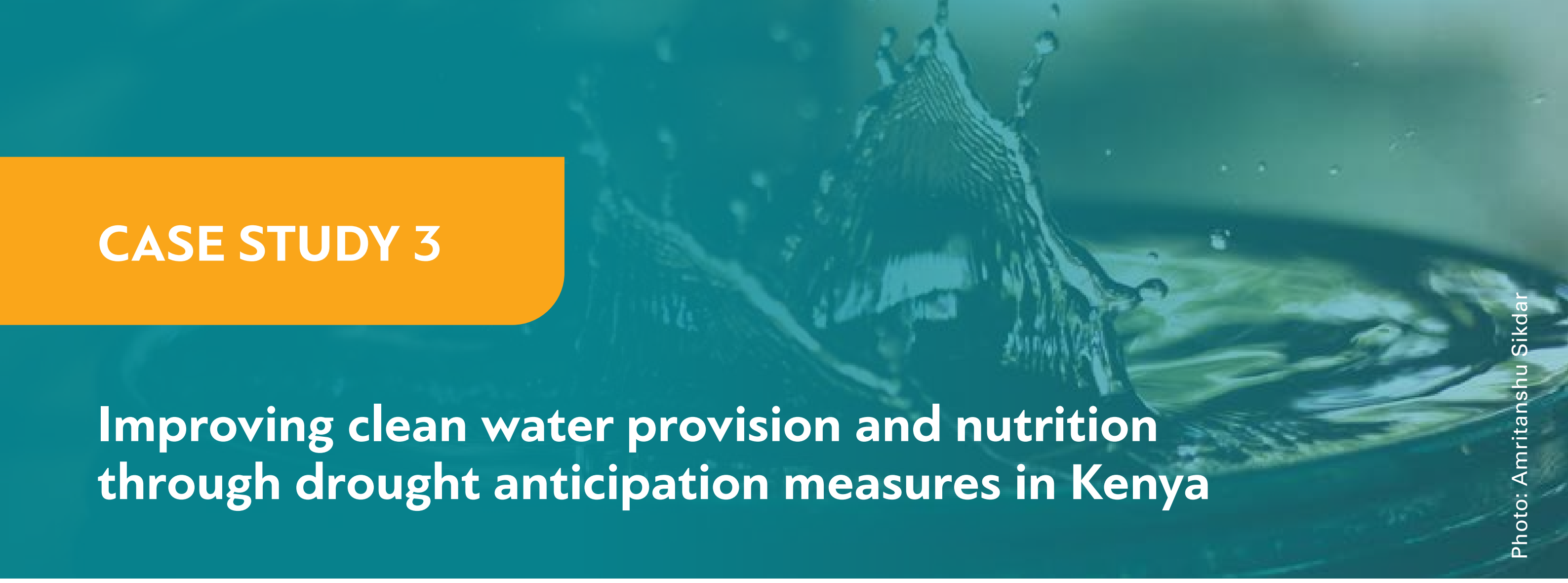


Photo: Amritanshu Sikdar

CASE STUDY 3

Improving clean water provision and nutrition through drought anticipation measures in Kenya

CHALLENGE

Kenya is vulnerable to drought due to its overdependence on rainfall as a source of water for the socioeconomic well-being of the population. In Kenya, drought episodes commonly lead to limited water availability, food production and pasture for livestock. In protracted droughts, the primary effects are evolving into secondary impacts on people, such as malnutrition.

For the past five consecutive major rainfall seasons, since October to December (OND) 2020, each of the March to May (MAM) and OND seasons have provided limited rains to support agricultural production and to recharge water resources, particularly in the arid and semi-arid land (ASAL) areas that constitute 70% of Kenya. About 2.7 million people were reported to be facing food insecurity in 2021. This number increased by 10% in early 2022 and was projected to double later in 2022, due to the coupled effect of the evolving drought and high food prices associated with the war in Ukraine. The anticipated impacts of these worsening statistics on people include acute malnutrition, limited food options and lack of clean water for animal and human consumption.

APPROACH

Since 2019, humanitarian actors have been developing anticipatory action (AA) approaches based on climate information and vulnerability indicators. Droughts from limited rainfall, such as the one observed in 2021–2022 period, can be reliably forecasted. In an AA approach, such meteorological drought forecasts can be overlaid with data on water demand for agricultural production and recharge of water sources, on livelihoods dependent on rainfed agriculture and pastoralism, and on food security status from assessment. The forecast models currently used have increased in forecasting skill, and this has been coupled with extensive drought assessments and information sharing. Thus, scientists can better quantify the health risks of forecasted droughts.

Therefore, objective criteria have been developed showing when to act in anticipation of drought, by combining climate forecasts with information about vulnerability on the ground and identifying areas with a high risk of humanitarian crisis arising from drought. Further, donors are creating funding streams such as Forecast-based Action (FbA) by the Disaster Relief Emergency Fund (DREF) of the International Federation of Red Cross and Red Crescent Societies (IFRC). The FbA by the DREF funds anticipatory actions for climate extremes whose anticipated impacts matches or exceeds a 1-in-5-year return period. The fund is accessible to national societies such as Kenya Red Cross Society through an Early Action Protocol (EAP).

RESULT

Kenya Red Cross Society implemented AAs in October 2021 following the release of national forecasts that indicated enhanced chance of a 1-in-5-year drought over the semi-arid parts of Kenya. In the intervention, the Society rehabilitated up to 8 boreholes to provide clean water, distributed drought-resistant seeds to farmers, distributed pasture seeds to pastoralists and carried out awareness-raising on climate-smart agricultural practices, water source management, water sanitation and hygiene. A survey conducted in September 2022 indicated that all the rehabilitated water facilities remained functional after the failed OND 2021 rainfall season and throughout the subsequent dry months, despite the increased dependence on them as a source of clean and cheaper water for household use, while drought impacts started peaking. The affected populations are benefiting from reduced need for repair and maintenance of the solarized water boreholes.

Interviews with community members who were recipients of awareness-raising on best agricultural practices indicated that they made use of the rainwater for production of drought-resistant crops and livestock pasture from a season whose rainfall was limited.

Monitoring reports indicated that the food consumption score for seed distribution improved from 38% to 65%, implying a significant increase in diversity of food options and sustained higher nutritional value among these beneficiaries.

The benefits of the interventions reduce the chances of malnutrition and waterborne and foodborne diseases among beneficiaries both in the short- and long-term.

CASE STUDY 3

LIMITATIONS AND LESSONS LEARNED

The beneficiaries indicated that at the time of distribution of the seeds they were observing local traditional indicators showing a chance of a dry spell early in the seasons, which was eventually observed. They made reference to interpretation of goat intestines by local forecasters. Consequently, most non-beneficiaries who were interviewed failed to implement drought anticipatory actions. In this case, the communities demonstrated a strong belief in their local knowledge. This provides an opportunity to use local knowledge and an AA approach should be flexible to accommodate this. As such, an arrangement had been made for the local forecasters to interpret forecasts for the season from goat intestines and compare them with scientific forecasts prior to the implementation of the anticipatory actions with the communities.

Some farmers suffered from failed crop harvest having planted late. There is need to scale up awareness-raising on the need to plant within timing of the rains, as the dry spell that followed the onset was anticipated from the seasonal forecast.

An impact analysis found that the combination of water provision and planting of drought-resistant seeds nearly doubled the food consumption score of beneficiaries and reduced negative coping strategies.

PARTNERS

Kenya Red Cross, British Red Cross, Netherlands Red Cross, International Federation for Red Cross and Red Crescent Societies, University of Sussex, National Drought Management Authority, Kenya Meteorological Department, Kenyan Government, county governments of Kitui, West Pokot and Kwale

Photo: Syed Ali

CASE STUDY 4

How Colombia's *Climate and Health Bulletin* is improving the management of environmental health and climate services

CHALLENGE

Vector-borne diseases, respiratory diseases and diarrheal diseases are among those that most affect Colombians. In addition to the difficult social, economic and sanitary conditions, climatic conditions have been decisive in their behaviour, especially the effects of climate variability and extreme events. Precipitation deficits are related to the increase in dengue cases, with the average monthly intensity of precipitation inversely correlated with the monthly number of dengue cases.

Therefore, it is necessary to systematically consider the climate component in epidemiological monitoring and prognosis[136] in order to improve the preparation of recommendations and the development of preventive actions by the country's health system.

APPROACH

Since 2016, the National Institute of Health (INS), the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) and the Ministry of Health and Social Protection have developed actions, within the Climate Variability and Change Board of the Comisión Técnica Nacional Intersectorial para la Salud Ambiental (CONASA), to establish the development of research and products and their dissemination within the national health system. For example, the IDEAM had conducted research into the relationship of rain, rain mean intensities, temperature and humidity with dengue and malaria cases, and incidences per hundred thousand inhabitants.

In April 2017, the first *Climate and Health Bulletin* was prepared and published, containing information on climate conditions and predictions, epidemiological conditions and recommendations. The publication and dissemination are carried out by the Sub-directorate of Environmental Health of the Ministry of Health and Social Protection, which sends the bulletin to departmental and local health bureaus to help inform their prevention and control plans and actions.

The INS and IDEAM have developed research on the identification and characterization of the favourability of climatic variables in diseases such as vector-borne diseases, susceptible to climate. A methodology was developed to relate the favourability with the epidemiological behaviour. The result of this work was used to develop the bulletin. In the monthly meeting of the bulletin contributors, the conditions, climatic and favourable predictions, and behaviour of the current and expected number of cases are presented, with their recommendations.

RESULT

The effort of the three institutions (INS, IDEAM and Ministry of Health and Social Protection) has been reflected in the formal integration in the Climate Variability and Change Board, as an intersectoral workspace, and in the *Climate and Health Bulletin*, as an information tool for decision-making by territorial entities, including departmental and municipal health secretariats.

It has also generated a space for discussion and the development of technical documents for policy formulation. With the research project financed by the Ministry of Science and Technology, and with the support of IDEAM, the INS has identified events of interest in public health and their relationship with climatic variables, designed to determine trends and cyclicality. For example, the organizations have led research into climate conditions and dengue in the Colombian Caribbean region.

Delegates of the departmental health secretariats have participated in meetings about the bulletin's objective and content, which has helped to develop capacities.

LIMITATIONS AND LESSONS LEARNED

In the development of this work, various difficulties have arisen. Changes of government have brought different objectives and conceptions that are reflected in the priorities of its management and in the resources assigned.

Also, there is a lack of experience in interdisciplinary and intersectoral work, which has been resolved through the exchange of knowledge, first between INS, IDEAM and the Ministry of Health and Social Protection, and secondly with regional and local health bureaus. It was necessary to define some priorities in the approach to vector-borne diseases, due to the limitations of information and its nature.

56 issues of the *Climate and Health Bulletin* have been published.

PARTNERS

Sub-directorate of Epidemiological Surveillance of the National Institute of Health (INS), Sub-directorate of Meteorology of the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) and Sub-directorate of Environmental Health of the Ministry of Health and Social Protection

Photo:SpaceX

CASE STUDY 5

Integrating climate and environmental information from satellites into health surveillance systems for Myanmar

CHALLENGE

Yangon is a tropical metropolis susceptible to infectious disease outbreaks. The Lepto Yangon Platform was developed to integrate climate and environmental risk information from satellites into health surveillance systems to develop early warnings and guide disease control.

The platform was developed to provide early warnings of the suitable environments for leptospirosis transmission, in order to improve its surveillance. Leptospirosis is a common bacterial zoonosis that remains rarely diagnosed in South-east Asia despite a high morbidity, as shown in several active investigations. Outbreaks of leptospirosis are strongly associated to water and often follow heavy rainfall and flooding events.

The integrated data platform was developed by the French National Research Institute for Sustainable Development (IRD) and partners of the ClimHealth project, funded by the French National Centre for Space Studies (CNES) and accredited by the Space Climate Observatory (SCO) international initiative. It builds on the ECOMORE 2 project,[137] coordinated by the Institut Pasteur, and funded by the Agence Française de Développement (AFD). In Yangon, this project supported the National Health Laboratory and hospitals of the Yangon metropolitan area to develop the diagnosis of leptospirosis and increase awareness.

APPROACH

The platform aims to model suitable climate and environmental conditions for leptospirosis through Earth observation, over the agglomeration of Yangon, Myanmar. The ECOMORE 2 project retrospectively analysed the locations of leptospirosis confirmed cases (versus non-leptospirosis controls) in 2019 and 2020. Time series of vegetation, water and moisture indices from Sentinel-2 satellite imagery (available at 10-meters spatial resolution, every 4 days, from the European Space Agency's Copernicus Programme) were produced to describe the dynamics of the environment around the locations of residence. This process relied on the use of the Sen2Chain processing chain developed in previous projects.

The most relevant indices were used to build a spatiotemporal prediction model of positive versus negative locations. This model was spatialized on homogeneous landscape units from the point of view of land use and describing the whole study area. The acquisition of Sentinel-2 images, their processing and the modelling were then automated as soon as a new image becomes available (every 5 days). An online information system was created to display this dynamic mapping of suitable environments for leptospirosis transmission and to inform the epidemiologists and physicians of the study. The online platform has been developed with the open-source software R and R-Shiny, and the processing chains are coded in Python, to be part of an open science approach.

RESULT

Lepto Yangon is an online early warning system providing information about the suitable environment for leptospirosis transmission in the metropolitan area of Yangon. A new risk map is produced every five days, as soon as a new Sentinel-2 image is available. The tool allows retrospective consultation of any date since the first image was available in March 2016 (over seven years ago). By clicking on the map, the user can select a landscape unit and view the temporal dynamics of the risk for that unit (that is, whether the risk is increasing or decreasing).[138]

The user can also view the vegetation, water and moisture indicators to get an idea of the environmental data more specifically. The platform is designed to be used by epidemiologists and physicians to visualize the most at-risk areas and those where the risk is increasing, to raise physicians' awareness of leptospirosis, which is often confused with other fevers.

LIMITATIONS AND LESSONS LEARNED

Implementing this tool in other territories is facing methodological challenges regarding the volume of satellite data to be processed. Detailed knowledge of the ecology of leptospirosis and exposure factors to adapt the models in different contexts is also needed.

This already operational risk monitoring tool provides proof of concept for the development of climate and environmental monitoring systems to increase the vigilance of health personnel and populations to the risk of leptospirosis.

> Lepto Yangon provides actionable and real-time (5-day) updates of leptospirosis transmission risk to epidemiologists and hospitals in Yangon.

PARTNERS

National Research Institute for Sustainable Development (IRD) (France), Université de La Réunion (France), National Centre for Space Studies (CNES) (France), Space Climate Observatory (SCO), Institut Pasteur (France), Institut Pasteur du Cambodge (Cambodia), Institut Pasteur de Nouvelle Calédonie (France), National Health Laboratory (Myanmar), Agence Française de Développement

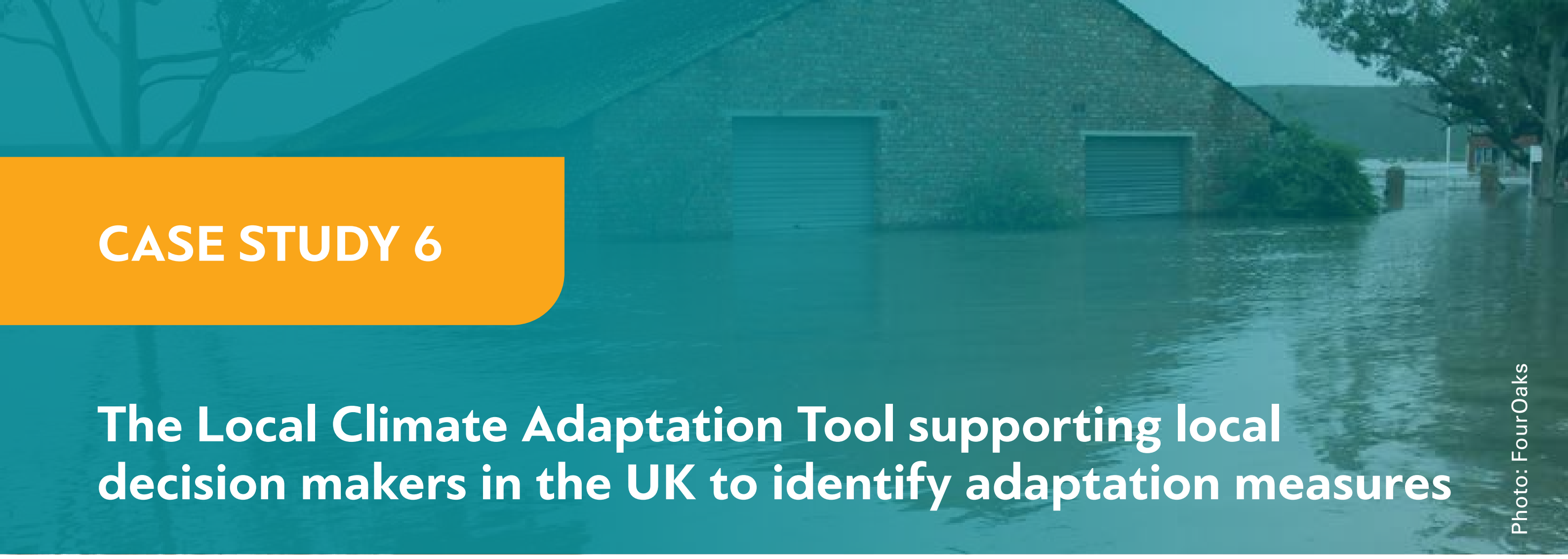


Photo: FourOaks

CASE STUDY 6

The Local Climate Adaptation Tool supporting local decision makers in the UK to identify adaptation measures

CHALLENGE

Many of the impacts of climate change are now locked in and the health consequences for vulnerable populations are likely to be significant. What steps should be taken to prepare for this? Discussions with stakeholders across the UK, including councils, the National Health Service, emergency services and other local service providers showed that there was an urgent need for local decision makers to have access to the latest climate information and scientific studies to make informed decisions about appropriate adaptations. Stakeholders urgently need: access to local future climate models; clear guidance on appropriate adaptation, that is evidence based; guided access to the evidence base; and support to work across traditional boundaries. The use of health outcomes to drive decision-making provided a common currency.

APPROACH

The Local Climate Adaptation Tool (LCAT) was developed by the University of Exeter and partners in order to offer decision makers data and evidence to not only understand, but to plan for the future climate.

The tool is free and open source, and is aimed at helping councils, the National Health Service and emergency services as well as local service providers to understand what is likely to happen and to prioritize their climate adaptation approaches.

The tool, which is in the prototype stage, brings together complex climate models, adaptation options and health impact evidence to help users understand the health implications of climate change in their local area. Importantly, LCAT also generates recommendations for appropriate adaptation approaches, based on the best available evidence, to support the health and well-being of local people.

Users can select a local area of interest and see the predicted climate over the coming decades, alongside evidence on the health impacts of climate change from the scientific literature. The aim is to enable the best possible health and well-being outcomes for local people. For example, planning cycle paths with shade for hotter summer months and protection from stronger cross winds in the winter, ensures that people can continue to gain the health and well-being benefits of cycling in a changing climate.

RESULT

The use of a health lens provides a common "language", relevant to all service areas, and facilitates a multi-agency approach to adaptation planning. Key to supporting informed decision-making is a link to the evidence base.

The tool identifies key, published evidence on health and well-being outcomes to support the recommendations and advice it will generate. Climate change impacts are not felt equally, as many people are more vulnerable due to personal, social and environmental factors. Furthermore, climate change is likely to increase current inequalities. Stakeholders involved in the co-design of LCAT have consistently voiced their concerns about deepening inequality and, as such, LCAT is being developed to provide data sets on vulnerable groups. Using insight and data from Climate Just,[139] as well as data from the UK indices of multiple deprivation, LCAT supports decision makers to identify who is vulnerable and therefore take a more equitable approach to planning adaptations.

LIMITATIONS AND LESSONS LEARNED

The tool is being developed in stages. As it is developed further, updated iterations will be published, with more data, content and evidence. The current version (as of November 2022) is a prototype. Using the third *UK Climate Change Risk Assessment 2022* (CCRA3)[140] as its starting point, and in consultation with stakeholders, the key risk areas for inclusion in LCAT have been identified as: heat, flooding and drought, extreme storms, coastal security and ocean system changes, and personal security, such as food or energy supply. As of February 2023, the prototype health impact maps explore heat (and cold) as well as test the methodology that is being used for the mapping. The other risks will be added by mid-2023.

LCAT offers decision makers integrated data and evidence to understand future climate conditions and make locally informed multisectoral planning choices.

PARTNERS

University of Exeter, Turing Institute, Cornwall Council, Then Try This

CASE STUDY 7

Model-based risk assessments of vector-borne disease emergence with climate change in Canada

Photo: FourOaks

CHALLENGE

Vector-borne diseases are sensitive to climate and weather, which affect vector survival, life cycles and activity, and the development of disease-causing microbes in the vectors. Climate change is anticipated to drive geographic range expansions of many vector-borne diseases towards the poles and to higher altitudes. People will be exposed to vector-borne diseases for the first time, so public health needs to know how to respond and adapt to these new health threats.

Canada's cold climate has protected people from most vector-borne diseases, but that is changing rapidly. The use of vector and disease transmission models coupled with outputs from climate models can better support in the task of projecting future risk.

APPROACH

A first step to adaptation is understanding which geographic regions are going to be affected and when future risks are likely to appear. This is achieved by developing comprehensive knowledge of disease risk occurrence, for example, in the form of risk maps, under current and projected future climate. Mathematical models (of vector species life cycles, and vector-borne disease transmission) allow us to assess climatic limits for a vector or disease, and how risk might increase as temperature warms and rainfall increases/decreases from current levels.

These models synthesize information on how climate affects disease risk, while accounting for other factors (environmental or socioeconomic) that also limit disease occurrence. For this, data on current climate are essential.

Once we understand how climate determines and influences where, when and how disease risk occurs, we can then predict future occurrence with climate change, by using outputs from global and/or regional climate models. Outputs from ensembles of climate models are used which employ a range of scenarios for greenhouse gas emissions. Therefore, projections account for variations in model performance at different locations and future time periods, and uncertainty as to how societies will respond to the challenge of the climate crisis by mitigating greenhouse gas emissions.

RESULT

Firstly, projections of the expansion of the range of the blacklegged tick vector of Lyme disease with climate change have been proven to be highly accurate and have given early warning of the emergence of Lyme disease in Canada. In addition, this allowed attribution of Lyme disease emergence in Canada to climate change. This early warning also enabled public health programmes to step up their surveillance efforts while also raising awareness of Lyme disease ,as well as preventative measures, within the public and medical community.

Similar projections have raised awareness that another tick vector of infectious diseases, the lone star tick, may also emerge in southern Canada in the near future. Projections of the occurrence of the Asian tiger mosquito (and the diseases it can transmit, like Chikungunya) alerted us that this mosquito may spread into Canada and may already be present in the warmest locations. This has been confirmed by surveillance, again providing early warning of possible future disease risks.

LIMITATIONS AND LESSONS LEARNED

Predicting future disease risks requires knowledge of the occurrence and biology of infectious diseases, while confidence in predictions depends on validation by surveillance. None of this is possible without data on current climate, and state-of-the-art climate models that provide us with the capacity to project future climate, particularly at the regional scales. Nevertheless, with adequate knowledge, accurate and useful predictions can be made.

Climate-informed projections for the occurrence of Lyme disease in Canada have allowed the government to attribute disease risk to climate change – and to get ahead of the epidemic curve to prepare public health responses.

PARTNERS

Public Health Agency of Canada, Département de Géographie and Centre pour l'étude et la simulation du climat à l'échelle régionale (ESCER) at Université du Québec à Montréal, Réseau Inondations InterSectoriel du Québec

CASE STUDY 8

Smart health-care facilities provide safer and greener health services in the Caribbean

Photo: Natanael Melchor

CHALLENGE

The Caribbean region is disproportionately affected by the occurrence and impact of disasters due to its geography. Its vulnerabilities are exacerbated by the impacts of climate change, which include rising sea levels, coastal erosion and the general escalation in the intensity of tropical storms and hurricanes and varying rainfall patterns.

Weather-related disasters impact the capacity of health-care facilities, both functionally and structurally, to provide critical services, including emergency care and ongoing health care for communities.

According to the Sendai Framework and the Pan American Health Organization (PAHO) *Plan of Action for Disaster Risk Reduction 2016–2021*,[141] 77% (13 566 out of 17 618) of the hospitals in the region are in areas of risk and require urgent remedial measures to protect personnel and patients' lives during and after a disaster.

Knowledge of the condition of the facilities, level of exposure and their role within the health service network is indispensable (for example, if the facilities are in areas prone to flooding, or along the hurricane path and so forth). Information on this was collected from health facilities' personnel, Ministries of Health and National Disaster Management Offices. Health-care facilities are also intensive energy users due to the services provided and their hours of operation, thus making significant environmental footprints. With energy prices in the Caribbean among the highest in the world, cost savings could be better used on improving health services.

APPROACH

The Smart Health Care Facilities in the Caribbean project, funded by the UK Foreign, Commonwealth and Development Office (FCDO), was implemented by PAHO and WHO in partnership with seven Ministries of Health in Belize, Dominica, Grenada, Guyana, Jamaica, Saint Lucia and Saint Vincent and the Grenadines.

A regional building code annex, guideline and toolkit for retrofitting existing or new facilities was developed. The toolkit provided a step-by-step guide and included the Hospital Safety Index (HSI), the Baseline Assessment Tool (BAT) and the Green Hospitals Checklist, utilizing cost-benefit analysis to support investment decision-making. PAHO has been providing technical assistance to Caribbean countries for the implementation of the Smart Hospitals initiative in two phases (2012–2014 and 2015–2022). During the project planning process, consultations were made with agencies and entities, such as ministries of environment and the Caribbean Community Climate Change Centre based in Belize. Entities were invited to participate in the implementation of the project (for example Town Hall meetings, ad hoc meetings and so forth). In addition to FCDO, the European Union funded five health-care facilities in Belize and four shelters in British Virgin Islands. The International Development Bank funded the La Paix Smart Hospital in Haiti.

RESULT

The Smart Hospitals initiative focuses on improving hospitals' resilience, strengthening structural and operational aspects and providing green technologies. Energy improvements include solar panel installation, electric storage batteries and low-consumption electrical systems, which, in addition to reducing energy consumption, reduce the health sector carbon footprint and provide the hospital with energy autonomy, allowing it to continue running during emergencies and disasters.

An additional benefit is the fact of not increasing the carbon footprint associated with new construction, because the project improves existing facilities. Health-care facilities are Smart (Gold Standard of A70) when they link their structural and operational safety with green interventions at a reasonable cost-to-benefit ratio. The Hospital Safety Index and the Green Hospitals Checklist as part of the Smart Toolkit are used the calculate the score.

Belize suffered significant damage to infrastructure following the passage of Hurricane *Lisa* in November 2022. The National Emergency Management Organization reported that the initial damage estimate to the housing sector was approximately USD 10 million. Although the health sector was slightly impacted by Hurricane *Lisa*, the five health facilities retrofitted as "smart" hospitals remained functional during the hurricane and after it made landfall. They were able to serve their catchment population, especially those who were affected by the hurricane. Critical services such as immunization, sexual, maternal and child health care, medical services for chronic conditions, and others were readily accessible to communities.

CASE STUDY 8

The required infrastructure and critical systems such as electricity through solar power, water supply via rainwater harvesting and the drainage system, among others, provided the backup system to enable the health facilities to remain operational during the COVID-19 pandemic, and also after the volcano eruption in St. Vincent and the Grenadines, when the Chateaubellair Smart Hospital was able to provide water from its tanks to the affected community.

The Smart Hospital initiative is focused on improving hospitals' resilience, strengthening structural and operational aspects and providing green technologies.

PARTNERS

UK Foreign Commonwealth and Development Office, European Union, International Development Bank, the seven Ministries of Health in the Caribbean project countries, Pan American Health Organization

Photo:Gearstd

CASE STUDY 9

Forecast-based financing and early action protocols for disease and health risks

CHALLENGE

Climate change is adversely affecting human health. Outbreaks and epidemics of climate-sensitive infectious diseases are of high public health concern, especially in lower- and middle-income countries that are highly vulnerable and exposed to climate change. As our understanding of linkages between climate and weather and infectious disease patterns improves, it may be possible to act earlier to prevent or minimize outbreaks and epidemics.

APPROACH

Forecast-based financing (FbF) is a programme that enables access to humanitarian[142,143] funding for early action, based on in-depth forecast information and risk analysis. The goal of FbF is to anticipate disasters, prevent their impact, if possible, and reduce human suffering and losses.

Typically, FbF programmes have been designed to reduce or mitigate the impacts of hydrometeorological hazards such as floods, droughts, cyclones, heatwaves or cold waves. These have been formalized into more than 20 Early Action Protocols (EAPs) in different countries.

Within these EAPs, early actions which aim to prevent or alleviate negative health outcomes, such as waterborne disease outbreaks, are quite common. For example, the cyclone EAP in Mozambique attempts to reduce the risk of diarrheal diseases due to damage to water infrastructure and resulting contamination. It does so by pre-emptively distributing chlorination tablets and buckets to families based on a trigger of forecasted wind speeds of 120 km/h or above at landfall. The lead time is 72 hours. Considerations for the impacts on the health sector have been integral to EAP development for hydrometeorological hazards. However, there is a new and growing interest in developing EAPs specifically for infectious disease outbreak risk, such as for dengue, malaria or cholera.

RESULT

In the future, EAPs could be based on climate-informed disease risk prediction models. A prototype is the Barbados dengue early warning system[144,145] developed in partnership with the Barbados Meteorological Services, Barbados Ministry of Health, French Red Cross, Red Cross Red Crescent Climate Centre and London School of Hygiene and Tropical Medicine. The climate-informed early warning model creates a probabilistic risk output of a dengue outbreak months in advance. If an above-average dengue transmission season is predicted several months in advance there is the opportunity to implement preventative public health action, such as vector control activities.

Alternatively, EAPs could be developed with triggers linked to aggravating factors for disease outbreak risk in endemic areas, such as population displacement, weather or an increase in disease caseload. For example, the cholera EAP template developed by the International Federation of Red Cross and Red Crescent Societies aims to use early actions for earlier detection and response to cholera outbreaks in endemic countries.

The climate-informed early warning model creates a probabilistic risk output of a dengue outbreak months in advance.

PARTNERS

International Federation of Red Cross and Red Crescent Societies, Red Cross Red Crescent Climate Centre, French Red Cross, German Red Cross, London School of Hygiene and Tropical Medicine, Barcelona Supercomputing Center (BSC)/Catalan Institution for Research and Advanced Studies (ICREA), Barbados Meteorological Services, Barbados Ministry of Health

Photo:Siriwannapat photos

CASE STUDY 10

Global mobile access and awareness of local UV radiation exposure risk and public health precautions

CHALLENGE

Up to 95% of melanoma and 99% of non-melanoma skin cancers are a result of over exposure to UV radiation. Despite being largely preventable, skin cancer remains a global problem, with an estimated 1.5 million people diagnosed in 2020 worldwide.

During the same period, more than 120 000 people across the world lost their lives to this highly preventable disease. The SunSmart Global UV app seeks to bring worldwide consistency to UV reporting and public health messaging, and to tackle the worldwide burden of skin cancer and UV-related eye damage. It does this by bringing sun protection advice to anyone with the app on their mobile phone based on their selected location.

APPROACH

While great gains have been made in relation to the implementation of the Montreal Protocol on Substances that Deplete the Ozone Layer that has reduced the impact of UV on human health, it is still vitally important for the public to garner a better understanding of the dangers of prolonged UV radiation exposure.

Evidence shows that personal habits in relation to ongoing sun exposure, including sunscreen use, clothing choice and time spent outdoors, are the most important individual risk factors for UV-related skin and eye damage.

Developed in Australia by the Cancer Council Victoria, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) and the Bureau of Meteorology, the SunSmart Global UV app was launched in July 2022 with the support of WHO, WMO, the United Nations Environment Programme (UNEP) and the International Labour Organization (ILO). The SunSmart Global UV app was designed primarily to influence sun protection behaviour by providing individual users with the times of the day when sun protection is required, no matter what their location.

The SunSmart Global UV app utilizes forecast UV data from the European Centre for Medium-Range Weather Forecasts (ECMWF) and weather information from the Hong Kong Observatory. The app also has the capacity to draw on live UV data when available. In Australia for example, the app collects live UV data from monitoring stations across the country. The live UV data is updated every 1–2 minutes and is available for anyone who is within a 100 km radius from a fixed UV monitoring site.

RESULT

The SunSmart Global UV app utilizes global UV forecast data sources and converts that information to provide clear public health advice in a way that is designed to motivate sun protective behaviour.

The app includes four-day UV forecast of sun protection times and weather information, and is available in eight languages including English, French, Spanish, Dutch, Chinese, German, Italian and Russian. Since its launch in June 2022, the app has been downloaded over 150 000 times.

The SunSmart Global UV app is available free of charge at both App Store and Google Play.

LIMITATIONS AND LESSONS LEARNED

Launching an app globally with the support of United Nations agencies requires a lot of work, time and tenacity – but is worth it. A key limitation has been containing costs. To build an app to suit a global audience across multiple languages requires a good budget, not just to cover the app build, but also the ongoing maintenance and promotion costs.

> With the support of world-leading health and meteorological organizations, combined with the benefits of technology to deliver location-specific health advice, we hope to decrease the significant global burden of skin cancer and eye disease.

PARTNERS

WHO, WMO, United Nations Environment Programme, International Labour Organization, Australian Radiation Protection and Nuclear Safety Agency, Bureau of Meteorology (Australia), Cancer Council Victoria (Australia)

Photo:CIMH website

CASE STUDY 11

The Caribbean *Health Climatic Bulletin* is the result of partnership-driven climate services for health

CHALLENGE

The Caribbean is recognized as one of the most climate-sensitive and disaster-prone regions in the world, with Caribbean small island developing States (SIDS) at the frontline in terms of climate impacts on human health. The development of climate-informed early warning systems for health is a priority need. Until 2017, tailored operational climate early warning information for health practitioners was largely not available.

APPROACH

Since 2009–2010, the Caribbean Institute for Meteorology and Hydrology (CIMH) has been operationally producing climate monitoring and climate forecast information for the public good. This freely available climate early warning information has been produced every month and was potentially useful to the health sector, as it provided advisories on climate extremes such as drought, extreme rainfall and heatwaves, which are becoming increasingly intense in a changing climate.

In a 2017 PAHO Country Survey on Health and Climate Change, Caribbean health professionals identified and rated as "extremely important" or "important" many topics about which the CIMH provided climate monitoring and forecasting and collaborated across sectors. These themes included vector-borne diseases, weather and emergencies, food security/safety, waterborne diseases and heat-related illness, among others. The CIMH seized the opportunity to use its suite of monitoring and forecast information as a basis for providing a more tailored service to the Caribbean health sector on climate-sensitive diseases.

Since 2017, the RCC-Caribbean has worked with regional health partners at the Caribbean Public Health Agency (CARPHA) and PAHO to prepare and disseminate messages on the expected seasonal impacts of climate conditions on the incidence of some climate-sensitive diseases. The quarterly Caribbean *Health Climatic Bulletin* (HCB)[146] has been jointly authored and disseminated by CIMH, CARPHA and PAHO since May 2017 and is the Caribbean's premier integrated climate-health early warning product.

RESULT

The Caribbean HCB is a tool that has the potential to help health practitioners in the region to reduce climate-related health risks. It provides them with the seasonal information required to identify and prepare for upcoming favourable or unfavourable climate conditions, three months in advance. Use of this information can help to inform strategic and operational decisions related to the management of diseases like dengue, which is estimated to cost the Caribbean over USD 300 million annually.[147] CIMH, CARPHA and PAHO continue to work with international research partners on the development of models in an effort to provide integrated climate-health advisories in the HCB in the future. This will lead to further improved, climate-smart health decision-making in Caribbean SIDS.

> The Caribbean *Health Climatic Bulletin* is the premier climate early warning information product in the region, providing health practitioners with information to prepare for upcoming climate conditions and risks, three months in advance.

PARTNERS

Caribbean Institute for Meteorology and Hydrology, Caribbean Public Health Agency, Pan American Health Organization

Photo: Prem Kurumpanai

CASE STUDY 12

Enabling environment for integrated risk monitoring and climate-informed early warning systems in Fiji

CHALLENGE

Fiji is prone to climate change hazards including sea-level rise, cyclones and floods, with increases in extreme weather events, such as shifting wet/dry seasons and extreme rainfall days, likely in the coming decades. These changes are expected to influence disease patterns, community resilience and health systems.

Fiji is already experiencing a rapidly growing health burden due to the increased incidence and prevalence of non-communicable and communicable diseases, combined with increasing climate change-related health impacts. In the absence of appropriate and rapid health-focused adaptation strategies, climate change has the potential to cause a range of significant negative health impacts.

In Fiji climate change affects human health through multiple pathways, including increased risk of waterborne diseases (such as diarrheal diseases) and vector-borne diseases (such as dengue), increased food and water insecurity leading to nutritional issues, and disruption of health systems due to climate-induced extreme weather events and sea-level rise. The combination of exposure to climatic hazards with limited capacity of the health system, including inadequate infrastructure, human resources and supplies, as well as communities that are remote and hard to reach, provide significant challenges in reducing climate change-related morbidity and mortality.

APPROACH

The Fiji Ministry of Health and Medical Services (MOHMS) has a close working relationship with Fiji Meteorological Services (FMS), starting in 2010 through the Climate Change and Health Steering Committee and various projects. Previously, climate information was accessed through "request for data" applications, particularly for large data sets, and was more project-focused and ad hoc.

In 2020, MOHMS and FMS signed a Memorandum of Agreement for collaboration to improve meteorological observation network coverage in data-sparse areas; to facilitate data sharing between the Parties, including meteorological data and health-related data on climate-sensitive diseases; and to enhance the capacity of health sector institutions to respond to climate-sensitive health risks, based on early warning information provided by FMS and development of early warning systems for climate-sensitive diseases. The plan was also to improve information systems supporting integrated assessment of climate-sensitive health risks in management and long-term planning, and to build capacity of health sector and key multisectoral partners in strengthening data management across sectors.

MOHMS is now working to develop its climate-based early warning system through the Korea International Cooperation Agency (KOICA)-funded project, Strengthening Health Adaptation Project: Responding to Climate Change in Fiji (SHAPE).

RESULT

An outcome of this collaboration has been the identification of the four climate-sensitive diseases (leptospirosis, typhoid, dengue and diarrheal disease) for Fiji, with the ambition to explore climate change linkages with non-communicable disease underway.

Statistical and spatial analysis training has also been integrated into existing divisional and sub-divisional outbreak response activities, focusing on identifying relationships between disease outbreaks and climate variables (for example, rainfall and vector surveillance). With this training, the sub-divisional outbreak response teams can correlate the relationship between disease outbreaks and climate patterns to map out "highly vulnerable" areas. This has assisted the teams to better prepare and respond to climatic changes in Fiji, including on seasonal timescales, which has helped reduce morbidity and mortality from climate-sensitive diseases in their sub-divisions.

LIMITATIONS AND LESSONS LEARNED

Communication is vital for information sharing and it is also a key limitation. The warnings/forecasts can be delayed, and at times irregular or inconsistent. The language used is also sometimes too technical for the health workers and is not well interpreted for prompt response. Additionally, the modality for requesting data still suffers from delays, sometimes slowing implementation of projects and/or research. However, there is continued consultation with FMS to improve on these challenges.

The collaboration has helped the teams to better prepare and respond to climatic changes in Fiji, including on seasonal timescales.

PARTNERS

Fiji Ministry of Health and Medical Services, Fiji Meteorological Services, Korea International Cooperation Agency, WHO

Photo:Patrick EvMearrxas4

CASE STUDY 13

Handheld access to actionable heat risk and response information in eight global cities

CHALLENGE

The health impacts of extreme heat are predictable and largely avoidable, provided that city authorities have access to timely and location-specific information. With the right data and tools, city authorities can identify local hot spots, optimize the allocation and management of cooling centres, ensure sufficient drinking water spots and cooling spaces and communicate the health-related risks of excessive heat. Citizens and visitors can plan their daily lives in the city safely knowing the risks, and can adapt their routines accordingly. The challenge then is to improve access to information so that city authorities can reduce heat-related illness and deaths.

APPROACH

EXTREMA Global[148] is a portfolio of digital services based on open Earth observation data as well as climate and atmosphere models and local data, targeting cities and citizens with city-specific customizations. It was originally designed to lessen the impacts of heatwaves on public health, and to make cities more heat resilient. The core services of EXTREMA Global include a free, multilingual mobile app that uses data and services to provide the current heat risk at the location of the user and recommendations for health protection, including directions to the nearest cooling places and drinking water spots and public announcements from city authorities. The app supports multiple profiles, allowing users to check on family members in multiple locations. The city authorities access tools and alerts through a dashboard to help them manage their resources to reduce heat exposure.

City authorities also have access to satellite-derived maps showing the distribution of surface temperature in order to identify hot spots and areas that need intervention, through for example, the planning, design and management of urban infrastructure.

The smartphone app also has optional modules that allow for the integration of air quality data from Copernicus Atmospheric Monitoring Service (CAMS) and provision of relevant health instructions.

EXTREMA Global services are already being used in the municipalities of Athens, Milan, Paris, Rotterdam, Greater London (UK), and in Chicago, Tampa and Newark in the USA.

RESULT

Athens (Greece) was the first city in which the concept was adopted in 2016. City authorities worked to design the app to meet the city requirements, and have since included the app in the #CoolAthens campaign. They have also included the add-on to provide air quality data at the location of the user, and use high-resolution temperature distribution maps to guide planning. The combination of air quality and heat risk proved to be very useful in July 2021 when Athens experienced a severe heatwave that lasted 10 days and saw temperatures reach about 44 °C, with very poor air quality due to nearby wildfires sparked by the heat.

The EXTREMA app suggests “cool routes” where users can walk safely around the city, for example, between tourist attractions, a feature much needed for tourists. In July 2023, during a heatwave that lasted 14 days, app requests by Athenians and visitors reached 10 000 hits. Furthermore, the app contributed drastically to strengthening communication between the departments of the municipality to exchange know-how and data.

In Milan, hundreds of drinking water spots are mapped in the app, making use of the digital infrastructure to also decrease the use of plastic bottles. Publicity and dissemination by the city authorities play a critical role in the use and impact of the app, with peak usage dates coinciding with days in which the city promoted the app in the local press. In 2022, the app received 6 324 requests for service from Milan. Milan is now using digital services to calculate the safest and coolest routes for bicycles.

> In Athens, the EXTREMA app supports six languages to help tourists find their nearest cooling space and the coolest route to their destination.

PARTNERS

National Observatory of Athens, Group on Earth Observations (GEO), Global Urban Observation and Information (GUOI) initiative, ARTi Analytics B.V., Copernicus Atmospheric Monitoring Service (CAMS), Bloomberg Associates

Photo:Alex Jones

CASE STUDY 14

Real-time monitoring and alerts of allergenic pollen risk across Europe

CHALLENGE

Currently, over 25% of the European population suffer from airborne allergies, and this number only continues to grow. Climate change affects allergy patients in a multitude of ways. For example, rising CO2 levels boost plant growth, which increases pollen emissions and thereby exacerbates allergies, forcing patients to alter their routines to avoid or mitigate the impact of pollen in their daily lives.

Air pollution, a key driver of climate change, also has negative effects on both plants and humans. Air pollution irritates the airways of all those exposed, particularly allergy patients, and plants produce more allergenic and irritant pollen when stressed by pollution. In addition to increased and more allergenic pollen, climate change is also changing plant distributions across geographic regions. As a result, people are being exposed to new types of allergens that they may not have been exposed to before. In some cases, this causes new allergies in people who have previously never suffered. Providing real-time information about the levels of aeroallergens, such as pollen and fungal spores, can help to significantly improve the quality of life of allergy patients. According to WHO the percentage of European allergy patients is expected to increase from 25% to 50% by 2050.

APPROACH

The EUMETNET AutoPollen Programme is facilitating the establishment of a European-wide monitoring network to provide information in real time and at high temporal resolution to all end users, including allergy patients, medical practitioners, forecasters and researchers.

The environmental observations that this network provides are dramatically improving the quality of forecasts, and help to better diagnose patients, evaluate current and future interventions and guide the direction of meaningful research. Furthermore, the observations are being extended to cover fungal spores, some of which are important agricultural pathogens, thus opening up the possibilities of environmental monitoring to sectors beyond just human health.

RESULT

The technology and methods to automatically monitor aeroallergens in real time can be applied in any country or geographical region. It is possible to modernize observational networks to provide real-time information to end users globally.

The EUMETNET AutoPollen Programme is helping to prove that this is possible across Europe, and creates the potential for further networks to grow in other parts of the world.

LIMITATIONS AND LESSONS LEARNED

Real-time monitoring of aeroallergens is now possible, and is helping to provide significantly improved information to end users. While developing monitoring networks is a key first step, the whole information chain needs to be considered – from the initial measurements through to how information is communicated publicly in a tailored and targeted way.

Working together with stakeholders from the outset is vital – whether with medical practitioners, patient organizations or instrument developers. For example, patients and health-care professionals can use data and communications to help mitigate and manage diseases, specifically respiratory diseases. National and/or regional governments will have easy access to streamlined information that can be translated or disseminated in their respective locations.

> Real-time observations of aeroallergens are revolutionizing the information available to patients and health practitioners – and improving the health of millions of European allergy patients.

PARTNERS

EUMETNET AutoPollen Programme is coordinated by the Swiss Federal Office of Meteorology and Climatology (MeteoSwiss). The key stakeholders include allergy patients, medical practitioners, patient organizations, the pharmaceutical industry, high-tech instrument manufacturers, national hydrometeorological services, decision makers and researchers from a wide range of domains such as climate change, agriculture and public health.

Photo: NOAA One health/CDC website

CASE STUDY 15

One Health approach helps NOAA to integrate weather, water and climate services

CHALLENGE

Human health is inextricably linked to the health of other animals and the environment, all of which are influenced by the weather and climate. However, human health is often addressed as a distinct field of its own (for example, medical doctors versus veterinarians versus ecologists).

In national governments, these components are often governed independently by different agencies, with some supporting human health, others managing animal health and others the environment.

This fragmented approach to science, policy and risk management may not only lead to inefficiency in fully understanding a health problem, but it may also result in lives lost and lost time in launching a multisectoral response to extreme weather, infectious disease or environmental pollution events.

Health systems are rarely equipped to understand and handle alone the increase in extreme weather events, sea-level rise or environmental pressures such as harmful algal blooms or wildfires. The National Oceanic and Atmospheric Administration (NOAA) has employed a "One Health" approach to help break down internal and inter-agency siloes that can lead to better service of the government to protect the health of Americans.

APPROACH

In the USA, many agencies take a One Health approach to understanding and managing the interconnected social, environmental and animal determinants of health. NOAA is a diverse agency that includes weather forecasting, climate data and service provision, fisheries management, and ocean and coastal management. Its One Health coordination team acts as a forum to raise and collaborate on intersectional health topics ranging from marine mammal disease, harmful algal blooms, extreme heat impacts, air quality and the environmental factors influencing vector-borne diseases. It also serves as a single point of entry for requests from partners in government (Centers for Disease Control and Prevention (CDC), Department of Homeland Security, Department of State and so forth) and non-governmental stakeholders and partners.

The One Health team meets monthly, but also collaborates through a variety of other agency and multi-agency fora. For example, the National Integrated Heat Health Information System (NIHHIS), which is led by NOAA and CDC, but inclusive of many other agencies, hosts several different inter-agency working groups that have addressed heat season messaging, technical guidance for exertional heat exposure, and most recently, developed and launched Heat.gov to serve as the United States Government's integrated resource for heat and health information. Through the One Health team at NOAA, NIHHIS can address the issue of heat, considering the downstream impacts of extreme heat on human, animal and environmental health.

NOAA's One Health team also provides climate expertise to the United States federal Interagency Crosscutting Group on Climate Change and Human Health (CCHHG). Co-led by NOAA, CDC and the National Institute of Health (NIH), it helps align 14 agencies across the United States federal government and coordinates, implements, evaluates and communicates federal research and scientific activities related to the human health impacts of global climate change. The CCHHG has enabled the first Climate and Health Assessment (CHA) to synthesize the state of the science around climate impacts to health in the USA. The CHA informs public health officials, decision makers and other stakeholders.

RESULT

NOAA's One Health team represents the health capabilities and interests of the agency in many ways, enabling NOAA to collaborate more seamlessly with other government agencies on health-related issues, from disease outbreaks to oil spills and extreme weather. For example, the CDC is developing a new Vector-borne Disease Strategy. Through the One Health team, NOAA provided One Health input to the strategy, incorporating consideration of marine mammal disease, vector-borne disease, environmental modelling, and seasonal and long-term climate information.

Another example is the CDC's Heat and Health Tracker which provides timely information on daily and weekly rates of emergency department visits associated with heat-related illnesses using data available through the National Syndromic Surveillance Program to public health officials. Users can enter their zip code to access tailored information and a heat vulnerability index. This climate-informed decision tool is made possible through seamless collaboration, data sharing and coordination between CDC and NOAA.

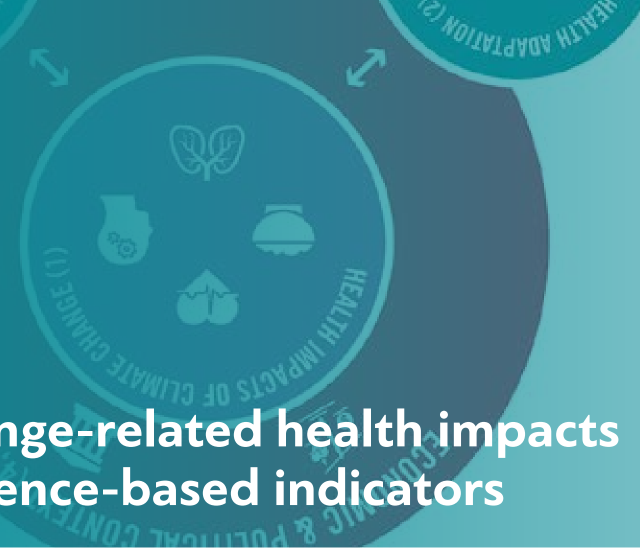
NOAA's dedicated health experts and One Health team act as an internal forum to collaborate on health-related climate science and research, operational research, community engagement and training, on matters ranging from marine mammal disease to extreme heat impacts. This internal function and staffing enable NOAA to better engage with and serve other federal agencies and partners managing the impacts of climate on human health.

Breaking down siloes internally and externally through a "One Health" approach allows NOAA to be a more effective partner in protecting health from climate and environmental risks.

PARTNERS

NOAA, WMO/WHO – Global Heat Health Information Network (GHHIN), PAHO National Institutes of Health: National Institutes of Environmental Health Sciences, Office of Climate Change and Health Equity, Centers for Disease Control and Prevention, National Center for Emerging Zoonotic and Infectious Diseases, Climate and Health Program, United States Global Change Research Program Interagency Crosscutting Group on Climate Change and Human Health

CASE STUDY 16



Tracking climate change-related health impacts in Europe using evidence-based indicators

Photo: LCDE website

CHALLENGE

Climate change impacts health through complex multidimensional pathways. These impacts include, for example, morbidity and mortality related to extreme climatic events, such as heatwaves and floods, and changes in the length of the transmission season and timing of climate-sensitive infectious disease outbreaks.

As one of the world's biggest contributors to cumulative greenhouse gas emissions, countries in the pan-European region have a global responsibility to respond to climate change and transition to low-carbon economies. While evidence and awareness of the health implications of climate change are increasing, there is a need for accessible tools and ready-to-use information that allow effective communication of complex historical, current and projected climate-health trends. This information can help inform advocacy and climate change decision-making.

APPROACH

Responding to this need at a European level, the Lancet Countdown in Europe (LCDE)[149] is a transdisciplinary research collaboration to develop indicators that monitor and quantify the health impacts of climate change and the health co-benefits of climate action since the 1950s. These indicators act as summary measures representing the heterogenous relationships between climate change and human health.

A subset of LCDE indicators also feeds into the European Climate and Health Observatory (ECHO),[150] a partnership between the European Commission (EC), European Environment Agency (EEA), Copernicus Programme Services, European Centre for Disease Prevention and Control (ECDC), European Food Safety Authority (EFSA), World Health Organization (WHO) Regional Office for Europe, Association of Schools of Public Health in Europe (ASPHER), International Association of Public Health Institutes (IANPHI) and the LCDE.

The European Climate and Health Observatory portal provides access to information and tools for climate change adaptation to the EEA's 38 member and cooperating countries. To ensure the reproducibility, scientific validity and relevance of LCDE indicators for policymaking, the project adheres to quality criteria mirroring WMO guidelines for climate indicators. A wide range of experts are involved in an iterative feedback process that further ensures the indicators align with the needs of policymakers – including experts affiliated with ECHO and its partner organizations, as well as EEA member and cooperating country representatives.

RESULT

In 2022, the LCDE collaboration developed 33 indicators[151] tracking the health dimensions of climate change across five key domains: (i) climate change impacts, exposures and vulnerabilities; (ii) adaptation, planning and resilience for health; (iii) mitigation actions and health co-benefits; (iv) economics and finance; and (v) politics and governance. Eleven of these indicators are available as interactive visualizations on the ECHO platform,[152] including indicators on allergenic pollen seasons, health impacts of temperature-related exposure, and the climatic suitability of several infectious diseases (such as dengue, malaria, *non-cholera Vibrio* and West Nile virus). These indicator visualizations allow users to interact and engage with the data. For example, users can select their country and time period of interest.

Indicators available on the ECHO platform are updated on a yearly basis and complemented with a continuously growing set of indicators tracking different aspects of the health dimensions of climate change, at an increasingly finer scale. This work is instrumental in setting the scene for commitments made under the European Green Deal and the EU4Health programme 2021–2027 – a vision for a healthier European Union, as well as for setting and tracking commitments on climate change and health under the WHO European Environment and Health Process.

Accessible tools and ready-to-use information can enhance effective communication of complex historical, current and projected climate-health trends.

PARTNERS

Lancet Countdown Europe (LCDE), European Environment Agency (EEA), WHO Regional Office for Europe

Photo: Kamchatka

CASE STUDY 17

Enhancing the climate and disaster resilience of the most vulnerable settlements in Lao People's Democratic Republic

CHALLENGE

Lao People's Democratic Republic is one of the most climate-vulnerable countries in the world, due to its high dependence on climate-sensitive natural resources and its low adaptive capacity. The country has been increasingly affected by natural hazards such as floods, droughts and storms, which often trigger secondary hazards such as landslides, fires, infestations and outbreaks of disease, causing each year loss of life and severe damage to livelihoods and infrastructure.

In Lao People's Democratic Republic, floods are projected to surge with climate change and deforestation. This will create conditions for the spread of vector- and waterborne disease, restricted access to clean water and food, inundation of unsafe sanitation facilities and isolation from health services. Poor communities who live in high-risk areas and already lack access to basic health and social services will be impacted the most.

APPROACH

The project's main objective was to enhance the climate and disaster resilience of the most vulnerable rural and emerging urban human settlements in southern Lao People's Democratic Republic by increasing sustainable access to basic infrastructure systems and services, emphasizing resilience to storms, floods, droughts, landslides and disease outbreaks.

To achieve its objective, the project combined multisectoral policy, planning and capacity development initiatives. At its core was the delivery of resilient infrastructure and services in target settlements that are characterized by a high exposure to climate hazards. The key stakeholders were the Ministry of Natural Resources and Environment, Ministry of Public Works and Transport, provincial and district governments, Lao Women's Union, Lao Youth Union, Lao Front for Construction (with representation of ethnic groups), hydrometeorological service providers and communities.

Local communities were actively engaged throughout the project cycle. The specific needs of women, disabled people and ethnic groups were considered at all stages of the project. This was accomplished through a community-based approach and "People's Process" – an approach that has been developed through the extensive experience of the United Nations Human Settlements Programme (UN-Habitat) in supporting post-disaster and post-conflict countries in Asia and the Pacific. It places people at the centre of the project by mobilizing and organizing them to provide input and make decisions.

RESULT

The project helped to strengthen the institutional capacities of the national government and local authorities to increase the resilience of human settlements and health and social infrastructure systems. It enhanced existing vulnerable infrastructure (including health clinics) and constructed new resilient infrastructure in response to climate change impacts. Enhancement of resilient actions were selected based on assessments from field visits and extensive consultations with communities, ministries, local authorities, mass organizations and development partners, including United Nations agencies and civil society organizations.

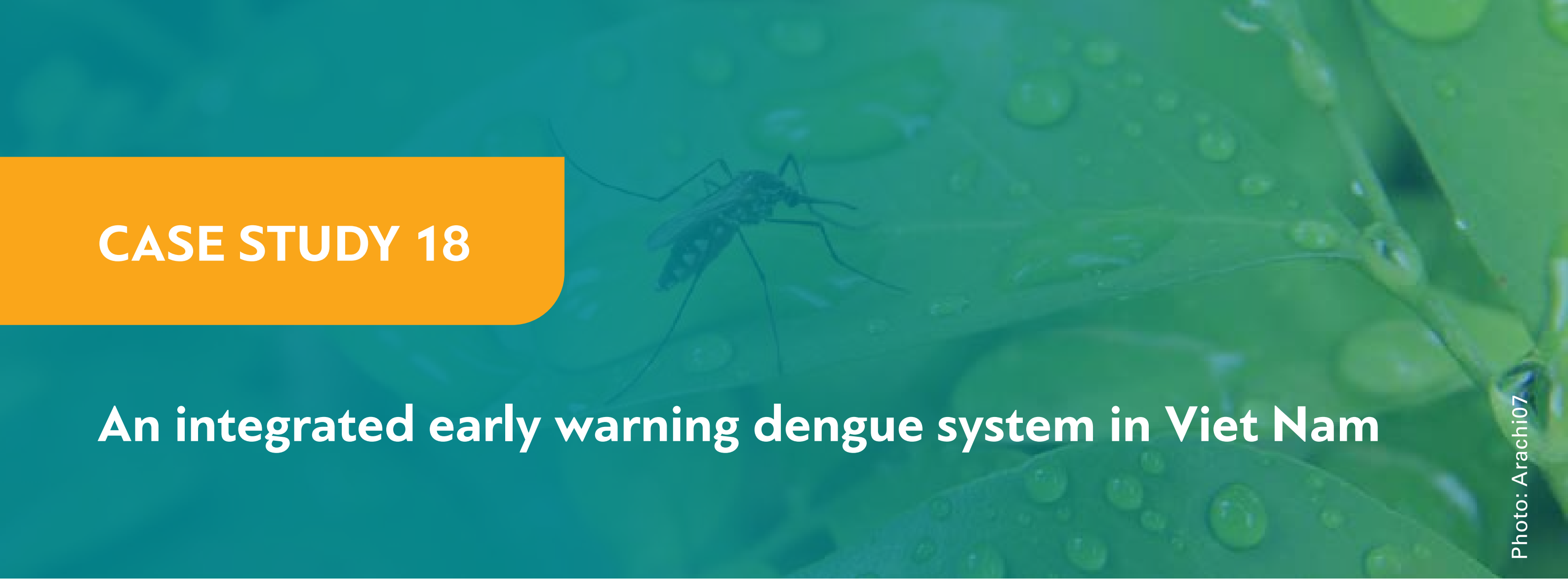
Consultations considered climate sensitivity and its underpinnings of urbanization dynamics and population growth, and underlying vulnerabilities including poverty, limited access to basic services such as water, sanitation and hygiene (WASH) and health, high percentage of ethnic minorities, gender inequalities, weather-dependent livelihoods, and limited adaptive capacity at household, community and governance level. Based on the vulnerability assessments, action plans were developed with specific actions to increase resilience in each village. Examples of actions are: improving prioritized community infrastructure such as health centres, schools, roads or drainage; building small-scale community-based water infrastructure; and building WASH facilities.

Overall, more than 130 000 people in very remote villages in the three southern provinces of Attapeu, Saravane and Sekong gained access to clean water, drainage, sanitation and health-related infrastructure systems. For long-term sustainability, the 189 villages benefited from capacity-building activities on climate resilience and sustainable infrastructure systems, including training on operation and maintenance of climate-resilient infrastructure and implications for land use. Twenty vulnerable development sector services and infrastructure (including health) assets were strengthened in response to climate change impacts, including variability. Three provincial climate change action plans were developed, including implications for land use, water management and infrastructure. Eight district-level climate change action plans, highlighting vulnerabilities of human settlements and infrastructure systems, were developed, and 100 staff from national and sub-national institutions were trained to respond to, and mitigate, the impacts of climate-related events. In addition, a tool was developed in the form of a database containing climate-related data for each of the 189 villages. The data is available to be used at the village level and will inform the prioritization and planning of future actions, increasing the adaptive capacity of these rural villages.

130 000 people gained access to clean water, drainage, sanitation and health-related infrastructure systems.

PARTNERS

Adaptation Fund, UN-Habitat



CASE STUDY 18

An integrated early warning dengue system in Viet Nam

Photo: Arachi07

CHALLENGE

In Viet Nam there is currently no system in place to forecast the probability of dengue outbreaks. Since 2000, there has been an increase of over 100% in the number of cases of dengue fever in Viet Nam due to the failure to maintain adequate control of the *Ae. aegypti* species of mosquito that spreads dengue fever. Considering the current regional trends in dengue epidemics, the setting up of a seasonal dengue forecasting system utilizing Earth observation (EO)-based information to provide probabilistic predictions of dengue outbreaks would greatly assist the Vietnamese Government to put cost-effective early actions in place.

From a water resources perspective, seven of the nine major river basins that drain to Viet Nam are transboundary in nature, and it is estimated that some two thirds of Viet Nam's water resources comes from neighbouring countries, making water management challenging. In recent years, countries upstream of Viet Nam have increased their water use and Viet Nam is currently facing reduction of water flow in the rivers. Climate-driven rainfall variability, especially the intensified rainfall, is causing flooding and water pollution in various old and coastal cities where there are inadequate drainage systems. In addition, sea-level rise and land subsidence are causing more frequent inundation and water pollution in populous and low-land deltas such as the Mekong river delta. The development of an EO-based water availability system will help the Vietnamese Government to improve its water resources monitoring and management in transboundary river basins.

The dengue fever and water management challenges are similar in other countries in South Asia, and the project has now been extended to cover Sri Lanka, Lao People's Democratic Republic, Cambodia, Thailand, the Philippines and Malaysia.

APPROACH

The objective was to develop a suite of innovative tools that will allow beneficiaries to issue alerts for dengue fever (with a view to developing the same for Zika virus, which is transmitted by the same mosquito species) and to provide assessments of vector-borne disease risk under future climate and land-use change scenarios. This will allow local communities to mobilize in order to pre-emptively eliminate mosquito breeding sites, thus reducing incidence of dengue. In combination with better outbreak response, the project is expected to contribute towards a reduction in dengue incidence over the project lifetime.

RESULT

The dengue fever forecasting Model Satellite-based System (D-MOSS) project is developing a forecasting system in which Earth observation data sets are combined with weather forecasts and a hydrological model in order to predict the likelihood of future dengue epidemics up to six months in advance.[153]

The early warning system includes a water availability component. Although water availability directly impacts dengue epidemics, due to the provision of mosquito breeding sites, it is rarely accounted for in dengue prediction models. The water availability forecasts are fed into statistical forecasting models of disease incidence, which integrate a range of other covariates important for dengue transmission (such as the number of dengue cases, land-cover, precipitation and temperature).

Key lessons from Viet Nam include the importance of national ownership and downscaling of climate data for local forecasting, and allocation of resources for timely early warning and response.

Since 2000, there has been an increase of over 100% in the number of cases of dengue fever in Viet Nam.

PARTNERS

United Nations Development Programme (UNDP), WHO and a consortium led by HR Wallingford

Photo: Himarkley

CASE STUDY 19

Identifying malaria risk in Niger

CHALLENGE

Malaria is a parasitic disease transmitted by Anopheles mosquitoes. According to WHO, malaria infected 247 million people in 2021, leading to 619 000 deaths, making it the deadliest parasitic disease in the world. According to the *World Malaria Report 2020*, 29 countries alone recorded 95% of cases and deaths, including ten West African countries (including Niger, accounting for 3%) and India (which recorded 70% of cases).[154]

As a vector-borne disease, malaria is sensitive to variations in temperature, humidity and rainfall, which influence the vector habitat and parasite development. It is therefore important to deepen our knowledge of the local climate and how it is changing in order to better control the incidence and spread of malaria. Few studies have considered the effect of climate on malaria in Niger to describe the relationships between the variation of key climatic parameters and malaria to inform the malaria control strategies and policies in Niger.

APPROACH

Niger's *Climate and Health Bulletin* is produced by the multidisciplinary Climate-Health Group, using a consensus-based approach for development through co-development with the health sector. Since its launch in 2017, it has provided an analysis of the climactic conditions as well as an epidemiological overview of areas with potentially high malaria transmission in Niger. Other diseases could also be assessed, according to the needs identified in annual planning meetings.

RESULT

Thanks to the *Climate and Health Bulletins*, recommendations and advice were sent to the various users, including health organizations, humanitarian partners, decision makers and the general public.

LIMITATIONS AND LESSONS LEARNED

The various working groups have functioned with the support of the United States Agency for International Development (USAID), and the World Food Programme (WFP). A funding gap in 2019 prevented the development of the bulletin, and insufficient funding has limited the implementation of the National Framework for Climate Services in Niger.

Limited training of the technicians who produce the analyses in epidemiological techniques and statistics means there have been limited methodological improvements in the sensitivity analyses.

Limited participation of group members in the various validation meetings is a significant constraint, and therefore certain points of expertise are missing in the production of the bulletin. The lack of reliable data, such as those on vector breeding sites, also limits the analyses.

The skills developed by the experts enabled them to understand that there is indeed an association between the variability of key climatic parameters and the proliferation of mosquitoes.

PARTNERS

Centre Africain des Applications de la Météorologie pour le Développement, Centre de Recherche Médicale et Sanitaire, Direction des Statistiques Sanitaires, Direction de la Surveillance et de la Riposte aux Epidémies, Hôpital National de Niamey, Direction des Médias Communautaires, Office de Radiodiffusion et Télévision du Niger, Université Abdou Moumouni de Niamey

Photo: Firmbee Com

Data and methods

WMO collects self-reported data from its Members (represented by the designated National Meteorological and Hydrological Services (NMHSs)) based on a framework developed by WMO intergovernmentally-appointed experts. The present report assesses the capacities of Members' NMHSs to provide climate services to health sector actors based on data currently available for 174 (90%) Members, as of May 2023. These include 96% of the world's least developed countries (LDCs) and 57% of small island developing States (SIDS). The data used for assessing the capacities of Members' NMHSs to provide the weather services is based on data currently available from 118 Members (61% of WMO Members).

WMO Members' NMHSs assess their own capacity for providing weather and climate services, and document associated socioeconomic outcomes and benefits through a survey that addresses functional capacities across the services value cycle. Functional capacities assessed are organized into six groups:

1. Governance
2. Basic systems
3. User interface
4. Capacity development
5. Provision and application of weather and climate services
6. Monitoring and evaluation of socioeconomic benefits.

Many of these functional capacities constitute "basic", "essential", "full" or "advanced" functionalities, according to defined technical criteria. The percentages of the functionalities in place in each functional group for each capacity level provide a basis for assessing Member capacities and needs in each area, and for categorizing the overall level of service provided by the Member according to WMO criteria. Quality assurance procedures based on WMO and International Organization for Standardization (ISO) standards are currently being applied to these data in a selected number of Members, limited to climate services aspects.[155]

In addition, self-reported data on progress to address climate and health from 88 countries are derived from a biennial survey of Ministries of Health conducted by WHO in 2021.[156] Data on three indicators which capture the use of climate information have been used: the conduct of climate and health vulnerability and adaptation assessments; the presence of health surveillance systems that use meteorological data; and climate-informed warning systems. The results presented in the present report are from the countries which have provided these data. The analysis of climate policy priorities utilized existing analysis of 193 NDCs carried out by WHO, as well as National Adaptation Plans (NAPs) and Health NAPs.[157,158]

Data from the WMO Country Profile Database were also used for the analysis of weather capacities and heatwave warning systems as part of the section on extreme heat, as well as data collected by the Global Heat Health Information Network[159] of WMO and WHO.

Further insights and analysis on the use, benefit, opportunities and challenges in the application of climate science to health-specific issues have been derived and cited from peer-reviewed scientific literature, and WMO and WHO technical reports.

The section on investment describes climate adaptation and research investments made by partners: the Green Climate Fund (GCF), Agence Française de Développement (AFD), Global Environment Facility (GEF), Climate Risks and Early Warning Systems (CREWS), Wellcome Trust and Belmont Forum.

Case studies provided by national and international development partners highlight how climate information services contribute to health outcomes and health system resilience. Some case studies were supported by research by students from the Graduate Institute of International and Development Studies (Geneva) and the University of Cambridge (UK).

The report was peer-reviewed by experts from the WMO Services Commission Study Group on Integrated Health Services.

Note: WMO and WHO country surveys are voluntary and self-reported. Therefore, both data sets contain reporting bias, data gaps and potential variation in responses due to the subjective nature of the questions. The survey questions do not reflect whether data is national or resulting from regional or global products. They do not reflect the potential use of all-sector forecasts or outlooks which are accessed and used by the health sector, nor climate services which may be provided by other sources than the NMHS.

Indicators used to monitor health sector use is limited to reflect use by ministries of health, which represent only one key actor in the health sector.

All case study contributors

The following organizations and individuals contributed to the present report with additional case studies for the WMO-WHO ClimaHealth.info portal:

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Assurance Services International

Barcelona Supercomputing Center

Australian Radiation and Nuclear Safety Agency

Barbados Meteorological Services

Barbados Ministry of Health

Bureau of Meteorology (Australia)

Caribbean Institute for Meteorology and Hydrology

Caribbean Public Health Agency (CARPHA)

Catalan Institution for Research and Advanced Studies (ICREA)

Centres for Disease Control and Prevention

Centre Africain des Applications de la Météorologie pour le Développement

China National Space Administration

Climate and Health Program

Climate Risk Management Solutions (France)

Comprehensive Health Research Center

Copernicus Atmospheric Monitoring Service (CAMS)

Cornwall Council

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Ethiopia Disaster Risk Management Commission Environmental Management Protection Authority

Ethiopia Public Health Institute

Ethiopia Red Cross Society

European Environment Agency (EEA)

European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)

European Space Agency

European Union

Federal Public Planning Service Science Policy

Finnish Meteorological Institute

France Centre National de la Recherche Scientifique (CNRS)

France Office National des Forêts

French Agricultural Research Centre for International Development

French Centre for Studies and Expertise on Risks, the Environment, Mobility and Urban Planning

French National Centre for Space Studies (CNES)

French National Research for Agriculture, Food and Environment

French Naval Hydrographic and Oceanographic Service

French Red Cross

FritzdorfSport (Sweden)

Gabonese Agency for Space Studies and Observations

Indian Space Research Organisation

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German Red Cross

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Institut Pasteur du Lao People's Democratic Republic (IPL)
Institut Pasteur (IP) (France)
Institute for Climate Change Studies
Inter-American Development Bank
International Federation for Red Cross and Red Crescent Societies
International Labour Organization
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Netherlands Red Cross
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Niger Direction des Médias Communautaires
Niger Direction des Statistiques Sanitaires
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Office for Space Technology and Industry of Singapore
Pakistan Meteorology Department
Pan American Health Organization
Philippine Space Agency
Portugal Space
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Slovak Space Office
Space Agency of the Republic of Azerbaijan
Space Climate Observatory
Sub-dirección de Salud Ambiental del Ministerio de Salud of Colombia
Sub-dirección de Vigilancia Epidemiológica del Instituto Nacional de Salud (INS) of Colombia
Sub-directorate of Environmental Health of the Ministry of Health of Colombia
Technical University of Denmark
The Chinese University of Hong Kong
The Mauritius Meteorological Services
The University of Hong Kong
Then Try This (United Kingdom)
Turing Institute
United Kingdom Foreign, Commonwealth and Development Office
United Kingdom Space Agency
United Arab Emirates Space Agency
United International Federation of Youth for Water and Climate
United Nations Environment Programme
United Nations Human Settlements Programme
United Nations Office for Outer Space Affairs
United Nations University – Institute for Environment and Human Security
United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology
United States Public Health Research Centre
Université Abdou Moumouni de Niamey
Université de la Réunion (France)
Université du Québec à Montréal
University Lisbon (NOVA)
University of Bern
University of Copenhagen (Denmark)
University of Sciences and Technology of Hanoi (Viet Nam)
University of Sussex
Uttarakhand Health and Family Welfare Society
UTU-Uttarakhand
Vrije University Amsterdam (Kingdom of the Netherlands)
WHO Regional Office for Europe (WHO/Europe)
WMO/WHO – Global Heat Health Information Network
World Bank
World Food Programme
Yale University


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