



**POWERING**  
OUR FUTURE WITH WEATHER,  
CLIMATE AND WATER



World  
Meteorological  
Organization

Weather • Climate • Water

WMO-No. 1084

WMO-No. 1084

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ISBN 978-92-63-11084-8

Cover illustration: Oil on canvas by Laurence Longueville

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# FOREWORD



**Every moment, every day, National Meteorological and Hydrological Services around the world gather and analyse data on weather, climate and water and convert it to value-added information that protects lives and livelihoods and is fundamental to the present and future well-being of our society and our planet. The World Meteorological Organization, a specialized agency of the United Nations, fosters international cooperation within its 189 Members to facilitate and promote this work.**

Each year, on 23 March, World Meteorological Day commemorates the entry into force, in 1950, of the WMO Convention creating the Organization.

The theme for World Meteorological Day 2012 is *Powering our future with weather, climate and water*. This focuses on the critical roles of weather, climate and water services in powering a sustainable future for us and for generations to come.

The examples of this are myriad. Our food and farming supply must be tailored to the climate of a region and the available water. Industrial processes need ample water and energy. Cities need clean air and protection from storms and floods. International trade and tourism depend on safe and efficient transportation.

We rely on up-to-the minute, reliable weather forecasts for everything ranging from social activities to multi-million dollar decisions. According to one recent study, U.S. economic output varies by up to US\$ 485 billion a year – about 3.4% of Gross Domestic Product – owing to weather variability.

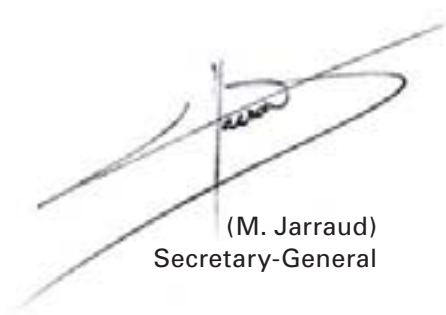
Human activities increasingly impact on our weather, climate and water. National Meteorological and Hydrological Services are at the fore of efforts to observe and understand this complex inter-relationship.

Now more than ever, we need climate projections for the future. And we need to increase our knowledge about how global climate phenomena play out at regional, national and local level.

This rationale forms the basis of the Global Framework for Climate Services, which was endorsed by the World Meteorological Congress in 2011 as one of WMO's top priorities.

This far-reaching initiative will help countries – especially those most vulnerable – manage the risks and seize the benefits of a changing climate. It will unleash the potential of the billions of dollars invested in climate observations, research, and information management systems. Disaster risk reduction, water management, food security and health are its top priorities.

The Framework will empower us, and power our future.



(M. Jarraud)  
Secretary-General

# CLIMATE KNOWLEDGE FOR ACTION



**When the early explorers set off from their familiar coastlines, the risks were considerable. Only those who were well prepared returned.**

Today we are on a journey of exploration in a changing climate. Our descendants will inherit a world left to them by their forebears. More than ever, we need scientific knowledge to guide us.

It is not only the natural variability in the Earth's climate, but also human-induced climate change that will challenge us. Increasing amounts of invisible greenhouse gases are slowly raising the temperature of the atmosphere. As the Earth warms, sea levels rise, Arctic sea-ice retreats, rainfall increases, and droughts are more severe.

Communities everywhere will be affected. Some changes may be positive, but many others will have

a negative impact. Our capacity for innovation, leadership and community responsibility will be tested.

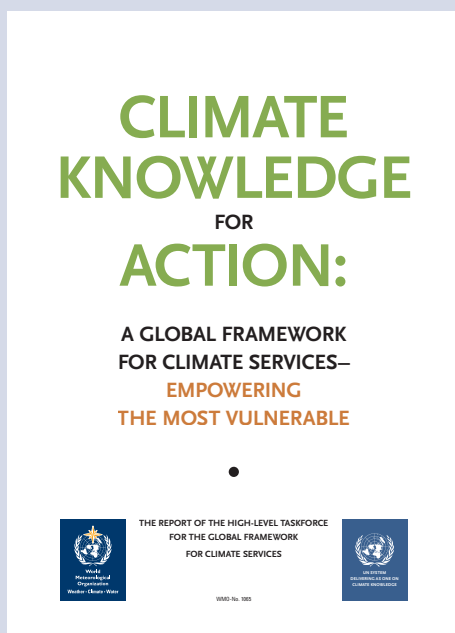
### **Global Framework for Climate Services**

The Global Framework for Climate Services is based on the philosophy that efficient management of the climatic risks today is the foundation for managing the changed climatic risks of tomorrow. Sound scientific knowledge underpins this foundation.

Where they exist, climate services are extremely effective. Prominent user sectors are agriculture, water management, health, disaster risk reduction, planning and energy.

But there is a wide gap between the needs for climate services and their current provision, especially in climate-vulnerable developing countries. The

## Key features



User interface platform will link the providers of climate services, including National Meteorological and Hydrological Services (NMHSs), with the users in priority areas to ensure the right information is provided at the right time to the right people.

Climate Services Information System to protect and distribute climate data and information according to the needs of users.

Observations and monitoring to improve the collection of data to meet service provision needs.

Research, modelling and prediction to increase our understanding of what is happening now and what we can expect in the future.

Capacity building activities to empower vulnerable countries and communities to take full advantage of available services.

High-level Task Force for the Global Framework concluded that about 70 developing countries have very few or almost no climate services and therefore insufficient information about the risk of extreme weather conditions.

There is already a solid basis for the global provision of climate services. This includes existing weather and climate observation systems, data exchange, climate research programmes and risk management techniques.

### **Plugging the gaps**

The goal of the Framework is to provide relevant and timely information to every sector ranging from government decision-makers to businesses to farmers.

Thus, for instance, advance warning of an impending drought, such as the Horn of Africa crisis in 2011, would be disseminated to farmers and pastoralists who need to know when to plant crops and slaughter livestock.

The Framework will represent a truly global effort, translating scientific advances into tools that enable universal knowledge to be downscaled to meet local needs.

### **Priorities and beneficiaries**

Initial priorities for the implementation of the Framework will focus on four key areas: food security, water, health and disaster risk reduction. In the longer term, other climate-sensitive sectors, including energy and transport and tourism will be incorporated.

The Framework will be implemented progressively in consultation with a wide range of stakeholders. Many technical capacities will need to be developed. However, there is already a strong knowledge base to improve the Global Climate Observing System and to target developing countries where quick upgrades are possible. Some projects could begin soon.

Most of the costs of implementing the Framework will be absorbed as part of the ongoing improvement

## **Potential uses of climate services**

- Land-use regulation and environmental protection
- Urban and industrial planning
- Structural design of weather-resistant buildings
- Infrastructure development for rising sea levels and storms
- Energy supply management
- Transportation and fuel efficiency
- Water supply planning and dam control
- Land cultivation and livestock husbandry
- Forest and coastal management
- Health system response to extreme heat and cold
- Water-borne disease control



of existing national programmes. Additional costs to manage and develop the Framework are mainly for priority projects to assist developing countries. These were estimated by the High-level Taskforce to be between US\$ 400 million and US\$ 550 million for the 10-year period 2012 to 2021. This is a small price to pay to reduce weather and climate-related losses in lives and property, and to unleash the

benefits of the billions of dollars spent on climate observation and information systems like satellites and super-computers.

As an illustration, the value of hydro-meteorological information in France alone is between 1–8 billion euros per year, or four to 30 times the cost of its production.

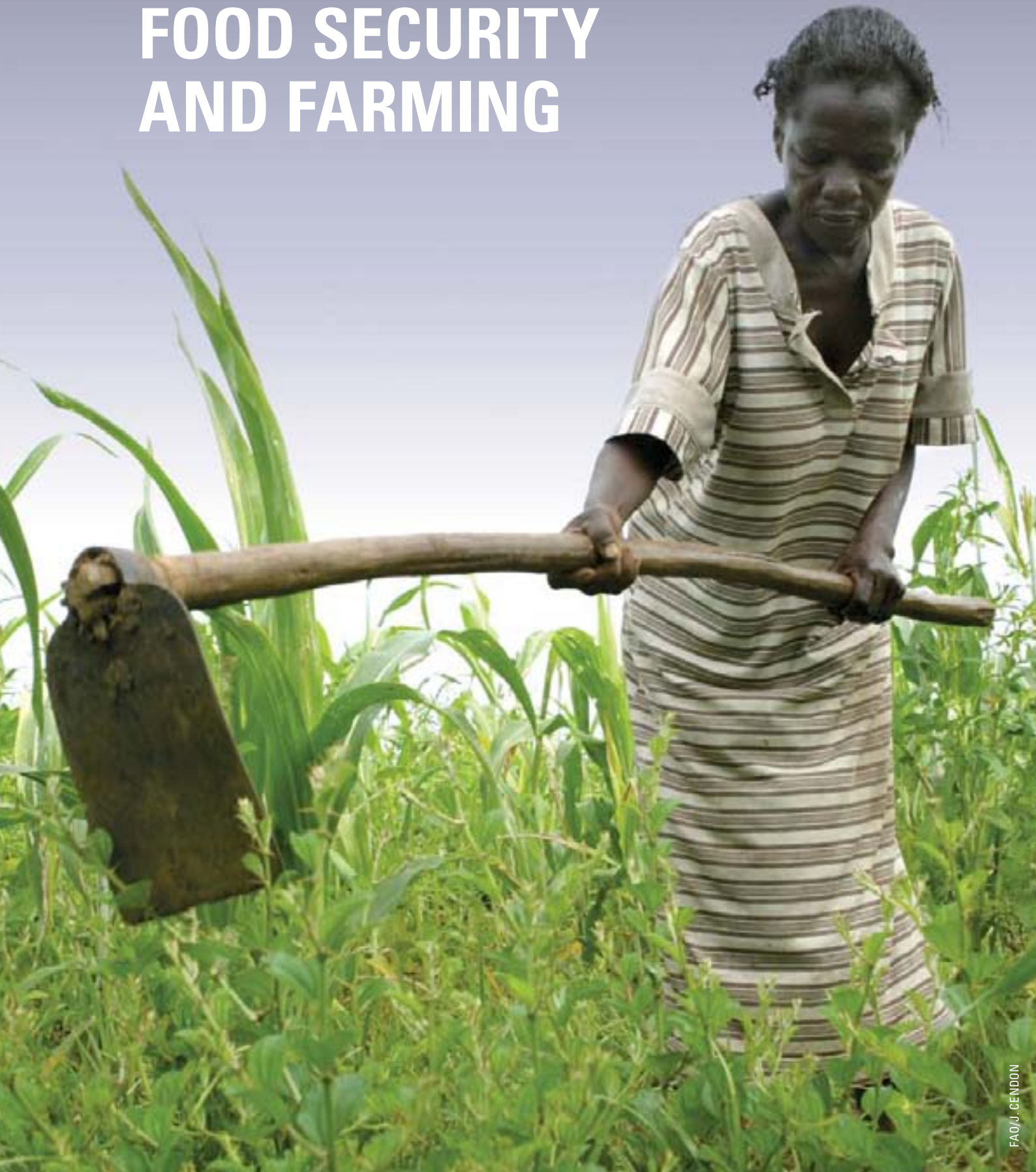
*“We’ve seen too often how hundreds of thousands of lives can be lost, and millions devastated by extreme weather events. These are more and more frequent, and affect more people, who are more exposed. The greatest injustice on our watch is that those who did the least to cause climate change are the first and hardest hit. We need to rectify this. Bringing climate information to the most vulnerable and enabling them to act is very important.”*

**Jan Egeland**, co-chair of the High-level Taskforce

*Food security and urban planning for our growing population are examples of potential uses of climate services.*



# FOOD SECURITY AND FARMING





**Naturally occurring climate variability and human-induced climate change are transforming the landscape for agriculture and food production, and threatening water resources in some areas, while expanding the growing season in others. Reliable weather, climate and water information is essential to guide the food and agriculture sector.**

For a billion people or more, most of whom live in sub-Saharan Africa and South Asia, hunger accompanied by poverty is a harsh reality. The regions affected are generally densely populated, with low agricultural productivity due to poor fertilization and water resources. Other stresses arise from environmental degradation, pollution, desertification, and competition from expanding urban areas for land, water and labour.

The United Nations Food and Agriculture Organization predicts that world food demand will double by 2050 due to population growth (an estimated 9 billion people) and socio-economic development. Climate change will add pressure to the already stressed food market. The use of sustainable land management practices is an important measure in responding to this challenge.

### **Agriculture as the foundation of economic growth**

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For several billion people, agriculture provides a way of life, their livelihood and their only source of nutrition. For some developing countries, agriculture may comprise as much as 50 per cent of the Gross Domestic Product (GDP).

There have been huge strides in agricultural productivity in the past five decades, thanks to improvements in plant breeding, irrigation and fertilizers, coupled with national policy initiatives. For example, the productivity of irrigated land can be three times greater than that of rain-fed land. From 1960–2007, global food production nearly tripled, while per capita availability of food increased from 2300 kcal/day to more than 2800 kcal/day, despite rapid population growth.

A recent study on the potential for agriculture in Africa concluded that, in many African countries, only agriculture has sufficient scale to increase economic growth significantly over the near future. The New Partnership for Africa's Development (NEPAD) has identified agriculture as a priority sector with a US\$ 250 billion programme of investments between 2002–2015.

### **Feeding agriculture with information**

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Ask any farmer whether they would like more information on weather, climate and water, and invariably the answer is yes – provided it is understandable and accurate.

Agriculture and food security are among the priorities of the Global Framework for Climate Services, which will increase the availability and relevance of climate information, especially for vulnerable communities like subsistence farmers. The Framework envisages a user-interface platform to link providers of weather and climate information with users in the agricultural community. This will ensure that scientists understand what farmers want and that farmers know how to access and use the information.

The need for the Framework has become more pressing in the face of climate change owing to the effects on agriculture of carbon dioxide enrichment, temperature increases and changes in the amount and the timing of rainfall.

It is likely that arid and semi-arid regions, mainly in continental areas, will experience increased water stress. This will affect food production, markets and food security. Historical climate data and scenarios of future climate, coupled with agricultural data, are already in high demand to identify hotspots and to explore agricultural alternatives. In order to be relevant, this information must be downscaled to meet national and community needs.

The Framework will be especially useful for long-term planning: big decisions such as the purchase of land; the design of irrigation schemes; the adoption of new farming systems; the introduction of more

drought-resistant seed; or a move from pastoral farming to higher-value horticulture.

### Agro-climatic indices

On a larger scale, satellite imagery can be combined with ground-based observations to provide

mapped information such as the Normalised Difference Vegetation Index – the index for monitoring vegetation and assessing and forecasting crop yield over regions and countries. Geographic information systems can also incorporate social and economic data to explore issues such as the vulnerability of rural populations to climatic risks.

## Roving seminars help boost production

A four-year pilot project involving 15 West African countries trained 5 700 subsistence farmers – including 1 000 rural women – how to access and use weather and climate information to maximize yields and minimize risks.

The project, known as METAGRI, organized 146 roving seminars to increase the interaction between NMHSs and farmers whose livelihoods depend on the weather.

These seminars increased the self-reliance of farmers by raising awareness of weather and climate risk management and the sustainable use of weather and climate information and services. They also provided crucial feedback from the agricultural community to the NMHSs.

In a region that is susceptible to extremes of droughts and floods, NMHSs distributed more than 3 000 rain gauges to 2 838 villages, providing farmers with a simple but invaluable crop management and planning tool.

Roving seminars have also been held in Bangladesh, Ethiopia, India, and Sri Lanka.

The State Agency for Meteorology in Spain (AEMET) funded the project and WMO provided technical coordination as part of a wider initiative to strengthen West African NMHSs, including programmes on climate and health and marine meteorology and management.

The concept of pilot projects with West Africa farmers was developed by the National Meteorological Service of Mali 25 years ago. The aim is to share experiences and improve agriculture and food security in all West African countries.

Mali now enjoys collaboration between government agencies, research institutions, media, extension services and farmers. Farmers taking decisions using agrometeorological information have experienced gains in yields and income. Studies have showed that the re-sowing rate has been reduced by 35 per cent and crop yields have increased by an average of 20-25 per cent, compared with non-agromet farms.





## Weather forecasts and climate predictions

Global numerical weather forecasts, especially useful in anticipating rapidly changing atmospheric conditions, have improved by more than one day per decade. The 7–8-day weather forecasts of today are as reliable as the three-day forecasts of the 1970s. This success is due to scientific and technological progress, such as more powerful computers and increased observing capacities by satellites.

Scientific advances have boosted the availability and reliability of monthly and seasonal climate predictions, especially at a national and regional level. The main signal in seasonal to inter-annual predictions is correlated to the El Niño Southern Oscillation (ENSO) phenomenon – the coupling

of sea-surface temperatures and atmospheric conditions - which has a major impact on climate conditions in tropical and sub-tropical parts of the world.

The economic consequences of ENSO are huge. From 1997–1998, the world experienced a severe El Niño event. This was followed by a strong La Niña in 1998-1999, which led to severe economic losses in the United States of America. Some studies put the value of a perfect ENSO forecast at several hundreds of millions of US dollars per year.

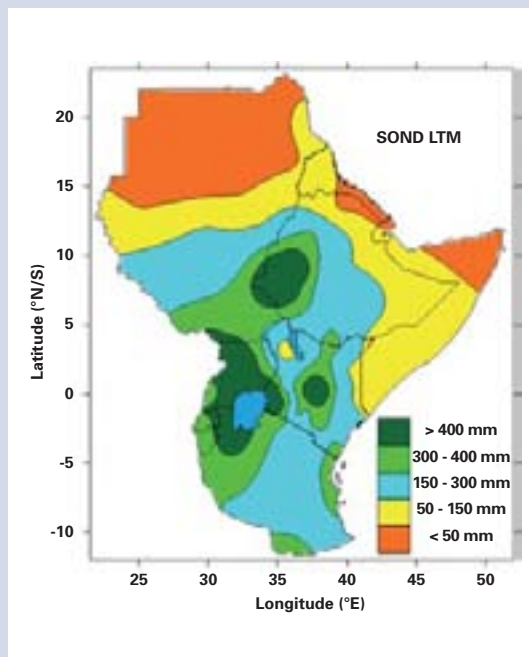
It is hoped that seasonal to decadal climate predictions will improve further to take advantage of more advanced knowledge of upper-ocean heat content, soil moisture, snow cover, polar sea ice and other factors.

## Seasonal predictions and drought planning

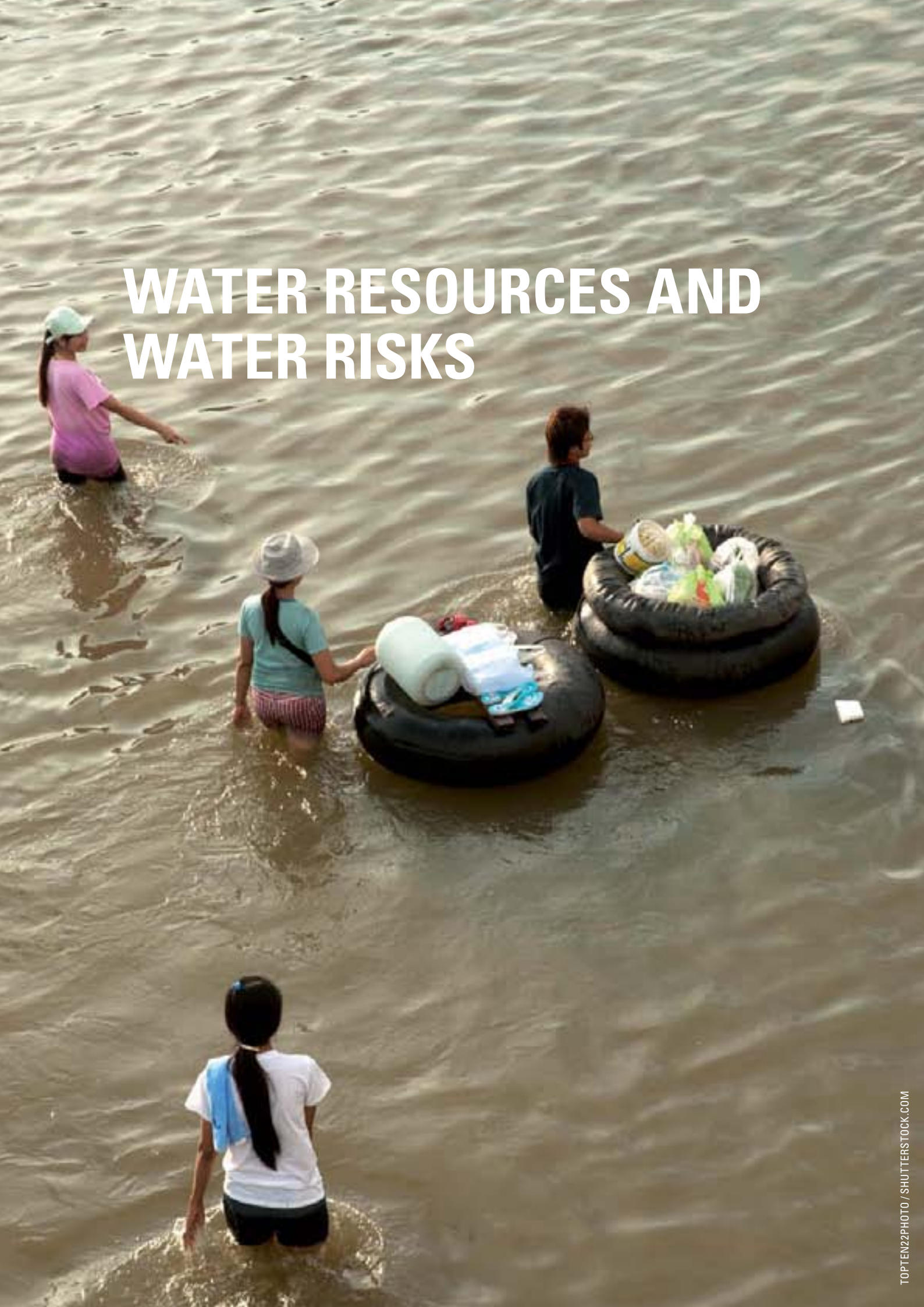
WMO and its partners are working to improve seasonal predictions in different regions. One example is the Greater Horn of Africa Climate Outlook Forum, which has issued regular Climate Watch Updates since late 2010 about the severe drought in Somalia and adjoining regions where the La Niña event affected consecutive rainy seasons.

In mid-2011, the United Nations estimated that more than 12 million people in the Horn of Africa needed humanitarian aid because of the food crisis triggered by the worst drought in 60 years.

Meteorologists, climate forecasters and other experts met in September 2011 to review the likely rainfalls for the September through December period (see map at right.) This pointed to the possible return of normal to above-normal rainfall conditions in famine-hit southern Somalia, but a risk of below-normal rainfall over northern Somalia and adjoining regions.



# WATER RESOURCES AND WATER RISKS



**Without water, nothing grows. Yet with too much water, all may be lost.**

Water is fundamental to all forms of life, with a key role in public health, agriculture, municipal services, industry, hydropower, inland navigation and environmental protection.

For example, about 70 per cent of all freshwater withdrawals are used in agriculture, especially for irrigated food production. For many countries, water offers cheap and renewable energy in the form of hydroelectric power.

Water is necessary for hygiene and good health, but it can also carry pollutants, diseases and disease vectors; each year millions of people get sick with waterborne diseases.

An important target for Millennium Development Goal 7 is to halve, by 2015, the proportion of the population without access to sustainable safe drinking water and basic sanitation. The world is on track to meet this goal, though much remains to be done in some regions.

Globally, water scarcity remains a major problem, affecting one in three people. In many places, the situation is worsening, owing to rising populations and growing household and industrial demands. Supplies are increasingly scarce in many areas including arid regions of South America and Africa and inland regions of Asia and Australia, leading to discussion as to whether water may one day become a valuable commodity that is traded like oil.

At the same time, excessive water in the form of flash floods and river plain floods can cause immense economic damage and loss of life. The economic

losses of the seven largest-ever recorded floods range from US\$ 10 billion to US\$ 30 billion.

In our interlinked global economy, the ripple effects are felt everywhere. For instance, the October to November 2011 flooding in Thailand not only damaged the rice crop of the world's top exporter, it also impacted on the international supply and price of computer hard drives and auto parts.

### **Climate change and water**

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Water in its different forms – ice, liquid and vapour – plays a key role in the physics of the climate system. It is a critically important element in the global numerical models used for weather prediction and for climate change projection. Basic hydrological cycle observations are essential to climate change adaptation.

We now know that water scarcity and flooding are likely to increase with climate change, because a warmer world will strengthen the atmosphere's hydrological processes leading to more droughts and more intense episodes of high rainfall.

In its key messages on climate change, UN-Water states:

*Adaptation to climate change is mainly about better water management. Adapting to increasing climate variability and change through better water management requires policy shifts and significant investments by (among other basic principles) improving and sharing knowledge and information on climate, water and adaptation measures, and investing in comprehensive and sustainable data collection and monitoring systems.*

*“Water use has been growing at more than twice the rate of population increase in the last century.”*

**Kirsty Jenkinson, World Resources Institute**



Industrialized and developing nations alike need hydrological support services. According to one estimate, the United States will need to spend US\$ 1.7–2.2 trillion between now and 2050 to keep water systems running and adapt to climate change.

Quality climate data will be particularly important for water management systems for shared basins that span more than one country. There are 263 trans-boundary river and lake basins worldwide. They account for an estimated 60 per cent of global freshwater flow, 40 per cent of the world's population and affect 75 per cent of all countries. Sound scientific information is vital to decision-making about the allocation of these water supplies and investments in infrastructure.

### Drought management

Because of its long-term socio-economic and environmental impact, drought is the most damaging of all natural hazards. Drought can last for a season or stretch for decades and cover areas from the size of a community to entire regions.

The droughts in 2011 in different parts of the world including East Africa, the southern United States and China have reinforced expert views that droughts have become more common over the past two decades. According to a 2011 special report of the Intergovernmental Panel on Climate Change, this trend is expected to increase.



## Pakistan

The devastating floods in Pakistan in 2010 affected an estimated 20 million people, causing nearly 2 000 fatalities and damaging nearly two million homes as well as general infrastructure. It was estimated that the 2011 floods in the province of Sindh – Pakistan's breadbasket – would cut GDP growth by 0.5 per cent.



WMO worked with the Pakistan Meteorological Department on an Integrated Flood Management plan to improve protection of life and property against flash floods. As a result, Pakistan has installed a Flash Flood Guidance System to provide early warning.

The system was developed by the Hydrologic Research Center, in the United States of America, through joint collaboration between WMO, United States National Oceanic and Atmospheric Administration, National Weather Service, USAID, and the Pakistan Meteorological Department.



Most countries lack policy development for national and regional management of drought. Likewise, drought early warning information systems, consisting of monitoring, prediction, risk assessment and communication, are inadequate in most regions.

WMO and its partners are promoting a policy shift from the current crisis-driven approaches to disaster-risk reduction policies that include drought preparedness and mitigation to be developed in high level National Drought Policies.

### Flood management

In 2011, many countries experienced devastating floods – Australia, Colombia, Indonesia, Japan, Pakistan, Sri Lanka, Thailand and the United States, to name a few.

While they can bring death and destruction, floods can also promote economic development. In many

parts of the world, communities rely heavily on agriculture, fisheries and other activities in rivers and flood-prone delta areas.

The Associated Programme on Flood Management led by WMO and the Global Water Partnership promotes an approach that emphasizes flood management to minimize risks and maximize opportunities.

Integrated flood management embraces flood preparedness and prevention strategies, rather than purely emergency response. It involves climate risk management, flood risk assessment, land use regulation, flood insurance, enhanced hydro-meteorological monitoring, flood disaster preparedness, emergency management and recovery. It aims to bridge gaps that exist between the flood research and development community and flood professionals responsible for mitigating the adverse impacts of major floods.

## The Andes

Snow and ice in the Andes Mountains, above the tropical regions of Bolivia, Peru, Ecuador and Colombia, supply the drinking water for 30 million people. Ice has been dwindling in recent years due to rising temperatures, threatening the region's water supply. Quito, the capital of Ecuador, and La Paz in Bolivia respectively draw 50 per cent and 30 per cent of their water from the glacial basin.



Since 1970, Andean glaciers have lost 20 per cent of their volume. Because these glaciers are the major regulators of the water supply, a global effort is underway to help the region cope with increased local climate variability and global climate change.

To address the situation, WMO Members contributed to a multidisciplinary project, led by the World Bank and Global Environment Facility. Several WMO Members are monitoring changes in the glaciers with the use of high-resolution satellite images. Improved observation and assessment practices enable better mapping of vulnerable areas and permit the region to develop adaptation strategies. These include the development of alternative water sources, diversification of the energy supply and shifting to alternative crops and advanced irrigation systems.

# CLIMATE AND HEALTH



**Early warning systems are critical to protect us from threats to life and health associated with weather events such as storms or heat waves. Some warning systems estimate the wind chill factor or the strength of ultra-violet rays from the sun. Specialized health warnings for allergen levels, air pollution and mosquito activity are of increasing value, and are often accompanied by advice on how to reduce health risks.**

For example, the exceptional heat wave experienced in Europe in August 2003 resulted in more than 70 000 excess deaths. As a result, French health and weather authorities collaborated to issue warnings targeting vulnerable groups, such as the elderly and the young.

### Collective approach

Public policy related to meteorology and hydrology plays an important role in population health, especially through clean water supply and sanitation services, management of infectious diseases, control of air pollution, support for safe and healthy housing, and well-organized disaster management.

Growing interest and research in health-climate problems have boosted the development of tools and policies for health managers and communities. This team approach combines the expertise of

public health specialists with that of economists, ecologists, hydrologists, climate scientists and meteorologists.

### Climate change and health

Climate change is likely to affect the health of millions of people in a variety of ways. More intense heat waves pose risks to the health of children and the elderly; the anticipated increase in droughts raises the potential for malnutrition. Drier conditions are more conducive to sand and dust storms that affect the respiratory system.

Many areas are at increasing risk of vector-borne diseases such as malaria, West Nile virus and dengue. Mosquitoes thrive in wetter, warmer conditions, which also make it easier for pathogens such as cholera to survive. Increased rain and flooding can mobilize contaminants.



## Leading improvements

The Institute of Tropical Meteorology in Pune spearheaded India's first major air research initiative, known as the System of Air Quality Forecasting and Research (SAFAR). It was successfully tested for New Delhi during the 2010 Commonwealth Games. The aim is to spread the initiative to other major cities in India. It provides location-specific information on air quality and is forecast 24 hours in advance.

The initiative is complemented by the weather forecasting system designed by the India Meteorological Department in New Delhi. The objective is to increase public awareness about air quality to facilitate appropriate action.

## Malaria

About 3.3 billion people – half of the world’s population – are at risk of malaria. Annually, there are about 250 million cases of the disease and nearly one million deaths. It is especially serious in Africa, where it is linked to one in every five childhood deaths. People living in the poorest countries are the most vulnerable.

In some semi-arid areas, the number of malaria cases typically peaks a month or two after the height of the rainy season, when mosquito populations expand. Heavy rain can lead to malaria epidemics. However, in some highland areas, temperature is the most important factor; epidemics occur during unusually warm seasons.



Based on these relationships, early warning systems are being developed and tested in several African countries. These combine seasonal climate forecasts with monthly data and observations relating to the weather, the mosquito count and the number of malaria cases to make projections. Seasonal forecasts for rainfall and temperature, made three to six months ahead, can provide valuable advance warning for regions at increased epidemic risk.

## Shanghai

Shanghai in China has a dense population of 18 million people. It is vulnerable to natural hazards such as typhoons, heat and cold waves and is also affected by atmospheric pollution.

During the 2010 Shanghai World Expo, the Chinese Meteorological Administration demonstrated new services for air quality, pollen, food poisoning and heat stroke to create an air pollution prediction system for the Shanghai area, and to improve the assessment techniques of environmental quality.





Conversely, other parts of the world may see reduced exposure to certain disease vectors and there will be fewer deaths from exposure to low temperatures.

The actual outcomes will depend on how societies prepare for the challenges. The use of weather, climate and water information and forecasts will help power this response.

## **Air pollution**

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Indoor and outdoor air pollution affects both developed and developing countries and contributes to the global burden of disease from respiratory infections, heart disease, and lung cancer. The World Health Organization estimates that indoor air pollution causes approximately two million premature deaths and may pose a risk to the health of more than half of the world's population.

The WMO-coordinated Global Atmosphere Watch, which collects information about ozone, ultraviolet

and solar radiation and greenhouse gases, also has a special unit to monitor pollution in the urban environment.

A joint report from WMO and the United Nations Environment Programme in 2011 showed there was big potential to cut pollution from black carbon, or soot. This would improve respiratory health. As a big added plus, tackling such pollutants with a short life span in the atmosphere would help reduce global warming.

WMO oversees a Sand and Dust Storm Warning Advisory and Assessment System. This facilitates sand and dust storm forecasting to give advance warning to affected communities, which tend to be in Africa, the Middle East, South-East Asia and the south-western United States. Meteorologists are collaborating with health experts in assessing the role of dust in meningitis epidemics in Africa's so-called meningitis belt, which spans from Senegal in west Africa to Ethiopia in the east.



# DISASTER RISK REDUCTION



**Millions of people are affected by floods, storms, droughts, landslides and other disasters related to weather, climate and water. Dozens of major catastrophes occur every year and can set back the economic progress of regions and countries. Hundreds of smaller events go unreported. These too claim lives, destroy houses, ruin crops and bankrupt enterprises.**

We can take steps to prevent natural hazards becoming disasters. By building cities with strong houses in safe places and using efficient warning systems, the scale of potential loss can be reduced. The 2005 Hyogo Framework for Action is an internationally agreed blueprint on how to build resilient communities. The scientific expertise and operational capabilities of NMHSs are fundamental to achieving this.

### Are disasters increasing?

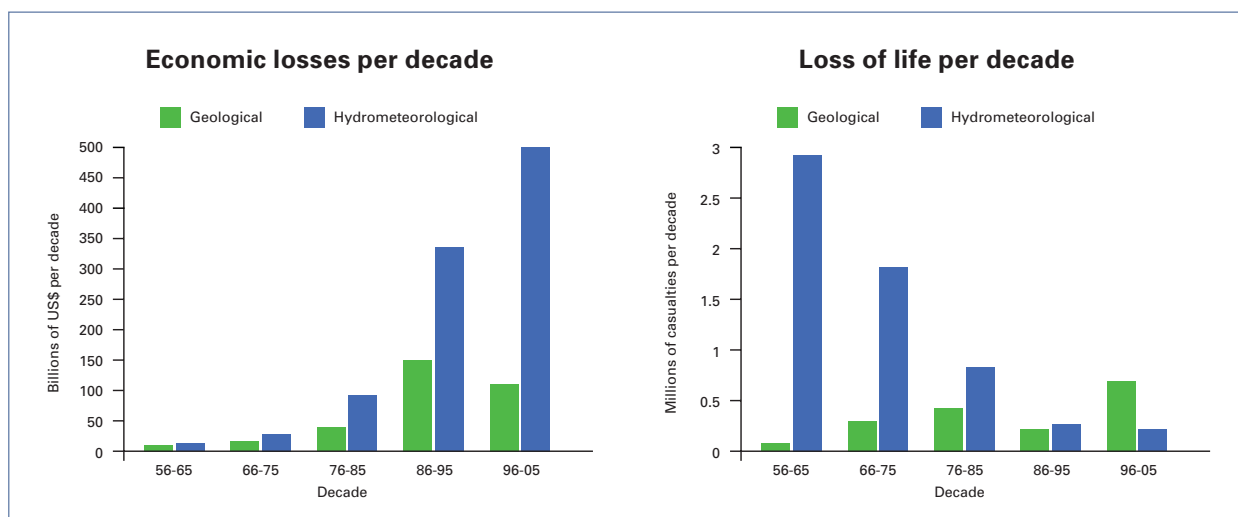
Climate change has to an extent, created a public perception that the number of natural disasters is rising. The truth is more complex. While scientific studies of meteorological data are starting to show increases in the occurrence of some weather

extremes, an important component lies in the exposure of communities.

The most dramatic trend in recent decades is the reduction of disaster death toll, principally in droughts and floods, through the development of early warning and response programmes. Combining meteorological and hydrological forecasting and warning with emergency management, mass evacuation and humanitarian response services has saved many lives.

However, rising populations and poverty combine to push people into higher hazard zones. Houses are built on floodplains or hillsides where landslides are common and drought-prone land is being farmed. In many countries, quantities of capital stocks and other assets are also growing at a rate faster than the population, resulting in greater economic, financial and insurance losses globally.

Climate change is likely to trigger more disasters in the future, not only because of the changes in meteorological hazards and the rise in sea levels, but because of pressures on the food chain, water resources and health.



*Trends in natural hazard impacts over the five last decades show increasing economic losses and decreasing loss of life associated with hydrometeorological hazards.*

## Better climate services for risk reduction

Good quality information and expertise on weather, climate and water are vital ingredients of disaster risk reduction and are a priority for NMHSs.

Warning services range from short-term weather forecasts and warnings, through to seasonal climate forecasts and beyond, to multi-decade projections of climate change.

For example, there are six Tropical Cyclone Warning Centres with regional responsibility to provide advisories on all tropical cyclones, hurricanes or typhoons.

The Global Framework for Climate Services has prioritized disaster risk reduction as a prime focus. The exposure of poor populations often results in frequent losses in lives and livelihoods even from moderate hazards. Development agencies therefore now recognise disaster risk reduction as a key ingredient for future successful economic and social development.

In developed countries, loss of life still occurs, but it is substantially lower than in poor countries due to greater planning, infrastructure and warning services. However, the value of economic assets

may be substantial and financial losses high. There is considerable scope for damage reduction and cost savings through the timely use of early warning services.

## Effective early warning systems

Effective early warning systems comprise four components, which must be coordinated across many agencies from national to community level.

**Hazards are detected, monitored, forecast, and hazard warnings developed.**

**Risks are analysed and information incorporated into warning messages.**

**Warnings are issued by a designated source and disseminated to authorities and the public.**

**Community-based emergency plans are activated in response to warnings.**

Failure to coordinate or execute every component will result in a breakdown of the system.

The success of disaster-related early warning systems also requires that careful attention be given to the communication, interpretation and use of warnings. To maximize their effect, the WMO is promoting good

## Cuba

Cuba's Tropical Cyclone Early Warning System is credited with a dramatic reduction in deaths from natural hazards. It includes an early warning system and an effective response, which gives communities at risk time to evacuate to emergency shelters.



Hurricane Gustav destroyed an estimated 100 000 homes in Cuba in 2007. Although considered to be the strongest hurricane in 50 years, the community was prepared and there was no loss of life.



practices. This involves extensive consultation, the development of a standard template for countries to document their experiences and the synthesis of standard principles, irrespective of political, social and institutional factors.

Good practices have been documented in seven early warning systems for meteorological and hydrological hazards: the Bangladesh Cyclone Preparedness Programme; the Early Warning System for Cyclones in Cuba; the Vigilance System in France; the Warning Management in Germany;

the Multi-Hazard Early Warning System in Japan; the Multi-Hazard Early Warning System of the United States National Weather Service; and the Shanghai Multi-Hazard Emergency Preparedness Programme.

The conclusion is that there is enormous potential to save lives and limit financial loss through the application of meteorological information and disaster reduction techniques. Moreover, such systems would benefit poverty reduction, economic development and adaptation to climate change.



# TRANSPORT, TRADE AND TOURISM



**Global trade has risen at 10 per cent per year for several decades to reach US\$ 15 trillion in 2010. Tourism is expected to reach one billion international arrivals in 2012. Weather services play a critical role in supporting the complex networks of shipping, aviation and land transport in several ways: to aid safety and reduce risks, and to optimize efficiency and reliability amid variable weather, climatic and oceanic conditions.**

### **International trade and shipping**

According to the United Nations Conference on Trade and Development global merchandise trade in 1960 was US\$ 130 billion, which grew to US \$15 230 billion by 2010, an average increase of 10 per cent per year. During this time, the share of global trade held by developing countries grew to 42 per cent.

International Maritime Organization statistics indicate that shipping serves more than 90 per cent of global trade. In 2008, it is estimated that the world's seaborne trade amounted to 33 trillion tonne-miles.

### **World-wide navigational warning system**

Ships are at the mercy of the seas and the weather. Systematic weather forecasting began in the 19th century to avert the terrible loss of ships and lives at sea. The Titanic disaster of 1912 spawned the SOLAS (Safety of Life at Sea Convention), still the most important treaty covering maritime safety.



*Ships will be facing extreme, and less predictable, weather in the Arctic region.*

The SOLAS Convention sets out specific requirements for weather information and refers to the key role of the WMO in coordinating weather services globally. For example, NMHSs provide information through the WMO Marine Broadcast System to support the Global Maritime Distress and Safety System and the World-Wide Navigational Warning Service. All of these services must operate around the clock.

The World-Wide Navigational Warning Service was developed in the late 1970s by the International Maritime Organization in collaboration with the International Hydrographic Organization. It divided the oceans into 16 navigational areas and assigned a country in each area with responsibility for disseminating navigational information. Meteorological areas – mapping areas identical to the navigational ones – were also established..

Five new navigational and meteorological areas have been recently added to provide intelligence to ships facing extreme and less predictable weather in the Arctic region. Sea ice is predicted to increasingly shrink as a result of climate change: the late-summer Arctic sea ice may vanish almost entirely by the middle of the century, triggering unprecedented maritime challenges.

With the anticipated increase in shipping and oil and gas exploration in high-latitude waters previously covered in ice, WMO is working with partners to improve safety. Marine designers and ship operators are collaborating to increase data on wave and sea conditions and promote risk management.

About 6 000 ships and ocean platforms contribute important observations about weather, climate and water.

### **Ship routing services save fuel and money**

With modern weather forecasting services, it is possible to compute an optimal route for any voyage to avoid damage from heavy weather; to arrive in port

on time without incurring extra fees or commercial penalties; and to minimize costs and fuel burn associated with head winds. Some NMHSs provide elaborate voyage routing services on a commercial basis. Parameters can be updated during the voyage to account for changed weather conditions or delays in berthing, as well as to allow other route options to be tested. Some shipping companies report significant reductions in heavy weather damage costs as well as fuel savings of five per cent or more using these methods.

Although international shipping is by far the most carbon-efficient mode of commercial transport, the industry's carbon dioxide emissions amount to about three per cent of global emissions, which is comparable to those of a major national economy. Systematic reductions in fuel use are therefore good for the climate as well as company profits.

## Aviation

The airline industry is the primary means for long distance travel for business and leisure travellers and it provides a rapid global distribution system for high-value or perishable goods. Commercial airlines generated global revenues of US\$ 564 billion in 2008, or about one per cent of global GDP. The industry is highly dependent on specialized up-to-the-minute aviation meteorological data and forecasts from NMHSs.

In 2011, the World Meteorological Congress designated aeronautical meteorology as one of its top priorities in recognition of its importance to safe, regular and efficient air navigation.

Pilots, airline operations and air traffic managers need information on wind speed and direction, clouds, icing potential, locations of thunderstorms, and weather conditions at airports. Commercial airlines also routinely use this information to calculate optimum routes and altitudes throughout a flight. This brings many benefits, such as avoiding dangers, achieving a smoother flight, reducing fuel usage and costs, and ensuring better adherence to scheduled arrival times.

## Aviation hazards

In 1982, all four engines of a passenger jet failed after it encountered a volcanic ash cloud from Mount Galunggung in Indonesia. This incident led to the creation of the International Airways Volcano Watch system in 1987 by the International Civil Aviation Organization (ICAO) in coordination with the WMO and other partners.

There are nine Volcanic Ash Advisory Centres worldwide. When an eruption occurs, the centre responsible for the area issues an advisory based on satellite and ground-based observations, pilot reports and weather prediction models that calculate where the winds will carry the ash and how much the ash clouds will be dispersed over time.

This system was used to protect aircraft from the ash plumes emitted from Iceland's Eyjafjallajökull volcano in April 2010 and Chile's Cordon Caulle volcano in June 2011.

ICAO, supported by WMO, is seeking to expand this regional advisory system to support national aviation weather warnings known as SIGMET (Significant Meteorological Information), which are issued to warn aircraft of hazards such as turbulence and icing. There is a pilot project providing SIGMET advisory messages involving three Members: China for eastern and south-eastern Asia, France for western and central Africa and South Africa for southern Africa.



*A volcanic ash cloud in Iceland.*



## Tourism

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The World Tourism Organization predicts that international tourist arrivals worldwide will continue to grow by about 3.3 per cent annually, an average 43 million additional international tourists every year. Arrivals are projected to pass 1 billion by 2012 and to reach 1.8 billion by 2030.

Climate change is already affecting the tourism sector. For instance, the ski industry is experiencing warmer temperatures with shorter ski seasons, necessitating investment in snowmaking equipment. A rise in sea levels is threatening beaches and coral reef systems. Enhanced competition for water can make former investments in tourist infrastructures unsustainable.

Managing climate risks and opportunities and promoting sustainable development in the tourism sector requires reliable climate information. Evolving climate variability in a changing climate will affect the tourist potential of many locations, necessitating well-informed adaptation strategies. Ski resorts can plan where to build new ski lifts based on climate models of temperature changes over 30 years, and coastal resorts can identify spots vulnerable to climate change and shore up their defences.

In addition, weather and climate predictions provide advance warning of natural hazards. When Hurricane Irene roared through the Bahamas in August 2011, no lives were lost because authorities had time to take precautions, such as the evacuation of tourists.



# ENERGY AND CLIMATE



**Most people agree that the energy sector – notably the burning of fossil fuels – is contributing to climate change. It is a two-way relationship because climate significantly affects energy in a variety of ways. Understanding how climate is changing, together with its influence on energy sources, is crucial.**

Because of population growth and industrial development, the potential rise of the global energy demand will not be satisfied by the current foreseen increase in supply capacity.

Developed industrial societies are dependent on relatively cheap and reliable energy. This is not the case, however, for the several billion poor people who rely mostly on biomass (see box on page 30.)

Developing countries face the additional problem of how to rapidly build energy production and distribution systems from a low base. Biomass is important as a heating source, oil still dominates the transportation sector, and coal remains a easy choice for large-scale electricity production. Nevertheless, nuclear, gas, geothermal, hydroelectricity, solar and wind energy are also important in different settings.

Climate change and other environmental impacts are major challenges for the energy industry. International measures necessary to cut emissions of greenhouse gases and avoid the worst effects



*Wood is a typical source of biomass.*

of climate change are under intense debate. The outcome of these debates will radically alter the technological configuration of the sector.

Globally, the energy industry will be dominated by the drive to increase efficiency and reduce consumption in developed economies and the simultaneous acceleration of energy production in developing countries to provide equitable access for citizens and to support economic development. In both cases, expert information on weather, climate and water will be essential.

### **Better energy outcomes and lower risks**

Whether for future planning, new plant design or minute-by-minute operations, the use of meteorological and hydrological information will improve the outcomes and lower the risks. Successful techniques exist to deal with such things as choosing optimal sites for facilities, controlling environmental impacts, scheduling maintenance and avoiding outages.

National climate databases operated by NMHSs contain a wealth of information that aids countries in planning their climatic resources, risks and requirements. These include supply side questions about how much rainfall, wind and sunshine is available and demand-side questions about needs for heating and cooling, and risk-related questions such as the probability of floods and hurricanes.

Heating and cooling are both major energy users. A simple measure of heating needs is the “heating degree-day”, calculated as the shortfall of a day’s temperature below a comfortable temperature, such as 18 °C. Talled over a year, these shortfalls provide the “annual total heating degree-days”. Similarly, “cooling degree-days” can be calculated for days exceeding comfort temperature zones (with adjustments for humidity).

There are vast differences in the heating and cooling needs of countries. In most countries, heating and cooling requirements exhibit significant differences between districts and seasons.



## Electricity and extremes

Historical data sets can be used to examine how a planned or existing energy system might perform in the future. This is especially important with climate change and the greater risks of extreme conditions. For example, electricity transmission lines have reduced capacities in high temperatures and may collapse under the weight of ice in winter. Cooling water for nuclear power plants, drawn from rivers, may be ineffective in periods of hot weather, drought and low river flows.

A climate change study for Switzerland indicates that by 2050 there will be a 5–10 per cent reduction in hydropower production due to lower runoff and a decline in cooling capacity for its nuclear power plants.

Energy system managers must deal with these sensitivities to weather, climate and water on a day-to-day basis as well, making decisions that

blend historical data with real-time monitoring, seasonal climate outlooks and weather forecasts. As a result, they may run more generators, routing energy through different parts of the distribution network, preparing for extreme conditions such as heat waves, or buying or selling contracts in the energy markets.

In the United States, for example, the demand for heating, ventilation and cooling amounts to about 45 per cent of electricity use and fluctuates according to the unfolding season and day-to-day weather. Wholesale energy prices can fluctuate wildly as a result. Markets for energy futures, which help to smooth the impact of price fluctuations on businesses, make active use of long-range weather and climate information.

Miscalculating the demand for electricity can result in power disruptions, as illustrated by blackouts in the United States and Canada in August 2003. The blackouts were the result of summer peak energy

## 2012 – International Year of Sustainable Energy for All

The UN General Assembly declared 2012 the International Year of Sustainable Energy for All. Currently, more than 3 billion people in developing countries rely on biomass for cooking and heating and 1.5 billion people are without electricity. Even where energy services are available, they are beyond the financial reach of many people.

The aim of the International Year is to promote better access to modern affordable energy services, especially in developing countries. This is essential to improve the standard of living for the majority of the world's population. The General Assembly also emphasizes the importance of investing in cleaner energy technology to achieve sustainable development and a climate-resilient future.

The International Energy Agency estimated that an investment of US\$ 48 billion would end energy poverty in developing countries. The Agency is now promoting efforts to raise this amount. The initiative would give access to electricity to more than one billion people in developing countries and could be achieved within the next 20 years.



demand exceeding the supply on hand. Energy managers require accurate weather and climate information to help avoid such situations and to manage everyday energy requirements and long-term energy investments and planning.

### Renewable energy systems

The use of renewable energies has been growing rapidly, accounting for approximately half of the estimated 194 gigawatts of new electricity capacity added globally during 2010. According to the International Energy Agency, the renewable energy electricity sector grew by 17.8 per cent between 2005 and 2009 and provides nearly 20 per cent of total power generation in the world. Hydro power is still the major source of renewable electricity. But wind power has grown the most in absolute terms. The Global Wind Energy Council says the world's wind power capacity grew by 31 per cent in 2009.

In 2010, investment in renewable energy reached a record US\$ 211 billion, more than five times the amount invested in 2004.

There is increasing use of cleaner fuels, low-energy industrial processes, low-emission transport, and sustainable housing. Such investments are heavily dependent on quality information on weather, climate and water parameters. Renewable energy production must deal with demand changes and significant supply-side variability, particularly shortages in rainfall for hydroelectricity, lack of wind for wind farms and cloudiness for solar energy installations.

For instance, the curtailment of hydropower generation from Lake Kariba in Zimbabwe as a result of the 1991–1992 drought caused estimated losses in GDP equal to US\$ 102 million, a loss in export earnings of US\$ 36 million and the loss of 3,000 jobs.

## Meeting the growing energy needs of a city

A typical hypothetical scenario: An energy planner has the challenge of responding to the growing energy needs of a small city. Construction of a coal-fired plant is perhaps the cheapest option, but would increase carbon dioxide emissions and might worsen air pollution.

Questions follow. Are the winds sufficient to disperse the plant's smoke and steam? Can the local river provide the cooling water needed, particularly during the dry season? How will climate change and associated policies affect its future viability?

There are other options. A hydroelectric dam system 100 km away has been mooted. Hydrologists have analysed historical data on rainfalls and river flows and believe that a 200 megawatt plant will operate 99 per cent of the time in the first few decades, though this might later drop to 95 per cent according to climate change projections. Transmission line engineers analyse the national climatic database and calculate that extreme winds and icing of the 100 km line occurs on average, once every 100 years.

The energy planner is impressed, but has two additional options to examine with the help of meteorologists and other experts: a large proposed wind farm on the adjacent coast, and a municipal energy conservation policy that is projected to reduce the city's energy demand by 15 per cent through incentives for domestic insulation and increased solar energy use.



# SUSTAINABLE CITIES

An aerial photograph of a densely packed urban area, likely a city center. The image shows a variety of high-rise buildings, some with modern glass facades and others with older, more traditional architectural styles. The buildings are closely packed together, with many having balconies and windows. A road with several lanes of traffic is visible on the right side of the image, with cars and buses moving through the city. The overall scene depicts a vibrant, high-density urban environment.



**United Nations data show that the world's population living in urban areas rose from 29 per cent in 1950 to 50 per cent in 2010; this is expected to grow to 69 per cent in 2050. The number of mega-cities – with a population of 10 million people or more – has grown from 2 in 1950 (New York City and Tokyo) to 19 in 2007. This is expected to rise to 26 by 2025, with many of them located in developing countries.**

Cities have a great need for historical information for planning as well as data and weather, climate and environmental forecasts for real-time decision-making.

### **Emissions and hazards**

Cities and urban areas use about 75 per cent of the world's energy and are responsible for 75 per cent of greenhouse gas emissions.

Analysis of weather, climate and water factors is critical to supplying the input needs of cities, managing their liveability and sustainability and reducing the risks and costs of natural hazards.

Three-quarters of all large cities are located in coastal regions. Globally, 60 per cent of the world's population lives in Low Elevation Coastal Zones (less than 10 metres above sea level), which are potentially vulnerable to sea level rise. Low Elevation Coastal Zones represent 2 per cent of the world's area, but 10 per cent of its population. Coastal zones are the most urbanized with 80 per cent of coastal populations living in cities. Fourteen of the world's 19 largest cities are port cities, according to UN-Habitat.

Extreme weather events and climate change underscore the need to involve meteorological and hydrological services in urban planning and engineering, infrastructure development, beach management and coastal defences to face future challenges.

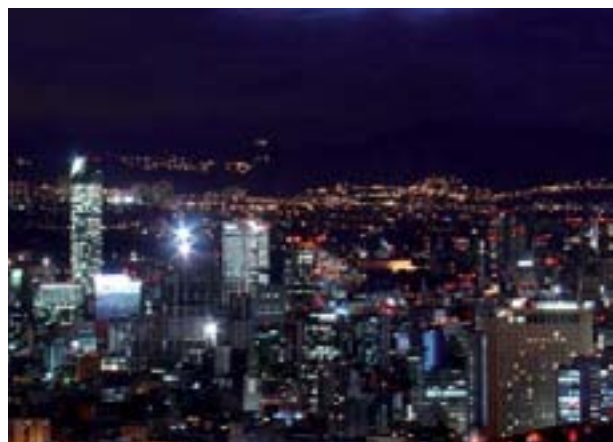
Planning for city transportation and energy generation and distribution systems needs to accommodate not just average conditions, but also extremes like blizzards when services are under greatest pressure.

Gradual rises in sea level are becoming a problem for cities near to oceans, especially during tropical cyclones and storm-related events. Poorer areas with inadequate drainage are especially vulnerable. Further, coastal cities have major port facilities that need to deal with floods and storm surges. Public road systems and major international airports are also often located at sea level.

### **Water needs and risks**

Almost all big cities face major fresh water challenges because of excessive groundwater withdrawal and disruptions to supply. Cities in subtropical dry zones, including Mexico City, Delhi and Dhaka, are likely to feel water stress from more frequent droughts and higher temperatures in their catchments.

Hydrologists, climate scientists and weather forecasters therefore need to work closely to develop water management strategies for mega-cities. Many planners are already making adjustments. For example, the government of Pune, India, which lies in a flood-prone area, has developed a programme of measures to reduce energy use and improve drainage systems. Similarly, the Greater London Authority is implementing the London Climate Change Adaptation Strategy that adopts a risk-based approach to the main impact of flooding, drought and overheating.

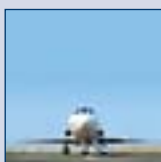


*Mexico City skyline.*

## Cities at work on weather, climate and water



**Public safety.** NMHSs are generally responsible for providing warnings of approaching storms and other hazards to allow public authorities to take action such as closing transportation systems or evacuating parts of the city.



**Airports and seaports.** NMHSs partner airport and seaport operators to help ensure safe, efficient and reliable operations. Services range from daily weather forecasts to specialized predictions of oil slick movements and volcanic ash cloud dispersal.



**Heating and air conditioning design.** Historical temperature and humidity data are essential in the design of heating and air conditioning systems. Increasingly, wind and solar radiation data is being used to design buildings that require less heating and air conditioning.



**Building codes.** Wind speed data can be analysed to estimate the strength of winds likely to be encountered in different parts of the city and for different heights of buildings. Likewise, snow depth data can be used to establish security criteria in regions where buildings have to be resistant to heavy snow packs.



**Water supply.** Historical data is the main basis for designing public water supply systems, but droughts can still occur and storage reservoirs may fail to meet demand. Water system managers use meteorological and hydrological information, including seasonal climate forecasts to assess risks and make key decisions.



**Sustainability.** Most initiatives on cleaner air and water, renewable energy and public transportation require information on weather, climate and water. Some require specific monitoring programmes, considered analysis and public education.



# POWERING AND EMPOWERING THE FUTURE

## **Human activities are contributing to far-reaching changes in our climate.**

The 13 warmest years have all occurred since 1997. Global temperatures in 2011 were higher than any previous year with a La Niña event, which has a cooling influence. The extent of Arctic sea ice in 2011 was the second lowest on record, and its volume was the lowest.

Concentrations of greenhouse gases in the atmosphere have reached a new high. Between 1990 and 2010, there was a 29 per cent increase in radiative forcing – the warming effect on our climate system – from carbon dioxide and other gases. The rate of increase is accelerating. But the fact is that even if we halted greenhouse gas emissions today, they would linger in the atmosphere for decades, even centuries, disrupting the delicate balance of our living planet.

Reliable and timely weather, climate and water information provided by National Meteorological and Hydrological Services will thus increasingly be required in view of the risks of a rapidly changing climate. Investment in NMHSs is more necessary than ever so that they can meet these demands.

Our scientific understanding of weather, climate and water has made great strides in recent years. We need to strengthen this international knowledge base and also make it relevant to local needs. We need to ensure that the information reaches all socio-economic levels, from government decision makers and captains of industry to farmers and local community leaders.

We need a Global Framework for Climate Services because weather, climate and water respect no national boundaries. The Framework is not a panacea to the problems associated with climate change and variability. But it will help to equip us with the information and tools needed to cope.

Looking well beyond the 2015 target for the Millennium Development Goals, the Framework will contribute to the sustainable development aspirations of future generations in a world where population increase and economic growth will strain scarce resources to the limit.

Weather, climate and water have powered the growth of our economies and societies in the past. Weather, climate and water services will empower our economies and societies to meet the challenges of the future.





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