

Weather Climate Water and Sustainable Development



**World
Meteorological
Organization**

Weather • Climate • Water

WMO-No 974

socio-economic development - environmental protection - water resources management

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Weather
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FOREWORD



Throughout the ages, weather, climate and water resources have influenced human progress. The World Meteorological Organization (WMO) actively contributes to sustainable development by mitigating the impacts of natural disasters, protecting life, property and the environment, as well as in applications of meteorology, climatology and hydrology to all other areas of human endeavour. This year's theme for World Meteorological Day—which celebrates the entry into force of the Convention creating WMO on 23 March 1950—is “Weather, climate and water and sustainable development”, in recognition of those outstanding contributions.

Today's is a fast-changing world. The growth of industry and population, globalization, modern agricultural practices, transportation and energy use have led to planet-wide concerns such as those related to climate change, dwindling water resources, more frequent and more serious floods, droughts and other natural disasters, and environmental degradation. And it is the poorest countries that suffer most.

Disasters aside, weather, climate and water influence virtually all human activities, so almost every sector of the economy—health, energy, transport, food security, management of water, tourism—needs hydrological and meteorological services.

Along with vital technological achievements, huge strides have been made in understanding and predicting the dynamical and physical processes of the atmosphere and ocean and interactions of the ecosystems within the planetary system. One of the scientific success stories of the late 20th century, for instance, was the ability to predict El Niño events up to a year ahead.

WMO is a driving force behind these developments. As the intergovernmental agency responsible for coordinating and implementing weather-, climate- and water-related programmes, the Organization works on many fronts: observation and monitoring, disaster mitigation, the protection of life and property, and facilitating and carrying out research and capacity building.

In all these endeavours, WMO continues to go from strength to strength. We will further build on efforts to enable all nations to modernize their National Meteorological and Hydrological Services (NMHSs) and promote new partnerships and strategic alliances. WMO remains at the forefront of the work with all nations to meet the objectives of regional and global strategies, including the Millennium Development Goals, and those of the World Summit on Sustainable Development.

We look forward to further coordinating efforts in a multidisciplinary approach with decision-makers, scientific communities, partner organizations, non-governmental organizations, the private sector, the media and the public to ensure that we work together in effectively addressing the environmental and developmental challenges, particularly in the context of weather, climate and water, that humanity will face increasingly in the 21st century.

A handwritten signature in black ink, appearing to read 'M. Jarraud'. The signature is stylized and somewhat abstract, with a large, sweeping stroke that loops back over the name.

(M. Jarraud)
Secretary-General

WMO is committed to leaving future generations a better world.

INTRODUCTION

In Asia, severe flooding causes loss of life, destroys property and crops and triggers a cholera epidemic. Rising sea-level inundates resorts on a small Pacific island, leaving its economy in tatters. Another hectare of African dryland—drought-ridden and overgrazed—blows away on the wind. In the blink of an eye, a cyclone destroys hundreds of flimsy houses in an East Asian city and another forces thousands of people in the Caribbean to evacuate. Tornadoes, heatwaves and floods ravage parts of Europe, South and North America.

These examples point to a single global reality: the profound impact that weather, climate and water have on the livelihoods and health of people, national economies, and the environment. Any country can find itself in a costly battle with the forces of nature, but the weakest suffer most: a single storm, if severe enough, can leave them struggling for years. Preparedness is essential—and, in this context, sustainable development is the best way of fostering it.

Defined by the 1987 World Commission on Environment and Development as “meeting the needs of the present without compromising the ability of future generations to meet their own needs”, sustainable development is the great watchword of our times. Through global agreements such as environmental conventions and Agenda 21 (drawn up at the United Nations Conference on Environment and Development in Rio de Janeiro, 1992) and the World Summit on Sustainable Development (Johannesburg, 2002) and countless regional, national and local programmes, millions of people are working towards economic and social development that does not harm the environment or the natural resources it contains.

In 2000, the United Nations refined and refocused this monumental effort by calling on all UN Members to achieve the Millennium Development Goals by 2015. Some of these, of particular interest to the programmes of WMO, are to:

- Halve the proportion of people living on less than a dollar a day or suffering from hunger;
- Halve the proportion of people who are unable to reach or afford safe drinking-water;
- Address vulnerability, risk assessment and disaster management, including prevention, mitigation, preparedness, response and recovery, as an essential element for a safe world;
- Address issues related to climate change, including monitoring, projection and implementation of relevant strategies at national, regional and international levels;
- Ensure environmental sustainability;
- Develop a global partnership for development.

The urgency of these tasks is unparalleled. The major problems faced by the poorest countries, such as population growth, pollution, epidemics and inadequate health care, are already damaging. They weaken nations and leave them that much more vulnerable to the threats posed by the lack of clean water and weather- and climate-related events such as cyclones, floods, mudslides, drought and pollution. Damage is correspondingly greater, and resources that could be used for development are diverted instead into disaster relief. Worse, it is projected that climate change may trigger more frequent and more serious natural disasters, cause sea-level rise and impact all aspects of sustainable development.

WMO's objective is to halve the number of deaths due to hydrometeorological disasters over the decade 2010–2019.



An integrated approach

It is not surprising that environmental management is now viewed as an integral factor in sustainable development. Responding to risk through prevention, mitigation and preparedness—effective hazard monitoring, planning control, legislation, appropriate land and water use, and pollution control—gives other development efforts the edge. There will be less risk that

natural disasters will kill thousands, sweep away hard-won achievements such as schools and clinics, and decimate ecosystems.

More, it will set up a beneficial cycle. People who are healthy, literate and living above subsistence level will have the wherewithal to be more aware of, and prepared for, the risks, while well-sited, well-built housing and infrastructure provide some of the best forms of insurance. Wise use of

The impacts of climate change will fall disproportionately upon developing countries—and the poor in all countries.

Locust plagues

Desert locusts inflict damage in Africa, the Middle East and Asia. When weather and ecological conditions favour breeding and force the insects into a small area, they stop acting as individuals and start acting as a group. Within a few months huge swarms form and fly downwind in search of food. Swarms can be dozens of kilometres long and travel up to 200 kilometres a day. A small part of an average swarm (or about one tonne of locusts) eats the same amount of food in one day as 10 elephants or 25 camels or 2 500 people. Locusts that originate in West Africa, for example, can invade the region to the north and reproduce; their offspring then return south in a cycle that can last years. In western and central Africa in 2004, the swarms were the worst in more than a decade. They covered an area of thousands of square kilometres, destroying hundreds of hectares of subsistence crops and jeopardizing the lives of millions of farmers and herders in an already fragile environment.

The relationship between weather and outbreaks of locusts and their migration is well known and the National Meteorological and Hydrological Services in affected countries are actively involved in locust control operations. They monitor and forecast meteorological elements such as precipitation, temperature, humidity and wind speed and direction, which are crucial for forecasting locust incubation and movement and for spraying. A major gap is the identification of clear and useful guidelines on the exact nature of the meteorological products that should be provided at regular intervals to the agricultural community, decision-makers and the public. WMO and the UN Food and Agriculture Organization (FAO) are collaborating in the preparation of guidance material for NMHSs and national locust control centres for more effective monitoring of this pest.



(Photo: FAO)

fossil fuels and greater development and use of renewable energy can help curb climate change. Ultimately, people who protect the environment will safeguard their own livelihoods and lives and their future well-being.

Active and aware communities are only part of environmental management, and indeed of the vast overall task of balancing social and economic development, and protecting the environment and natural resources. This task is an ongoing global challenge. It demands an understanding of the complex interactions of the Earth's natural systems, and of these systems and human activities. This is giving rise to a new, holistic kind of scientific enquiry—sustainability science.

Observations of Earth, including its atmosphere, are essential for the transition to sustainability, as they help bring forth the workings of some of the greatest threats facing humanity: stratospheric ozone loss, global warming, sea-level rise, air and water pollution, floods, drought, desertification, deforestation and the loss of biodiversity. Such observations feed into more accurate forecasting and prediction tools, improved warnings, and better understanding and use of weather and climate information.

WMO and sustainable development—in brief

WMO is enabling nations to address these threats to sustainable development within the framework of Agenda 21, international agreements on climate, desertification, biodiversity, ozone depletion and natural disasters, and action plans on the sustainable development of Small Island Developing States, food security, energy production, habitat and urban environments, health, and protection of the atmosphere. Through its global observing, forecasting and data exchange systems, WMO contributes to increased safety on land and at sea, agriculture, and food security, combating drought, ensuring

economic growth and protecting the environment.

Multidisciplinary approach

A number of multidisciplinary partnerships are also evolving. These include UN system, inter-governmental and non-governmental organizations, academic institutions, the media and the private sector.

This kind of collective response is increasingly important. The challenges at hand, such as water stress, desertification, ozone depletion and climate change, are global. Meeting them demands a coordinated international effort and the issues must be tackled with an eye to the larger picture.

Fortunately, there has recently been a shift from the simple monitoring and warning of hazards towards disaster risk reduction and early warning that takes socio-economic aspects of a community's vulnerability into account. Risk management is now integrated more frequently into overall long-term sustainable development planning and specialized information centres are increasingly dedicated to sustainable development.

The next few decades will see tremendous new challenges arising from globalization, population growth, market-led economies and environmental degradation. WMO will meet them by continuing to support the three pillars of sustainable development—environmental protection, and social and economic development. This booklet explores some of the many ways it accomplishes the task.

WMO and National Meteorological and Hydrological Services provide vital support to the three pillars of sustainable development: environmental protection, social development and economic development.

Deserts cover about one-fifth of the land surface of the Earth

(Photo: R. Pelisson, SaharaMet)



CHANGING CLIMATE, CHANGING WORLD

Climate and weather affect humankind but, in order to understand these complex reciprocal relationships, it is necessary to look at how climate works, and how change may affect weather.

Anatomy of climate—challenges to well-being

If a range of weather conditions—temperature, precipitation, atmospheric pressure, duration of sunshine and wind, humidity and cloud cover—are averaged for one region over a period of time, we call that climate. But the Earth's climate system is something much larger and more complex. It involves the atmosphere, oceans, land surface, the biosphere, the permanent snow and ice of the cryosphere, aerosols and incoming solar radiation in continuous interplay, a kind of global choreography.

Overall, this system is a marvel of balance. Driven by energy from the Sun, the climate keeps its energy budget in equilibrium by emitting solar energy back into space—but not all at once. Certain gases in the atmosphere, such as water vapour, carbon dioxide and methane, retain some of the energy radiated back from the planet's surface, creating the warming greenhouse effect that makes life on Earth possible. But over the last half-century, emissions from cars and industry, urbanization, agricultural practices and land clearance have boosted concentrations of greenhouse gases. The Intergovernmental Panel on Climate Change (IPCC), sponsored jointly by WMO and the United Nations Environment Programme (UNEP), has shown that concen-

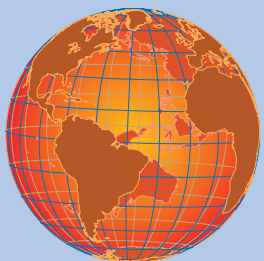
trations of carbon dioxide are over 33 per cent higher now than they were before the industrial revolution.

This being said, however, change and variability are intrinsic parts of our global climate. It is a dynamic system that shifts over decades, millennia and millions of years as a result of alterations in the Earth's orbit and tilt and solar radiation, as well as volcanic eruptions and other natural phenomena. Temperature, wind and precipitation are in constant flux, and extreme events such as droughts, blizzards and storms are natural features of its variability. What makes today's climate change different is that the rate of warming in the last century is greater than at any other time in the last few thousand years.

The effect on the global environment has been dramatic. Sea-level rose at an average rate of 2 mm a year during the 20th century. The range of many plants, insects and birds shifted to higher altitudes and latitudes. Precipitation in the mid- to high-latitudes of the northern hemisphere increased by up to 10 per cent, with some unusual events such as severe floods in parts of Europe, while droughts became more intense and frequent in parts of Africa and Asia. Glaciers worldwide are melting at an unprecedented rate and Arctic ice is thinning. Changes in ecosystems continue to be reported from various parts of the world.

Population growth, fossil fuel and renewable energy use, changes in industrial practice and land use will all affect future levels of greenhouse gases and hence warming rates. Sea-level could rise by between 9 and 88 cm by the end of this century. Summers could become drier and more drought-prone in some areas.

The rate of global warming today is greater than at any other time in the last few thousand years. Global warming presents an unprecedented challenge to sustainable development.





These changes could, in turn, profoundly affect progress towards sustainable development. They pose a real threat to all countries and in particular to the fragile economies of developing countries, and their fundamental needs—clean water and sanitation, food security, good health, the eradication of poverty and better protection of the environment and natural resources. Countries can find a way to address these hydrometeorological challenges. But first, the “anatomy” of extreme weather and climate events will be explored.

Natural disasters and climatic variations

We live in tempestuous times. Over the period 1992-2001, weather- and climate-related disasters killed about 622 000 people, affected more than two billion, left millions more homeless, devastated arable land and spread disease. Such events are increasing. Studies suggest that the number of weather-related disasters have increased three-fold over the past 30 years.

Storms, floods, storm surges, landslides and avalanches

Also known as typhoons and hurricanes, tropical cyclones are born when areas of low atmospheric pressure form over warm waters in the tropics or subtropics. These can grow into giant whirling masses of air and heavy rainfall, up to hundreds of kilometres in diameter, cutting a swathe of destruction as they move inland from the sea, whipping up high seas, storm surges, floods and tornadoes.

Coastal and inland regions of the Pacific, Atlantic and Indian Oceans, the Bay of Bengal, Gulf of Mexico and even the North Sea are often exposed to storm surges. When a cyclone moves over a continental shelf, strong onshore winds and low atmospheric pressure form a monumental dome of seawater that can stretch 80 km across and reach several metres in height. If the cyclone hits a coast, the surge can form a wall of water that crushes everything in its path. Low-lying coasts are particularly vulnerable to damage from surges.

There is concern that rising sea-level could herald larger storm surges. The predicted rise in sea-surface temperatures could also lead to a change in the intensity and frequency of tropical storms.

Haiti is chronically vulnerable to hurricanes, floods, and mudslides—a problem exacerbated by massive and continuing deforestation, wood being the basic domestic fuel.

(Photo: WMO)

Inland flooding can occur wherever water accumulates faster than soils can absorb it or rivers accommodate it, ranging from flash floods to massive inundations covering thousands of hectares. They can be set off by El Niño events, monsoons, melting snow or dam breaks, as well as by storms and rainfall. Floods are not always bad news—they replenish wetlands, fisheries and irrigation systems—but they are a significant threat to lives, property and livelihoods. In the last decade of the 20th century, floods affected some 1.5 billion people. An alarming factor is the growing number of people who are putting themselves in jeopardy by settling in floodplains or on adjoining slopes.

Landslides and mudflows are essentially semi-solid floods, often set off by heavy rain or rapid snowmelt. Soil degradation is a big factor as deforestation and land burnt by bush fires make soils less stable and prone to break away when saturated. Mudflows are formidable hazards, so dense and viscous they can completely bury built-up areas. By contrast, avalanches—large masses of snow and ice that race down steep slopes—kill far fewer people a year because they occur mostly in remote, sparsely populated regions. They do, however, pose a great hazard for populations, skiers, tourists and travellers in

mountain areas. However, forecasts for such events have considerably improved over the past decades.

Drought and desertification

When rains fail or dwindle over a long period of time—usually a season or more—drought can follow. Heat, strong winds and low relative humidity can contribute to its severity and length.

Drought can occur virtually anywhere but some areas are particularly susceptible. Drylands cover one-third of the world's land area and can support agriculture, grazing and human communities only if they are maintained with care: the soils are fragile and easily damaged by inappropriate farming methods and most cultivated drylands are facing degradation.

Desertification results when patches of degraded dryland join up, and desert-like conditions take over. Wind- and duststorms can exacerbate the process begun by farmers and pastoralists, severely eroding soils and carrying away what little topsoil there is. Beyond direct effects on people such as famine, biodiversity can decline and warming increase, as degradation removes the vegetation that acted as a carbon “sink”.

Long-term integrated strategies are needed that focus on improved productivity of land, and the rehabilitation, conservation and sustainable management of land and water resources.

(Photo: FAO)





Heatwaves

Heatwaves, higher maximum temperatures and an increase in the number of hot days are already happening. The risks are significant: some heatwaves are associated with pollution; they kill or affect more people than tornadoes, earthquakes or hurricanes.

Cities are hardest hit because even small increases in global temperatures can be amplified via the “heat island” effect. In the urban environment, concrete, tarmac and tall buildings absorb solar radiation and release it to the air, while the relative lack of vegetation means there is less cooling by evaporation. Deaths from heatstroke in large conurbations could become much higher. Away from the cities, livestock and wildlife can suffer from heat stress, crops fail, and tourism may decline.

Ozone depletion

The stratospheric ozone layer protects plants, marine life, animals and people from solar ultraviolet B (UV-B) radiation, which has a number of harmful effects. In the mid-1980s, the discovery of a “hole” in the stratospheric ozone layer over the Antarctic sparked intensive research into the chemistry and transport of ozone in the atmosphere. Increased UV radiation harms DNA in animals, inhibits photosynthesis in

plants and damages the plankton that form the base of the marine food chain.

The subsequent finding, based on monitoring, that chlorofluorocarbons from industrial and cooling processes, along with other anthropogenic chemicals, were responsible for this catastrophic thinning of ozone prompted the drawing up of the 1985 Vienna Convention on the Protection of the Ozone Layer and the 1987 Montreal Protocol on Substances that Deplete the Ozone layer and its subsequent Amendments. The Antarctic hole will take several decades to heal. Meanwhile, ozone thinning over Europe varies from 5 to 30 per cent and remains a significant health concern.

El Niño and La Niña

Among Earth’s climatic variations, none is more dramatic in effect than the El Niño/Southern Oscillation (ENSO). An El Niño strikes every three to seven years, when trade winds in the tropical parts of the Pacific Ocean weaken or reverse their usual route. The winds then blow surface water warmed by the tropical Sun to the eastern Pacific Ocean and the equatorial west coast of South America. Rain follows the current, and eastern South America may then experience flooding, while Australia, southern Africa and Indonesia may have drought. A La Niña event is the opposite,

Cities are hardest hit during heatwaves because of the “heat island” effect.

(Photo: WWF/Paul Forster)

with warmer waters in the the western Pacific and cooler waters off the west coast of South America.

The weather brought by El Niño events is often so extreme that its prediction is now a top priority for National Meteorological and Hydrological Services around the world. Careful monitoring of the sea-surface temperatures of the Pacific Ocean enables prediction of El Niño/La Niña events and their impacts in all parts of the world up to several months ahead.

A weather eye on change

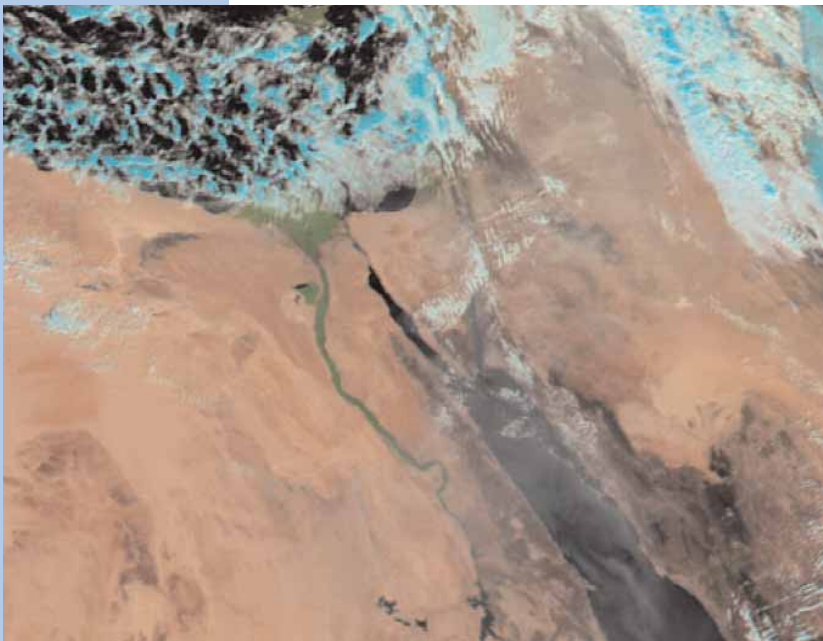
Keeping track of global warming, rising sea-level, air and water pollution, extreme weather events and other processes and related issues facing the world is necessary for achieving sustainable development. While no one can control the weather, accurate observations and predictions with a higher level of accuracy and lead time can radically improve people's chances of living in relative safety, building more comfortable lives and protecting precious natural resources effectively. For

vulnerable economies facing an uphill battle to achieve these goals, knowledge of the physical environment is crucial—help which WMO and the NMHSs are in a unique position to offer.

Their systems for observing weather, climate, the chemical composition of the atmosphere and water resources provide a vital global service for forecasting, prediction and research. The mechanisms they have put in place for the exchange of data and the application of those data in agriculture, water-resources management, energy use and other socio-economic areas, and environmental protection are invaluable for all countries, especially developing nations which are striving to build up their capacity. WMO's role of coordinating the regional and global activities of Members' NMHSs, and its support for training and the sharing of technology, have proved indispensable. The range of WMO's activities stretches literally from local to global.

Satellite products are of increasing importance for tracking and predicting weather events. METEOSAT-8 followed the evolution of a duststorm in the Middle East for three days in January 2004.

(Image: EUMETSAT)



THE HUMAN BASICS—SOCIAL DEVELOPMENT

We live in a world of social inequality. One person in every five survives on less than one dollar a day. More than one billion people in developing countries lack access to clean water, and 2.4 billion do not have basic sanitation. One person in three suffers from malnutrition. Meanwhile, the world is becoming more crowded: it is estimated that some nine billion people will inhabit the planet by 2050, of whom more than seven billion will live in less developed regions. The impacts of extreme weather can be catastrophic. Since 1991, some 98 per cent of deaths from natural disasters occur in poorer nations.

Poverty and disasters are indeed a deadly mix. Many countries are already beset by conflict, disease, poverty and displacement. People thus afflicted are simply less able to cope with the twin hazards of prolonged drought and famine. Natural disasters are as much a socio-economic phenomenon as they are a hydrometeorological one. This is why managing the impacts of weather and climate and applying related information to human activities must be part of any programme working towards fundamental social development goals such as clean water, food security and better health.

The world's water

It is no accident that Earth is called the “blue planet”. Water is synonymous with life. Human beings are 70 per cent water, and water is vital for sanitation, agriculture and industry, as well as the environment. Yet a mere 2.5 per cent of the global supply is freshwater, and the vast bulk of that is frozen solid in the Antarctic and Greenland. So it is the



rivers, lakes, groundwater and shallow aquifers that form the world's sources of usable water.

Their volume at a particular place does not stay constant, however. Climatic conditions over the preceding months and years which determine how much water is available at any one time can be variable, as can the hydrological cycle. As the Sun causes water to evaporate into the atmosphere, it precipitates as rain and snow. It is rapidly evaporated back into the air, drains into lakes, rivers or oceans, or infiltrates the soil to become groundwater, and variations occur from place to place and day to day.

Human actions also affect water supply through the hydrological cycle. From climate change to deforestation, irrigation and dam-building, we are continually modifying water resources. With the added huge demand from factories, farms and burgeoning megacities, the need for assessing and ensuring adequate water supplies is paramount.

Most of the world's small freshwater supply is frozen solid.

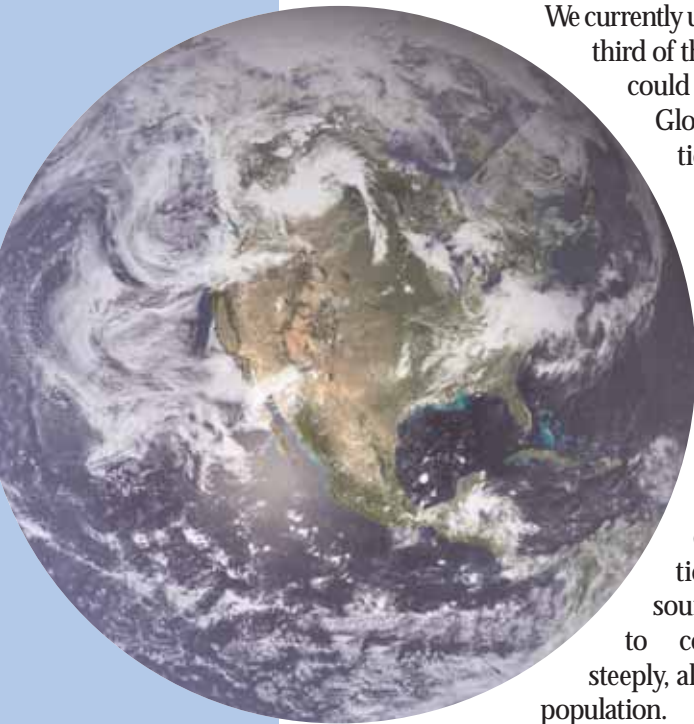
(Photo: Marijke Unger, US National Snow and Ice Data Center)

Weighing up water

How do we know there is enough? Hydrologists have estimated the average annual flow of all the world's rivers as a guide to the sum of Earth's freshwater resources. Many of the largest rivers and aquifers are some distance from major cities, transport costs are prohibitive and the same cities themselves are producing pollution. Many rivers downstream from cities in developing countries are highly polluted. In some countries, as little as 2 per cent of sewage is treated. Nitrate pollution from agricultural runoff is another serious, widespread problem. Acid rain continues to affect lakes and rivers whose water may also contain lead and be unfit to drink. In the end, only about 12 500 km³ of freshwater a year are available to humankind.

The blue planet seen from space

(Image: Earth Observatory/NASA)



We currently use less than one-third of that total, but that could soon change. Global consumption of freshwater rose six-fold between 1900 and 1995, far outstripping population growth. The demands of agriculture (about 80 per cent), industry, energy production and other sources, look set to continue rising steeply, along with global population.

As demand grows, a number of environmental problems with rivers, lakes, groundwater and aquifers are emerging. The extraction of water from rivers is shrinking their flow downstream, as well as the lakes they feed. Overpumping is sinking groundwater levels in some aquifers by tens of

metres—which also reduces the flow of rivers fed by groundwater. Some aquifers are being depleted faster than they can recharge from filtered precipitation—a real problem on small islands, where sea-water can intrude, and in arid areas with little hope of replenished supplies.

Wastage is another factor: as much as 60 per cent of the water used for irrigation either seeps away or evaporates before it can feed crops; and in about 20 per cent of the world's irrigated land, seepage causes salinization of the soil, leading to reductions in yields: as much as 50 per cent of public water-supply systems can be riddled with leaks.

The inevitable outcome of current patterns of use and abuse of water supplies is water stress. Countries are defined as water-stressed when they consume more than 20 per cent annually of a renewable water supply. Currently, about two billion people are living in countries that have neither adequate water resources nor the funds to abandon intensive irrigation for more sustainable agricultural practice. If current trends persist, this number could spread to cover most of the world by 2050.

There is fear in some quarters of future water wars. More water will be needed if agriculture is to feed the extra billions, yet climate change could mean less rain in regions producing the most food. Half the populations of developing countries will be living in cities, which impose huge demands on supplies. Many of these cities already have more than 10 million inhabitants and uncertain water supplies. With bigger and bigger conurbations competing for less and less water, the scene is set for potential conflict among users at national level and among countries sharing a river basin.

Food security

Food is a fundamental need. One-fifth of the world goes hungry every day, and malnutrition is a major factor in several million deaths every

year. Food security—meaning that the population has access to enough food to ensure health—is an essential stage in sustainable development, but continues to be elusive in poorer regions. In fact, the average annual growth rate of food production in the developing world declined from 4.2 per cent in the period 1991-1995 to 3.5 per cent in the period 1996-2000.

Many factors lie behind these figures. Some are the direct effect of unsustainable practices such as overgrazing, which can degrade soils and leave them unable to support any vegetation. Greater culprits are variations in climate and water availability, and natural disasters, which can destroy entire harvests or a season's livestock production. Storms, floods and locust infestations all play havoc with food security. And disasters are affecting more countries.

Population growth meanwhile is increasing the pressure. By 2020, farmers around the globe will need to produce 40 per cent more grain to feed everyone. An understanding of climate change, assessment of available water resources and early warning of natural disasters are among the vital adjuncts to sustainable agriculture.

A growing concern

Farmers are at the mercy of the weather. A single storm can drown or flatten a crop, kill herds of livestock and raze agricultural outbuildings, irrigation tanks and food stores to the ground. The economic loss may leave farmers unable to buy seed, supplies or material for a new start.

In regions repeatedly hit by storms, agriculture may not recover fully for years. Tropical cyclones are a threat to food security. Their high winds and violent rainfall can lay waste staple and cash crops.

Floods too can sweep away all before them, even topsoil. Coastal flooding from storm surges may leave vast areas of cultivated land salinized, killing off crops. Recurrent inland flooding may

leave land degraded and unfit for planting—as can happen on sandy soils subjected to flash floods. Unfortunately, the richest soils often lie in floodplains. Severe and prolonged flooding can devastate a country's crops, leading to widespread famine.

Droughts can be equally catastrophic, if slower to inflict damage. Recurrent or lengthy droughts can wither rainfed crops and decimate livestock. The fragile, arid soils of drought-prone areas such as drylands are prone to another natural hazard: wind erosion. This serious problem can be hard to gauge, as it is a low-grade, long-term, cumulative process. The most vulnerable areas are desertified by unsustainable farming practices—overcultivation of the soil, overgrazing and deforestation, and poorly drained irrigation which leave soils nutrient-poor, saline, and lacking structure and cohesiveness. This process has taken hold in large tracts of land. A combination of warmer winters and drier springs with soil degradation can lead to desertification and more frequent sand- and dust-storms, which kill livestock and destroy crops.



Food security is an essential part of sustainable development.

(Photo: FAO)

Malaria on the move



(Photo: WHO/Pasteur Institute)

By far the most widespread condition spread by mosquitoes is malaria—a disease in which fever and chills can give way to convulsions, coma and death. Malaria kills an estimated one million people a year in sub-Saharan Africa alone, and overwhelmingly targets children: under-fives make up over 70 per cent of all malaria deaths.

Mosquitoes are cold-blooded and extremely sensitive to climate and weather. Warming trends have caused them to shift their geographic range to higher altitudes in many regions since 1990, when the hottest decade on record began. A number of countries in Asia and Europe are seeing a resurgence of the disease. Contributing factors may include population growth and land-use changes, as well as poor health services and resistance to treatment.

Crustaceans are an important source of protein for many. Their habitats are at risk from warming and storms.



In the longer term, high temperatures triggered by climate change may lead to an array of impacts on food security. Certain crops respond badly to excessive warming: higher night-time temperatures, for instance, can affect grain formation. Yields of grain and other staple crops could fall.

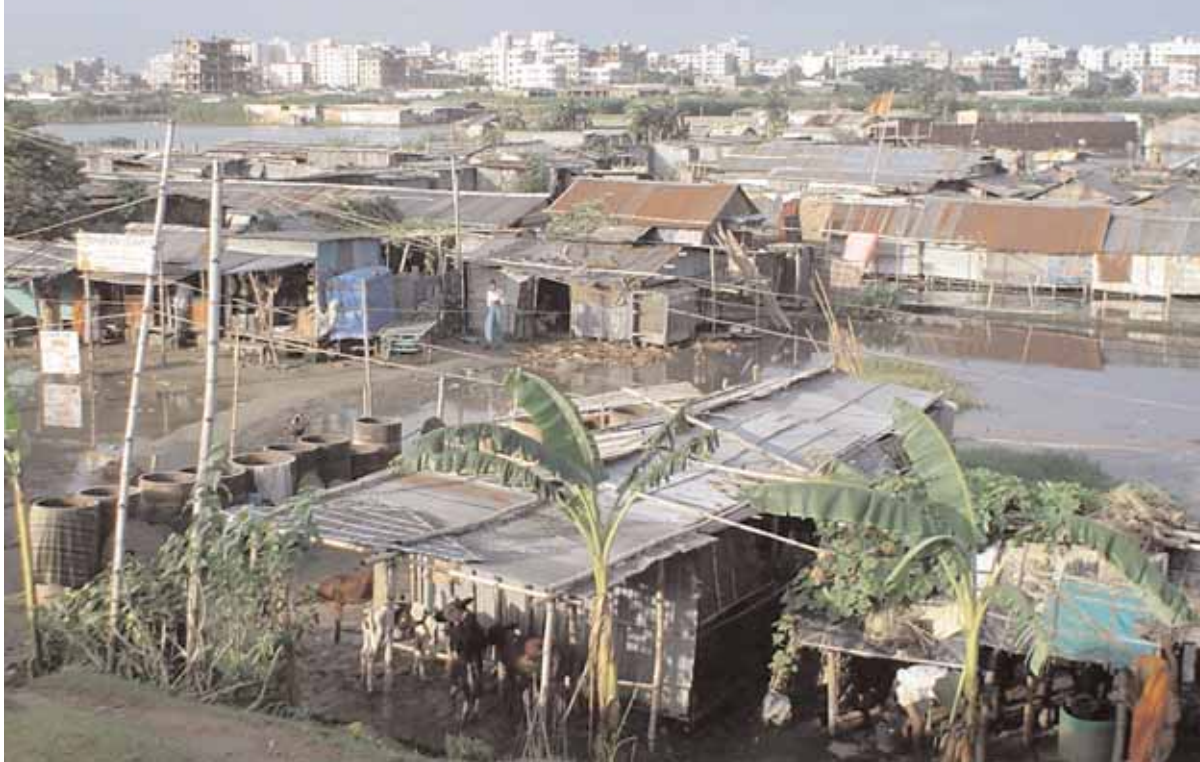
Aquaculture and mariculture could also suffer from warming. Fish provide one-fifth of the world's supply of animal protein and are a mainstay of many cultures, so any changes could have a powerful impact at all levels. Warmer lakes and rivers or a decrease in river flow could kill off inland fisheries. Higher sea temperatures would disrupt ocean currents and fish breeding patterns, and reduce amounts of the plankton that the fish feed on.

Human health

Both water supply and food security are closely linked to health. Every year, diseases linked to unsafe water kill an estimated five million people and other health problems are exacerbated by malnutrition. Climate change may add significantly to overall health risks through the rise in numbers of disasters and in temperatures, which are both direct and indirect causes of disease. Disease, in its turn, could jeopardize future development, as it so often targets the most vulnerable—children.

Disasters and health

It is estimated that, during the 10-year period 1992–2001, some 622 000 people died in natural disasters such as violent storms and floods. When severe climate and weather events strike poor, polluted, overcrowded and badly built cities, the death toll can be shockingly high. A number of illnesses and diseases can be an indirect result of disasters. The number of hot days and heatwaves—which are implicated in a range of illnesses and diseases—are increasing. Heatwaves



The urbanization of poverty is particularly acute in the developing world. Overcrowded, flimsily built cities are at the mercy of severe weather events.

(Photo: E. Al-Majed/WMO)

cause thermal stress, leading to progressively greater discomfort and physiological distress. The most serious response is heatstroke, which occurs when a person's core body temperature (the temperature of the internal organs) exceeds 40.6°C and can be fatal. Psychological distress during heatwaves can also be profound, especially on people in poorly ventilated, crowded urban areas which are hotter anyway because of the "heat island" effect (see also page 11).

It has been shown that, during heatwaves, deaths from all causes increase and death rates can rise to over 50 per cent above baseline levels. The 2003 summer heatwave across Europe killed an estimated 20 000 people, many of them elderly. Indeed, the aged, infirm or very young are the most vulnerable during heatwaves.

The effects of warming—potentially more storms and rainfall of greater intensity, more droughts and sea-level rise—are also dangerous to health. Prolonged or severe drought can lead to malnutrition and famine if crops and natural forage fail, and the intensive use of shrinking water supplies can lead to their contamination. Sea-level rise can disrupt stormwater drainage and sewage disposal in coastal areas, and leave freshwater supplies contaminated or salinized. Inland flooding can also release contaminated

water and promote the spread of infectious diseases such as cholera

Flooding and copious rain also mean more pools of standing water—the ideal habitat for some insect vectors of warm-climate, water-related diseases, including malaria, dengue and haemorrhagic dengue fever, yellow fever, encephalitis, onchocerciasis (river blindness), and schistosomiasis, a parasitic infection endemic in over 70 countries that can stunt children's growth and cognitive development.

El Niño's periodic disruptions of global weather can also impact on human health. In 1983, for instance, after El Niño-related flooding in Peru, there was a considerable increase in acute diarrhoeal and respiratory diseases and the climatic phenomenon has also been linked to disease epidemics in Asia and Central America.

In the catastrophic El Niño of 1997/1998, which affected over 100 million people worldwide, heavy rainfall in eastern Africa enabled the development of mosquito eggs carrying the Rift Valley fever virus. This virus mainly affects livestock but can infect humans, causing inflammation of the brain, severe bleeding and death. The outbreak killed hundreds of people and infected nearly 90 000.

Troubled waters

Poor sanitation and contaminated water are a daily reality for billions of people. Drinking- and washing-water contaminated with harmful micro-organisms or chemicals can cause diseases ranging from the unpleasant to the deadly. Contamination with sewage from municipal works, septic tanks or latrines is particularly dangerous.

Diarrhoea is a formidable, often lethal and unfortunately common condition. In 1998, it killed around 2.2 million people, most of them children in developing countries. In South-East Asia alone it is responsible for up to 8.5 per cent of all deaths. Other potentially lethal diseases contracted from contaminated food and water are cholera, typhoid and hepatitis. Water quality monitoring is a must in all countries.



The spread and concentration of pollutants in the air are determined by climate and weather conditions.

(Photo: WWF/Tantyo Bangun)

Breathing uneasily

Pollen, fungal spores and emissions from vehicles and factories fill the air we breathe. Ground-level ozone, nitrogen dioxide, carbon monoxide and sulphur dioxide have significant negative effects on our health. Carbon monoxide, for instance, can be fatal very quickly if inhaled in an enclosed space. Of even graver concern are the persistent organic pollutants, which can cause hormone imbalances, cancers, breakdowns of the immune system, birth abnormalities and neurological disorders.

Climate and weather influence the concentration of these materials in the air. Prevailing weather conditions—air currents, temperatures, humidity and precipitation—determine their spread. Heavy rain can clear smog, while certain weather conditions, such as slow-moving anticyclones can, by contrast, offer the static conditions that allow particles and gases to accumulate.

Asthma attacks, which are on the rise in many countries, can be the result of pollen, dust, ozone and other air pollutants or a mixture of these. Sometimes, thunderstorms, in conjunction with high pollen counts, cause attacks. There was even a case where dust from soybeans being loaded onto ships in harbour triggered asthma attacks when it was transported by prevailing winds over residential areas.

Ozone depletion is another threat to health. Stratospheric ozone levels are not expected to return to normal before several decades. In the meantime, there is less of it to deflect UV radiation from the Sun, which can encourage the development of cataracts, cancer of the conjunctiva (the membrane that covers the front of the eye and lines the inside of the eyelids) and skin cancers.

TOWARDS A SUSTAINABLE FUTURE

Working with the Earth: protecting the environment and natural resources

All life depends on a healthy planet. But this vast web of interwoven systems—atmosphere, oceans, watercourses, land, ice cover and biosphere—is now clearly threatened by human activities. Where air is polluted, water is depleted or contaminated, soil is degraded, biodiversity is threatened and urban sprawls grow unchecked, neither wildlife, nor human life and livelihoods, can be supported indefinitely. Such an environment will, at the same time, become more vulnerable to natural disasters.

A beleaguered world

Air quality

The threat to the atmosphere arises from heightened pollution. Industry and vehicles continue to pump pollutants into the atmosphere, with fossil fuels accounting for the bulk of them. Industrial emissions vary widely from region to region—from 3.5 per cent to 40 per cent—but all regions live with the effects.

One result is global warming, which affects many natural systems, from polar and high-altitude ecosystems to tropical coasts and wetlands. Forests might extend north or to higher altitudes as temperatures rise, but diminish in the south; their composition could also change, with unpredictable effects on the organisms the trees support. It is believed that rising ocean temperatures have caused the widespread



bleaching of coral reefs, which support huge populations of marine life. During the El Niño of 1997/1998, all the world's reefs were affected, and the Indian Ocean lost as much as 90 per cent of its corals.

Air pollution generated in industrialized regions, can travel vast distances. The sulphur dioxide and nitrogen oxides produced by coal combustion, for instance, become acidic in the atmosphere and can be carried by wind hundreds of kilometres to fall as acid rain, harming forests, soils, lakes and rivers, and aquatic organisms. Persistent organic pollutants become volatile in warm air, and are transported by air masses—even as far as the Arctic. They can also seep into groundwater and travel in rivers.

Mangroves are highly productive ecosystems and provide a valuable habitat for shrimps and other marine life and birds. Their existence is threatened by severe storms and sea-level rise.

(Photo: V. Torres)



Marine weather information is vital for shipping: for the safety of mariners, their boats and cargoes. Oil spills can destroy marine life and coastal ecosystems.

(Photo: Douane/F. Guyader)

Water quality

Many freshwater ecosystems have been damaged by pollution, as well as excessive extraction and the introduction of non-native species. The effects of a range of pollutants include:

- Organic matter depletes oxygen, suffocating aquatic animal life;
- Nitrates and phosphorus from agricultural runoff stimulate the growth of algae, which eventually robs water of oxygen and harms aquatic life;
- Toxic heavy metals from industry and mining accumulate in fish and shellfish;
- Some organic compounds, such as oil and pesticides, can poison aquatic fauna;
- Silt from erosion of degraded soils smothers aquatic habitats and can disrupt spawning.

These materials accumulate in rivers, lakes, wetlands and deltas, causing much damage to wildlife. As rivers run to the sea, pollutants end up in coastal marine ecosystems such as lagoons, estuaries and bays, as well as the deeper sea. About 80 per cent of marine pollution comes from the land.

The Black Sea is an extreme example. It is connected to the wider ocean system only through the Mediterranean, and is fed by major European rivers, including the Danube. Its shores are heavily developed, and the surrounding countries—a number of which have transitional economies—emit large volumes of untreated

wastewater, industrial pollutants and agrochemicals. The nutrient overload has led to eutrophication—the reduction of oxygen in the water—and a significant loss of biodiversity. Such “dead zones”, now found in over 150 bodies of water round the world, pose a significant threat to marine life.

Marine industries also contribute to pollution. Spills from oil tankers can devastate coastal ecosystems, poisoning or suffocating mammals, seabirds, crustaceans and other organisms. Aquaculture can also be a problem, as the harmful chemicals used to treat parasites and disease in the stocks can drift into and damage coastal ecosystems. Farmed fish may also transmit disease to wild ones and modify local genetic pools.

Soils

The health of soils is crucial to life, as they contain and support organisms at the base of the terrestrial food chain—billions of bacteria along with fungi, worms, insects and vegetation. Soils are also an essential player in the hydrological cycle. But erosion, deforestation, pollution and acidification are causing catastrophic damage, and it is estimated that as many as two billion hectares could be degraded worldwide.

Biodiversity

Globally, around a quarter of mammal species and 12 per cent of birds are threatened, and extinction rates are at least a thousand times greater than they would be naturally. The trend has serious implications for all Earth systems.

Biodiversity helps keep the global environment working. A huge range of organisms perform essential environmental “services”. These include helping regulate the composition of the atmosphere, the hydrological cycle and soils; aiding the breakdown of waste; pollinating crops; and absorbing pollution. The cornu-

copia of species is important to us as well. Wild plants are the raw material for pharmaceuticals, and also serve to keep crops in good genetic shape.

The ongoing damage to watercourses, lakes, oceans and land destroys habitats—the biggest factor in biodiversity loss. A mangrove ecosystem, for example, is made up of mud, seawater, roots and tree canopy, a range of habitats that support a multitude of organisms, from bacteria to pelicans. But over half the world's mangroves were lost in the 20th century, and with them, entire populations of the creatures they harboured.

The impact of coastal megacities

One of the biggest threats in the world today is the runaway growth of megacities. There are now 21 conurbations of more than 10 million people each and it is estimated that, by 2020, they will support 30 per cent of the world's population. Any large city is a significant threat to the environment, burying land under concrete, consuming energy, polluting air and waterways and creating landfill. Seventeen of those 21 megacities, however are coastal, involving dredging, the erosion of shores, construction, port development and marine pollution on a large scale. Coastal habitats such as wetlands may be destroyed or degraded. Most of the new coastal megacities are in the developing world. Where their growth is uncontrolled and chaotic there is a greater risk of damage from tropical cyclones, storm surges and rising sea-level.

At the same time, relatively pristine coasts are being developed to satisfy the demands of tourism. The construction of hotels, marinas, roads, airports, car parks and restaurants, with attendant problems of sewage and pollution; the decimation of marine life to satisfy demand for seafood; and unregulated snorkelling, diving or boating round reefs can all extinguish ecosystems.

The energy gap

To a great extent, energy drives development. But our traditional reliance on fossil fuels is unsustainable: the extracting, storing, transporting and burning of them damages the global environment and climate. The alternatives are renewable energy sources such as water, wave, wind and solar power.

Apart from hydropower, renewable technologies currently supply only a tiny fraction of global energy production. Fossil fuels will run out; although estimates vary as to when, most predict that it is a matter of 50 to 100 years. The challenge is to obtain enough energy from renewable sources to meet global demand. Today, some two billion people lack access to electricity and, as their countries develop, their needs for energy for schools, homes, hospitals, industry and agriculture are foreseen to double by 2025. The need for reliable, non-polluting power is clearly urgent.

Most new coastal megacities are in the developing world. They are at particular risk from tropical cyclones, storm surges and rising sea-level.

(Photo: Marine Photobank)



Towards a greener world

An eye on weather, climate and water

The observational data and forecasts of weather, climate and the atmosphere that are collected and disseminated to all nations keep policy-makers informed of the state of the environment, so that they may be in a better position to prevent its further degradation.

Systems such as the Global Climate Observing System, with the support of WMO programmes, play a key role in the formulation and implementation of major global initiatives such as the United Nations Framework Convention on Climate Change (UNFCCC). Observational data are provided through a number of WMO programmes, the Global Observing System, the Global Atmosphere Watch (GAW) and the hydrological networks.

As for research, the main thrust of the World Climate Research Programme's work is to increase our understanding of the basic behaviour of climate—research with obvious importance for the Intergovernmental Panel on Climate Change (IPCC) and the UNFCCC. It

focuses on uncertainties in areas identified by the IPCC, such as the movement and storage of heat by the ocean, the carbon cycle and cloud formation, and its effects on atmospheric temperature.

GAW was set up to discover the mechanisms of natural and anthropogenic atmospheric change, and improve our understanding of the interactions of the atmosphere, ocean and biosphere. GAW's measurement stations and calibration centres provide data on aerosols, ozone, the chemistry of precipitation, UV radiation, greenhouse gases and reactive gases to the international scientific community and policy-makers and is invaluable in implementing major environmental agreements such as the Montreal Protocol on Substances that Deplete the Ozone Layer.

Monitoring water quality is of vital importance in ensuring that lakes and rivers are as healthy as possible for aquatic life. Equally important is monitoring drought through observations of floods, wind erosion and climate variability in arid regions. Many NMHSs are working towards meeting the requirements of the United Nations Convention to Combat Desertification by using early warning systems for each of these phenomena, which can be key indicators of the kind of soil degradation and climatic conditions that lead to desertification.

Fuelling the future

Renewable energy may not pollute, but is it viable? At the moment, hydropower supplies 24 per cent of the world's electricity and is used by more than one billion people. Other renewable energy technologies make up only about 2 per cent of global energy, but some are growing fast.

It is cheaper to produce wind energy now than it was 20 years ago, and it could be even more cost-effective in the future. The market for wind power is also rapidly expanding. Between 1998 and 2002 it grew by an average 33 per cent a year,

The need for clean, reliable power is paramount. Wind-generated energy is becoming more popular and more cost-effective.

(Photo: M. Alliod/WMO)



and it has huge potential. In choosing a location for a wind farm, prevailing wind direction, its threshold value and constancy are important; if winds are relatively slow, for instance, but blow reliably over the year at a site, it is a good option for inclusion in a power grid. Established wind farms can benefit from short- and medium-range wind forecasts for estimating power outputs and keeping the operation cost-effective. Solar energy is also showing promise, as the market for photovoltaics, while small, is growing at a rate of 30 per cent a year. Photovoltaic cells, or solar collectors that concentrate direct solar radiation, are most reliable in areas with steady and relatively unvarying sunshine. The technology could thus have great potential in some of the least developed regions. When the collectors are in place, short-term estimates of cloud cover and precipitation can help in estimating power production and deciding on whether to use back-up power sources.

Siting a hydropower plant requires research into historical records and up-to-date observations. Once a catchment area is chosen, the past distribution of rainfall by month and season must be studied. Once the plant is running, rainfall forecasts will ensure good power generation without excessive outflow. Three- to ten-day predictions of dry and wet spells in the catchment area are useful for planning the energy-generating flow. WMO's Climate Information and Prediction Services project of the World Climate Programme provides long-range forecasts of rainfall and climatic anomalies that are valuable for longer-term planning.

Finally, technologies focusing on biomass—materials such as wood and straw—are progressing. Biomass is the world's largest and most sustainable energy source: although burning plant matter adds carbon dioxide to the atmosphere, the plants themselves consume an equivalent amount of gas while growing. Estimating yields of fuel wood by monitoring rainfall, temperature and cloud cover can help in predicting likely energy output.



Because renewable technologies harness the power of natural phenomena and resources, they are, inevitably, highly sensitive to any variation in weather or climate. Gale-force winds can play havoc with energy generation on wind farms, for instance, while drought can bring hydropower plants to a halt. A rise in sea-level could threaten the installation of wind turbines, while higher temperatures from a rise in solar radiation could actually boost solar energy generation. All this makes it clear that an integrated approach, drawing in National Meteorological and Hydrological Services, energy experts and town planners—who can ensure that town and industrial design will be energy-efficient—is the best way forward.

Hydropower currently supplies 24 per cent of the world's electricity to more than one billion people. Weather and climate information are vital for siting plants and planning their operation.

(Photo: N. Sehmi)

ATTENDING TO BASIC SOCIAL AND ECONOMIC NEEDS

WMO supplies the basic tools for sustainable development in the areas of weather, climate and water.

A sustainable future requires that humankind addresses the three pillars of sustainable development—environmental, social and economic. WMO with its unique systems for monitoring and predicting weather, climate and the water cycle provides the world community with the basic tools to plan and implement policies for sustainable development.

Making water work

Earth's water supply is finite, so it is clear that we need to use what we have in a sustainable fashion. Yet, planning and decision-making are complex processes, given the countless demands for water for industry and households, sanitation systems and hydropower production, irrigation and drainage, and the needs of the aquatic ecosystems that supply it all to us. None of this can happen unless we have better assessments of the quantity and quality of available water resources.

It is the responsibility of NMHSs to take regular measurements of the natural elements controlling water availability—precipitation, evaporation, river flow—and of amounts stored underground, in reservoirs, and elsewhere. Quantity, quality and biological characteristics of water resources also have to be monitored. WMO's Hydrology and Water Resources Programme (HWRP) coordinates activities aimed at the collection of data and the provision of hydrological forecasting.

Hydrological data are also essential in the study of climate, so the work of the HWRP contributes to that of the World Climate Programme, and there is a reciprocal flow of information to the HWRP from the World Climate Research Programme (WCRP).

One of the WCRP's ongoing core projects is the Global Energy and Water Cycle Experiment (GEWEX). To address the thorny issue of whether Earth can provide enough water for all future requirements, GEWEX is trying to answer questions such as whether the rate of water cycling through the atmosphere changes with climate change, and how much climate change is driving local weather, precipitation and shifts in water resources.

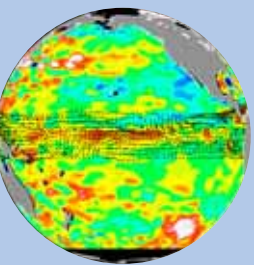
Despite the many thousands of hydrological measuring stations globally, there are serious inadequacies in coverage—particularly in the developing world, where the need is greatest. In addition to the existing stations, a global system for near-real-time monitoring is being built, based on regional components for meeting the challenges of the 21st century. With the support of some of its partners, WMO launched the World Hydrological Cycle Observing System (WHYCOS) in 1993.

The system is being built up gradually. Eventually, it will consist of some 1 000 hydrological stations on the world's largest rivers, gathering data on water quantity and quality in near-real-time (this is essential, given the variability of water supplies at any one moment). The data will then be transmitted by satellite to national and regional data-collection centres. WHYCOS is being established via regional components called HYCOSs, with emphasis on regional cooperation, rather than national interests.

And what of tomorrow? If regional water crises are to be averted, action must begin now. Governments must carefully monitor supplies and patterns of use in order to pave the way for the sensitive development and management of water supplies that are truly integrated according to the multiplicity of needs for water. National

El Niño has far-reaching ecological and economic impacts. Accurate prediction of El Niño events would have enormous benefits for all countries.

(Image: NASA)



Building better drought prediction in the Sahel

The Sahelian countries of West Africa have to contend with a fearsome enemy—recurrent drought. Helping these countries battle drought and desertification and work towards food security is an urgent task. WMO supports the regional Agrometeorological and Hydrological (AGRHYMET) Centre of the Inter-State Committee on Drought Control in the Sahel (CILSS), based in Niamey, Niger. The AGRHYMET Centre builds up capability in observations and telecommunications, provides training in agrometeorology and maintains warning and crop-yield forecasting systems. WMO will be working with the AGRHYMET Centre and NMSs to set up new operational early warning methodologies and will analyse the vulnerability of CILSS countries. WMO also supports the River Niger Basin Authority.



(Photo: FAO)

Hydrological Services (NHSs) will need to play a significant role in any national and regional water management strategy.

WMO will also continue to support the world's hydrological community in addressing environmental issues, particularly by establishing global databases, developing improved methods of analysing hydrological processes and effecting studies of how climate change affects water resources. Hydrology programmes focusing on the conservation of water resources and the protection of ecosystems will become increasingly important. Meanwhile, governments could conduct campaigns against wastage by promoting pragmatic, economical technology such as installing drip irrigation systems and recycling waste water. Such measures would contribute to meeting the foreseen extra demand.

Helping agriculture adapt

WMO promotes sustainable agriculture on a number of fronts, through its own programmes and via collaboration with other UN agencies and intergovernmental organizations.

It is increasingly recognized that early warning and prediction systems for impending weather and climate hazards, with good lead-time, are key to ensuring food security. In mid-latitudes, weather can now be forecast for up to a week, but predicting the longer-term climate is a considerable advantage. Understanding El Niño is the first big breakthrough in our ability to do this. Coupling climate models with high-resolution regional models are providing climate outlooks for up to several seasons. It is now possible to predict El Niño-related anomalies in sea-surface temperatures up to a year in advance, as well as to provide early warning of phenomena associated with El Niño, such as

Sustainable availability of adequate freshwater requires planning based on monitoring and projections of future state.

Development strategies are needed that integrate adaptation measures which respond to climate change impacts.

unusual patterns of rainfall. Information on the El Niño of 1997/1998, for instance, was rapidly disseminated round the globe, allowing a number of governments to minimize agricultural losses. WMO's Climate Information and Prediction Services (CLIPS) project has helped countries use this kind of climate information to good effect.

The Agricultural Meteorology Programme runs a number of projects enabling NMHSs to provide weather and climate services to farmers. Its aim is to help develop sustainable, economically viable systems of agriculture, improve production and quality, reduce losses and risks, increase efficiency in water, labour and energy use, conserve natural resources

and decrease agricultural chemical pollution. Climate information is used primarily for planning, and weather forecasts for hands-on projects.

Cyclones are an agricultural nemesis, but now it is possible to track them from start to finish, thanks to the NMHSs and to WMO's Regional Specialized Meteorological Centres (RSMCs) in Miami, Fiji, New Delhi, Tokyo, La Réunion and Honolulu. The RSMCs harness data from satellites and ships and land-based stations and radar to monitor the cyclones and predict their landfall with considerable accuracy. These activities are coordinated through WMO's World Weather Watch and Tropical Cyclone Programmes.

The human side of global change

Unravelling the many links between human activity and global change—in climate, land and sea use, biodiversity and socio-economics—is vital for integrated solutions to global problems. In 2001, the Earth System Science Partnership was launched to explore these connections. The World Climate Research Programme works with other international programmes to examine critical issues of global sustainability through several intensive research projects, including the following:

The **Global Water System Project** investigates important questions about the world's fresh-water, such as the magnitude and key mechanisms of human and environmental changes in the global water system; the main links and feedbacks within the Earth system that arise from global water changes; the resilience of the global water system to change; and the best sustainable water strategies.

The **Global Environmental Change and Food Systems Project** looks at three fundamental questions of food security: the regional effect of global change on the vulnerability of food systems; how food systems might adapt to cope with global change to enhance food security; and what the environmental and socio-economic consequences of those adaptations might be.

The **Global Environmental Change and Human Health Project** studies how global changes such as temperature extremes or levels of UV radiation directly affect health, and how interactions of environmental conditions, the functioning of ecosystems and socio-economic conditions indirectly affect it.





Children are particularly at risk from the lack of access to safe drinking water.

(Photo: ICRC/Horvath, Sándor)

The agricultural community, from farmers to policy-makers, needs to develop strategies for adapting to climate change. The central task is to change production methods to reduce the amount of greenhouse gases produced, choosing the most appropriate crops and planting times for the prevailing climatic conditions, and optimal land and water use.

Agrometeorologists can offer much assistance in finding ways to cope. Afforestation, for instance, is important for providing carbon sinks as well as better stability for soils. Adjusting planting times, water conservation (including harvesting rainwater), and choosing crops with deep roots or resistance to dry conditions can help in adapting to drought. In drylands, simple techniques such as mulching, tilling in fallow periods, and managing soil moisture through multiple cropping, can improve the efficiency of water use, while simultaneously preventing desertification.

A healthier tomorrow

Clearly, ensuring clean water supplies is one of the most important ways to safeguard health, and National Hydrological Services (NHSs), bolstered by WHYCOS, are working towards this goal. The World Weather Watch Programme, under which WMO Members exchange their meteorological observations and forecasts and warnings and use shared global information, also contributes to saving lives through disaster management and preparedness and applications to various socio-economic activities.

Seasonal predictions also have great implications for health. In the future, it will be possible to use them to prepare for weather-related outbreaks of some serious vector-borne diseases, allowing health services to stockpile vaccines and otherwise prepare. Bioclimatic maps are a valuable tool which use climatic satellite data to identify habitats that promote high survival rates for vectors.

2004: the year of the tropical cyclone

Hurricane experts with the US National Oceanic and Atmospheric Administration had predicted early in the year that the season in the Caribbean Sea, Gulf of Mexico and North Atlantic Ocean would be an active one, with a 50 per cent chance of having more numerous and more intense storms than usual. It proved to be not only an above-normal season but a record-breaking one as well. August was unusually active with eight named storms, one more than the record of seven set in 1933 and 1995. By mid-September, there had already been 12 named storms, seven of which were hurricanes. Preliminary estimates of *Charley's* path across Florida range from 13 to 15 billion US dollars making it the second costliest tropical cyclone in US history. *Charley* brought death and destruction to the Caribbean and Florida, with damage to property in Cuba in excess of US\$ 1 billion. *Frances*, a slow moving hurricane, caused more devastation in Florida and the Bahamas: insurance claims were made for some four billion US dollars. *Ivan*, the fiercest of the four significantly affected at least eight islands in the Atlantic and Caribbean. *Ivan* was the most powerful storm to hit the Caribbean in 10 years. It made a direct hit on the island of Grenada, then Jamaica and then the state of Alabama in the USA, leaving in its wake more than a 100 dead and property damage estimated at 12 million US dollars. *Jeanne*, the weakest of the four, swept across the northern coast of Haiti on 16 September, leaving more than 2 000 dead, its population and economy in shreds.

2004 was also a record year for typhoons in the western North Pacific Ocean. Ten typhoons made landfall in Japan—two within 10 days. After *Meari* and *Ma-on* came *Tokage*, which was the most powerful typhoon to hit Japan in 16 years. The year's number of typhoons surpassed the previous record of six set in 1990 and left the largest number of people dead (some 220) and injured since 1983.



Hurricane Ivan (Image: AP/NOAA)

Biometeorology studies the effects of weather on living systems. Some National Meteorological Services routinely provide pollen counts, measurements of dust, comfort indices, ozone levels, pollutants and UV and sunburn forecasts with their weather reports. Warnings derived from epidemiological studies gauging the effects of air pollution on health are also widely available.

In several countries, heat-health watch warning systems operate in combination with public health education campaigns. A new system based on synoptic climatological methods—i.e. gathering meteorological data over a large area—has also been developed. Health commissioners and NMSs cooperate in issuing alerts, watches and warnings.

Climate experts had projected an active record-breaking season of destructive hurricanes and typhoons in 2004. Studies are being pursued to establish links between such occurrences and global warming.

Reducing poverty: economic development

Poverty is a major aspect of social deprivation. But what are the economics of poverty? The per capita growth of the poorest countries' GDP was slower in the 1990s than it was in the 1980s, and the gap between rich and poor nations is widening. What is keeping poor countries poor?

Natural disasters, for one thing. The financial cost of disasters runs into billions of dollars every year, with the amount in richer countries being numerically higher. This is, however, largely because they put a higher price on their infrastructure. When cost is calculated as a percentage of GDP, it is actually 20 per cent greater for poorer countries than it is for richer ones.

The lack of insurance in developing countries makes them doubly vulnerable. Since 1980, the cost of disasters in uninsured countries, while amounting to just one-third of the global total, exceeded US\$ 300 billion. Developing countries must dig deep into their own scarce resources, or rely on international aid, to pay.

The human price of disasters is also higher for developing countries. On average, about 50 times more people die from disasters in countries with low levels of development compared with highly developed countries.

Getting the world to work in partnership

Disasters aside, weather and climate are also vital to the economic success of less developed countries. Their dependence on agriculture means export crops are an economic mainstay for many—and often dependent on rainfed agriculture. For many countries, tourism is often important to the national economy, and outdoor pursuits such as mountaineering, skiing, watersports and exploring ancient sites are all heavily depend-

ent on good weather and relative climatic stability.

Some 60 per cent of the world's population live within 60 kilometres of the sea and, for developing maritime nations, coastal and marine economic activities are highly important. Fisheries and aquaculture, for instance, employ around 140 million people worldwide and ocean fisheries provide a large proportion of those livelihoods but, in recent years, the capability of commercial fisheries has grown so fast that managing them sustainably is a significant challenge. Fish and shellfish are a valuable export for developing maritime countries, but careful governance is necessary for both fisheries and aquaculture if the industry as a whole is not to implode. Population growth exerts ever greater pressure and overfishing in some areas has led to a collapse in stocks.

Shipping, so firmly linked to economic development and trade, is a vital component of many economies. In 2003, it was estimated that the developing world's share of the global fleet was about 20 per cent, while its percentage of world seaborne trade in terms of goods loaded was almost 50 per cent. Ships are, however,

Fish and fishing are the mainstay of millions of coastal dwellers. In many developing countries, fishing is a perilous activity, especially in unfavourable weather conditions.

(Photo: G.B. Bizzani/FAO)



Trouble in paradise

To tourists from the developed world, tropical islands may seem the ultimate in exotic destinations. But for the people who live and work there, life can be precarious and sustainable development an elusive goal.

Small Island Developing States (SIDS), as well as other low-lying countries in the developing world, are particularly vulnerable to cyclones, storm surges and flooding. SIDS are also twice as vulnerable to sea-level rise as other developing countries. At the same time, many (some 80 per cent) are highly dependent on tourism. But their tropical setting, small size, abundant beaches and tourism-oriented economies leave them open to serious damage and economic loss from natural hazards.

Coasts can be eroded, sea walls undermined and villages blotted out by gales and massive waves. For coastal populations, fragile resource bases, high transportation and communication costs and limited economic choices, the result can be catastrophic. Worst of all, entire islands may be inundated, forcing populations to evacuate.

WMO has been helping the SIDS to meet priority areas outlined under the 1994 Barbados Programme of Action for Sustainable Development of Small Island Developing States, such as monitoring sea-level rise and the exchange of weather information and warnings. Meteorological data and information collected by the NMHSs of SIDS participating in the World Weather Watch feed into sustainable development activities. Other WMO programmes have helped modernize NMHSs. The Climate Computing (CLICOM) project provides computers and computer programs, allowing quality control, storage, retrieval and analysis of climate observations and data. The Data Rescue (DARE) project, which transfers data from manual climate records to computer-accessible format, has been essential in determining climate trends and changes.

This mass of work on climate, natural disasters, oceans and pollution is also essential for integrated, sustainable coastal management. From the design of coastal buildings and the management of ecosystems and nature reserves, to the control of transport and provision for tourism and outdoor sports, wise management of coastal areas demands extensive knowledge and analysis of meteorological and oceanographic conditions.



(Photo: Martin Ferm, IVL Swedish Environmental Research Institute)

In the Maldives 80 per cent of the 1 200 islands are only one metre above sea-level. On one island, tidal surges flood homes every two weeks; 60 per cent of the population have volunteered to evacuate over the next 15 years.

highly vulnerable to wind, waves, fog and ice. Ensuring that shipping is safe and efficient from port to port is crucial.

Under the World Weather Watch, WMO Member countries observe weather and climate at the ocean surface around the clock and around the world, providing a steady flow of data which are then transmitted worldwide for use in weather, wave and ice forecasts for maritime organizations and to aid sustainable development planning. It is a unique system that networks each observing station to national, regional and global centres 24 hours a day in real-time, delivering data from the land surface and from space for forecasts and warnings for end-users and the public.

For example, meteorological warnings and forecasts for shipping are used by ship routing services, which develop the most economically viable routes, and by towing and pollution clean-up operations. Fisheries use data on high winds, large waves, ice and freezing spray to keep their operations safe, and information on ocean circulation, temperature patterns and changes in ocean climate to determine the distribution and health of fish stocks.

Aviation is concentrated in developed countries but is of particular importance to the nations that rely heavily on tourism. Aircraft, too, are largely at the mercy of the weather and this factor, along with ever more crowded skies, means that accurate forecasts and warnings are vital for safe air travel. Under the Aeronautical Meteorology Programme, WMO works with its international partners and the aviation industry to provide the meteorological information needed for safe, efficient air travel. The World Area Forecast System provides global upper-atmosphere wind conditions, temperatures and weather forecasts for flight planning for 156 countries. The Aircraft Meteorological Data Relay system provides some 150 000 upper-air observations daily from aircraft in flight.



Tourist revenue can be a prime source of renewable income and profits can be ploughed back into environmental protection and maintaining and cultural attractions. But, if the pressure on the environment is too extreme or funds are not used wisely, tourism can destroy the very sites it aims to promote, and economies will suffer. Coastal cities and resorts are most vulnerable because they are not only magnets for tourism, but are also environmentally fragile. Unsustainable development, coupled with rising sea-level and increasingly severe weather, leave them open to devastation. Low-lying countries, particularly Small Island Developing States, are most at risk.

Avalanches pose a great hazard to inhabitants, skiers, tourists and travellers in mountain areas.

(Photo: David E. McGuirk)

CONCLUSION

The quest for sustainable development is long and complex. Development strategies and technologies must emerge which do not harm the environment or the climate and which include adaptation measures to help all countries, especially the developing ones, address the potential impacts of climate change.

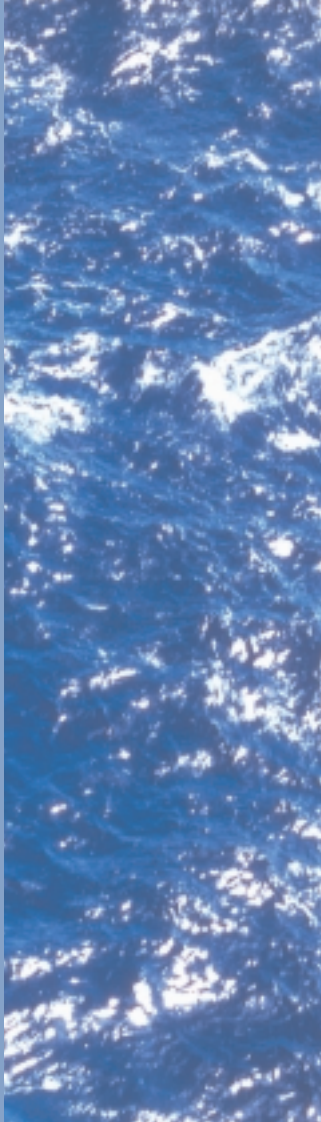
Information about weather, climate and water is used in every aspect of socio-economic activity and is increasing in importance as more numerous and more severe natural disasters strike populations, destroying lives and livelihoods and setting back economies of the most vulnerable for decades. The provision of that information requires a high level of commitment among nations and support to international cooperation. These form some of the basic tenets of the United Nations Millennium Development Goals and World Summit on Sustainable Development.

As this brochure has attempted to demonstrate, the issues at stake are intricately linked, interdependent and cross-cutting. No nation can achieve sustainable development alone and no organization alone can provide all the necessary assistance.

WMO is uniquely placed, together with its Member and partner organizations, and its networks of observing, monitoring and prediction systems and centres that underpin its operational and research programmes, to ensure a vital contribution in the field of weather, climate and water for human welfare and environmental protection in ensuring sustainable development in the 21st century.



WMO aims to provide leadership and expertise in issues related to weather, climate, water and the environment, and so contribute to the safety of well-being of people and the economic benefit of all nations.



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