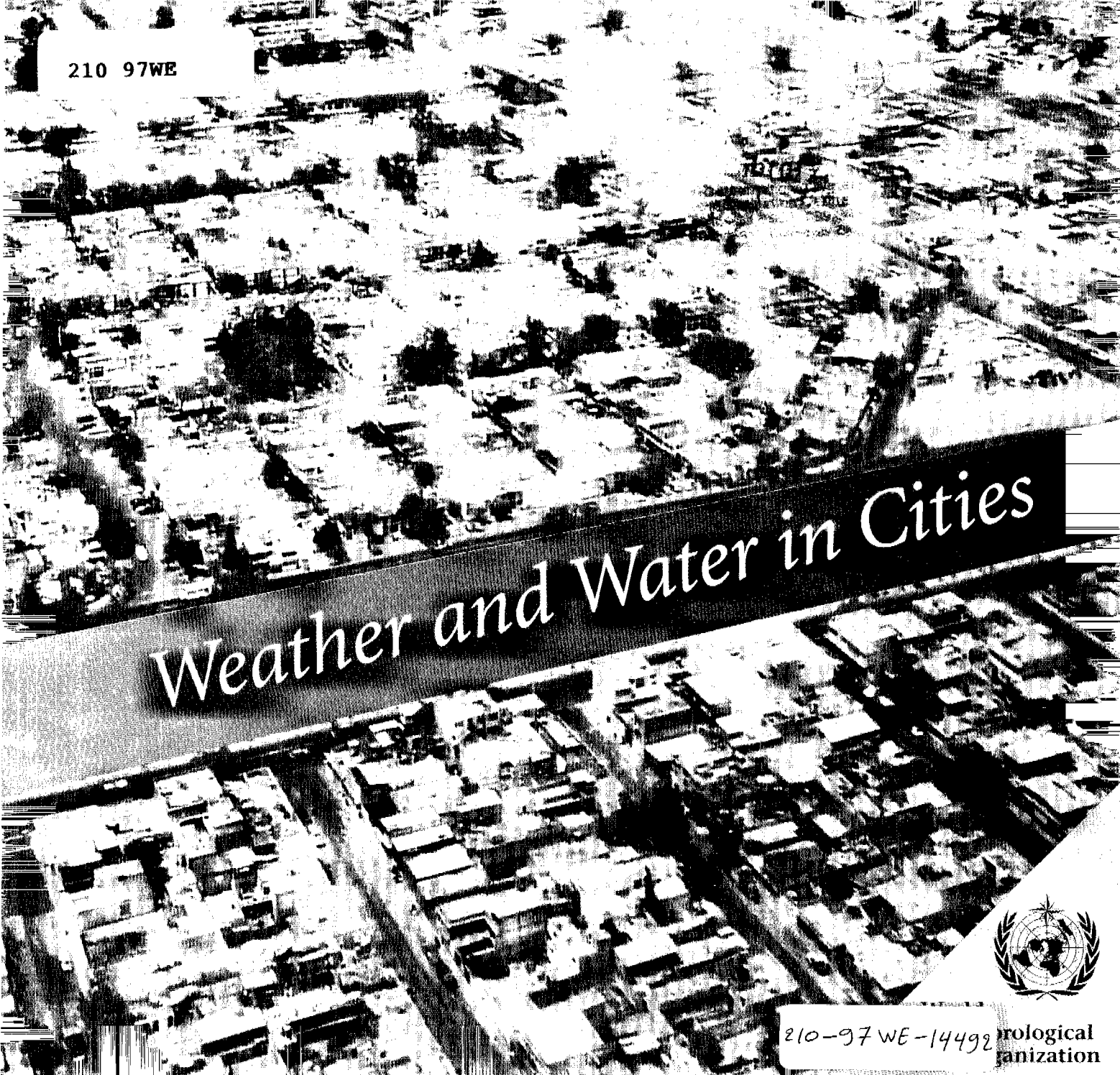

Weather and Water in Cities

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Weather and Water in Cities

WMO–No. 853

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1997

Cover: *Air pollution in Mexico City and many other cities in the world is a major health hazard* (P. Forster/WWF)

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NOTE

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FOREWORD

World Meteorological Day is celebrated annually on 23 March to commemorate the coming into force of the Convention of the World Meteorological Organization (WMO) in 1950. Each year, WMO celebrates the Day by focusing on a theme of topical or current interest to humankind. In view of the pressing urbanization problems facing our world today, and as a follow-up to the Second United Nations Conference on Human Settlements (HABITAT II) which was held in Istanbul, Turkey, in 1996, this year's theme — *Weather and water in cities* — is indeed appropriate.

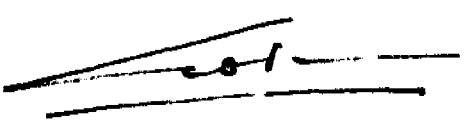
Large populations, heavy industrial activities and intensive energy use in urban areas have implications for local climate and the environment, agriculture and human health. In particular, urbanization has serious consequences on the availability and use of freshwater resources. A significant portion of urban dwellers in developing countries have limited or no access to a safe, potable water supply. As cities expand, so do their water requirements for domestic, industrial and agricultural use. It is therefore imperative for all nations to put in place appropriate mechanisms to ensure the effective monitoring and management of water.

Natural disasters pose one of the most serious threats to urban dwellers and severe meteorological and hydrological events account for 70 per cent of these disasters. Urban and peri-urban areas have become increasingly vulnerable, with high population density and human settlements rising along coastlines and on flood-prone lands. WMO places high priority on the enhancement of the capabilities of national Meteorological and Hydrological Services (NMHSs) to provide timely and accurate warnings and other advice to mitigate against natural disasters.

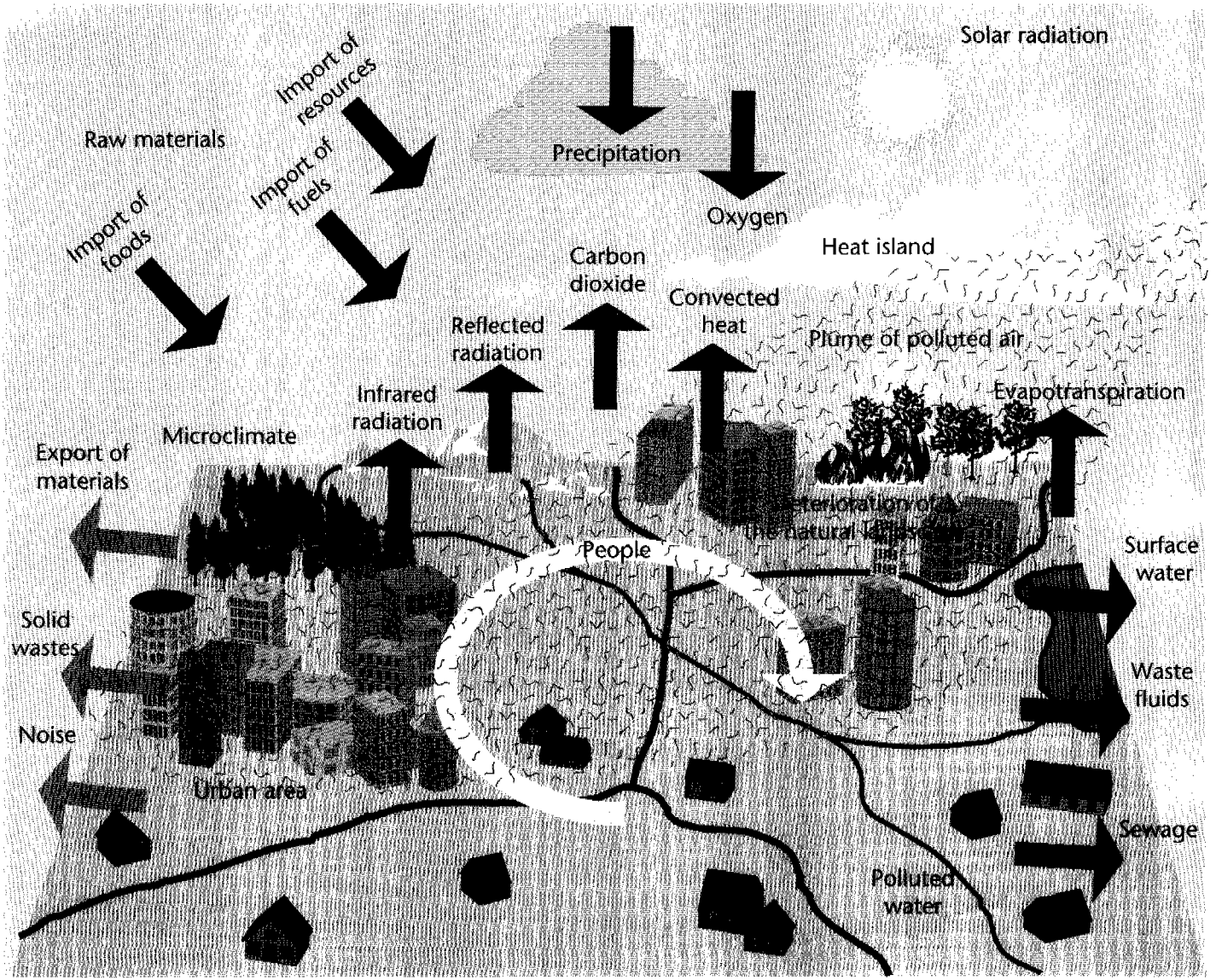
WMO's efforts to integrate climate knowledge into sound urban planning and management are therefore aimed at improving the quality of human life and the opportunity to use the city to its fullest and healthiest advantage, while seeking to prevent the climate from being jeopardized for future generations.

I wish to thank Mr Alex Kirby, a well-known journalist and environment correspondent, for his contribution to the preparation of this booklet. I also wish to express my appreciation to those experts within the meteorological and hydrological communities who were consulted on this publication.

On this World Meteorological Day, it is my hope that policy-makers, particularly city officials and planners, as well as the general public will recognize the value of meteorological, hydrological and climate information, as provided by the NMHSs in conjunction with WMO, towards "healthy cities" and sustainable urban development.



(G. O. P. Obasi)
Secretary-General



Developing sustainable human settlements

WEATHER, WATER AND CITY LIFE

What is the city but the people?

W. Shakespeare, *Coriolanus*

Major cities are not only centres of population and wealth but also of political power and trade. The World Bank describes cities everywhere as "makers of wealth, magnets for the industrious, motors of invention". It is not surprising then that nearly half of all people, generating more than half of all gross domestic product, now live in cities. The change is particularly striking in the developing world, where in 1960 hardly more than a fifth of the population lived in cities. By 1990, the proportion exceeded one-third and it will be more than half by 2020.

For many people, cities offer the prospect of something better than grinding rural deprivation. They are real "beacons of hope", holding out the prospect not only of survival but of satisfaction and fulfilment. Cities will inevitably occupy an increasingly important place in human affairs and the best efforts of policy-makers are aimed at improving the conditions of urban lives.

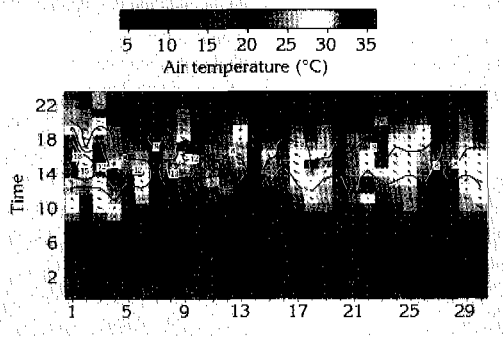
Climate, weather and water all affect cities directly and are at the same time affected by them. Weather and water shaped the emergence of civilization and remain central factors in sustainable development.

- The availability of water led to the rise of the first cities in Mesopotamia, the Indus Valley, by the Yellow River and the Nile 5 000 years ago. Cities whose populations exceeded their water supply, such as Ur in Mesopotamia and Mohenjo-daro in the Indus Basin, eventually declined.
- Despite the technological advances of the twentieth century, much of the world's population remains vulnerable to extreme weather and water events. In 1991, for example, 140 000 died as a result of a tropical cyclone in Bangladesh.
- The pressure of growing populations on global water resources is emerging as a serious long-term threat; almost 40 per cent of the world's population struggle daily to obtain enough water to meet their needs. Polluted water affects the health of some 1.2 thousand million people and each year contributes to the deaths of some 15 million children under five.
- Most cities in the developing world will suffer severe water shortages by 2010.

The weather and climate which still do so much to affect human activity remain largely beyond our control. If we are not much closer to being able to control them, we are, nevertheless, making rapid strides in our ability to understand the weather and the climate and to recognize how our activities affect them, thanks to the efforts of national Meteorological and Hydrological Services which also play a major role in both flood warning activities and in water-quality and conservation studies.

Ozone in the southern summer

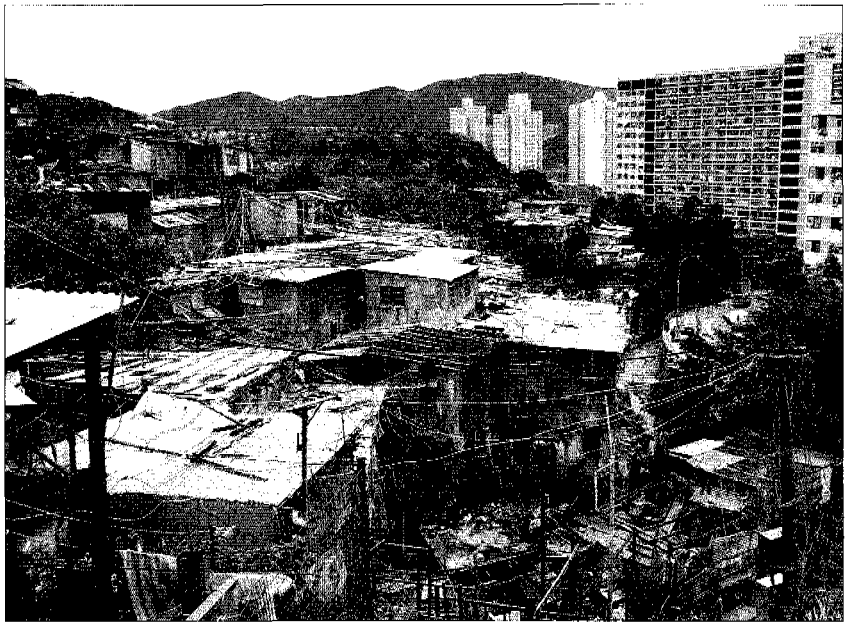
Ozone, produced by the action of sunlight on primary emissions mainly from cars, is particularly weather-sensitive. The weather conditions in Melbourne, Australia, for some 30 high ozone days (ranked by daily maximum ozone concentration — contours denote parts per hundred million) all with afternoon temperatures above 25°C are analysed below. Winds are commonly northerly in the morning turning south-west in the afternoon when ozone levels are at their highest. Pollutants from the morning peak hour apparently drift south over Port Phillip Bay, where the sun produces ozone, and then return with the afternoon sea-breeze to the city area.



chlorofluorocarbons and nitrous oxide are also significant contributors to what is known as global warming. Energy consumption in cities is one of the main sources of greenhouse gases. Climate change is examined in more detail on page 22.

Effluents

Another factor which determines the sustainability of cities and poses an increasingly serious dilemma to urban planners is the disposal of both solid and liquid wastes. Cities which dispose of their waste into rivers and lakes menace downstream communities and rural areas; some waste also seeps into groundwater reservoirs, resulting in disastrous consequences for all who draw drinking water from them (see also pages 14 to 17).



In many rapidly growing cities around the world, shanty towns and high-rise apartment blocks share the same neighbourhood (Peter Williams/WCC)

EFFECTS OF WEATHER AND CLIMATE ON DAILY LIFE

Human health and well-being are in many ways influenced by the local climate of cities and by the urban infrastructure which can contribute to increased heat stress and other health hazards. Nowadays, special weather forecasts are issued for many cities to alert urban populations of the likelihood of heat waves, storms, freezing weather, poor air quality and other hazards.

The weather and climate affect many of the activities in a city, from transport to recreation. Understanding the seasons and having access to good forecasts allows planners and businesses to make the best use of the prevailing conditions. In this way, the overall costs of maintaining a city and its population can be minimized, while economic opportunities can be seized to everyone's gain.

Fog over Melbourne (Chris Dewhirst)

Health

The human body operates best within a fairly narrow temperature range and abnormal heat or cold can impose severe stress. Some police forces, for example, believe that significantly more violent crimes are committed during very hot or stormy weather. Cardio-vascular disease is more likely to affect people suffering from severe stress because of extreme heat (or cold). There is a marked relationship between human mortality and thermal stress: during unusually hot episodes, deaths from all causes can rise by more than 50 per cent above normal levels, with the elderly at greater risk than others. Comparison of daily summer mortality rates with maximum temperatures suggests that this occurs only in the hottest summers. The actual temperature at which mortality rates begin to rise is related to average summer temperatures; it is much higher in places where summers are regularly extremely hot.

The core temperature of the human body itself has to remain near 37°C. Maintaining this in urban conditions — heated air, heightened humidity, reflected sunshine, winds funnelled by tall buildings and so on — can be difficult.

A recent WMO public awareness initiative, in cooperation with the US National Weather Service/National Oceanic and Atmospheric Administration, provided heat index cards to athletes, trainers and other visitors to Atlanta for the 1996 Summer Olympics. The size and shape of a credit card, the index cards allowed the user to see at a glance what the apparent temperature was, taking into account air temperature and relative humidity. The graph which related the two was colour-coded, to warn users whether they needed to exercise caution or were in actual danger. An air temperature of 34°C, for example, on a day

with 85 per cent relative humidity would give an apparent temperature of 57°C, an indication of extreme danger and of a high probability of heatstroke or sunstroke.

Even indoors, there can be problems. The tolerable worldwide thermal range in a building lies between 17° and 31°C; but the tolerance range of any one individual is generally smaller and usually decreases with age or illness. People who can afford to do so often try to ensure that they can enjoy a comfortable temperature indoors, whatever the season. Their efforts are sometimes overdone, suggesting that they are more concerned with providing an indoor refuge in sharp contrast to the blizzard or the furnace outside than with finding the best temperature in which human beings can operate. In some countries, supermarkets, shopping malls, offices, schools and restaurants seem to have their thermostats set to 23°C in winter, but as low as 20°C in summer.

Many infections are facilitated by weather conditions. Apart from the dangers of stagnant water and bad drainage, cold, heat and humidity can encourage disease.

Ambient temperatures

While good design and the application of new technology (and energy) can provide excellent conditions indoors and within vehicles, external temperatures are not controllable. Millions of city dwellers have no solid homes and are directly vulnerable to the weather. In tropical countries, most people can keep cool enough to survive normal conditions, but are in severe danger from extreme weather including heat waves, floods and storms. In cooler regions, normal winter conditions can pose a grave threat to the homeless and the shanty dwellers.

Storms

Thunderstorms are widespread, especially in tropical latitudes and during warmer months. Producing the strongest upward air motion of any weather system, they can spawn the most violent weather phenomenon: the tornado. Storms may also be associated with damage from large hailstones, strong wind gusts and downdrafts, flash flooding and lightning.

Extreme winds can wreak enormous damage even in well-built cities. In more dilapidated quarters, the danger to life from building collapse and falling masonry can be great. Coupled with the high population density in many developing cities, tropical cyclones can threaten the lives of hundreds of thousands of people.

Precipitation

Heavy rainfall is often unpleasant and may endanger the lives of street dwellers. Flash flooding can be a major threat to life and property in most urban areas. The threat is particularly high in large cities where heavy

Tornadoes which strike built-up areas may bring heavy tolls of death and destruction in their wake (AES, Canada)

"The most senseless extravagance sometimes observed in affluent countries is the practice of cooling buildings in summer to temperatures lower than those to which they are heated in winter!"

Climate and Human Health (WMO/WHO/UNEP, 1987, 1996)

rainfall can flood drainage systems quite quickly, often causing major disruption and damage.

If there is a danger from flash floods, planners could emulate the example of Phoenix in Arizona, which does not build homes on the areas at risk of flooding, but uses them instead for parks, golf courses, or similar more expendable functions. However, water management and emergency service agencies must continually remind communities of potential hazards where parts of natural flood plains are used for both flood control measures and recreational purposes. Children find opportunities for skate boarding, cycling and exploration in the concrete pipes and culverts used to improve the flow characteristics of natural watercourses. These artificial channels can flood quite rapidly.

In cold climates, snow is a major cause of difficulties. It disrupts rail, road and water transport links preventing commuters from reaching their destinations, cutting off services to many city dwellers and hindering commercial activities. Food and other essential supplies soon run low, prices rise and the poorest suffer first. The cost of keeping a city running in extreme cold conditions can put a major strain on its resources.

Accidents

While hot conditions may provoke unpredictable behaviour, icy cold can portend a grave increase in accidents. Just walking the city streets can be hazardous. When freezing conditions are rare, citizens are unfamiliar with them and in trying to disperse ice and snow on slippery surfaces may make the situation much worse, causing injury rates to rise to winter sports proportions.

Traffic accidents are also a feature of severe weather. Even well-prepared vehicles are much more likely to be involved in collisions when it is icy. Heavy rain and high winds contribute, too. Cities, with their high-density traffic, are particularly affected and many fatal accidents can be partially attributed to meteorological conditions.

Energy

Climate is a major factor in determining the demand for energy. Cities consume enormous quantities: to keep warm or cool, to keep transport moving and shops stocked with provisions all need energy. Some is produced by burning fuels within the city — fuel that has to be carried or piped into the urban areas consuming yet more energy.

Certain types of energy production and use depend on the climate: wind, solar radiation and rainfall determine the feasibility of renewable energy from wind and solar power and from hydro-electricity. Agricultural and forestry products grown for fuel are other forms of renewable energy which depend on climate.

The design of many energy installations depends on weather and climate information, for example, offshore oil-rigs require accurate sea and swell climatologies; and their safe day-to-day operation depends on accurate sea and wind forecasts. Regular weather forecasts are also essential to ensure that production meets demand.

WATER FOR GROWING CITIES

A human being can survive for weeks without food, but for only a matter of days without water. So it is with cities: it is possible to imagine a modern city coping in some way without its normal power supply, even — for a time — without mechanical transport. But deprive it of its supply of clean water, and it will very quickly turn into a disaster area.

During the HABITAT II Conference, a dialogue on "water for thirsty cities", in which WMO participated, warned that water was going to be "the most hotly contested urban issue facing the world community in the twenty-first century", because of rising population levels, pollution and the fact that half of all the developing world's drinkable water is either wasted or lost. This bleak analysis shows that most developing world cities will face extreme water shortages by 2010, threatening the health and even the lives of their inhabitants.

It has been said that the wars of the future are more likely to be fought over access to water than over oil. The recent agreement between India and Bangladesh on sharing the waters of the Ganges is a welcome positive precedent for future accords.

Freshwater resources as well as the world's oceans are closely linked with the atmosphere, weather and climate. They can only be husbanded and developed on a global scale. The freshwater issue calls for urgent and high-level international attention.

In most cities in the rich world, it is still possible to regard water as a given, something to be taken for granted. Water shortages simply don't happen, or, if they do, are caused by freak weather conditions, such as exceptional droughts. In many poor cities of the world, though, water is something nobody can afford to take for granted. What Dakar (see box above)

Economies under threat

In 1961, Dakar, the capital of Senegal, was a city of about a quarter of a million people. Most of its drinking water was drawn straight from the basalt aquifer on which it is built. But by 1988 Dakar's population had expanded to one and a half million. Pumping too much water from the aquifer had allowed salt water to penetrate it. So supplies had to be drawn from sedimentary aquifers 80 km away. These in their turn approached exhaustion and, finally, a pumping station was established in the Lac de Guier, a shallow reservoir created in a fossil river valley 200 km from the city. Despite this expensive undertaking, the overall water shortage threatens severe environmental decline and serious economic difficulties.

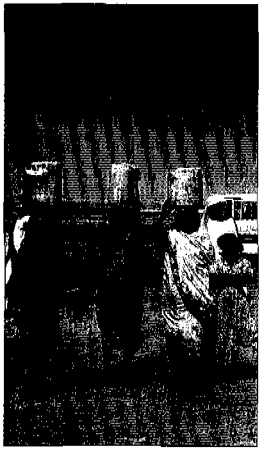
Senegal is not the only country to have experienced such problems. Peru was hit by an outbreak of cholera in 1991. It started in the capital, Lima, as a result of poor water and sanitation and spread quickly, killing 2 600 people. Tourism fell and other activities, including fisheries, were adversely affected. The economic loss was estimated at US $1.5 billion in three months — a sum which would have paid for a water supply and sanitation system for the entire population of Lima, at a cost of about US $50 per household.

International Water Decade

The UN General Assembly proclaimed the years from 1981 to 1990 the International Drinking Water Supply and Sanitation Decade, more popularly the Water Decade. On an average day during those ten years 330 000 people in developing countries gained access to safe water, with 210 000 acquiring better sanitation facilities — more than double the rate of provision during the 1970s.

However, during the decade, the urban population of developing countries grew by about 200 000 people a day. At the end of 1990, about one in five urban dwellers in developing countries still lacked adequate water supplies and about one in three were still without proper sanitation.

Poor sanitation and drainage in many cities of the developing world are the main causes of water-related illness and disease (UNCHS/Habitat)



Women bear the burden of managing and controlling the use of water (R. Helmer/WHO)

The World Bank says that several developing world cities will face severe water shortages and so will some in developed countries, including:

Africa	*Asia*	*Latin America*	*Developed countries*
Cairo	Bombay	Sao Paulo	Houston
Lagos	Shanghai	Mexico City	Los Angeles
	Beijing		Warsaw
	Calcutta		Tel Aviv
	Dhaka		Cardiff
	Djakarta		
	Karachi		

is suffering today is certain, on present trends, to confront other cities tomorrow. Water shock stares many of us in the face.

Water supplies

Rising numbers of people require water and sanitation. But the amount of water is itself finite. Some 70 per cent of the world is covered with water, but only about one-fortieth is fresh water and over two-thirds of that is frozen in the ice caps of Antarctica and Greenland. Most of the remainder is present in glaciers, as soil moisture, or deep underground, inaccessible for human use. As a result, less than one per cent of the world's fresh water is readily accessible for direct human use. Effectively, the sustainable water resources are equivalent to the precipitation falling on land. About 42 700 km^3 of water flows through the world's rivers every year. Divided by the world population of 1995, that amounts to an average of 7 300 m^3 of water per person, about 10 times the actual requirement, depending on local conditions. However, nowhere near all this water is accessible to population centres, much of it is lost and the unequal distribution and rapidly rising populations in the developing world cities mean than many millions suffer from severe water shortages.

Most of the available fresh water is destined for agriculture, and in a hungry and increasingly crowded world that proportion is very unlikely to diminish significantly. Industry uses some ten per cent of water resources, and contaminates a proportion of what is left over with its effluent streams. A bare five per cent is left for domestic consumers, to provide both safe drinking water and the means of disposing properly of waste.

The very fabric of some cities is being altered by the water crisis. Taking out too much groundwater has caused severe subsidence in a number of places, including Bangkok, Houston

and Venice. Parts of Mexico City have sunk by 10.7 metres in the last 70 years.

A wasted resource

Getting the available water to cities is a major problem, but huge amounts of it are then simply wasted. In most countries in the UN Economic Commission for Europe region, for example, between 40 and 60 per cent of treated water is lost in the network before it ever reaches the tap at a cost conservatively estimated at US $10 000 000 000 a year. In Kenya, the amount of water lost as "unaccounted for" in the capital, Nairobi, is equivalent to the needs of the country's second city, Mombasa. Many Asian cities have high loss rates: 62 per cent of water is described as unaccounted for in Dhaka, 58 per cent in Manila, 57 per cent in Djakarta. Often the problem is caused by the age of the pipe network, yet the loss can be reduced. In Brazil, Sao Paulo has cut the amount of water leaking from its distribution system by 50 per cent over a decade.

Not all the water destined for irrigation is actually used on the crop; much is lost. So there is scope for significant savings, as there is in industry, partly through changes in processes and partly through the wider use of recycling water. Only about five per cent of industrial and domestic waste receives significant treatment, and if this proportion could be significantly increased it would lessen the strain on freshwater resources.

Sanitation and drainage

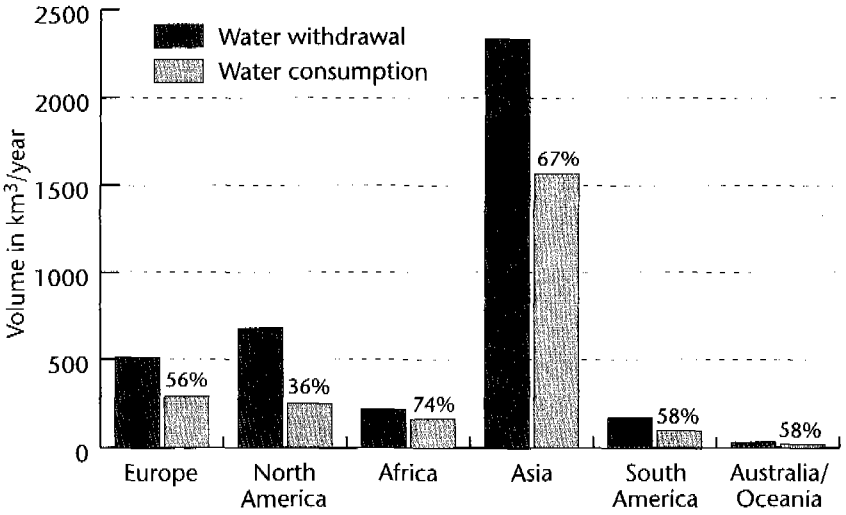
The developed countries learnt the benefits that flow from better water management in the nineteenth and early twentieth centuries with the gradual introduction of the water closet and main drainage. In 1850, life expectancy in a French city was about 32 years. By 1900 it had increased to 45, with a close correspondence

Habitat II

HABITAT II considered a number of mutually-reinforcing solutions needed to avoid a catastrophe early in the next century, including:

- Treating water as an economic commodity to allocate the true cost of water use for rich neighbourhoods and for industry and to help reduce wastage;
- Public-private partnerships to bring in extra investment. An example is the management leasing contract in the Côte d'Ivoire, where the operation and maintenance of the water services in Abidjan and several hundred other municipalities are provided by the private sector;
- Community participation, which promotes local employment and the acquisition of skills; women are especially important as agents of change.

Water withdrawal and consumption — regional distribution



Millions at risk

Today, in the developing world, more than one thousand million people cannot get clean drinking water and nearly double that number lack access to adequate sanitation facilities. Globally, of the two million tons of human excrement produced daily in the world's cities, less than two per cent receives any treatment. The rest is discharged into watercourses. Unsafe water is responsible for 80 per cent of diseases, affecting 1 200 000 000 people, and 33 per cent of deaths. Water-borne diseases account for more than four million infant and child deaths annually and compromise the physical and mental development of tens of millions more. UNICEF estimates that fifteen children in every thousand die before reaching the age of five from diarrhoeal disease.

In some cities, urban settlers may have to do their washing in a river

between the timing of the advances in health and changes in water supply and waste water disposal. Early this century, some US cities in the Ohio river valley used untreated water, while others treated theirs. Over a ten-year period death rates from typhoid remained constant in the cities which did not treat their water. In the others, death rates declined by more than 80 per cent.

Many long-established cities are facing considerable problems because their old sewage and drainage systems are falling into disrepair. The situation in the growing mega-cities in developing countries is even less satisfactory. Not only do they have to cope with seriously underdeveloped water and drainage systems, but also with dwindling water supplies, all of which makes the provision of adequate sanitation and drainage ever more problematic.

A costly necessity

The need for structural change is urgent. Not only are the poor far less likely to have access to safe water supplies and to adequate sanitation than the rich, but they will also often pay much more for the meagre supplies that are available to them. Globally, the urban poor may pay as much as half their income for water which is liable to be contaminated enough to make them ill. Its cost, by reducing their ability to buy food, also adds to malnutrition and child mortality.

Safe and sufficient water supplies and adequate sanitation could, today, more than halve the numbers of infants and children in the developing world who die preventable deaths.

PLANNING FOR THE EFFECTS OF WEATHER AND CLIMATE

Building cities that work is not only a matter of finding the right technical solutions and then applying them. That suggests that the people of the city are entirely passive, an inert medium which the planners can mould as they will. The greatest resource a city has is its people. And if attempts at turning cities into true beacons of hope are to have any chance of success, planners must start by asking what people want and responding to their needs.

Urban climate can be improved by appropriate city design, such as opening urban corridors and utilization of night-time breezes. Adapting buildings to urban climate, using climatological information available from the national Meteorological Services, helps to provide the needed comfort without having recourse to advanced technologies. Climate information helps design more liveable, comfortable and less energy-dependent cities. For instance, in climates with a cold winter and hot summer, where wind direction usually changes markedly with the seasons, streets at right angles to the winter wind offer shelter from cold winds, while opening them to summer breezes.

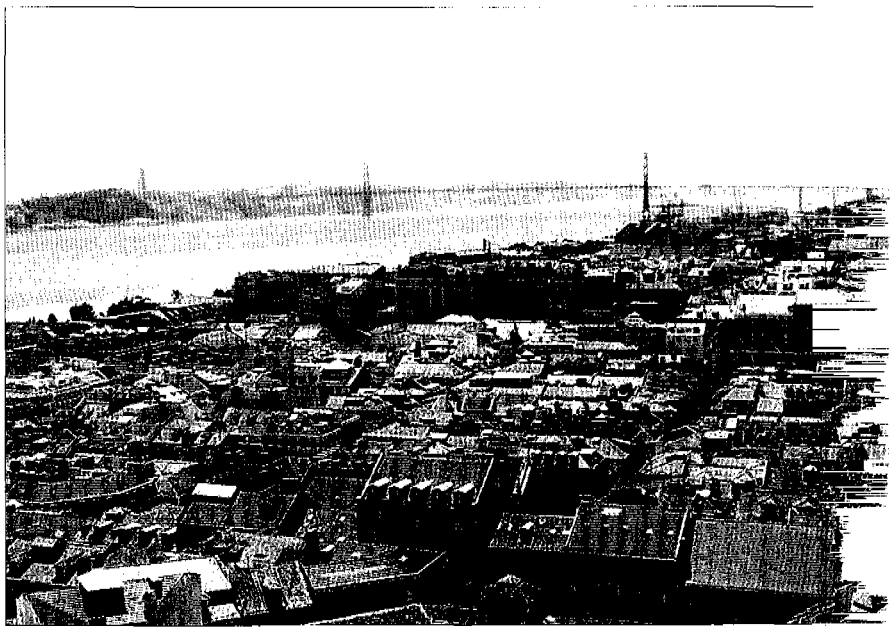
It is well-known that the weather in a city may be quite different from that in the surrounding countryside. This mainly man-made "local climate" manifests itself through urban heat islands, changes in wind, temperature, humidity, precipitation and solar radiation patterns, as well as through various forms of atmospheric pollutants such as high levels of tropospheric ozone. The resulting impacts include increased heat stress and other health hazards. In the context of its activities relating to the meteorological and climatological aspects of the urban environment, WMO is placing emphasis on the development and implementation of the Tropical Urban Climate Experiment in cooperation with national and international organizations, to coordinate the development of boundary-layer models in order to improve understanding of tropical urban climate and provide recommendations for urban and building design.

Building design

Meteorological information is essential when designing safe, viable, cost-effective structures to withstand climate hazards that may include wind, rain, hail and frosts, snow, tropical cyclones, flooding and storm surges. Climate knowledge also helps in the design of comfortable, low-energy buildings.

Architects working in the tropics aim to mitigate the effects of high temperatures and

Throughout the world, there is an accelerating trend towards urbanization and the ever growing cities are a



Good urban design ensures space for relaxation (Sabine/WMO)

humidity; in temperate climes, they seek summer heat protection while maximizing winter sunlight. Their tools include sun position charts which give the bearing and altitude angles of the sun.

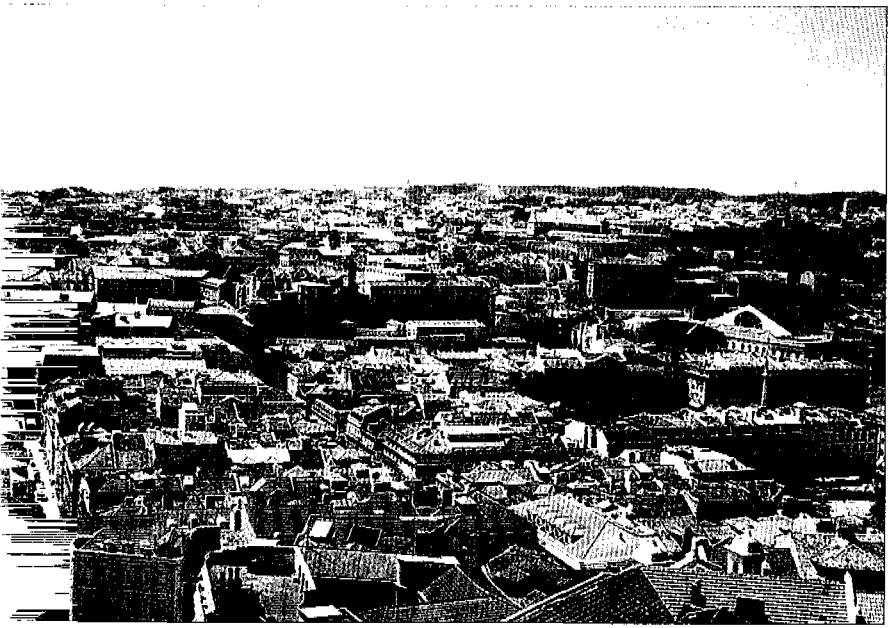
Planners and architects use detailed climate advice to minimize energy use, maximize comfort and reduce other weather impacts. Insulation against heat gain or loss is relatively expensive to install, but can be well-justified by the long-term savings on cooling or heating costs.

In some instances, an architect may orientate a house (or even a new suburb) to prevailing winds, calculate the optimum sun-angle of verandas, gauge guttering size for maximum expected rainfall, and work out cost-effective ceiling insulation. Climate-based wind tunnel tests help estimate the effect of wind disturbances on alternative designs of new buildings.

Engineers using the city's maximum rainfall estimates can design drains, culverts and flood basins to cope with rapid runoff and to replenish water reservoirs. Planners promoting sustainable development through water conservation and waste-water recycling depend on meteorological and hydrological advice.

There is very great scope for the provision of detailed practical advice on building, or rebuilding, cities in a way which will reduce their ecological footprint and make them pleasanter places in which to live and work. It is not a new science to make a city one or two degrees cooler than the surrounding desert, by providing space between the buildings, the use of trees and water, etc. Similarly, aligning the streets of a tropical city with the prevailing winds can create valuable natural ventilation.

WMO itself is in the course of constructing a new Headquarters building which should prove to be one of the most energy-efficient in the world. Double-skinned, and with automatic shutters, energy reservoirs and carefully calculated air-flows, the building will require minimum heat input in winter and no air conditioning in summer.



major source of greenhouse gas emissions because of their intensive use of energy (Gorre-Dale/WMO)

Service provision

The people in a city require a vast range of services and materials for their daily life: food, water, energy, clothing, transport, medical

CLIMATE CHANGE AND CITIES

It is not yet possible to say with certainty what climate change will mean in detail, how marked its effects may be, or which regions may expect particular consequences. But despite the uncertainties, there is a measure of broad agreement among the world's leading climate scientists within the WMO/UNEP Intergovernmental Panel on Climate Change about the likely range of consequences of global and regional climate changes which may ensue if nothing is done to mitigate or to avert them.

Cities make a heavy contribution to the gases considered responsible for global warming. It is estimated that a city of one million people generates 25 000 tons of CO_2 every day. At the same time, cities also stand to lose heavily as global warming intensifies. Several cities situated in coastal regions will be at direct risk from rising sea level. The inhabitants of almost every city will need to brace themselves to cope with more frequent and more intense heat waves. Many experts also predict that climate change will bring with it the hazard of increasingly severe weather events that will place an even greater strain on the already beleaguered city administrations and on their preparations to cope with natural distasters.

Flooding in Montezuma, Georgia, USA, in July 1994 (Johnny Crawford)

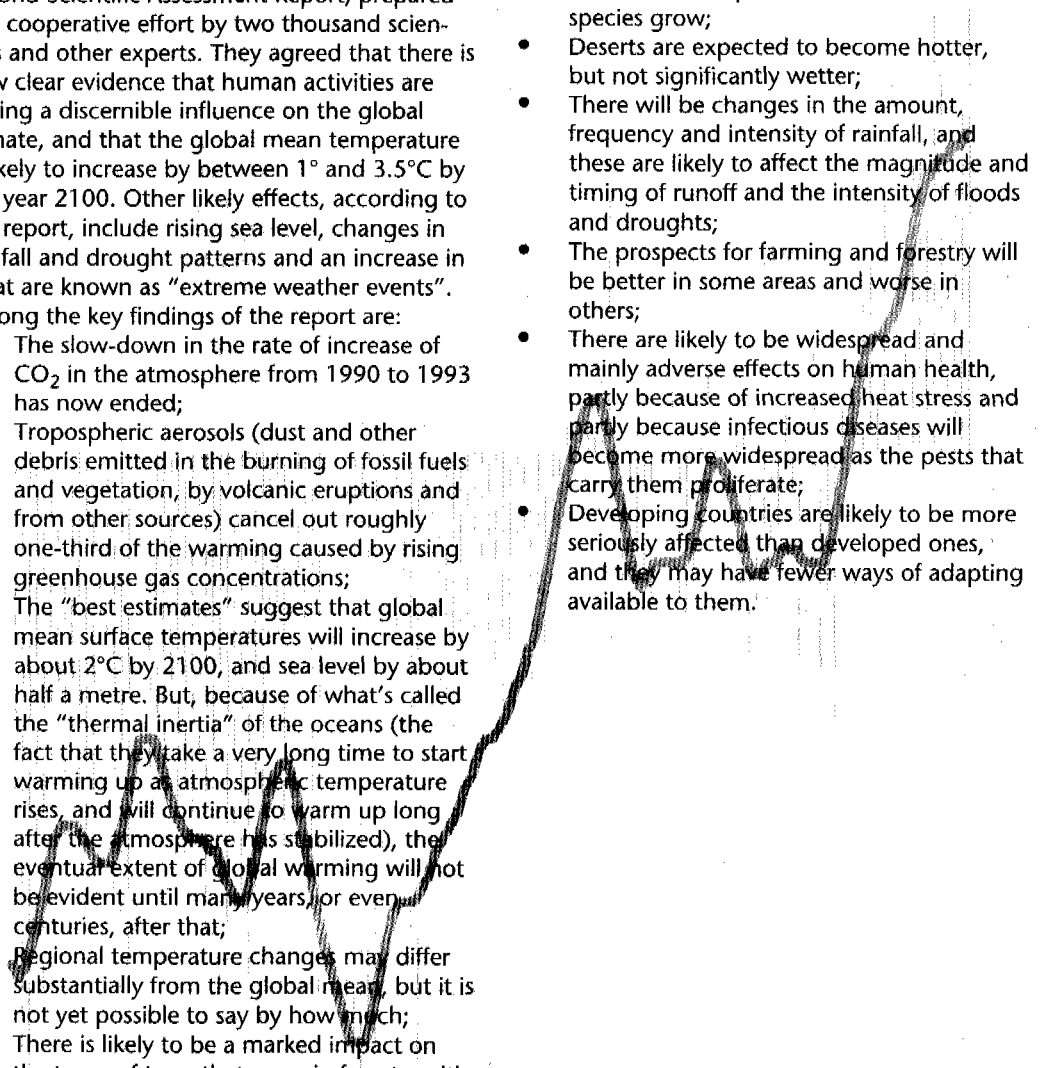
The food and water drawn in from the hinterlands that keep cities alive will themselves be subject to unpredictable stresses and increased demands. Supply lines may grow even longer and more difficult.

It is becoming increasingly urgent for governments to recognize the role of cities in worsening global warming, and the risks city dwellers will run as global warming builds up.

IPCC conclusions

In December 1995, the IPCC presented its Second Scientific Assessment Report, prepared in a cooperative effort by two thousand scientists and other experts. They agreed that there is now clear evidence that human activities are having a discernible influence on the global climate, and that the global mean temperature is likely to increase by between 1° and 3.5°C by the year 2100. Other likely effects, according to the report, include rising sea level, changes in rainfall and drought patterns and an increase in what are known as "extreme weather events". Among the key findings of the report are:

- The slow-down in the rate of increase of CO_2 in the atmosphere from 1990 to 1993 has now ended;
- Tropospheric aerosols (dust and other debris emitted in the burning of fossil fuels and vegetation, by volcanic eruptions and from other sources) cancel out roughly one-third of the warming caused by rising greenhouse gas concentrations;
- The "best estimates" suggest that global mean surface temperatures will increase by about 2°C by 2100, and sea level by about half a metre. But, because of what's called the "thermal inertia" of the oceans (the fact that they take a very long time to start warming up as atmospheric temperature rises, and will continue to warm up long after the atmosphere has stabilized), the eventual extent of global warming will not be evident until many years, or even centuries, after that;
- Regional temperature changes may differ substantially from the global mean, but it is not yet possible to say by how much;
- There is likely to be a marked impact on the types of trees that grow in forests, with the greatest changes occurring in high latitudes and the smallest in the tropics. Climate change is expected to be rapid in relation to the speed at which forest species grow;
- Deserts are expected to become hotter, but not significantly wetter;
- There will be changes in the amount, frequency and intensity of rainfall, and these are likely to affect the magnitude and timing of runoff and the intensity of floods and droughts;
- The prospects for farming and forestry will be better in some areas and worse in others;
- There are likely to be widespread and mainly adverse effects on human health, partly because of increased heat stress and partly because infectious diseases will become more widespread as the pests that carry them proliferate;
- Developing countries are likely to be more seriously affected than developed ones, and they may have fewer ways of adapting available to them.



Global surface temperature variations from 1860 to present

IN CONCLUSION

Urban population growth is exerting enormous pressure on the environment and on the dwindling finite resources of our planet, making consideration of weather and water in cities appropriate and timely.

The implications of environmental changes for cities were recently addressed during HABITAT II. Its outcome, the Habitat Agenda, reflects the priority issues to be addressed, such as natural disasters, availability of fresh water, environmental pollution and climate change. With high population density and settlement in flood-prone marginal lands, city dwellers are becoming increasingly vulnerable to adverse weather conditions.

The effects of urbanization and its environmental impacts have serious consequences on the availability of freshwater resources. Between 1900 and 1995, water withdrawal from existing sources increased six-fold. A significant proportion of urban dwellers, particularly in developing countries, have limited or no access to a safe, potable water supply.

As cities expand, so do their water requirements and it becomes more and more difficult, and more expensive, to meet this demand to the point that water rationing is being introduced in many cities. Furthermore, water often has to be transported from very distant locations, at a very high cost. Urban development is driven by socio-economic and strategic forces, which often have little to do with the resources required. However, history has shown that the provision of water resources can determine whether a city will flourish or not.

WMO, as the authoritative scientific voice in matters relating to the atmosphere, climate and water, is playing a leading role in international efforts to monitor and protect the environment, through its scientific programmes, such as the World Weather Watch, the World Climate Programme, the Atmospheric Research and Environment Programme and the Hydrology and Water Resources Programme.

Through its collaboration with other UN agencies and the national Meteorological and Hydrological Services of Member countries, WMO continues to support relevant conventions such as the UN Framework Convention on Climate Change, the ongoing negotiations on the International Convention to Combat Desertification and the Vienna Convention on the Protection of the Ozone Layer and its Protocols and Amendments. These activities contribute towards ensuring the well-being of all people in all nations, whether living in cities or in rural areas.

The day-to-day well-being of all people, especially the burgeoning urban populations, depends on ever more complex and accurate meteorological and hydrological information. This can only be supplied through well-funded national Meteorological and Hydrological Services, which are more than ever vital to the wise management of our environment.

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