

# A CAREER IN METEOROLOGY



**World  
Meteorological  
Organization**

Weather • Climate • Water

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# **A CAREER IN METEOROLOGY**

## **A career in meteorology**

This book is a brief introduction to a career in meteorology. For more information about qualifications, training and opportunities, you are invited to consult your career advisor or your local or national weather service.

For more information about the work of WMO, see the Organization's homepage at [www.wmo.int](http://www.wmo.int). A list of national weather services worldwide, including those with an Internet link, is available at [www.wmo.int/pages/members/members\\_en.html](http://www.wmo.int/pages/members/members_en.html).

Publications offering an insight into the activities of meteorologists and climatologists include: *WMO at a glance*, the *WMO Bulletin* and *MeteoWorld* (print and Web versions).

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# FOREWORD

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The weather. We all talk about it, make our daily plans based on forecasts and complain when bad weather spoils our weekend. But some people take this general interest in weather even further and try to do something about it: they choose a career in meteorology.

The weather does much more than determine how people dress or how they can enjoy themselves outdoors. Weather can be dangerous, causing floods, storms and heatwaves that can kill or injure. Individuals and communities need to remain alert to weather conditions and forecasts in order to protect their lives and property.

Agriculture, civil aviation and shipping, and many types of business, also depend heavily on modern weather monitoring and prediction. With access to reliable forecasts, farmers can adapt their schedules for planting, harvesting and other activities as needed. Transport is highly vulnerable to wind and storm conditions, which is why many weather stations are based at airports. Construction, energy, tourism and many other industries are also strongly affected by weather conditions.

Improved scientific understanding of how the atmosphere, ocean, land and water cycles interact to produce the weather makes it increasingly possible

to address the impacts of climate – defined as the average weather over a 30-year period – on people and economies. Meteorologists and climate scientists are starting to make seasonal and longer-term forecasts and to blur the boundaries between weather and climate prediction by developing “seamless weather and climate forecasts”. Climate services that draw on these forecasts will become all the more essential as human-induced climate change affects weather patterns and extreme events over the coming decades.

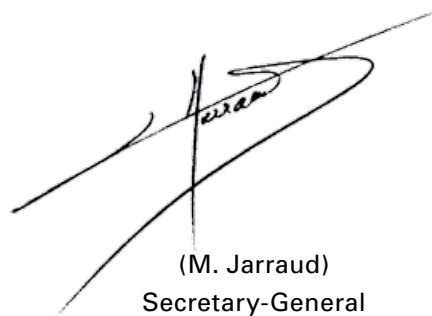
Choosing a career in meteorology would allow you to make a vital contribution to the safety and well-being of your community and country. It would also give you the opportunity to develop and apply a wide variety of skills and knowledge that can be personally satisfying. As described in this booklet, meteorology is a subject that cuts across many disciplines. Meteorological services require people who understand physics, management, information technology, engineering, communications, and many other domains. There is plenty of room in meteorology for people with a wide array of talents and interests.

This second edition of *A Career in Meteorology* is being published to mark the 2014 World Meteorological Day, whose theme is “Weather and climate:

Engaging youth". Since the first edition was published in 2006, weather and the related concerns of climate and hydrology have gained an increasingly high profile. In 2007, the Intergovernmental Panel on Climate Change (IPCC), established by the World Meteorological Organization and the United Nations Environment Programme, won the Nobel Peace Prize. Today, weather and climate are featuring prominently in the development of the United Nations post-2015 Sustainable Development Goals and of the post-2015 phase of the Hyogo Framework for Action on disaster risk reduction.

From the daily concerns of friends and family to the success of key economic sectors and answers

to major global concerns, meteorology has a vital role to play. I encourage all young people to learn more about this highly gratifying field.

A handwritten signature in black ink, appearing to read 'M. Jarraud', is written over a thin vertical line.

(M. Jarraud)  
Secretary-General  
World Meteorological Organization

# TOWARDS A BETTER WORLD

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## **Promoting sustainable development and environmental protection through governance and policymaking**

Nearly all areas of human activity are weather-, climate- and water-sensitive. Of particular importance is the impact of weather and climate fluctuations on food production. Other areas, including fisheries and forestry, energy and water resources management, land, marine and aviation transport, banking and insurance, construction and urban design, all benefit directly from services provided by meteorologists. The provision and application of accurate and timely weather information, forecasts and warnings contribute to human well-being and are of considerable benefit to socio-economic development and environmental protection.

There is growing concern about the impacts on human societies of extreme events such as tropical cyclones, floods, droughts and heat waves. Some of these events cause enormous destruction and loss of life with long-lasting effects. Meteorologists, in collaboration with atmospheric chemists and hydrologists, issue early warnings of natural hazards so that immediate action can be taken to reduce the loss of life and property. They provide advice about how to prevent and manage the risks and impacts of these events in the longer term.

Climate variability and change, ozone depletion, dwindling freshwater resources, desertification and increased pollution have important impacts on the global environment. Meteorologists put much

effort into monitoring, assessing and predicting these changes and helping policy-makers develop strategies for dealing with them. Hydrologists also play a vital role by studying the water cycle – the continuous movement of water on, above and below the surface of the Earth – and its impact on the distribution and supply of water.

Exactly what meteorologists do depends upon local requirements and the structure of the national meteorological service. This brochure aims to give an insight into the nature and scope of work carried out by meteorologists.

Meteorologists must not only understand weather, climate and water but also be able to present the information to users in a manner that is timely and easy to understand and use.

Meteorology is an exciting, challenging and highly rewarding profession.





**The combination of skills required of a meteorologist means satisfying and demanding jobs that contribute to social well-being and economic development.**

Weather information facilitates long-term planning to meet expected demands for water, energy and food security.

Weather and climate information is a vital input to planning for building design and location, siting of energy structures and flood control and prevention structures.

Every dollar invested in meteorological and hydrological services produces an economic return many times greater, often 10 times or more.

Agriculture, aviation, land and sea transport and fishing rely on weather and climate information for optimal results.



# IMPROVING OUR WELL-BEING

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## Helping individuals and organizations make decisions

Weather and climate are both natural resources and hazards. They support but can also pose a threat to life, property and the environment. In some cases, such as tornadoes and thunderstorms, the impact is usually limited to a relatively small area over a short period of time and affects relatively few people. By contrast, drought and flooding cause widespread and long-lasting damage, as does desertification. As well as the immediate threat posed by severe and extreme weather, indirect effects include disease and famine.

Meteorologists play a key advisory role when disasters occur. In cooperation with governments, they help educate the public and raise awareness about weather-related disasters. Their advice assists in preparing for disasters and finding ways of preventing them from happening.

Many commercial organizations use specialized weather and climate information services to support their decision-making. Agriculture, road and marine transport, energy and water resources management, offshore exploration, aviation and tourism are particularly sensitive to the weather. Good forecasts and climate information help ensure that these activities are carried out safely and efficiently and that long-term plans take full account of any expected changes in the climate.

Demand for energy supplies is highly weather-dependent (heating in cold weather, cooling in hot). Forecasters provide information that assists suppliers in ensuring that day-to-day requirements for gas and electricity are met. Similarly, the management of water resources requires timely and accurate information about the weather, especially rainfall, to be provided by forecasters.

Weather information, forecasts, and warnings improve public safety and are of enormous potential economic benefit.

The weather and climate information given to the public helps them take decisions, for example:

- How to react in response to warnings of severe weather or poor air quality;
- Whether to participate in sporting and other outdoor leisure activities;
- Making travel arrangements;
- Where to go on holiday.





**Arctic regions of the globe sustain a significant number of inhabitants whose livelihood and traditional ways of life are at risk from climate change. Weather and climate information helps ensure that indigenous peoples can preserve their traditional cultures.**

Meteorologists provide governmental bodies, industrial concerns and members of the public with forecasts and warnings that allow them to make better decisions about weather-sensitive operations.

The tourism industry uses weather and climate information to contribute to the safety and security of tourists and to promote specific regions as attractive destinations.

Disasters caused by weather-, climate- and water-related hazards are on the rise worldwide. Both industrialized and non-industrialized countries are bearing the burden of repeated floods, droughts, temperature extremes and storms.

In the United States of America, the value of weather- and climate-sensitive industries has been estimated at about US\$ 3 trillion.



# OBSERVING THE WEATHER

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## Taking the pulse of the planet

Accurate observations about the current weather are the basis of a good weather forecast. This information is also required to monitor the climate. Traditional sources of observations are observing stations on land and at sea and upper-air soundings. Today, satellites, radar and aircraft are an increasingly vital source of information.

There are many different instruments at an observing site. Some measure temperature and humidity. Others measure air pressure, wind speed and direction, rainfall and sunshine duration.

Weather Services of maritime countries make arrangements with ships to take observations at sea and transmit them to shore. The observations are usually provided free of charge by shipping companies in return for the instrumentation and the forecasting and warning service.

Upper-air soundings are obtained by releasing a balloon that carries instruments through the atmosphere. Information about pressure, temperature, humidity and wind is sent back to a ground station.

Wind and other useful atmospheric information is also deduced from satellite data. Satellite meteorologists develop the processes for turning the vast amount of data into useful information and products.

The improved accuracy of weather forecasts over the last 30 years is partly due to the increase in

the amount of satellite data available, along with advances made in extracting useful information for use in computer models.

Radar meteorologists have developed techniques for obtaining information about rainfall and wind from radar signals. This information shows the distribution and intensity of the rainfall and is used to forecast tornadoes.

Forecasters depend upon information from satellites to help identify the location and development of weather systems, especially over the oceans. In addition, radar products provide forecasters with detailed information about the structure of rainfall. A series of satellite and radar images helps forecasters make detailed predictions of the weather over the next six hours or so. Such techniques are especially useful for providing warnings of heavy rainfall.





**Observations are the very foundation of meteorology and climatology. Meteorologists acquire, process and interpret data from instruments on land, at sea, in the sky and in space for use in weather forecasting, climate monitoring and the provision of meteorological services and products.**

The WMO Global Observing System includes 10 000 manned and automatic weather stations and 1 000 upper-air stations.

Over the oceans, observations are provided from 100 moored buoys, 1 000 drifting buoys and 7 000 ships.

Geostationary satellites sit 36 000 km above the Equator and orbit the Earth once every 24 hours.

Polar-orbiting satellites are about 1 000 km above the ground and orbit over the poles every few hours.

In addition to monitoring weather and climate, satellites are used to estimate crop and soil conditions and concentrations of atmospheric ozone.

# ENGINEERING SOLUTIONS

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## Sharing information about our environment

The need for high-quality observations underpins nearly all activities carried out by meteorologists. Networks of observing stations provide this information, using a wide variety of equipment for data acquisition.

Increasingly, automatic weather stations using electronic components for data sampling and processing are being installed. These stations contain sensors that, unlike traditional instruments, do not require observers to read them.

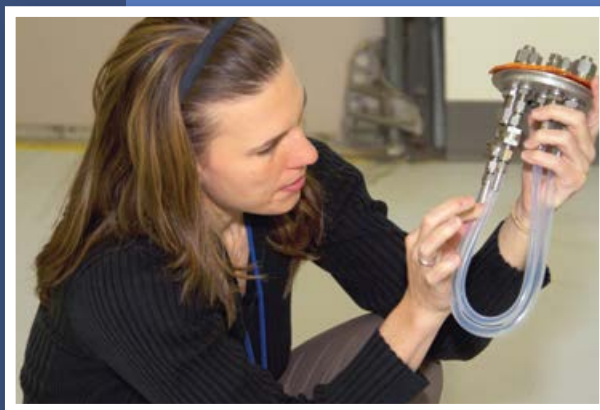
Engineers are responsible for installing, commissioning, maintaining and repairing equipment. These activities are often performed in remote areas and in difficult conditions, so engineers have to be resourceful.

The installation of instruments is often far from straightforward. Permission for use of the land may be required. Power supplies and access to the telecommunications network may be problematic. Some site work may be needed, such as the provision of concrete plinths, cable trenches and equipment shelters. This may involve the use of contractors who are supervised by instrument technicians. Liaison with instrument manufacturers may also be required.

Technical documentation must be prepared, along with operating, maintenance and calibration procedures. Technical problems and instrument failures have to be monitored. If fundamental faults with equipment are identified, remedial action is taken to avoid such problems occurring again.

Some engineers develop computing and telecommunications equipment to support the observing network. Some work with research scientists to design, build and calibrate new instruments and sensors, such as those used in automatic weather stations and on board satellites.





**Engineers provide the solutions for maintaining essential observing equipment. They invent new instruments and sensors on land, in the air, at sea and in space, to ensure the optimal collection of data.**

Engineers develop and maintain observing systems that provide the data needed for research and the provision of a wide variety of meteorological services.

The basis of weather- and climate-related work is observations. To carry out observations, reliable instruments are required.

Reliable instruments mean reliable measurements.

Equipment, sensors, computers and computer programs are constantly evolving to meet the growing needs of operational and research meteorologists.



# TURNING DATA INTO PRODUCTS

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## Using advanced information and communication technology

Observations are collected using national telecommunications networks and transmitted around the world through the WMO Information System (WIS). WIS incorporates the Global Telecommunication System (GTS), which was established as a dedicated network to support the WMO World Weather Watch Programme, and is used to share weather, climate and water products.

Responsibility for acquiring and commissioning the systems needed to support WIS lies with the information and communication technology (ICT) specialists who develop and maintain the associated software. They also develop, maintain and monitor the national networks needed to support the flow of data and information. This is essential for ensuring that observations are collected and weather services provided without serious interruption.

Observational and forecast data need to be stored in databases so that the data are available whenever required. The quantity and variety of data and the need to provide ready access pose significant problems for ICT specialists who are responsible for the infrastructure that supports operational activities. This involves implementing and maintaining a variety of hardware and software, including servers, meteorological workstations and supercomputers. Web technology is increasingly being used. ICT specialists

ensure that services are maintained, infrastructure is working effectively and new technologies are supported.

Forecasters need to be able to display observations, analyses and forecasts on meteorological workstations. These workstations prepare weather products and warnings and send them to the appropriate users. ICT specialists maintain and develop these systems to meet ever-changing requirements.

The development of software to process satellite and radar data, run computer models, and prepare meteorological products requires expertise in programming languages, network requirements and user interfaces, as well as meteorology.





**ICT specialists maintain and develop programs to prepare products such as forecasts and warnings and to transmit them to all concerned.**

ICT specialists develop and maintain the infrastructure and application software that allows weather information to be collected, processed, displayed and communicated.

ICT specialists in meteorology need to know about programming languages, network requirements and user interfaces – and meteorology!

Meteorological information systems (data management and processing and telecommunications) are becoming the centre of attention of most weather services.

The WMO Information System is the backbone of multi-hazard early warning systems.



# FORECASTING THE WEATHER

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## Using computers to forecast the weather

The behaviour of the atmosphere is simulated using computer models which make a detailed analysis of the state of the atmosphere at a particular time, using the latest available observations, and then apply the laws of physics to forecast what will occur.

Most computer models use a three-dimensional grid to represent the atmosphere. At each grid point, information is recorded about pressure, temperature, humidity and wind.

The starting point for making a forecast is to collect observations from around the world using the WMO Information System, which transmits surface observations, as well as data from satellites, radar and aircraft. Once the observations have been checked, they are used to determine the atmospheric variables at each grid point at the start of the forecast.

Some of the complex processes taking place in the atmosphere cannot be fully described and represented precisely in the models so their effects have to be estimated. This is called “parameterization”. Research meteorologists use field experiments and physical principles to understand these processes and then develop the parameterization schemes.

The numerical models use the initial grid-point values, laws of physics regarding the behaviour of fluids and parameterization schemes to make a prediction of the change in grid-point values a short time ahead. New grid-point values are then

calculated and the process is repeated. In this way, a forecast is built up.

With powerful computers becoming more widely available, the models are being improved constantly, allowing the behaviour of the atmosphere to be better modelled and resulting in ever-increasing accuracy of the forecasts. More and more data are being used in the modelling of the atmosphere as soon as they are collected (this is what is called “real time”). New modelling methods are also being used to improve the estimates of the confidence we should have in the forecasts.

Today, predictions made by computer models include a wide range of geographical coverage and time-scales. Some models can predict weather conditions with great detail in the short range, i.e. two to three days into the future, while others can predict general weather patterns several seasons ahead.

The increasing power of computers is allowing meteorologists to benefit from multiple runs of atmospheric models to create ensemble forecasts (based on a group of forecasts) or probabilistic forecasts (e.g. there is a 30 per cent chance of rain). This is useful because sometimes small changes in initial conditions can lead to big differences in the resulting forecast.



**Weather forecasts are becoming increasingly accurate and reliable, thanks to better understanding of atmospheric processes, improved techniques and greater computer power.**

Computer models take into account processes such as cloud and rainfall formation, radiation transfer and interactions at the Earth's surface.

The skill of the models varies considerably. Some can predict weather conditions accurately two to three days ahead; others can predict general weather patterns several seasons ahead.

Some results of weather forecasts are incorporated in hydrological models that are subsequently used to make decisions on how to manage water resources, hydraulic works and reservoirs, and to issue warnings such as of imminent flooding.





# REACHING PEOPLE

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## **Presenting the weather – radio, television and newspapers**

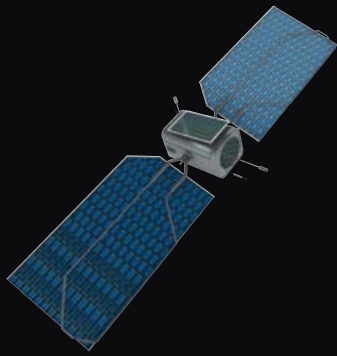
Weather forecast presentations on television are popular and attract a consistently high number of viewers worldwide. Radio broadcasts are another important way to provide weather information to the public. The increasing use of Internet technologies and smart phones is further expanding access to weather information. A professional meteorologist who presents the weather is called a broadcast meteorologist.

Broadcast meteorologists must have the ability to turn detailed and complex information into a “weather story” that is readily understandable to the public. Those who present weather forecasts on television are able to use a wide range of visual meteorological information, including satellite and radar pictures. This, coupled with improvements in display technology, has made presentations more attractive and informative.

Broadcast meteorologists making radio presentations have a rather more difficult task. They need great skill in presenting the information in a way that listeners can easily assimilate.

Weather presenters inform the public about the onset of severe weather events and their likely impacts, as well as any preparations they are advised to take. Recent improvements in the accuracy of forecasts and better use by meteorologists of the media have contributed significantly to the reduction of deaths and injuries associated with severe weather events.

An enormous amount of weather information is available via the Internet. Some meteorological websites are frequently updated, providing access to up-to-date weather information on demand. Developing good websites requires the same combination of meteorological knowledge and presentation skills possessed by broadcast meteorologists, as well as those of information and communication technology.



**TV weather presenters need to be able to combine scientific knowledge and the skill to communicate that knowledge to a wide range of interested viewers. Their role is vital at times of impending severe weather events.**

Broadcast meteorologists inform and educate the public about the weather using radio and television. They have a key role in providing warnings about severe weather.

The most common means of reception of weather forecasts and warnings is by radio (100 per cent worldwide) and television (93 per cent worldwide).

National television weather broadcasts cover large geographical areas, but the broader the area, the more general the forecast.

Radio is often the only effective mechanism for providing warnings of severe weather events and information in the aftermath of disasters. It is particularly useful for communities in remote rural areas.

# DEALING WITH CLIMATE CHANGE

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## Monitoring and predicting the climate

Climate influences a wide variety of human activities and is very important for social and economic well-being. It varies naturally and may lead to extreme weather events such as severe storms, floods and droughts.

Climatologists monitor the climate. They do this by examining averages and extreme values of various weather elements, such as rainfall and temperature, and the frequency with which weather events occur over a long period of time, usually about 30 years. Climate summaries of this information and analyses of change over time help people make decisions about weather-sensitive activities. Construction, agriculture and insurance are a few examples.

In the past, the climate has changed due to natural causes, such as major changes in ocean circulation, volcanic activity and solar variation. There is now clear evidence that human activity has contributed to the increase in mean global temperature over the last 100 years. This warming has been attributed mainly to the increase in carbon dioxide and other greenhouse gases in the atmosphere, with the increased burning of fossil fuels being the major cause.

The polar regions are powerful engines behind the global climate. A great deal of research in these areas needs to be carried out in order to further our understanding of climate and our ability to make climate projections. Much evidence of past climate variations is stored in the ice of these frozen regions.

Changes in the climate affect the health, economic development and general well-being of large numbers of people. The ability of climate researchers and modellers to forecast future conditions is of vital importance. Their work makes it possible to evaluate options for reducing climate change and its impacts on ecosystems, tourism, sustainable development and even the very existence of some small islands.





**Ice cores contain samples of gases in the air up to 800 000 years old. This information is significant for ongoing studies of climate change. The polar regions are also studied to understand their role in the global climate system, its variability and changes.**

Climatologists provide information about the present and future climate to help individuals, companies and governments make long-term decisions about weather-sensitive activities.

The average surface temperature has increased by about 0.85°C during the last 130 years. It is estimated that the average temperature will exceed pre-industrial levels by 1.5°C by the end of the century, unless ambitious reductions are made in emissions, and it could increase by more than 4°C under “business-as-usual” scenarios. The mean sea level has already risen by 19 cm since 1900 and is expected to rise by 32–98 cm by 2100.

Each of the last three decades has been successively warmer at the Earth’s surface than any preceding decade since at least 1850.

Climate change could cause water requirements to outstrip supply, flood damage and coastal erosion to occur in low-lying countries and island States, and encourage the spread of tropical diseases into mid-latitudes.



# MAKING TRAVEL SAFER

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## **Providing timely and accurate information about conditions in the air, at sea and on land**

Aviation forecasters provide services that help reduce departure delays, flight times and fuel consumption, and ensure the safety and comfort of passengers. Of particular importance in these forecasts is advice concerning weather conditions that may be hazardous to aircraft on take-off, landing and in flight, such as strong wind, thunderstorms, turbulence and icing.

Forecasters must understand the causes of aviation hazards and know how to forecast their occurrence. In addition, they must know how to issue weather products in a clear and structured manner to a variety of users, including pilots and air traffic controllers.

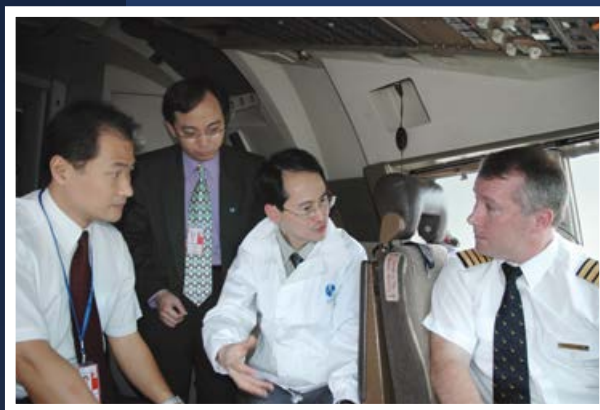
Marine meteorologists prepare advice for shipping which includes information on the location, track and intensity of severe storms and warnings of strong winds, fog and other hazards, as well as general forecasts of weather and sea state. Ships are therefore able to alter course so as to avoid adverse weather conditions. By so doing, the safety of ships, their cargoes and passengers is enhanced and savings in fuel are made.

Marine meteorologists are also involved in responses to hazards at sea. They support search-and-rescue activities and provide important information in the event of oil spills. They are often called upon to investigate the weather and sea conditions at the time of maritime accidents.

Fog, blowing snow, heavy rain, strong winds and icy roads create hazardous conditions for road and rail traffic. Forecasters provide warnings about the possibility of their occurrence, taking into account expected changes in local weather. Drivers act on warnings to cancel or postpone a journey or be prepared for a longer journey time or choose another mode of transport. Highway authorities take decisions about salting roads.

Good forecasting means that the costs of keeping traffic flowing and increasing safety are reduced. Accurate predictions of road conditions lessen the environmental impact of the materials used for treating roads.





## **Meteorologists brief pilots about potential hazardous conditions on take-off and landing and during flight.**

During the 10-year period 2001-2010, weather-, climate- and water-related disasters killed 388 110 people around the world and affected over 2.3 billion others. Economic losses over the same period were estimated at US\$ 842,5 billion (at 2011 prices).

Approximately 33 per cent of all aviation accidents are weather related and 40 per cent of fatal accidents are caused by the weather.

Shipping carries more than 90 per cent of world trade by bulk. The world's cargo-carrying fleet consists of 55 000 ships. On average, three large ships sink every week.

Each year, 500 Canadians die and 37 000 are injured in road accidents where weather is the major or a contributing factor.

In the United States, 80 per cent of all flight delays greater than 15 minutes are reported to be caused by the weather, resulting in an economic loss of US\$ 1 billion per year.

Monitoring road surfaces, accurately predicting the formation of ice and treating roads before icing occurs can mean a 20–30 per cent reduction in the use of salt.



# PROTECTING LIVES AND PROPERTY

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## Reducing losses from natural hazards

Natural hazards include tropical cyclones (also called hurricanes and typhoons), severe storms, tornadoes, floods, drought, storm surges, landslides, mudslides, avalanches, wildland fires and sandstorms.

Every year, disasters due to weather, climate, and water hazards cause significant loss of life and set back economic and social development by years, if not decades. Between 1970 and 2009, such events caused at least 7 870 disasters, 1.86 million deaths and US\$ 1.9 trillion of economic losses.

Human and material losses caused by natural disasters are a major obstacle to the sustainable development of developing countries, where their economic impact is often devastating. The destruction of buildings, transport infrastructure and agriculture has catastrophic impacts on local and national economies. In the last decade, developing countries shouldered a greater share of the economic impacts of natural disasters than developed countries. The consequences of such events continue to be felt long after they have occurred.

Multi-hazard early warning systems, coordinated by WMO, transmit vital weather and climate information using the latest information technology. Observations

and forecasts from the hydrological community also contribute to the effectiveness of these systems.

Forecasters identify natural hazards in the early stages and monitor their progress. With the use of surface and satellite data, computer models and knowledge of local climate and weather conditions, they predict future developments. This information is then shared with local and national disaster prevention and preparedness authorities and the media. The warnings the authorities issue to the populations at risk enable them to take measures to safeguard lives and property.

Thanks to the increasing availability of real-time data, the wider dissemination of accurate forecasts and the recognition by governments and the media of their importance, numerous lives are saved, destruction averted and damage reduced every year.





**No country is immune from natural disasters. Because of their geographical location, however, some are persistently vulnerable to the impacts of hazards such as tropical cyclones.**

Historical, geo-referenced information about deaths and damages can be used to estimate risks before the next natural disaster occurs. It can support practical decisions on reducing potential impacts by, for example, investing in early warning systems, retrofitting critical infrastructure or enforcing building codes for new buildings. Information about past impacts can also be used to assess the resilience of a society.

Forecasters provide predictions and warnings about the intensity and track of hurricanes so that action can be taken to minimize destruction and loss of life.

Worldwide, floods are the most destructive of all weather-related hazards.

One-third of the world's population is threatened by the impacts of desertification.

In intense hurricanes, surface wind speeds can exceed 200 km/h.

The ocean surface near hurricanes can rise by 3–4 metres.



# PROTECTING OUR HEALTH

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## Providing advice about environmental issues that affect our health

Increasing concern about environmental and sustainable development issues has created a demand for scientific advice and information on topics such as air quality, solar radiation, the spread of pollutants and infectious diseases and the onset of extreme climatic conditions. Environmental meteorologists provide this advice. By observing changes in air quality, they are able to assess the impact of legislation and action that have been put in place.

Poor air quality is a serious problem in many large cities. Vehicle exhaust, emissions from industrial plants and power stations, duststorms, forest fires, volcanic eruptions and pollen all contribute to poor air quality. They cause breathing problems, coughing, throat irritation and even cancer.

Environmental meteorologists have developed tools and techniques to predict the spread of these pollutants so that warnings can be issued to the public when their levels are dangerously high. They use atmospheric dispersion models to simulate and make predictions about air quality in different weather conditions. Models are also used to provide warnings of nuclear accidents and chemical leaks and spills.

Weather and climate play a key role in the initiation and propagation of potentially dangerous infectious diseases such as bird flu, which are carried in droplets and particles in the air.

Mosquitoes are carriers of several deadly diseases such as malaria, dengue, yellow fever and Rift Valley fever. Hot and wet weather conditions favour their development and trigger outbreaks of these diseases.

Infants, the elderly and the infirm are particularly vulnerable during extreme weather events such as heat waves and cold snaps.

Exposure to high levels of harmful ultraviolet radiation from the Sun leads to damage to eyes and skin and the immune system.

Early warning systems for these hazardous conditions are developed by weather and climate experts in partnership with health and social services, allowing the public to be suitably prepared.





**Meteorologists advise health and other authorities when weather conditions favour the outbreak and spread of air- and insect-borne diseases. Their advice is critical after natural disasters, when conditions are ripe for epidemics, particularly through unclean drinking water.**

Malaria kills up to one million people a year in sub-Saharan Africa; 70 per cent of all deaths from malaria are of children under 5 years of age.

During heatwaves, deaths from all causes increase. Death rates can rise to as much as 50 per cent above average. The 2010 heatwave in the Russian Federation killed an estimated 55 736 people.

Heavy rain and flooding mean more pools of standing water – the ideal habitat for mosquitoes.

An outbreak of Rift Valley Fever in East Africa in 1997/1998 killed hundreds of people and infected nearly 90 000.

The transmission of waterborne diseases is affected by the quality and distribution mechanisms of drinking water, which, in turn, are affected by rainfall patterns.

# FEEDING THE WORLD

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## **Agrometeorologists serve the agricultural community by providing advice for day-to-day activities and long-term planning**

All around the world, agriculture is critically dependent upon the weather. Accurate weather and climate information helps farmers cultivate healthy crops and livestock and expand production. Similar information is used by fishermen, foresters and horticulturalists.

Agrometeorologists provide services based on an understanding of the interaction of weather and agricultural activities. They use data concerning the development of crops, including damage by pests and diseases and soil moisture.

Each day, farmers need to make decisions about which activities to carry out. To help them do this, weather bulletins are issued on a daily, weekly or monthly basis. These bulletins provide information about past and forecast weather and identify the activities that can be carried out.

Environmental factors affect the incidence of plant and animal diseases and pests. For example, desert locust swarms ravage crops and destroy livelihoods, leading to starvation. Knowledge of these factors and of the stages in the development of diseases and pests when they are most harmful to crops and livestock allows farmers to take preventive action.

Information provided by agrometeorologists helps farmers with control operations, such as forecasting optimal wind conditions for spraying crops with insecticide.

Farmers need to be aware of the likely range of variability in the climate from year to year. Awareness of the likely onset of droughts, heavy rain and temperature extremes enables farmers to decide which are the most resistant crops to grow to minimize losses.

Supporting farmers in areas that are drought-prone is particularly important. Agrometeorologists make extensive studies of rainfall records to assess the frequency, duration and severity of droughts and the prediction of their occurrence. Hydrologists observe, model and forecast trends in the water cycle and in the water supply. This information helps farmers and governmental bodies formulate well-informed strategies about agricultural activities.





**Information provided to farmers helps them make decisions about planting, applying fertilizer, pesticide spraying, irrigating and harvesting.**

The control of diseases and pests increases agricultural production.

Providing farmers with information about the likelihood of droughts, floods and temperature extremes helps them decide the best kind of crops to grow.

In India, around half of the population depends on agriculture for its livelihood and rural areas contribute nearly half of the country's economy.

Almost 40 per cent of China's labour force is engaged in agriculture.

A small part of an average swarm of locusts eats the same amount of food in one day as 10 elephants or 25 camels or 2 500 people.



# MANAGING FRESHWATER RESOURCES

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## **Hydrographers and hydrologists support the sustainable management of water supplies**

Freshwater is fundamental to human life and to the health of ecosystems. Providing access for all to clean drinking water and to sufficient water for agriculture, industry and households requires that the world's limited resources of freshwater be sustainably managed. However, water supplies cannot be managed without information about where they are, their quantity and quality, and how they may vary over time. Providing accurate and useful hydrologic information on a regular basis is a challenge in most parts of the world. The extremes of water availability – floods and droughts – add to the complexity of this challenge.

Hydrographers – technical specialists who monitor water resources – measure the flow of rivers and the supply of groundwater. Maintaining the networks of measuring instruments requires constant attention, and keeping up with emerging technologies and methods is vital. By standardizing hydrological observations and relying on the best available technologies, hydrological services provide the hydrological data and information required to satisfy the many competing uses of freshwater in a sustainable manner.

Engineers and hydrologists use these measurements to assess the quantity and quality of water resources available for meeting the needs of society. They rely on both observations and models to forecast trends in water availability. This information also makes it

possible to address water-related hazards and to protect and nurture the natural environment.

Hydrologists, hydrometeorologists and engineers also use hydrological information for designing and operating hydrological structures such as dams, weirs and culverts. A particular benefit is seen in the management of floodplains, where hydrological information makes it possible to reap the full benefits of these fertile and productive areas while protecting them from the sometimes damaging effects of floods.

Because effective early warning systems for flood forecasting require close collaboration between meteorologists and hydrologists, a new breed of hydrometeorologists is emerging. Their role is becoming more and more important as flood risks continue to evolve under changing environmental conditions.





**Continuing population growth, urbanization, rapid industrialization, and the expansion and intensification of food production are all putting pressure on water resources.**

Water is at the core of sustainable development and is critical for socio-economic development, healthy ecosystems and for human survival itself.

The current use, development and management of the planet's finite water resources, and the services they provide, have become unsustainable.

Water-related disasters are the most economically and socially destructive of all natural disasters.

Economic losses from the inadequate delivery of water and sanitation were estimated to amount to 1.5 per cent of gross domestic product of the countries included in a World Health Organization study on meeting the Millennium Development Goals.

A total of 768 million people still do not have access to even an improved drinking water source, and existing indicators do not address the safety and reliability of water supplies.

In a recent United Nations survey for the Rio+20 Conference in 2012, more than 130 countries confirmed the widespread adoption of integrated approaches to water management but warned that significant challenges remain.



# HARNESSING ENERGY

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## **All energy is derived from natural resources which are dependent on weather and climate**

Communities which have access to affordable energy resources are better able to develop their economies. For instance, time spent fetching water and fuel is time that could otherwise be spent in education or income-generating activities.

Energy services lie at the core of the quest by communities to achieve sustainable development. Understanding the relationship between energy, climate and sustainable development is key to developing appropriate policy response. Meteorologists and climate scientists play vital roles in providing advice to governments and the public on how best to harness energy, including renewable resources, in a sustainable manner.

Renewable sources capture existing flows of energy from natural processes such as sunshine, wind, flowing water, biological processes and geothermal heat.

Renewable energy may be used directly or indirectly to create other, more convenient forms of energy. Examples of direct use are solar ovens, geothermal heating and water- and windmills. Examples of indirect use requiring energy harvesting are electricity generation through wind turbines or solar photovoltaic cells and the production of fuels such as ethanol from biomass.

Methods to harness renewable energy sources are heavily dependent on climate knowledge. For example, the key climate parameters needed for the adequate design and management of hydropower generation are the daily and monthly values of rainfall, river levels and discharges and the daily mean and extreme values of temperature.

In the case of harnessing the Sun's energy, data are required about solar radiation, cloud cover, temperature, rainfall, humidity and the frequency and severity of extreme weather and climate events, such as tropical storms.

For wind farms, knowledge of prevailing winds and frequency of strong winds is necessary.





**Renewable technologies are highly sensitive to any variation in weather or climate. Climate scientists provide services for the development of renewable energy resources throughout the world.**

Energy is the lifeblood of the world's economy and the underlying means by which all societies function.

Most renewable energy ultimately comes from the Sun.

Hydropower supplies some 20 per cent of the world's electricity to more than one billion people.

Boosting the world's supplies of renewable energy and improving energy efficiency are vital to reducing the greenhouse gas emissions that cause climate change.

Biomass is the largest and most sustainable energy source. Although burning plant matter adds carbon dioxide to the atmosphere, the plants consume an equivalent amount of gas while growing.



# ENJOYING OUR ENVIRONMENT

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## Providing advice for optimal and sustainable tourism and outdoor recreational activities

Travellers consult their local or national weather service for information on climate averages (temperatures, rainfall amounts, sunshine duration) and risks of natural hazards (hurricanes, avalanches, etc.) when planning a holiday.

Resort operators check the day's forecasts to see if they have to organize indoor activities or reschedule others such as balloon rides, bikes or down-hill skiing.

Long-term climate statistics, representing what one might expect for a given season, are used by many operators for planning. Increasingly, however, they are looking for reliable predictions for the month, season or year ahead for more realistic and effective planning.

Investors planning a new "ski" or "sun and sand" resort will be very keen to know about possible climate change – will the temperatures in 25 years still sustain the activities of the resort; will there be more or fewer climate-related hazards (typhoons, storm surges, tornadoes, etc.); will there be more cloudy or rainy days?

Research projects are undertaken to assess the level of interest in, or use of, climate information by travellers, sector operators and investors; climate

aspects that influence activities such as travel; the supply of food, water, electricity and other goods/consumables at the destination; safety (risks to persons and infrastructure from hazards); and even the human physiological response to sunshine, rain, heat, cold and other factors known to be part of our sense of well-being. Specialists in applications for tourism help establish site and layouts for stadiums and other infrastructure for major sporting events such as the Olympic Games and the football World Cup.

More and more holidaymakers are concerned about the impacts of tourism on the environment. There are now an increasing number of opportunities for meteorologists and climatologists to advise those sectors that cater to tourists' needs and that respect environmental concerns at the same time.





**Meteorologists provide crucial information to be taken into account when considering human interaction with nature in fragile environments.**

Tourism is one of the world's largest economic sectors and is growing rapidly. In some countries, especially small island developing States, it is the main source of income.

Climate experts in Poland are developing a "weather recreation index" for Europe, to identify the best seasons and locations for certain recreational activities.

In 2003, the International Olympic Committee indicated it would consider climate change in its evaluation of future sites for the Olympic Winter Games.

Meteorologists and climatologists work together with environmental scientists, tourist specialists and local and national governments to protect precious natural resources.



# THE WORLD METEOROLOGICAL ORGANIZATION

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Established in 1950, WMO became the specialized agency of the United Nations in 1951 for meteorology (weather and climate), operational hydrology and related geophysical sciences.

As weather, climate and the water cycle know no national boundaries, international cooperation on a global scale is essential for the development of meteorology and operational hydrology as well as to reap the benefits from their applications. WMO provides the framework for such international cooperation.

WMO contributes to the safety and welfare of humanity. Under its leadership and within the framework of its programmes, National Meteorological and Hydrological Services (NMHSs) contribute substantially to the protection of life and property against natural hazards, to safeguarding the environment and to enhancing the economic and social well-being of all sectors of society.

WMO facilitates the free and unrestricted exchange of data and information, products and services in real or near-real time on matters relating to safety and security of society, economic welfare and the protection of the environment. It contributes to policy formulation in these areas at national and international levels.

WMO plays a leading role in international efforts to monitor and protect the environment. For instance, in collaboration with United Nations agencies and the National Meteorological and

Hydrological Services of its Members, WMO supports the implementation of conventions such as the United Nations Framework Convention on Climate Change, the United Nations Convention to Combat Desertification, and the Vienna Convention for the Protection of the Ozone Layer and its Protocols and Amendments. WMO is instrumental in providing advice and assessments to governments on matters relating to the above conventions. These activities contribute to ensuring the sustainable development and well-being of nations.

In the specific case of weather-, climate- and water-related hazards, which account for nearly 90 per cent of all natural disasters, WMO's programmes provide vital information for the advance warnings that save lives and reduce damage to property and the environment. WMO's activities also help alleviate the impacts of human-induced disasters, such as those associated with chemical and nuclear accidents, forest fire and volcanic ash.

The World Meteorological Organization has played a key role in improving the scientific understanding of climate variability and climate change. Together with partners, WMO co-sponsors the Intergovernmental Panel on Climate Change, the World Climate Research Programme and the Global Climate Observing System. The Organization has also taken the lead in launching the United Nations system-wide Global Framework for Climate Services, which promotes the provision of actionable information on climate to decision-makers.





**The World Meteorological Organization has its Headquarters in Geneva, Switzerland.**

**It coordinates the activities of the National Meteorological and Hydrological Services of its 191 Members and seeks to build the capacity of the Services of developing countries for the benefit of humankind.**

The World Meteorological Organization (WMO) is an intergovernmental organization with a membership of 191 Member States and Territories.

WMO is the United Nations system's authoritative voice on the state and behaviour of the Earth's atmosphere, its interaction with the oceans, the climate it produces and the resulting distribution of water resources.

WMO's Headquarters building reflects the Organization's commitment to enhancing the local and global environment. The efficient, cost-effective and environmentally friendly utilization of energy and light was a paramount concern.

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