Socio-economic benefits of meteorological and hydrological services

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The challenge today is to create and sustain effective partnerships between users and providers of weather, climate and water services and to find new ways of delivering information that meet the growing expectations of users of those services.
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If there were any doubt about climate change, a visit to the Earth’s Poles would dispel it. The impact of the Poles is not limited to high latitudes but also affects the global climate system with far-reaching implications for the entire land-ocean-atmosphere system and human society. Understanding these global impacts is key to our ability to provide the tools to help society adapt. This is the theme of World Meteorological Day 2007, which will highlight the International Polar Year (IPY) 2007-2008 and this issue carries a message from the Secretary-General on the occasion.

This issue of the *Bulletin* highlights the societal and economic benefits of weather, climate and water information, which will be the focus of the WMO International Conference – Secure and Sustainable Living: Social and Economic Benefits of Weather, Climate and Water Services to be held in Madrid, Spain, 19-22 March 2007 (Madrid07). The Secretary-General introduces the overall theme of this issue and that of the Madrid conference within today’s socio-economic and political context.

The intrinsic value of weather, climate and water services is derived from the use of this information in decision-making, which improves societal and economic outcomes. Even if a forecast is technically accurate, it is the user or decision-maker who ultimately determines the benefit and, hence, the value, of the weather, climate or water service. Thus it is critical that users have the tools and knowledge needed to realize fully the benefits of forecasts and assessments. It is generally easy to understand the impact of extreme weather on society, but it is much more difficult to assess the impact of forecasts on the decision-making process. In a collaborative article “Deriving societal and economic benefits from meteorological and hydrological services”, the co-authors identify some of challenges and limitations in the uptake of weather, climate and water information and recommend that, in the short-term, much more attention be given to improving decision-making and decision-support tools.

Madrid07 is another step towards this goal by bringing experts from a variety of societal and economic sectors together with providers of weather, climate and water services to explore ways to increase the benefits of these services. Conference sessions will be arranged to maximize participant dialogue and interaction.

Madrid07 builds on the recent WMO Conference on Living with Climate Variability and Change, which took place in Espoo, Finland, in July 2006 and on ongoing regional societal and economic benefit workshops, which are discussed in this issue. Madrid07 aims to identify specific actions to improve the uptake of weather-, climate- and water-related information by users.

Owing to its high climatic variability, Africa faces serious water-security challenges in the form of extreme floods and droughts. Maria Mutagamba is Minister of State for Water in Uganda and President of the African Ministers’ Council on Water. In her interview for the *WMO Bulletin*, she underlines the need to sensitize politicians and decision-makers on the importance of meteorological and hydrological data and products—and the need to do so in a language they will understand. Ms Mutagamba welcomes Madrid07 as an opportunity for dialogue between weather, climate and water information and service providers and users.

Food security is critical for all societies, but developing and least developed countries are particularly vulnerable because of their high dependence on agricultural production. Motha and Menzie highlight the importance of meteorological information for the evaluation of agrometeorological risk and uncertainty for agricultural market systems and the role of the World Agricultural Outlook Board (WAOB) in minimizing this risk. The WAOB uses weather, climate and remotely sensed information to analyse the impact of global weather on crop production, determining the vulnerability of crops and markets worldwide. There are five categories of risk: yield, production, price volatility, and income, which can be mitigated by accurate, timely, consistent, objective and widely available hydrometeorological information.
In a specific example of the impact of climate on agricultural production, Gawander describes the sensitivity of Fiji’s sugar cane industry. Sugar cane is a major revenue earner in Fiji contributing up to 12 per cent of Gross Domestic Product and employing 25 per cent of the workforce. The industry is particularly susceptible to climate variability and extreme weather events. While the relationships between the crop and the environmental conditions are known and mitigation is possible, the lack of accurate data locally currently limits the growers’ ability to anticipate and adapt to environmental change.

Renewable energy is an increasingly economically viable alternative to fossil fuels, but heavily dependent on weather and climate data to determine the availability of solar, wind and biomass energy sources. Robles Gil discusses the importance of this information in the planning and design of renewal energy systems and their day-to-day operations. Wider use of renewable energy systems is a challenging and technical and socio-economic process that must involve the cooperation of scientists in many disciplines, including climatologists, meteorologists and hydrologists to advise and inform engineers, planners and system operators.

Climate and weather information features prominently in modern building codes, but must also be considered in the preservation of our ancient monuments. The article “Climate data and services: preserving our cultural heritage” highlights the activities of the World Heritage Committee to raise awareness of the risk of climate change on our natural and cultural heritage, which are irreplaceable sources of life and inspiration and central to human development.

Environmental hazards have a disproportionate impact on Africans, who are amongst the most vulnerable to agricultural insecurity, adverse health impacts and economic disruption. Afiesimama describes how weather forecasting in West Africa has developed over the last 25 years and how daily and seasonal information has been used to improve agricultural productivity and water management through National Meteorological and Services and the African Centre of Meteorological Application for Development.

Underlying each of these articles is the recognition that weather, climate and water services exist to provide societal and economic benefit. This is most effective when the user of the information is well informed and able to apply the knowledge effectively. Today we are paying more and more attention to the application of weather, climate and water information. The challenge today is to create and sustain effective partnerships between users and providers of weather, climate and water services and to find new ways of delivering information that meet the growing expectations of users of those services.
Polar meteorology
Understanding global impacts
Polar meteorology: understanding global impacts

Message by Michel Jarraud, Secretary-General of WMO, on the occasion of World Meteorological Day 2007

Every year, on 23 March, the World Meteorological Organization (WMO), its 187 Members and the worldwide meteorological community celebrate World Meteorological Day. This Day commemorates the entry into force, on that date in 1950, of the WMO Convention creating the Organization. Subsequently, in 1951, WMO was designated a specialized agency of the United Nations System.

In 2005, on the occasion of its 57th session, the WMO Executive Council decided that the theme for the year 2007 would be “Polar meteorology: understanding global impacts”, in recognition of the importance of, and as a contribution to, International Polar Year (IPY) 2007-2008, which is being co-sponsored by WMO and the International Council for Science (ICSU). To ensure that researchers can work in both polar regions during the summer and winter months, the event will actually be held from March 2007 to March 2009. The fundamental concept of the IPY is an intensive burst of internationally coordinated, interdisciplinary scientific research and observations focused on the Earth’s polar regions and their far-reaching global effects.

In recent years, there has been renewed interest in the climate and the environmental conditions in the polar regions, which has some important historical antecedents, since these regions have traditionally played a crucial role in WMO’s activities and in those of its predecessor, the International Meteorological Organisation (IMO). In 1879, Second Meteorological Congress approved the concept of an International Polar Year, which was held in 1882-1883. The second International Polar Year, which was also initiated by IMO, took place in 1932-1933. The success of the first and second IPYs led to the development of a wider international geophysical year, extending to encompass the lower latitudes, rather than simply a new international polar year. This was the International Geophysical Year (IGY), which lasted from 1 July 1957 to 31 December 1958 and had far-reaching consequences in terms of scientific research, through the involvement of 80 000 scientists from 67 countries.

Through the National Meteorological and Hydrological Services (NMHSs) and other institutions of its Members, WMO will be making substantial contributions to the new IPY in the areas of polar meteorology, oceanography, glaciology and hydrology, in terms of scientific research and observations. Another essential input to the IPY will be provided through WMO’s Space Programme. Ultimately, the scientific and operational results of the IPY will be offering benefits to several WMO Programmes, by generating comprehensive datasets and authoritative WMO scientific knowledge to ensure further development of environmental monitoring and forecasting systems, including severe weather prediction. Moreover, it will provide valuable contributions to the assessment of climate change and its impacts, in particular if the observing networks to be established or improved during the IPY period can be kept in operational mode for many years.

As far as in situ meteorological observations are concerned, polar regions are some of the least densely covered areas on Earth. Polar meteorology has, therefore, been relying extensively upon polar-orbiting satellites. Early meteorological satellite data derived from these regions consisted mostly of visible and infrared imagery but, in recent years, a much wider range of products has become available from active and passive microwave instruments, allowing in particular...
for the determination of temperature and humidity profiles, even during cloudy atmospheric conditions, as well as of winds, the extension and concentration of sea ice and several other parameters. In addition, this relative lack of in situ observations has also been partially compensated by the deployment of automatic weather stations (AWSs) and of buoys, fixed or drifting on ice.

Although the polar regions are generally distant from widely populated zones, there is a great need for reliable weather forecasts in these areas. Around the Arctic, forecasts are needed for the protection of indigenous communities and in support of maritime operations, as well as for oil and gas exploration and production. In the Antarctic, reliable forecasts are required for complex air and marine logistical operations, as well as in support of scientific research programmes and the expanding tourism industry. Weather forecasting in both parts of the world presents some unique challenges, as compared to the extra-polar regions, but the notable advances made during recent years in terms of observing systems and numerical weather prediction have led to considerable improvement in the skill of weather forecasts, including those made for the polar regions.

During the last decades, significant changes were detected in the polar environment, such as a decrease in the perennial sea ice, the melting of some glaciers and permafrost and a decrease in river and lake ice. These changes, which are even more evident in the Arctic than in the Antarctic, have been subject to considerable study. The 2001 Third Assessment Report of the WMO co-sponsored Intergovernmental Panel on Climate Change (IPCC) indicates that the Earth’s global mean surface temperature increased by approximately 0.6°C over the 20th century. The Report further estimates that globally averaged surface temperatures would be rising by 1.4 to 5.8°C over the period 1990-2100. Overall, the IPCC has estimated that, by the year 2100, sea-level will have increased between 9 cm and 88 cm, which would pose a very significant problem for many Small Island Developing States and, in general, for all low-lying areas of the world. Currently, the IPCC is in the process of preparing its Fourth Assessment Report, which will be released during 2007.

Shrinking of sea ice might induce serious changes in marine ecosystems, thereby affecting marine mammals and the vast krill populations that feed countless seabirds, seals and whales. Permafrost is also sensitive to long-term atmospheric warming, so there is likely to be a progressive thawing of the frozen grounds around the Arctic, accompanied by the expansion of wetlands and the potential for considerable damage to supported buildings and infrastructure. This melting would also have implications for the carbon cycle through the release of one of the major greenhouse gases, methane, which is trapped within the permafrost.

Ozone is an extremely important stratospheric gas, since it protects the biosphere by absorbing solar ultraviolet radiation. The atmospheric ozone was first measured over the Antarctic by surface-based instruments during the 1957–1958 IGY. Since the mid-1970s, a different pattern was detected at the end of southern hemispheric winters, since increasingly lower values of ozone were consecutively measured each year until the spring warming of the stratosphere set in. Accordingly, the discovery of the Antarctic ozone hole was an important consequence of the IGY. It was finally determined that the “hole” developed in great part as a result of emissions of some widely used industrial gases. However, following the response measures adopted, it now appears to be stabilizing. If the provisions of the Montreal Protocol of 1987 on Substances that Deplete the Ozone Layer are adhered to, it is estimated that the ozone layer at mid-latitudes will be recovering its normal values by the middle of the present century and that, over the Antarctic, recuperation will demand an additional 15 years.

However important the study of polar meteorology may be per se, it is impossible to overemphasize the fundamental impacts of the polar regions on the global climate system as a whole. Changes at higher latitudes can and do have significant impacts on all ecosystems and on all human societies, regardless of the geographic latitude. Therefore, the impacts of polar meteorology must be considered within the broadest context.

There are indeed numerous examples of the global outreach of polar issues. For example, polar ice constitutes effective thermal caps playing a critical role in sustaining the global oceanic circulation. Moreover, the polar regions have a primordial role in determining the global climate system, which is driven by the energy received from the Sun, mostly at lower latitudes. As a whole, the
Equator receives over the year about five times as much heat energy as the Poles, and the atmosphere and the oceans respond to this large temperature gradient by transporting heat towards the Poles. Therefore, the two polar regions are linked to the rest of the Earth’s climate system through rather complex paths based on combined atmospheric flow and oceanic circulation.

The El Niño–Southern Oscillation (ENSO) is a major mass fluctuation across the tropical Pacific Ocean, which is associated with periodic variations in the sea-surface temperatures of the eastern Pacific Ocean. ENSO is in fact a large climatic cycle and it has been shown to affect regions far removed from the Pacific basin. Statistical evidence shows, for example, that, in certain parts of Africa, ENSO can contribute to interannual rainfall variance and even to drought, as in fact attributed to the 1991-1992 El Niño event, when a devastating drought episode threatened some 18 million people with famine. “Teleconnections” are defined as atmospheric interactions between widely separated regions and researchers are now investigating such relationships between polar weather and other weather and climate events.

The International Polar Year 2007-2008 will, therefore, be addressing a wide range of physical, biological and social issues, closely or indirectly linked to the polar regions. The urgency and complexity of the changes being observed in the polar regions will demand a broad and integrated scientific approach. Enhanced international collaboration and open partnerships resulting from this landmark scientific effort will, no doubt, stimulate and facilitate unrestricted data access and cross-cutting research initiatives. Through an ample outreach effort, IPY will also represent a major step forward in making scientific knowledge available and accessible to the general public. At the same time, a foremost concern will be the fact that the impacts derived from the polar regions are also important to the global climate system as a whole, so that many changes detected at the higher latitudes will also be found to have significant impacts on the sustainable development of all societies, regardless of geographic latitude.

Meteorology has long been recognized as a paradigm of a science without frontiers and polar meteorology is perhaps the ultimate example of this principle. Therefore, as the international meteorological community celebrates World Meteorological Day 2007, it is my hope that all Members of the World Meteorological Organization will recognize the importance of polar meteorology and its potential global impacts on their lives, their security and their prosperity. Moreover, it is also my expectation that the outcomes of this endeavour will contribute to a better understanding of climate variability and climate change, as well as to the development of much needed climate applications to address some of the major challenges of the 21st century.

A folder, a brochure (WMO-No. 1013), a poster and a film have been produced for World Meteorological Day 2007 on the theme “Polar meteorology: understanding global impacts”.

A World Meteorological Day 2007 Website has been created which can be accessed via the WMO homepage. It contains the brochure and the poster (in pdf format) and the Secretary-General’s message (in Word).
SECURE AND SUSTAINABLE LIVING: Social and Economic Benefits of Weather, Climate and Water Services

Madrid, Spain, 19 to 22 March 2007
www.wmo.int/Madrid07
Fifteenth World Meteorological Congress will take place in May this year, in Geneva. It will meet in a context of the growing recognition globally of the importance of meteorological and hydrological information, products and services. The intersessional period has been characterized by an increasing toll of extreme weather and water events such as droughts, floods and tropical cyclones. The devastating and tragic tsunami of 2004 and other natural disasters have brought the work of WMO to the fore in the development of early warning systems and disaster-risk preparedness. Congress will make key decisions which will take into account the events of the intersessional period and will guide the work of Members and the Secretariat in the areas of weather, climate and water.

As governments respond to the challenges of meeting the United Nations Millennium Development Goals, there is growing recognition that weather, climate and water have an increasing impact on civil society and economies. There is also greater awareness that it is possible to make more effective use of meteorological and hydrological information not only to mitigate some of the adverse consequences of weather, climate and water but also to use them as a resource.

WMO assistance to its Members in improving the quality and utility of their products and services to users through its various programmes and activities of a cross-cutting nature is increasingly being appreciated.

This issue of the WMO Bulletin is devoted to the all-important theme of the socio-economic benefits of meteorological and hydrological services. Given the changing needs of civil society, NMHSs must constantly assess users’ current and emerging requirements for weather, water and climate information and adapt their services to meet these needs. This will demand an effective dialogue between information users and providers, as well as efficient communication between NMHSs and their governments.

A major international conference on the social and economic benefits of meteorological and hydrological services will be held in Madrid, Spain, from 19 to 22 March 2007 under the high patronage of HM Queen Sofia. By promoting dialogue between providers and users of related information, the conference will promote better understanding and application of the products of NMHSs for social and economic benefit. A wide range of users and decision-makers, planners, economists and social scientists will participate. The outcomes of the conference should provide guidance for the enhancement of products and services. Above all, more effective partnerships between users and suppliers of weather, climate and water products and services will be promoted.

WMO can provide even stronger support to sustainable development through the application of weather, climate and water information to reduce and mitigate natural disasters; improve and sustain human health; enable human adaptation to climate change; improve the management of energy and water resources; manage and protect ecosystems; develop sustainable agriculture; and to undertake other activities that affect societies and national economies in areas such as finance, recreation and tourism, transportation and civil engineering.

I hope readers will find this issue useful, interesting and informative.
In terms of water security what are the major challenges facing the African continent?

Africa faces serious water security challenges. The availability of freshwater in Africa is characterized by high variable levels of rainfall, resulting in extreme floods and droughts. The solution to this extreme climatic variability is increasing water-storage capacity and regulation of flows. Currently, the average storage capacity in Africa is about 200 m$^3$/person/year, while, in North America, it is about 5 961 m$^3$/person/year. Africa’s share of global freshwater resources is about 9 per cent or 4 050 km$^3$/yr. Currently, only 3.8 per cent of water resources are developed for water supply, irrigation and hydropower use. The freshwater resources are distributed unevenly across Africa, with western Africa and central Africa having significantly more than the rest of Africa. By 2025, it is expected that 25 African countries will be subject to water scarcity or water stress.

Enhancing Africa’s food security, particularly of the poor and vulnerable, calls for intensive development of water resources. It requires creation of storage of water for meeting the demand during the dry season. Agricultural production has not kept pace with population growth in the Region. As a result, the nutrition position of the region is now worse than it was 30 years ago. One of the reasons contributing to this is the heavy dependence of African economies on rain-fed agriculture with the attendant risks of droughts and floods. Hence, the region is faced with a challenge to develop expeditiously the huge potential of irrigated agriculture as a strategy for eradication of absolute poverty and hunger. It has been estimated that a 3.3 per cent increase in annual agricultural output is needed to achieve the continent’s food security objectives.

Access to electricity in most African countries is less than 200 kWh/person/year and, in some countries, is less than 30 kWh/person/year. In comparison, access to electricity in North America is more than 12 000 kWh/person/year. The technically feasible hydropower potential of the region is estimated to be about 1.4 million GWh/year and so far only about 3 per cent has been developed. If Africa is to achieve its goal of regional food security, the energy supply for agricultural should be increased two- to three-fold.

In Africa, about 300 million people lack access to adequate water supply and about 313 million people lack access to adequate sanitation. This figure could double if the business-as-usual approach is maintained. Low access to sanitation and water supply is the root cause of many diseases that affect Africa. People with HIV/AIDS who are victims of opportunistic diseases are also affected by the situation. Innovative measures will...

Interview with Hon. Maria Mutagamba

Hon. Maria Emilly Lubega Mutagamba is Minister of Water and Environment of Uganda. She is the first woman to be appointed Minister of Water in her country. She has also been President of the African Ministers’ Council on Water for the last two years. She is a strong advocate for water issues in Africa and has been promoting the WaSH message at both national and international levels. Born in the Gamba-Kakuto-Rakai district of Uganda, Ms Mutagamba received her college degree from Makerere University and began her professional career as a research officer for the Bank of Uganda. She is Member of Parliament for Rakai District.
have to be undertaken to deal with this crisis.

In order to address the above challenges, it is imperative that appropriate good water-governance systems are put in place that take into account the interests of all stakeholders in the management of water resources through appropriate legislative and institutional mechanisms.

Promoting peaceful cooperation and developing synergies between different uses of water at all levels within and, in the case of transboundary water resources, between States concerned, through sustainable river-basin management, are essential.

Efforts to deal with all the above issues require financial and human resources, which, unfortunately, are not always available. Lack of sufficient financial and human resources for water development and management continues to be a major cause of concern.

**Which of these challenges do you consider to be the most serious and how would you like to see them addressed?**

We need to recognize that access to safe and sufficient water and sanitation are basic human needs and are essential to securing food supply and for people’s health and well-being. We need a healthy population that can contribute actively to the economic development of the continent. The attainment of the water-related United Nations Millennium Development Goals (MDGs) in Africa by 2015 continues to be a major challenge. To meet that water target in Africa, an estimated additional 300 million people must obtain access to some form of improved water supply with an average of over 30 million every year, 577 000 every week and 82 000 every day, starting in January 2006. To meet that sanitation target in Africa, an estimated additional 313 million people must get some form of improved sanitation by 2015 with an average of over 31 million every year, 600 000 every week and 86 000 every day, starting in January 2006.

Africa has articulated the issues and challenges confronting the water and sanitation sector and has defined an agenda comprising desired measures through the New Partnership for Africa’s Development (NEPAD) and the African Ministers’ Council on Water (AMCOW) initiatives and programmes. Implementation of the agenda requires mobilization of adequate human and financial capacity for which Africa needs support. We need to forge strong partnerships and mobilize adequate internal and external funds to support investments in the water and sanitation sector to meet the financial requirement of about US$ 20 billion per annum to enable attainment of the MDGs and the African Water Vision by 2025. At the same time, we need to follow up closely previous pledges to existing water initiatives such as the Rural Water Supply and Sanitation Initiative and the African Water Facility.

At the same time, Africa urgently needs to accelerate development of water resources for increased water supply, food and energy security, increase storage capacity, assist in mitigating the effects of climatic changes and water-related natural and human-induced disasters. Support should be extended to national governments to develop adequate policies and strategies that can make the above a reality.

The lack of adequate financial and human resources for water development and management continues to be a serious challenge facing Africa. Under the given global economic framework, the majority of African national economies continue to be weak. Different public sectors and services commonly have to compete for the meagre national resources available. Consequently, budgetary allocations for water development and management are always inadequate to meet the required needs. Government bodies and individuals involved in water-management programmes must provide the funds needed for water-management activities.

It is also worthwhile to mention that water-resources development and management require well-trained and skilled people in engineering, hydrology, chemistry, the environment and other related disciplines, who are commonly lacking in many of our countries. We need to build sufficient capacities through appropriate training of staff in these fields. Africa must also create an enabling environment which will keep and retain the trained human resources and not lose them through “brain drain”.

The institutional framework for water management should include the policy-making bodies that establish the rules or legislation on the development and use of water resources, and the legislative bodies and agencies with regulatory and political functions...
and responsibilities. These bodies should strive to reconcile the various interests of water users at any given time. They should ensure that, for water management to be effective, it should be envisaged in an integrated form, through an integrated water-resources management framework.

How do you expect these challenges to be affected by climate change and are decision-makers taking the issue seriously enough?

Africa is a wide continent and its climate needs to be addressed on a regional basis. The potential for adequate rainfall on the continent depends on the response of the African atmosphere to prevailing global patterns of seasonally varying climate variables.

There is evidence that, with or without climate change, both droughts and floods have increased in frequency and severity over the past 30 years. The Sahelian zone, in particular, is now experiencing continued decline in rainfall compared to the average of the pre-1960s. Lake Chad, for example, has shrunk to 5 per cent of its size 35 years ago.

Climate change is projected to increase the risk of floods over much of Africa and drought over much of southern Africa in the 21st century, partly through altering the frequency of El Niño events. Decision-makers have to take the climate change issue seriously, as it is likely to continue affecting the African countries economically, environmentally and socially. Although our larger problem is the climate now with its variability and extremes, we have to adapt our water-resources plans to this emerging new reality.

How important is the role of women in African water security and is this role adequately recognized?

In the African context, the woman and the girl child are the ones who bear the greater burden of ensuring that families are provided with water for cooking, washing and other amenities. Mainstreaming gender within the context of integrated water-resources management is therefore critical to attaining the Millennium Development Goals, as well as the targets of the Johannesburg Plan of Implementation. Government bodies should ensure gender-sensitive water and sanitation infrastructure and services and equal access, voice and participation of women and men in decision-making at all levels of water-resources management. At the grass-root level, however, we are far from involving women in the planning processes. This requires a great deal of effort in education and building awareness of the issues involved and a move towards changing the culture of decision-making.

How can decision-makers use meteorological and hydrological services more effectively?

If you allow me, I would put the question in a different perspective. Decision-makers have to perceive the importance and usefulness of meteorological and hydrological services. They have to be more aware of the economic value of meteorological and hydrological services and should allocate adequate amounts of resources for such services. They have to be convinced and should appreciate that resources allocated for these services are not expenditures but creditable investments with high-quality future returns. However, the onus for all this lies with the departments providing the hydrological services. National Hydrological Services have to interact with the user departments and clients to study their requirements of such services that could help decision-making processes at various levels not only at the top. They have then to prepare themselves and make their services available.

This is necessary in order to increase the ability of National Meteorological and Hydrological Services (NMHSs) to provide long-term data and information
We need WMO to help the National Hydrological Services of our countries in monitoring, evaluating and providing vital information on the state of our water resources.

As I said earlier, given the present realities of resources, both financial and human, we have an uphill task to meet our goals of ensuring water security. We have been receiving good support from various UN agencies under the banner of UN-Water/Africa. With their support, AMCWOW has made certain progress. The African Water Facility has been established and we have a mechanism to support countries financially in undertaking certain projects, for which we are grateful to partners in the Facility. But it is not enough. It is still too little to address the gigantic task.

The United Nations and its specialized agencies, and WMO in particular, have a crucial role in developing the capacities of African countries to enable them to address these complex issues. They need to give special attention to African countries in their quest for solutions to attain water security. They can help us to adapt and adopt new technologies and avoid the tortuous path of learning through mistakes and thereby leapfrog over the adverse situations that are encountered in the development process. I call upon these agencies to facilitate the carrying-out of research on appropriate adaptation techniques to avoid catastrophic consequences of climate change.

At the 4th World Water Forum (Mexico City, 16-22 March 2006), Ms Mutagamba said that Africa was being held hostage by its hydrology, which was preventing Africans from improving their living conditions.

We need WMO to help the National Hydrological Services of our countries in developing and providing vital information on the state of our water resources.

Meteorological and hydrological services are often low down on the political food chain, yet their supportive role is crucial for the well-being of other sectors such as agriculture, hydropower and tourism. How can this imbalance be addressed?

Effective water-resources development and management depend on the adequacy, quality and management of data on the various components of the hydrological cycle and the environment. Meteorological and hydrological services have to provide the scientific bases for effective water resources development and management in each country. Regrettably, NMHSs do not effectively convey the economic value of the services they provide and, as such, decision-makers are unable to appreciate or prioritize these services. Consequently, budgetary allocations for hydrological services have been systematically diminishing, particularly in developing countries and, above all, in Africa.

To address this unfortunate state of affairs, NMHSs need to sensitize politicians and decision-makers about the importance of meteorological and hydrological data and products, in the language they appreciate, as the necessary basis for proper and reliable designs and optimal management of water-related schemes.

This an area where an Organization like WMO has a vital role in demonstrating
the value of meteorological and hydrological services to decision-makers, politicians, the private sector and the public at large.

As you may be aware, the WMO international Conference on Social and Economic Benefits of Weather, Climate and Water Services will take place in March 2007 in Madrid. What would you like to see come out of the conference?

I am happy that WMO is encouraging the NMHSs to interact with users. This is a very important conference. I see it as an opportunity for hydrological and meteorological service providers to have a better knowledge about how their products and services are used and where improvements are needed to increase their value to civil society and the economy; and for users and decision-makers to appreciate better the current capabilities, responsibilities and limitations of the various service providers.

What I would like to see come out of the conference is how governments can make more effective use of weather, climate and water information to reduce poverty, increase water and food security, improve health and ensure safety. I would like to see solutions for African nations to reduce and mitigate natural disasters, improve and sustain health, adapt to climate change, improve the management of energy and water resources, manage and protect ecosystems and develop sustainable agriculture.

What effective role could the private sector take in improving the water situation in Africa?

Traditionally, it has been argued that a good network of utilities and services such as water supply and sanitation are a prerequisite for investment. While this is largely true, the private sector can contribute proactively to programmes that will ensure a better environment for business, especially as regards improved water-resources management. Indeed, the private sector is already playing a part, albeit to a limited extent, in contributing to the improved water situation in Africa. Most of the equipment and instruments used in data collection, monitoring, operation and maintenance of water utilities are manufactured by private companies and firms. Most of this equipment and these instruments are not available in local markets in Africa and hence are purchased from overseas at high cost. These firms can make a significant contribution by investing in African local markets and producing the equipment within African countries, thereby reducing the financial burden of these countries.

There is also an issue of privatization of public water utilities, which is currently a subject of debate in some African countries. Where this has been adopted, it has attracted the participation of international institutions as shareholders in the capital of the operating company and has thus enhanced project funding.

Enhancing Africa’s food security, particularly of the poor and vulnerable, calls for intensive development of water resources.
Introduction

Meteorological and hydrological services provide a wide range of benefits to society from the early warning of extreme hydrometeorological events that threaten lives, livelihoods and property to the routine day-to-day weather, climate and water information used to manage agriculture, water resources, energy and transportation (Whung and Wilhite, 2007; Dubus 2007; Puempel, 2007; Dexter et al., 2007).

Today, weather and climate affect society more than at any other time, with different sectors vulnerable to even small changes in environmental conditions. A mixture of social, economic, political and environmental factors contribute to this exposure. In particular, between 1960 and 2000, the world population doubled from 3 to 6 billion people and the global economy increased more than six-fold. Despite global increases in food production, certain human populations are facing greater food and water insecurity because of declines in fisheries and crop production and degradation of water quality. Ecosystem changes have resulted in increases in the incidence of floods and major fires. This, combined with migration to marginal areas, which are subject to more natural hazards than other places, has significantly increased the risk and the human and economic costs, of disasters (Millennium Ecosystem Assessment, 2005). More funds, earmarked for development, are being spent on humanitarian assistance in response to natural disasters, which is undermining development goals. In addition, climate change is now viewed as a major threat to societies and their economic development (Stem, 2006).

Population and economic growth have changed the requirements for energy, manufacturing and transportation. Electrical power generation, which is fundamental for economic security and sustainable development, is reaching capacity in many countries. Major disruptions to power supplies are likely and, in some countries, economic development will be set back. Risks to energy supplies are associated not only with extreme meteorological hazards: renewable energy is highly dependent on weather, climate and water conditions and the whole system can be subject to blackouts and brownouts if there are unanticipated changes in energy demand as a result of unpredicted changes in weather conditions. The growth in global trade exposes more goods and services to potential delays. Manufacturers generally maintain low inventories of goods to minimize costs. The result is that supply chains are more susceptible to transport network disruptions, which can seriously impact the availability of essential commodities from food to heating-oil supplies. Conversely, if approved with adequate lead-time, such agencies can increase stock and resources in anticipation of requirements.

The blending of social, economic and environmental information is central to sound planning and decision-making. Timely and accurate weather, climate and water information and forecasts have many

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applications but the utility of these services often is poorly understood, resulting in low demand and lack of public investment in National Meteorological and Hydrological Services (NMHSs). Unless demand-driven services can be created, new societal and economic benefits, which could be provided by NMHSs, will always be viewed as a low priority for government spending amidst the needs and costs of other public goods and services. This is apparent in many countries, particularly the developing and least developed, which have limited observing capability, communication facilities and ability to inform and advise their governments on issues such as climate-change risks (Tsirkunov et al., 2007; IRI, 2006; Justice et al., 2005; Obasi, 2001). If NMHSs receive higher priority it will be because they can demonstrate tangible benefits to other public services. The task for the NMHSs is to understand the needs of these other public services for weather, climate and water information and create a demand for them. In developing countries, national development planning is emerging as one of the most important client sectors and new methods are needed to engage effectively with this community.

Here, we consider the challenge to NMHSs to meet the changing needs of society for meteorological and hydrological information and services. In particular, we discuss the growing importance of demand-driven advisory services for development planning and to manage the risks associated with climate change and natural disasters.

Creating societal and economic value

Weather and climate can cause significant societal and economic losses. These can be reduced by better preparedness and by using forecasts to make better decisions (Ulatov et al., 2007). Most of the value of weather, climate and water information added or lost in the so-called value chain between the weather and its impact occurs in communicating the information to users and in the behaviour of users in response to that information and ultimately the effect of their decisions on the societal or economic outcome (Lazo, 2007). If the user cannot make changes or if there is no effect on the outcome, the information has no direct value.

There are three areas where value could be increased; namely by improving the forecast, by improving communication or by improving the decision-making process. If currently available information is underutilized, added value will likely accrue if the communication or decision-making process is improved (Lazo, 2007). If the information available is insufficient to influence decisions, then value will be added by improving the weather, climate and water information, itself.

A flood-warning system illustrates how and where value can be added. The determining factors in the effectiveness of a warning system are lead-time and willingness to act. In the case of a flood, the lead-time depends on the proximity of the meteorological event to the watershed outlet, which is the site of the impact. If the event is close to the outlet, the time to respond may be too short to enable effective actions. Conversely, knowledge of a thunderstorm approaching the watershed or a quantitative precipitation forecast prior to the event, gives additional potential lead warning time for the same outlet location. This time may be reduced and value lost, however, if decision-makers are unable or unwilling to respond to the flood threat based on the forecast or rainfall measurement at the watershed (Carsell et al., 2004).

In this case, value will be increased only if the decision process can be improved to accommodate an earlier response. This is achieved by properly constructing and operating the warning system.

Meteorological and hydrological information must be combined with vulnerability assessments in a threat-recognition plan with specific actions to take in the event of a warning. This increases the value of the decision-making process which informs the public and emergency responders so that they can act. The value of the meteorological and hydrological service is increased by adding real-time data and forecasts to the threat evaluation and recognition that

In developing countries, access to reliable energy sources is vital for poverty eradication. Climate-change risk and the absence of reliable environmental data crucial for the development and safe operation of energy systems are growing concerns for the energy sector.
identified thresholds have or will soon be exceeded.

Value is also added by increasing the speed with which this information is available and analysed. By developing well-designed preparedness plans, ad hoc responses are eliminated and the added value of the meteorological and hydrological information, communication and decision steps increase the time available for action (Stewart, 2007).

The issue of underutilization of weather, climate and water information is a significant impediment in creating value. In some countries, this has been identified as a major issue. It draws attention to the need to improve communication and the decision-making process. In response, the new WMO strategic plan identifies this as a service-delivery strategic thrust and proposes initiatives to improve the understanding of, and ability to, address the needs of users (WMO, 2007).

In particular, the WMO strategic plan emphasizes:

- Enhanced capabilities of Members to provide and use weather, climate, water and environmental applications and services by:
  - Increasing the understanding of societal and economic requirements for weather, climate, water and air-quality services;
  - Improving relevant, timely, cost-effective and useful products and services that can be used beneficially by end users;
  - Expanding the use of weather, climate and hydrological outlook services provided by Members;
  - Increasing assistance to countries in flood management; and
  - Increasing training and guidance material that enhance Members’ ability to deliver quality services.

- Enhanced capabilities of Members in multi-hazard early warning and disaster prevention and preparedness by:
  - Improving the capacity of Members to provide inputs and make decisions, where appropriate, for multi-hazard early warning for disaster preparedness;
  - Increasing participation of Members’ NMHSs in national risk-reduction planning and disaster-management processes and activities;
  - Improving the capacity of Members in the delivery of weather, climate and hydrological hazard information and advice in support of risk identification, risk transfer and development planning; and
  - Increasing collaboration and cooperation of Members’ NMHSs within ministries, agencies and economic sectors involved in disaster-risk management.

Weather, climate and water services as a collaborative enterprise

The importance of collaboration between producers and users of weather, climate and water products and services cannot be overestimated. This cooperation ensures value is added where it is needed to make certain that environmental information is properly considered and acted upon by users.

Aeronautical meteorology, marine meteorology and agricultural meteorology are obvious examples of fields that have developed within the framework of this close relationship. In each of these cases, the decision-maker is a knowledgeable user of weather information, usually with some training or education in meteorology because of the high risk to the activity from adverse weather. New services are frequently developed, tested and implemented with the direct cooperation of users through a well-defined requirements process.

The meteorological community recognized the importance of meteorology for economic development as early as 1968 with the first international Seminar on the Role of Meteorological Services in Economic Development in Africa (WMO, 2003). This application posed a new problem, however, because, unlike the mariner or aviator, the development planner is not likely to be knowledgeable about meteorology—and much less certain of its value to his decisions.

Addressing this issue, E.A. Bernard prepared the Compendium of Lecture Notes for Training Personnel in the Applications of Meteorology to Economic and Social Development (WMO, 1976). At that time, he was optimistic that meteorologists would be called upon by governments and economic planners more frequently in the future to address food shortages, water requirements, energy needs and environmental pollution. He drew attention to the need for meteorologists to be acquainted with social and economic factors and to be able to express themselves in appropriate economic terminology. He noted that any dialogue between economists, development planners and other competent authorities would be impossible, unless the meteorologist is able to speak their “language”.

Internationally, the basis for collaboration and partnership is rooted in numerous initiatives. These include the Earth Summit (United Nations, 1992) and the Conventions on Biodiversity, Climate, and Desertification; the Small Island Developing States Barbados Plan of Action and its 10-year review in 2004 (Drakulich, 2005); the New Partnership for Africa’s Development (NEPAD, 2003); the United Nations Millennium Development Goals (United Nations, 2006(a)); the Johannesburg Plan of Implementation for Sustainable development;
the Earth Observation Systems of Systems (GEO, 2005); the Ministerial Declaration of the Third World Water Forum; and the process leading to the World Conference on Disaster Reduction (United Nations, 2006(b)).

Although each of these has a role for NMHSs, the statements in themselves do not create a demand for new weather, climate and water services. Because no one has the capacity to work alone, partnerships are critical to the implementation and successful outcomes of these initiatives. The United Nations encourages action and cooperation between the United Nations system and other intergovernmental, governmental, and non-governmental subregional, regional and global institutions. This is an opportunity to help NMHSs, particularly in developing countries, become more proactive in development programmes, which will increase their societal impact. Where new services are largely unproven, such as climate forecasts and assessments, it is important that these applications are developed in partnership with potential users. Otherwise, demand is unlikely to be created. The partnership strategic thrust of the new WMO strategic plan (WMO, 2007) emphasizes

- Broader use of weather, climate and water outputs for decision-making and implementation by Members and partner organizations by:
  - Increasing the utility and uptake of assessment reports, bulletins, statements and other provisions by policy- and other decision-makers;
  - Increasing the interaction of WMO with various users through participation in relevant fora; and
  - Increasing the cooperation between WMO Members’ institutions, including universities, national laboratories, the private sector and NMHSs.

A new paradigm for development

Although climate and natural disaster risks have always been a factor in development, development planners have not always known how to use weather, climate and water information effectively; hence, they have not partnered with their NMHSs. Conversely, meteorologists have not understood enough about the impact of climate and disaster risk on development planning to create a demand for their products and services. In other words, the operational meteorologist has not learned the language of the development planners. Another issue is the difficulty connecting science and technology with socioeconomic problems. Politicians and the public want quick solutions. The perceived slow and cautious approach of science to problem solving and the uncertainty conveyed in the results is at odds with the need to make rapid, unequivocal decisions. It is often difficult, therefore, for decision-makers to benefit fully from scientific information and know-how and for the science to satisfy the needs of the user.

The affordability of technological fixes is also an issue, particularly in developing countries. The need for cooperation was highlighted by Nyangenya (2006), an economist from the Kenyan Ministry of Planning and National Development, who identified the need for hydrometeorologists and national planners to work together to mitigate the effects of floods, mudslides and the impact of El Niño, which in 1997/1998 damaged infrastructure and led to the outbreak of climate-sensitive diseases; and the drought of 2000, which led to reduced power generation and significant economic losses in Kenya. He observed that each of these impacts could have been reduced with proper planning but that integrating meteorological and hydrological information into the planning process is presently limited by the lack of tools.

It is easy to say that NMHSs should align with development issues in their countries. It is difficult, however, for them to make this happen on their own. What is needed is a catalyst. In this case, donor governments and development banks, which have the
attention of government leaders, could assume this role. In particular, they can help by encouraging greater intragovernmental cooperation to ensure that there is national capacity to address environmental issues. Bringing both potential service providers and users together at the national level would create the opportunity to develop more robust environmental services. These services would also address the concerns of development banks and donors, which have expressed the specific need to mainstream climate change and disaster risk into national development planning (van Aalst, 2006). An important first step in this direction has been taken by the United Kingdom Department for International Development and the Global Climate Observing System (GCOS) in response to the need for climate information for development in Africa (GCOS, 2006).

In many developing countries, NMHSs lack the capability to provide more than the most basic services and sometimes not even that. The WMO Strategic Plan 2008-2011 identifies a capacity-building thrust and proposes initiatives to improve the institutional infrastructure needed to deliver more societal and economic benefit to a Member State (WMO, 2007). In particular, the WMO Strategic Plan 2008-2011 emphasizes:

- **Enhanced capabilities of Members, particularly Least Developed Countries (LDCs) and developing countries, to fulfil their mandates by:**

  - Increasing their ability to plan, monitor and assess weather, climate and water phenomena more effectively in support of national development plans and policies;
  - Successfully implementing capacity-building activities that improve service delivery;
  - Enhancing the capabilities of Members to support poverty alleviation programmes; and

- Creating the capacity to improve service delivery depends on investment and modernization of services. Achieving this goal, in turn, depends on being able to assess the potential economic benefit of a hydrometeorological modernization programme, which can be used to support the decision to allocate public funds for NMHSs. The World Bank, jointly with a number of NMSs in Europe (including Albania, Armenia, Belarus, Georgia, the Russian Federation and Serbia) and Central Asia have developed benchmarking and sector-specific assessment tools to estimate the additional economic benefits that would be accrued from the modernization and development of hydrometeorological services, as well as assessing the current benefits (Tsirkunov et al., 2007; Ulatov et al., 2007).

**New challenges**

While improvements in forecasting offer opportunities to provide new services better tailored to specific economic sectors, society at large faces new challenges brought about by a combination of demographic changes, climate change and development. Societies nearly everywhere are concerned about stability, food and water security, energy and transportation infrastructure as a means of reducing poverty and achieving the internationally agreed Millennium Development Goals (United Nations, 2006(a)). Poverty eradication has become a major challenge that shapes all aspects of societal and economic development and the benefits that might be accrued from better use of environmental information.
In developing countries, access to reliable energy sources is vital for poverty eradication. Climate-change risk and the absence of reliable environmental data crucial for the development and safe operation of energy systems are growing concerns for the energy sector (Dubus, 2007). NMHSs need to provide data to help in deciding the location and size of future electrical grids and production units, especially those based on renewable sources (Dubus, 2007). They must also be able to provide services for the short- to medium-term management of energy systems, and warnings to minimize the impact of rare environmental events.

For example, unanticipated extreme weather events such as droughts or floods have seriously affected the energy resources of Ethiopia, where 97 per cent of the hydroelectric power comes from the Koka Dam. Major strategies need to be developed to mitigate risks from flash floods and periods of water scarcity. The Ethiopian Electric Power Corporation reported drought-induced hydroelectric power failures that led to revenue losses of US$ 8 million. While this dollar loss is modest for a developed country, for Ethiopia it is enough to destabilize the economy (GEO, 2005). Similarly, in Kenya, where hydropower makes up 75 per cent of electricity generated, drought-induced water rationing in 2000 decreased the overall production of electricity to 40 per cent (Nyangenya, 2006). It was estimated that the loss to the economy approached US$ 100 million per month (GEO, 2005).

Global urbanization is increasing vulnerability as more people live in megacities with new challenges to provide adequate disaster-risk management, public security, climate change risk management, energy supplies, environmental protection and transportation control (Tang Xu, 2007). In Shanghai, for example, multi-agency preparedness, multi-hazard integration and multi-phase response are crucial factors in managing disaster risks (Tang Xu, 2007). Information is integrated across sectors in a geographic information system-based urban information platform, which includes land-type infrastructure systems, emergency-response facilities, meteorological data and other information associated with city operations. From this platform, information can be disseminated to policy-makers, social and economic users and the public. In Shanghai, meteorological services to the public and emergency services are provided using the same grid that is used to monitor and manage community information for city operations. Joint development of information products is also encouraged. This improves decision processes for social and economic activities within the city (Tang Xu, 2007).

The impact of climate on human health is an increasingly important concern with more than 500 million Africans living in regions endemic to malaria, which is highly correlated with the seasonality of climate and a further 125 million living in regions prone to epidemic malaria, which is correlated with climate anomalies (Connor and Thompson, 2005). Climate-sensitive diseases, such as malaria, cholera and dengue are promising candidates for the development of early warning systems designed to allow sufficient time for interventions to mitigate the development of epidemics. Respiratory diseases, linked with air quality, are a problem facing many societies and may become more serious with the development of larger and larger urban settlements. For example, between 20 and 40 per cent of the excess deaths during heat waves are due to air pollution. NMHSs, alone or working with environmental agencies, issue advisories based on air-quality indices. Increasing attention is being paid to the development of dynamic air-quality forecasts as a tool to modify behaviour to improve health outcomes (Jalkanen, 2007).

Ecosystem services are an underlying constraint on food and water security, health, disaster risk management and sustainable development (Millenium Ecosystem Assessment, 2005). Weather, climate and water information continues to be essential for agricultural production system management, particularly crop planning and irrigation scheduling. However, risk assessment of the potential spread of plant and animal diseases, invasive species and the probability of extreme climate events is becoming increasingly important because of the inherent vulnerability of the agricultural system to climate variability (Whung and Wilhite, 2007).

The management of coastal resources is critical for many communities affecting human habitations, coastal and shoreline industry and engineering, food production, coastal marine ecosystems and marine protected areas and the increasingly important marine tourism and recreation industry (Dexter et al., 2007). Monitoring and forecasting change in this system is an important new activity for many Meteorological Services (see for example, the National Centre for Ocean Forecasting, which was started in 2005 by the United Kingdom’s leading marine and oceanographic centres and the Met Office (http://ncof.gov.uk/).

Malaria in Africa (Sources: A. Platt McGinn: Malaria, Mosquitoes and DDT. World Watch, Vol. 15, No. 3)
A new challenge to traditional weather services is the change occurring in commercial aviation. Like most sectors, the aviation industry needs to increase efficiency and minimize costs without compromising safety. While the benefit-to-cost ratio for aeronautical meteorology is positive, there is growing pressure to increase the margins by increasing the efficiency of services, while creating greater societal and economic benefit through more accurate and useful weather forecasts (Puempel, 2007). As consolidation of services increases, the pressure to reorganize aviation weather services will grow. Similar changes are occurring throughout the traditional weather service client base, including broadcasting, road-weather and marine forecasting.

Competition between meteorological service providers in the public and private sector may ultimately improve the efficiency of services, but the transition from a collaborative intergovernmental environment to a market-driven service will need to be carefully managed to avoid undermining the broader societal and economic benefit of the public goods and services associated with NMHSs.

Conclusion

A major limitation in the uptake of weather, climate and water information by users is their inability to use the information to affect the outcomes that they are trying to achieve. It is in the long-term interests of Meteorological and Hydrological Services that resources are invested to increase the value of the weather, climate and water enterprise to improve societal and economic outcomes. In the near-term this may require investment in improving decision processes; for example, developing and using better risk-management tools, at the expense of investment in improving the forecast products. Future services are likely to be more collaborative so that advances in decision processes will be coupled to improvements in forecasts and assessments. The neglect of any part of the value chain—forecasting, communication and decision-making—undermines society’s ability to receive benefit from weather, climate and water products and services.

Development is a special focus for many countries and a growing opportunity for NMHSs to strengthen their climate services and integrate hazard-risk information into decision-support systems in partnership with their clients. Realistically, the expansion in services from weather and hydrological forecasting to climate assessments and partnerships with client sectors, such as health services and planning agencies, cannot be achieved without additional investment. An underpinning assumption is that, if other public sectors such as health and transport are able to make better use of weather, climate and water and other environmental information, they will reduce their operating costs and improve their service delivery. Some of the economic benefits achieved should then flow back to the NMHSs to enable them to continue to modernize their service provision.

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Social and economic benefits of meteorological and hydrological services—a regional overview

Introduction

Following two international conferences focused on understanding the role of National Meteorological and Hydrological Services (NMHSs) in creating social and economic benefits, a third conference entitled "Secure and sustainable living: social and economic benefits of weather, climate and water services", which focuses on users and decision-makers, is planned for 19-22 March 2007 in Madrid, Spain.

Leading up to the Madrid conference, WMO-sponsored national and regional workshops were held, focused on:

- Discussing various issues pertaining to social and economic benefits of meteorological and hydrological services;
- Promoting understanding of various approaches to social and economic valuation of services provided by meteorologists and hydrologists;
- Sharing a variety of useful experiences; and
- Examining difficulties experienced in making optimum use of weather-, climate- and water-related services.

Some areas in which presentations were made were:

- Issues relating to approaches to evaluating socio-economic benefits of weather-, climate- and water-related services;
- Socio-economic benefits of meteorological and hydrological services vis-à-vis investment promotion, poverty alleviation and sustainable development activities;
- Case-studies and good practices on socio-economic benefits of meteorological and hydrological services, with emphasis on the different needs of different countries;
- Users’ needs and how to respond to them; and
- Policy and fiscal issues.

Discussions across regions focused on how to close the gap between producers and users of meteorological and hydrological information and services. Problems of poverty alleviation and how to augment effective implementation of forward-looking environment and development programmes also featured prominently.

These discussions emphasized the need for strengthened communication and collaboration among NMHSs, government ministries and other institutions so as to enable better understanding and appreciation by decision-makers, users and the general public of the social and economic value of weather, climate and water information and services.

List of workshops held

Africa

- Subregional workshop on the social and economic benefits of meteorological and hydrological services—

The crux of economic production in developing countries is agriculture.
Least Developed Countries

Source: UN Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States

Afghanistan  Madagascar
Angola  Malawi
Bangladesh  Maldives
Benin  Mali
Bhutan  Mauritania
Burkina Faso  Mozambique
Burundi  Myanmar
Cambodia  Nepal
Cape Verde  Niger
Central African Republic  Rwanda
Chad  Sao Tome and Principe
Comoros  Senegal
Democratic Republic of the Congo  Sierra Leone
Djibouti  Solomon Islands
Equatorial Guinea  Somalia
Eritrea  Sudan
Ethiopia  Timor-Leste
Gambia  Togo
Guinea  Tuvalu
Guinea-Bissau  Uganda
Haiti  United Republic of Tanzania
Kiribati  Vanuatu
Lao People’s Democratic Republic  Yemen
Lesotho  Zambia
Liberia

of meteorological and related services for north, central and west Africa (Bamako, Mali, 29 May-1 June 2006)

• Subregional workshop on evaluation of the social and economic benefits of meteorological and related services to society in the eastern African region (Nairobi, Kenya, 28-30 August 2006)

• Subregional workshop on the evaluation of social and economic benefits of meteorological and related services to society for southern Africa (Arusha, United Republic of Tanzania 1-3 November 2006)

The Americas

• Regional Technical Conference on Social and Economic Benefits of Weather, Climate and Water Services Brasilia, Brazil (12-14 July 2006)

Asia

• National seminar workshop on the social and economic benefits of meteorological services to Philippine society (23-25 November 2005, Manila, Philippines)

• Subregional workshop on social and economic benefits of weather, climate and water services to society for the League of Arab States (Kuwait City, Kuwait, 18-21 November 2006)

Key issues emerging from the workshops

The most important economic production in developing countries is agriculture. As noted by Sentelhas (2006), about 70 per cent of global land use is for agriculture, rangeland and forestry. Of this, 12 per cent is for arable and permanent crops, 31 per cent for forest and woodlands and 27 per cent for permanent pasture.

In Kenya, for example, Musyoki (2006) notes that agriculture is responsible for 25 per cent of the Gross Domestic Product (GDP), while industry produces 13 per cent, tourism 5 per cent, and services 57 per cent. With respect to the use of water in Kenya, agriculture accounts for 76 per cent of water consumption, with industry using 4 per cent and wildlife and inland fisheries using 1 per cent. This indicates that 81 per cent of the water use in the country has a direct bearing on economic production. On a similar note, Sentelhas (2006) observed that around 80 per cent of crop yield variability is due to changeable weather during the growing season, especially for rain-fed crops. It has been estimated that, directly or indirectly, weather contributes to approximately 75 per cent of annual losses in farm production.

The impact of weather variability is related not only to crop growing and yield but also to farming operations, especially in Least Developed Countries located in arid and semi-arid eco-geographic areas, such as Mali...
(Camara, 2006). Indeed, increased cooperation between meteorologists and the farming community in Mali stemmed from a clear desire to ensure that meteorology makes a practical contribution towards achieving the goal of self-sufficiency and food security set by national authorities following the Sahelian droughts of the 1970s.

In terms of agricultural policy, several issues should be taken into consideration. An interesting example of how important it is to be vigilant when taking decisions was cited by Tahir (2006), who noted that failure to utilize weather and climate information can result in a negative impact on livestock development programmes. He made reference to the case of the Ministry of Trade of Sudan where a decision was taken in the late 1980s to import live sheep from Australia to augment the local meat market. The decision was made in haste, without consideration of the weather and climate situation and whether the imported sheep could withstand Sudan’s tropical climate. After leaving Khartoum airport, more than 60 per cent of the flock developed symptoms of laboured breathing, heart failure and heat stress and died.

Aside from their effect on agriculture, the impact of weather and climate on societal affairs as a whole cannot be overemphasized. As an example, for maximum benefit to society, regional and urban planning should rely considerably on these environmental phenomena. The social effects of extreme weather and climate events were highlighted by Amadore (2005), who noted that education and culture, health and nutrition, employment and social services could suffer tremendously from such events. Amadore also noted that impacts on health could be measured to some extent through mortality rates during disasters which are closely related to infectious diseases.

Other impacts may result after the occurrence of disasters, such as an increased burden on urban resources arising from the migration of displaced local workers to the cities for jobs, increased dependence on government subsidies, worsening poverty, etc. In regions prone to natural hazards, socio-economic losses would be much greater without effective weather- and climate-related early warnings. Samar (2005) cited the case of typhoons Undying, Violeta, Winnie and Yoyong in December 2004, when losses could have been much more than US$ 102.6 million in the absence of relevant weather advisories.

The health sector is an important area of concern. Pérez et al. (2006) reported that, in Cuba, it has been possible to set up a prediction system for various health problems based on expected climate conditions that can offer information sufficiently well in advance on epidemiological risk conditions, based on climate anomalies. This improves the decision-making process arising from scientific, interdisciplinary criteria. Future follow-up research efforts will focus on fine-tuning the epidemiological surveillance system, thereby facilitating the planning of disease-control activities, taking the corresponding political, economic and social effects into account.

Mhita (2006) listed several areas of the economy in which NMHSs play an important role. Reference was made to a range of sectors such as insurance, land-use planning and recreation. The United Republic of Tanzania has shown that meteorological and hydrological information continues to play an important role within the overall framework of national recurrent and prospective socio-economic activities.

Climate information is of key benefit to the tourism industry. Marguerite (2006) highlighted how weather and climate information and services are significant to the tourism industry in Seychelles. Being seasonal, the tourism sector relies on appropriate meteorological and hydrological products, which enable better decision-making on planning and management. These products are useful for advisory services to...
tourists, as well as for wider planning and management of the environment, for sustainable development.

The energy sector is one specific area, in addition to agriculture, in which weather plays an important role. Any form of useful information makes a difference to the economy of a country like Argentina, where, according to Estevez (2006), there is a strong correlation between temperature and demand for natural gas. At a generic level, Dao (2006) described the socio-economic benefits of weather and climate information to the energy sector in Mali.

Estevez (2006) also observed that more than 60 per cent of all households are connected to natural gas supply networks. He noted that properly forecasting the temperature and its effects is essential for determining whom to supply and in what quantities. Analysis shows that the temperature of both the present and the previous day affects daily demand. The time slots when temperature has the greatest impact are 10-12 a.m., 4-6 p.m. and 9-11 p.m. Average temperatures for the previous two days also affect daily demand. The analysis shows that, on peak days, in addition to temperatures for the most significant time slots for the current day, temperatures for up to the third previous day are relevant. In view of this, a model was developed for the office of the Argentine natural gas sector which helps in deciding, according to gas availability, who should be cut off.

The water sector, of course, relies heavily on weather and climate information. Reliance on information could be significant to the national economy of countries like Lesotho, for example, where water export to South Africa is an important foreign exchange earner (Motsomi, 2006).

One area, which is not often mentioned, is the benefit of meteorological and hydrological services to security and law and order. According to assistant police commissioner Barmao (2006), reliable meteorological information can be harnessed to carry out policing duties to the benefit of society. For example, extreme conditions affecting the socio-economic and environmental situation include shortage of food, water, electricity and many other basic needs that lead to human conflicts and can have devastating effects on national security.

Climatic conditions dictate the kind of economic activity to be undertaken by the community. Any negative change of these conditions results in the members of a community reacting in order to protect themselves from adversity. As a result, they may find themselves being victims of, or being involved in, criminal activities, mostly as a result of the circumstances. On another note, heavy rainfall obliges motorists to drive at low speed, making them vulnerable to carjacking. It hinders police pursuit of escaping criminals and contributes to traffic jams and accidents. In Kenya, under extreme temperatures, for example, the police increase vigilance, stop and search suspicious, abnormally overdressed persons who could be bearers of dangerous weapons. Police officers dress appropriately to cope with extremes of temperature so as to remain focused on the job. With reliable and timely meteorological information, therefore, the police benefit through planning and preparedness based, among others, on weather information.

Luganda (2006), Musukuma (2006) and Traore (2006) are of the view that special reference should be made to the role of the media in enhancing the use of climate information, especially on the level of societal and policy responses, hence influencing vital decision-making. Indeed, they note that a strong correlation exists between levels of media coverage of a climate-related issue and public response. In this connection, there is an overwhelming correlation between media coverage and humanitarian response. Indeed, the media can help in averting catastrophe.

During the drought in Ethiopia in 1984, for example, the international media led the response. Local media report on recent droughts in Kenya (2005/2006) led to the saving of lives and property. The media contributed to alerting the world about the 2000/2001 floods in Mozambique. With modern technological know-how, the media continues to play an increasingly important role for the public and policy-makers alike. Traore emphasized the monumental
effect of media and communication to wide-ranging policy formulation for socio-economic development in a Least Developed Country such as Mali.

One of the most appropriate aspects to examine is the planning sector. An important presentation on this issue was made by Nyangena (2006), an economist from the Ministry of Planning and National Development, Kenya. Citing the example of Kenya, Nyangena noted that events which highlight how important it is for hydrometeorologists to collaborate with national planners include:

- Floods which often affect several river basins;
- Drought affects large areas of eastern, Rift Valley and northeastern provinces and high rainfall resulting in mudslides in hilly areas;
- The El Niño episode of 1997/1998 which damaged infrastructure and led to the outbreak of certain diseases such as Rift Valley Fever affecting pastoral communities;
- The drought of 2000 which led to reduced power generation and resulted in blackouts and power rationing estimated to have cost the economy US$ 20 million.

Nyangena (2006) further observed that the effects could have been minimized with proper planning. Rainfall information has been used to identify regions/districts at risk, leading to higher budgetary allocations. Integrating meteorological and hydrological information in the planning process is a major challenge. This is not only because the appropriate planning ministries lack tools and competencies to make the integration, but rather because the available information is reliable only over a short time period. Planners obviously prefer deterministic information to probabilistic ones. Hence, a major challenge is the development of tools for more accurate and longer-term forecasts.

There is no doubt that, within the highly challenging eco-geographic region of the Arab States, weather-, climate- and water-related information and services are of great importance to policy formulation and implementation.

The importance of collaborating with a wide range of users was highlighted in the presentation by Al-Shulaimi (2006) of the Department of Motor Vehicles and Road Emergency, Ministry of Interior, Kuwait. It demonstrated a strong correlation between weather and climate on the one hand and incidences of insecurity and road accidents on the other. According to Al-Shulaimi, when it rains in Kuwait, the number of reported road accidents soars and statistics reveal an average of not less than 90 cases per event. As is the case in Kenya noted earlier (Barmao, 2006), the crime rate in Kuwait, especially smuggling, has strong links with weather with particular regard to visibility, comfort and wind conditions.

In delivering information to users, Rabadi (2006(a)) emphasized the importance of making available factual information based on sound science. With this approach, according to Rabadi, it would be easier to communicate with actual and potential users in a more credible manner. An effective way of approaching users in a professional manner is through dialogue. This could be initiated through an open lecture organized for specific sectors, such as for traffic police and related security operatives.

Other indications of strong links with users in the Arab region were given by Bukhari (2006), who stressed the usefulness of information on wind in the building sector in Saudi Arabia; Edham (2006) emphasized how vital it is to take meteorological information into consideration in Bahrain; and Shuaibi (2006), who revealed the efforts being made to enhance collaboration between users and the meteorological community in Kuwait.

... the media can help in averting catastrophe ...
The role of meteorology in disaster risk management was also elucidated by Rabadi (2006b).

The foregoing overview reflects the nature, diversity and extent of weather- and climate-related disasters, vis-à-vis socio-economic issues worldwide, with further emphasis on the need for an improved approach to management response as a means of preventing loss of life and property.

**Conclusions**

While some individual presentations raised specific issues, the workshops summarized participants’ views on addressing prevailing problems that hamper the optimum use of meteorological and hydrological products for the benefit of society.

The important issues which emerged could be summarized as follows:

- Need to enhance the potential for improved cooperation between producers and users of meteorological and hydrological services and information;
- Need to understand the link between meteorological and hydrological services and users;
- Better appreciation of the need to embark on a systematic approach to the evaluation of social and economic benefits of meteorological and hydrological services;
- Need for incorporation of issues relating to social and economic benefits of meteorological and hydrological services in training programmes, hence, appropriate operators, technicians and managers should be trained accordingly;
- Sharing of essential experiences across countries and regions;
- Challenge to producers and users to prepare proposals for projects, training, policy and fiscal options;
- The involvement of stakeholders such as the media, the private sector and the academia.

The outcomes of the various workshops have gone a long way to contributing towards enhancing understanding of various issues concerning social and economic benefits of meteorological and hydrological services. A key achievement has also been the enhancement of dialogue among practitioners, service providers and policy-makers.

In achieving the objectives of the regional workshops, it was ensured that the various events involved, to an uncommon extent, a considerable number of users of meteorological and hydrological products. Through frank and clear dialogue, overall recommendations revolved around the need to do more in promoting the understanding and application of the benefits of weather, climate- and water-related services.

Social and economic sectors that featured prominently were agriculture, the environment, energy, water resources, health, tourism and transport. Views were exchanged as to how developing and Least Developed Countries could seize the opportunity of lessons learnt from developed countries. On this note, countries were advised to conduct more investigations into identifying the key issues that could be of benefit to the development and implementation of appropriate policy options.

**References**


The presentations given at the regional workshops will shortly be made available by WMO on CD-ROM.
Meteorological information for evaluating agrometeorological risk and uncertainty for agricultural marketing systems

by R.P. Motha* and K.L. Menzie*

Introduction

Agrometeorological risk and uncertainty permeate the global agricultural marketing system with far-reaching consequences for all market participants. Important socio-economic benefits can be achieved by designing business strategies to minimize the impact of these risks. In order to optimize business decisions relative to agrometeorological risk and uncertainty, accurate, timely, consistent, and widely available information is essential. This information requirement can be met in part through periodic review and estimation of global supply and demand for agricultural commodities. The quality and usefulness of such estimation are contingent upon many factors, the single most important of which is accurate and timely assessment of the impact of meteorological events on crop production.

It was the recognition of the need for timely, accurate, and widely available information about global crop production that led to the creation of the World Agricultural Outlook Board (WAOB) within the United States Department of Agriculture. With a staff of about 30 economists and meteorologists, WAOB serves as USDA’s focal point for agricultural market intelligence. Under WAOB direction, interagency committees of experts develop official forecasts of supply, demand, and prices for major agricultural commodities. Parallel to its commodity supply, demand, and price forecasting function, WAOB’s Joint Agricultural Weather Facility (JAWF) coordinates weather, climate, and remote-sensing work among USDA agencies. In addition, and in support of its commodity supply and demand forecasting function, JAWF has operational responsibility for monitoring and analysing the impact of global weather on crop production, which directly affects the quality and timeliness of WAOB forecasts. This activity is conducted jointly by WAOB/JAWF and the National Weather Service of the Department of Commerce.

Global agricultural weather assessments—tools and analysis

The impact of weather on crop progress, condition and, ultimately, production and price, is well documented. For example, timely rainfall and seasonable temperatures can significantly enhance crop production. In contrast, untimely precipitation and temperature extremes can significantly reduce crop production. Given the influence of weather on crop progress and conditions, JAWF meteorologists monitor weather conditions worldwide to help staff economists to better forecast changes in agricultural commodities in the most timely manner.

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JAWF meteorologists employ various techniques to monitor and analyse global weather conditions. Time-series analyses are frequently used to diagnose the timing and cumulative affects of weather throughout the various stages of crop development. These analyses help analysts determine the vulnerability of crops to weather extremes at point locations or within small regions. Analogue comparisons are used often to identify similarities among recent and historical weather data. These analyses enable meteorologists to estimate the likely impact of weather on current crop production based on comparable data from those years when similar weather patterns were observed.

Spatial analyses are also employed to regularly plot and analyse meteorological data relative to geographically important features. Such features may include political boundaries, terrain or crop-growing regions. JAWF meteorologists have implemented operationally a geographic information system to monitor changes in the weather relative to major crop-producing regions worldwide. Applications were developed to facilitate and automate data processing and display, improving meteorologist capabilities to identify and delineate crop areas of concern.

JAWF meteorologists prepare crop weather assessments using a suite of software tools and techniques. Although each of these methods differs in functionality and applicability, they generally fall into one of three independent categories describing the type of analysis performed: temporal, analogue and/or spatial. Each of these analyses is discussed below.

Time-series analyses are frequently used by JAWF meteorologists to determine the timing and cumulative effects of weather on crops during the growing season. When compared with a crop’s growth cycle, time-series analysis can be used to evaluate the impact of hot or cold weather on crops and to track the cumulative rainfall in a particular area. If the combination of heat and dryness occurred during the highly weather-sensitive tasselling and silking period for corn, for example, it would significantly reduce yield prospects. Although excessive heat and dryness can stress crops throughout much of the growth cycle, the timing of these events can result in significantly different yield and production realizations. For this reason, multi-seasonal time-series of weekly cumulative precipitation and average temperature are generated worldwide each week. JAWF currently has the capability to display historical time-series from 1978 to the present for comparative analyses.

When compared with appropriate normals, these time-series provide a useful indicator of favourable or unfavourable growing conditions. Significantly, these temporal analyses also provide a means for identifying similar weather patterns among multiple growing seasons.

A simple yet effective technique for analysing agricultural and meteorological data involves comparing past years for similar growing seasons or time periods. Such comparisons are typically achieved by graphing data from different years over the same time period or growing seasons. Visual comparisons of these data plots can reveal trends and patterns in rainfall or temperatures that are especially valuable in crop weather analysis because of the critical role timing plays in determining the affects of weather on yields and production.

Another effective tool in determining yield potential is the comparison of percentile rankings. These are typically computed for historical monthly or seasonal time periods, enabling analysts to identify similarities in temperature and precipitation patterns among multiple years. With this information, years with similar rankings can be identified to determine what relationship exists, if any, between the yields in years with similar weather occurrences.

Measurements of weather and climate variables are recorded frequently (e.g. hourly, daily, monthly) at numerous weather observation sites worldwide. These data are critical in understanding current and historical trends in the weather and climate at each of these point locations. One of the first steps in JAWF’s data-analysis process is to display individual station data on maps containing the political boundaries of the agriculturally important regions. These maps are used to identify areas where crops may be experiencing weather-related problems caused by extremes in temperature or precipitation and
Risk and the agricultural marketing system

The global food and fibre system—from producer to final consumer—is subject to a wide range of risks and uncertainties. Economic and social benefits can be realized by minimizing the impact of these risks. Risk in agriculture can be broadly defined into several categories (USDA, 2006). Yield risk is probably the most commonly considered risk in agriculture, because it reflects directly the impact of weather on farm operations. Temperature and moisture variation are the typical causes of yield risk, with irrigation being one of the only significant approaches to minimizing the impact of hot or dry conditions.

Production risk entails all the factors that affect yield risk, plus the additional impact that adverse weather may have on producers’ ability to plant. Two crop-specific examples of planting risk include corn/soybeans in the USA and soybeans in India. For the USA, cool and wet spring weather may not allow for timely planting of corn. After a certain date, corn planting becomes infeasible due to the number of days until maturity and, as the spring days pass, the increased likelihood of the crop being affected by freezing episodes in the autumn. Initially, producers can consider shorter-season varieties of corn but, eventually, acreage that had been intended for corn may be shifted to soybeans.

Another example is soybean planting in India. Area devoted to planting soybeans can be significantly affected by the timing and consistency of the monsoon. If the monsoon begins early and rainfall remains relatively consistent, soybean planting often continues beyond initial expectations, with a resulting increase in total area planted to soybeans and a likely increase in expected production.

Price volatility is another important source of risk. Commodity price information is critical to producers, buyers and sellers up and down the supply chain. Agricultural commodity prices are subject to sharp fluctuations over relatively short periods of time and over a wide geographical range, depending on both local and global supply and demand conditions. Adverse or favourable agrometeorological conditions in one part of the world can lead to uncertainty and price risk in distant markets.

Income risk is caused by the three types of risk previously described, plus additional factors, including variation in the price and availability of the inputs required for production. For example, if a particular variety of wheat planting seed is grown in Argentina and producers in southern Brazil prefer that type of seed, then availability and price of the planting seed will have an impact on the incomes of Brazil’s wheat producers. The global interconnectedness of agricultural markets increases the influence of risk beyond local markets.

Directly or indirectly, each economic agent at every level of the global agricultural marketing system is affected by one or several of the risk types defined above. All market participants derive economic benefits from improved resource allocation made possible with timely information about the condition of crops.

Another example of risk is the direct impact of drought on producers in an affected area. Lower yield reduces production for each producer, potentially putting each producer’s income at risk. If the drought is widespread, national production levels may be reduced, resulting both in higher prices and an atypical seasonal pattern of prices. Higher prices and atypical seasonal price affect producers’ decisions about quantity and timing of sales that can maximize income.

Producers beyond the region immediately affected by drought are also affected. The decisions these producers make ultimately affect soybean supply and demand, first in local markets but, ultimately, in global markets. Because drought affects the level and seasonal pattern of prices but not production levels for producers beyond the geographical reach of the drought, these producers have an opportunity to maximize income by taking advantage of higher prices caused by the drought. Because the drought affects the seasonal price patterns, causing a sharp departure from normal, however, these
producers must also consider the timing of sales to maximize income.

The grain storage business is also potentially affected by drought. Specific effects depend on the location of the storage. For storage facilities in the drought region, the main issue is whether there will be enough crop volume to efficiently utilize available storage. For storage facilities located in parts of the country not directly affected by the drought, the main issue is one of timing. While there is enough volume to utilize storage capacity efficiently, the impact of the drought is the level and pattern of cash and futures prices and how these impacts will affect the optimal timing of sales.

The grain transportation system, like the storage system, depends on volumes of grain to maximize income. For the rail system, one of the main issues is positioning of rail cars during the harvest season and in the months that follow. When drought strikes a region, demand for rail cars may diminish there but may increase in parts of the country not directly impacted. Increased demand in the non-affected producing areas may come from domestic soybean crushers and exporters as these enterprises attempt to meet business needs. Water transportation services are affected in the same manner as rail transportation. Barges and oceangoing vessels may be in less demand because of reduced soybean supplies and increased prices that may reduce buyer demand. Profit and income is at increased risk for businesses that provide water transportation for grain.

Global soybean supplies are distributed almost equally between the northern and southern hemispheres, so a drought in the northern hemisphere likely leads to global supply adjustments six months later. South America accounts for more than 50 per cent of exportable supplies of soybeans, soybean meal and soybean oil. When global supplies are disrupted owing to a drought in the US Midwest, higher prices occur in global markets. Higher prices signal producers in South America to expand the area devoted to soybeans in the fall planting season subsequent to the drought. Higher production in South America leads to increased exports of soybeans and products from the southern hemisphere and a shift in the demand for storage and transportation services from the region.

The entire agricultural marketing system is dependent on timely information about crop development in order to operate efficiently. Economic benefits are derived by both producers and consumers from accurate and timely information. WAOB/JAWF assessments of meteorological effects are critical to providing such important information.

Conclusion

Risk and uncertainty affect every aspect of the agricultural commodity marketing system, from producer to final consumer. Weather-related yield and price risk translates into income risk in agricultural markets around the world. Accurate, timely, consistent, objective and widely available information, resulting from analysis of the impacts of weather on crop production, improves economic efficiency and provides socio-economic benefits to agricultural producers and consumers alike.
Impact of climate change on sugar-cane production in Fiji1
by J. Gawander2

Sugar-cane and climate

The climate of the South Pacific region is strongly modulated by the El Niño-Southern Oscillation (ENSO) phenomenon. This leads to significant interannual variability in the frequency of many extreme weather types, such as tropical cyclones and associated storm surge, floods and droughts in the region (Prasad, 1979).

Sugar-cane is one of the most important agricultural crops in Fiji. As it is totally rain-fed, climate variability has a major impact not only on sugar production but also on the national economy. Therefore, it is essential to understand the impact of major changes in climate patterns that affect sugar-cane and sugar yield. Sugar-cane industries worldwide are exposed to climate-related uncertainties across an integrated chain of industry sectors, including cane cultivation, harvesting, transport, milling, marketing and shipping (Muchow et al., 1999). There are feasible management options such as introducing irrigation systems to mitigate some of the adverse impacts of climatic variability.

As many decisions in the Fijian sugar industry are affected by climate, advance knowledge of climate variations using climate-forecasting tools can therefore enhance planning across each of the sectors of the industry. This would reduce the adverse effects on the socio-economic system in rural areas.

Increased capacity for utilizing climate predictions in management decisions would be beneficial to the sugar-cane industry in Fiji and needs to be further pursued, given the present and anticipated impacts of climate variability on sugar-cane and other agricultural crops.

The sugar industry in Fiji

The sugar industry was established in Fiji over 100 years ago and is the third highest revenue earner for the country, after tourism and garment manufacturing. Owing to the manual planting and harvesting techniques employed and the special land-tenure system for small farm units, it is unique. There are only a few countries in the world whose economies depend on sugar as much as Fiji.

Sugar is a major foreign exchange earner, accounting for about 40 per cent of the country’s total merchandise exports and 12 per cent of Fiji’s Gross Domestic Product (GDP). The industry provides employment for about 25 per cent of the economically active population of Fiji and a large number of people are indirectly dependent on it for their livelihoods. Furthermore, the smallholder system of cane-farming confers widespread benefits and has a strong multiplier effect on the economy.

While efforts to diversify the economic base of the nation are continuing rapidly, sugar will remain the economic backbone of the nation for some time to come, barring strong international market changes and national changes. Being an industry whose product is traded in the international market, it has to face up to major price fluctuations. Thus, in the past and at present, its fortunes have fluctuated accordingly. Despite this, the industry has survived, prospered and maintained its dominant position in the Fijian economy, even though the single most important factor responsible for production is climate variability.

Climate as a resource

Climate is rarely considered as a valuable natural resource available for economic and social growth until a major event disrupts the production of energy, agriculture or poses a risk to the health of the population. Recent awareness of climate change has to some extent assisted in using this important resource wisely.

Recent studies have revealed that Pacific island countries have warmed...
on average between 0.3°C and 0.8°C during the last century. In the past four years of this century, they have continued to record higher-than-normal temperatures, while the number of hotter days and nights per year have been increasing.

State-of-the-art global climate model (GCM) (Lal, 2004) projections indicate that, in the South Pacific, the average annual mean surface temperature rise by the end of this century is projected to be between 2.5°C and 3.5°C. An average increase of some 3-8 per cent in annual mean precipitation is simulated.

This is a major concern for sugar production in Fiji as sucrose accumulation could be affected with increased minimum temperature accompanied by rising sea-level and saltwater intrusion and large-scale inundation of coastal areas due to storm surges.

Recent impacts of climate on sugar-cane and sugar production

In view of the fact that the sugar industry is totally rain-fed, climate variability has a major impact not only on sugar-cane and sugar production but also on the economy of the nation. The sugar-cane and sugar yields have fluctuated with extreme events in Fiji. In 1994, a record production of 516 529 tonnes of sugar was recorded, thanks to excellent ripening weather conditions during the months of April and May. A record for the 1970s and 1980s was established in 1979 and again in 1986, when cane production peaked at 4.06 m and 4.1 million tonnes, respectively, and sugar production reached 473 000 and 501 800 tonnes, respectively. Unfortunately, drought conditions in the year 1997 and tropical cyclones Evan and Freda (19 January-2 February 1997) and Gavin (8 March 1997), led to a decline in production to 2.2 million tonnes of cane and 275 000 tonnes of sugar. In 1998 and 2003, production again dropped substantially to 255 703 and 293 653 tonnes of sugar, respectively, due to droughts. A similar drop occurred in 1983, but production was restored to the pre-drought level in the following years. Thus, it is essential to understand the impact of major changes in the climate patterns that are the important resource affecting sugar-cane and sugar yields.

Seasonal climate outlooks in the South-West Pacific

The climate of the South Pacific region is strongly modulated by the El Niño-Southern Oscillation (ENSO) phenomenon and this leads to significant interannual variability in the frequency of many extreme weather events, such as tropical cyclones and associated storm surge, floods and droughts in the region (Prasad, 1979). Droughts related to ENSO are common. In the South-West Pacific, droughts can occur at both ENSO extremes (El Niño and La Niña).

Other persistent weather events in the region are associated with the influence of Madden-Julian Oscillations (MJO) on the shifts in the mean position of the South Pacific Convergence Zone (SPCZ) and associated extreme rainfall events (Madden, 1986; Kiladis et al., 1989; Salinger et al., 2001). High-resolution global climate modelling studies (e.g. regional climate models, variable resolution models, time slices) carried out at major international research centres during the past decade have provided a useful means of studying the mechanisms of the genesis of ENSO episodes, MJO and SPCZ in the equatorial Pacific Ocean (Jones et al., 1998; Latif et al., 1999; Li and Hogan, 1999; Landssea and Knoff, 2000; Lambert and Boer, 2001; Li and Yu, 2001; Folland et al., 2002). Today, these models are able to demonstrate the capability of simulating some aspects of interannual and interdecadal variability in climate variables when forced by historical sea-surface temperatures. Efforts are also underway to gain a better understanding of mechanisms related to extremes in weather and climate in association with large-scale circulations.

Effect of climate at various levels of the industry

Climate affects all levels of the industry, even up to policy level. At the policy level, advanced knowledge of climatic conditions for the season helps in formulating and planning policies associated with possible extreme events. At the selling level, an accurate estimate of crop size helps in making advanced shipping-schedule arrangements and advanced selling and storage strategies. Even the global supply-and-demand situation could be better understood by having advanced knowledge of climatic conditions in other countries.

At the factory level, good forecast information has a major impact on management decisions. An accurate idea of crop size influences the beginning of the crushing season and the closure of the mills. It also helps in planning for general maintenance of the mills in the slack season, i.e.
whether it is going to be a short or a long slack season.

In normal times, the mill opens in June and closes in early December but in years when the crop size is large, adverse climatic conditions late in the season result in standover crop or huge losses due to a low percent age of "pure obtainable cane-sugar" in the wet season. In Fiji in some years, mills had to operate up to mid- to late January, resulting in the tonnage of cane exceeding the production of sugar. However, if a few months before mill opening, it is known rainfall will be low in May-June and high in November-December, then the mills can open earlier. On the other hand, if the crop is small, mill opening could be delayed so that the crop could achieve high sugar levels in September. This ensures better profit from a high percentage of pure obtainable cane-sugar levels.

Advanced knowledge helps in planning for wet weather disruptions on flat and hilly land areas. At the farm level without irrigation, cane yield is highly dependent on rainfall. Most of the management decisions for the grower are dependent on weather and climate forecasts from initial land preparation to planting, fertilization, herbicide spraying, weed management, cane harvesting and shipping.

Thus, the need for accurate forecasts is extremely important but this is not appreciated by many people in most sectors until a major catastrophic weather event occurs.

Climate change in the Pacific

Pacific island communities are faced with new challenges resulting from changes taking place elsewhere in the world—climate change and sea-level rise, in addition to natural and environmental disasters already in place. There is increasing evidence available today that the Earth’s climate has changed during the past century.

Global mean temperature data indicate that the year 2002 was the second warmest on record, exceeded only by 1998 and well above the average temperature of 14°C that prevailed from 1951 to 1980 (Jones et al., 1999). According to recent projections (IPCC, 2001, TAR WG II, Chapter 17), the rise in annual mean surface temperature of the Small Island Developing States of the Pacific is likely to range between 1.5°C and 2.0°C in the 2050s and between 2.5°C and 3.5°C in the 2080s due to future increases in greenhouse gases.

A decline in summer rainfall over some islands is also projected, leading to low soil moisture and, hence, reduced water availability for agriculture and other domestic and industrial uses. Future increases in the frequency of heavy rainfall events (leading to more flash floods and landslides) and a decrease in the number of wet days per year are also projected (Kothavala, 1997; Hulme and Viner, 1998).

Recent analyses of surface temperature data over a network of stations in Fiji also suggest that the 1990s were the warmest years on record (relative to the 1961-1990 average) and that the past three years of the 21st century have continued to record higher-than-normal temperatures (Lal, 2004). The warmth in the west Pacific during 1998-2002 has no precedent in at least the past 150 years (Folland et al., 2002). Climate attribution studies find that this warming (approximately 1°C since 1950) is beyond that expected of natural variability and is due partly to the ocean’s response to increased greenhouse gases. This may be a harbinger of future droughts.

Not only sugar-cane productivity but also that of cassava and other root crops, which are important daily foods for the communities in Fiji, could be adversely affected should there be a change in rainfall pattern and rise in temperature above a threshold. Fiji’s sugar-cane productivity, already vulnerable to extreme events such as droughts, tropical cyclones and cyclones, may be able to tolerate
moderate variations of the climate mean within a cropping season for some hybrid varieties. Changes beyond these bands of tolerance (region-specific), however, may require shifts in cultivars, new technologies and infrastructure, or, perhaps, conversion to different land uses.

Global and regional climates will continue to change in the future if greenhouse gases from anthropogenic sources continue to increase. The threat of global warming and likely changes in regional climate variability in general and the intensity of El Niño events in particular has added another dimension to our concern in Fiji. A marked shift in teleconnection links between rainfall in Pacific Island countries and El Niño/La Niña/SO/MJO/PDO is almost certain (Ishii et al., 1998; Knutson & Manabe, 1998; Knutson et al., 1998; Knutson et al., 1999; Kharin and Zwiers, 2000).

Climatic factors affecting cane and sugar production

Rainfall

Rainfall is the single most important factor responsible for sugar-cane production in the rain-fed sugar industry of Fiji. As rainfall is significantly affected by extreme events such as El Niño and La Niña, cane production is also accordingly affected. The annual rainfall averages between 1 700 mm and 3 000 mm, of which 75 per cent falls in summer between November and April. Most cane-growing locations receive less than 25 per cent of annual rains in the period of May to October. This low rainfall has a major effect on crop production.

Radiation

Solar radiation is the main source of energy for photosynthesis and is also responsible for loss of water from soil and plants. As radiation cannot be conserved, it is essential to have management strategies to intercept most of the radiation by appropriate times of planting and row spacing. The objective is to plant the crop in April and May so that it closes its canopy by late spring and thus intercepts maximum solar radiation in summer.

Temperature

The rate of photosynthesis is dependent on temperature, as are many other biochemical processes controlling meristematic activity for leaf and bud development. Photosynthesis efficiency of sugar-cane increases in a linear manner with temperatures in the range of 8°C to a maximum of 34°C. Cool nights and early morning temperatures 14°C in winter and 20°C in summer significantly inhibit photosynthesis the next day. In Fiji there is little variation in temperature and thus sprouting and emergence are not much affected, even though, in cool conditions, some varieties take longer to emerge than others. The variety Nadiri in Fiji emerges in only five to seven days and is one of the fastest emerging varieties. The stalk elongation of sugar-cane is also sensitive to temperature, with general acceptance that the peak growth phase is terminated by onset of mean day temperatures less than 21°C.

Temperature and percentage of pure obtainable cane-sugar

It is generally accepted that leaf growth is constrained at temperatures less than 14°C-19°C. Cool night temperatures and sunny days slow down growth rates and carbon consumption, while photosynthesis may continue, thus enhancing sucrose accumulation. The stalk elongation is more sensitive to lower temperatures than are photosynthetic rates. Thus, accumulation of sucrose is not favoured at high temperatures as growth rate increases more than photosynthetic rates.

Baseline climatic studies

Temperature and rainfall data for the baseline period 1961 to 1990 have been analysed for four mills, namely Lautoka, Rawawai, Penang and Labasa. They indicate that surface air temperatures have registered increasing trends at all the mills during the period 1961-2003. There has been a steady increase in the number of days per year with warmer night-time temperatures in recent decades. The rise in annual mean surface air temperature over Labasa is ~1.5°C over the 43 year period considered (at a statistically significant increasing rate of 0.38°C per decade, which is more than twice that of the trend in global average temperature increase during the past century). The rate of increase in annual mean surface air temperature at Lautoka and Penang is 0.17—only 0.05°C per decade—but at Rawawai there is no significant change.

No trend has been observed at any of the locations in annual mean rainfall. Significant interannual variability in annual as well as summer rainfall observed at all the sites, including extreme rainfall events during the 43-year period, could be largely attributed to ENSO events and intra-seasonal oscillations in the mean position of the South Pacific Convergence Zone.

There are several feasible management options to mitigate some of the impacts of climatic variability, even in Small Island Developing States (SIDS) like Fiji. These would reduce the adverse effects on the socio-economic system in rural areas. The sugar industry has been totally dependent on climate patterns since its inception and as a result is vulnerable to extreme events such as droughts, tropical cyclones and cyclones, as well as ENSO-related climate variability. There is sufficient data to evaluate the impact of such climate events on the production of sugar-cane in Fiji.

Agricultural industries in all small island States are exposed to climate-
related uncertainties and the sugar-cane industry is no exception. It affects all levels of the industry, from cane cultivation to harvesting, transport, milling, marketing and shipping (Muchow et al., 1999). A series of recently completed studies offers a partial understanding of the full relationships and associated benefits of the integrated knowledge of the climate-sugar system. Among these are lessons on methodologies for the use of a forecast in a region, appropriate use of climatic information, water-soil relationships, implications for pest management, economic benefits of different crop modelling approaches and the need to understand decision processes. These studies have been carried out in Australia (Everingham et al., 2001), Trinidad and Tobago (Pulwarty et al., 2001) and elsewhere.

In Small Island Developing States there are limited technical recommendations because of a lack of accurate weather forecasts to develop strategies at grower level. There is a need for closer cooperation between the growers and implementing agencies of strategies to minimize the adverse effect of climate on cane. It is proposed here that such an approach would more strongly link scientific knowledge of the agro-climatic calendar (contingent on forecasts), to the annual cycle of decision-making, especially where probabilistic information is being employed (Pulwarty and Melis, 2001). A preliminary project was undertaken to develop a crop simulation model which can assist in practical application but the project fell short of providing the answers that were being sought.

There is a strong consensus in the international and national communities that climate change is occurring and that the impacts are already being felt in some regions, particularly in Small Island Developing States. It is also important to note that, even after introducing significant measures to reduce greenhouse gas emissions there would still be a degree of climate change occurring, which would have economic, social and environmental impacts on all SIDS.

Whilst the impacts would vary on a regional basis, all areas of the country and every economic sector would be affected in Fiji. This is because climate is a natural resource, not only for Fiji but also for many SIDS, as they lack other natural resources, have a narrow range of skills and low economic resilience and are susceptible to natural hazards such as tropical cyclones and tsunamis (Hess, 1990).

**Conclusion**

Climate is an important resource for small island agricultural countries such as Fiji, where the contribution to global greenhouse emission is negligible but where the future effects of climate change and sea-level rise are expected to be significant. These impacts will be felt by many future generations because the islands have low adaptive capacity, high vulnerability to natural hazards and poor forecasting systems and mitigating strategies.

A nation’s economic and social well-being are greatly influenced by food security, health and sustainability of its natural resources, including climate, water, crops, forests, fish stocks and the reliability of transportation and health care systems. Research into impacts and adaptation strategies suggests that the most significant challenges would result from increases in the frequency and intensity of extreme climate events, such as floods, droughts and tropical cyclones. Extreme events, as well as rapid climate change, can cause critical thresholds to be exceeded, often with severe or catastrophic consequences.

More needs to be done by the international community in small island countries such as Fiji, therefore, to ensure reliable and accurate forecasting systems that can be used by growers and which demonstrate to decision-makers at all levels the advantages of using seasonal forecasts.
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The socio-economic benefits of climatological services to the renewable energy sector

by S. Robles Gil

Introduction

Renewable energy technologies, such as solar, wind and biomass are considered to be technically feasible and economically viable options in the near future. They can help solve the problems of using fossil fuels and provide many other benefits that together make them worthwhile, even at slightly higher costs.

Weather and climate play an important role in the availability of renewable energy resources, the consumption of energy and the selection of fuels. They also affect the performance of the renewable energy systems and their conversion processes, and some of the activities related to their use.

This article briefly outlines the solar, biomass and wind-energy conversion systems, their socio-economic value to various nations and their requirements for climate information.

Overview of the renewable energy sector

Solar energy

Solar energy is the largest renewable energy source and, ultimately, it is inexhaustible. It has a wide geographic distribution and can be used in a decentralized way. Various solar energy technologies that have been developed to take direct advantage of both light of the Sun and its heat.

Thermodynamic systems

Thermodynamic conversion has been, since ancient times, the most exploited form of solar energy use. Through this process, solar radiation (direct or diffuse) is converted into heat. An exposed collector increases in temperature and the heat absorbed is transferred to a fluid and transformed into mechanical, caloric or electrical energy.

Passive solar systems

Passive solar systems help to enhance and control the input of solar energy for space heating and cooling and lighting needs, as well as to conserve energy. The technology has been widely developed and used in Europe, Canada and the USA, and it has been gaining interest in developing countries. Passively solar-heated buildings are highly economical, well received and of interest to architects. Their use has many different technical, environmental,
Costs of renewable energy technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Current energy cost (US$/kWh)</th>
<th>Potential future energy cost (US$/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar heat</td>
<td>0.03-0.20</td>
<td>0.02-0.03</td>
</tr>
<tr>
<td>Solar thermal electricity</td>
<td>0.12-0.18</td>
<td>0.04-0.10</td>
</tr>
<tr>
<td>Solar photovoltaic electricity</td>
<td>0.3-1.5</td>
<td>0.05-0.06</td>
</tr>
<tr>
<td>Wind energy</td>
<td>0.12</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Source: UNDP-WEC, 2005

and socio-economic advantages: they work naturally, cleanly and simply by using climate (sunshine and wind) as a favourable energy resource. This locally generated energy supports energy conservation and helps reduce the demand for conventional fuels.

Active solar systems

Active solar systems capture solar energy by a collector that converts the energy into heat. The heat is used for multiple applications, such as domestic hot water, heating swimming pools, pumping and irrigation systems, water desalination, cooking, drying agricultural products, refrigeration and industrial process heat or steam for generating electricity.

Solar water heating at low temperatures is the most widely used solar technology. It is considered to be the best application for active solar-heating in Europe, especially in Austria, Germany and Greece. It is also widely used in some other developed countries such as Australia, Israel, Japan and the USA and is gaining more attention in developing countries. China, especially, has increased its use and now is the largest solar market worldwide (Huang, 1993; Everett, 2004).

In many regions, the dissemination of solar water-heating depends strongly on governmental policy, mainly because of the relatively high heat-production costs, which are about US$ 0.03–0.20 a kilowatt hour (kWh) but, for the long term and under favourable conditions, the cost might be one of the lowest to produce heat—US$ 0.02–0.03 kW/h (see table above).

Concentrated solar power uses large sun-tracking mirrors to concentrate solar radiation. These may range from small multi-kW systems to large power stations producing tens or hundreds of megawatts. Solar thermal electricity is technically feasible and in many countries is well proven and cost effective. It is the lowest-cost solar electricity in the world, promising competitiveness with fossil-fuel plants in the future. Electricity production costs of grid-connected solar thermal electricity systems may come down from US$ 0.12–0.18 kWh today to US$ 0.04–0.10 kWh in the long term (see table above).

Photovoltaic systems

Photovoltaic systems convert sunlight directly into electricity by using photovoltaic cells. Solar energy is an intermittent source with a relatively low energy density that makes collection and conversion to some extent expensive and inefficient; therefore, some applications require batteries for storage, increasing the complexity and the cost of the systems. The use of grid-connected photovoltaic systems eliminates the need for storage and also allows the owner to sell the excess energy to the local utility.

The cost of the photovoltaic cell has been one of the main constraints for the conversion of solar energy into electricity, but prices are currently falling and the industry is expanding rapidly. Photovoltaic electricity production costs are about US$ 0.3–1.5 kWh (see table), depending on sunshine duration, turnkey costs, depreciation periods and interest rates. Under favourable conditions, the lowest cost figure may come down to US$ 0.05–0.06 kWh.

Photovoltaic technology has an enviable record for the generation of power in stand-alone homes and buildings. Its high reliability and low maintenance requirements have led to a high degree of consumer satisfaction, both in developed and developing countries, and especially in remote, environmentally sensitive areas with no electrical grid. The installed photovoltaic capacity base is concentrated in a relatively small number of countries, such as Japan (48 per cent), Germany (21 per cent), and the USA (16 per cent).

Photovoltaic systems use free and abundant fuel and a locally generated energy, reducing the reliance on foreign energy sources. They are environmentally safe, reliable, flexible in size, and easily transportable, require little maintenance and have a long life. They are also beneficial to the national economy for they create jobs, are economically effective, may improve the quality of life of people living in remote and isolated areas, and may be used as hybrid systems (Shepperd and Richards, 1994).

Biomass energy

Biomass was the main source of energy until the beginning of the 20th century, when fossil fuels largely replaced it. At present, biomass is the world’s fourth largest energy source, providing about 11 per cent of the world’s energy supply and covering almost four-fifths of all renewable energy use (European Commission, 2002). These energy-conversion systems range from simple, traditional and low efficiency processes that burn feedstock directly, to modern, highly efficient technologies that convert feedstock into
higher-value or more convenient solid, liquid, and gaseous fuels (Kaltschmitt and Dinkelbach, 1997).

Traditional biomass continues to be the major source of energy in developing countries, reaching 33 per cent of the total energy use, especially in rural areas, where it may reach 90 per cent (Larkin et al., 2004). The share of biomass in industrialized countries averages only 3 per cent of their total energy consumption, but modern biomass energy technologies have been increasing and can be significant in some countries with large forestry industries or well-developed technologies for processing residue and wastes, such as Finland and Sweden, reaching around 20 per cent.

Thermochemical conversion
This technology is based on the decomposition of biomass by means of heat. It uses open fires, stoves, boilers and furnaces for direct combustion and kilns to produce charcoal and gasifiers to make producer gas.

Direct combustion
This is the simplest and most common method of capturing the energy contained in biomass. It is economically attractive only in regions where the costs of feedstock are cheaper than fossil fuels and in areas situated far from urban centres.

Most wood-fuel consumption is for traditional use in households, for cooking, heating water, lighting and space heating. It is also used to fire ovens and kilns and to produce steam and electricity for mechanical power in some industries. It is a proven technology for generating electricity, particularly in those industries that produce residues, such as sugar mills, pulp and paper industries and sawmills. Large contributions of sugar-cane bagasse to total primary energy are found in countries such as Brazil, Cuba and India.

The use of improved stoves in many countries allows benefits such as saving fuel, decreasing local pressure on wood resources, using local construction materials, reducing gas emissions, improving health, saving money, reducing effort, saving time and improving the quality of life. The greatest improvement in stoves is being undertaken in China and India (Bhattacharya, 2004).

Solar panels can deliver about 30-40 per cent of electricity needs in some countries.

Wood energy in Europe and OECD (Organization for Economic Cooperation and Development) countries accounts for about 4 per cent of the total primary energy supply. In some countries it is higher, as in Austria, where it reaches 14 per cent, and in Sweden and Finland where it reaches more than 17 per cent (Van den Broek, 1997). For municipal solid waste, Europe is ahead of the rest of the world: energy from waste is ideal for effective and sustainable waste management.

Pyrolysis
This system has been used since ancient times for making charcoal and, until more recently, for the production of gaseous fuels and oil. The technology is well established and kilns can be made at a minimal cost, so the potential for cost reduction is low. Charcoal is used mostly for cooking, space heating and sanitizing water. It remains an important source of energy in many African, Latin American and Asian countries, mostly in urban populations. Brazil, where the introduction of improved kilns has been successful, is the main charcoal-maker in the world (WEC-FAO, 1999). The use of charcoal has several advantages over fuel wood: a higher efficiency and convenience, and an easier distribution.

Biomass gasification
This technology converts solid biomass to gaseous fuel. The availability of the resource is high, because gasifiers can use feedstock with varying moisture and ash content. Biomass gasification is still in a developing stage and costs are relatively high. Biomass gasifiers supplying low-to-medium BTU (British thermal unit) gas are now in operation in both industrialized and developing countries, but the number of units installed is small. They produce heat for boilers, driers and kilns or power for electricity generation, water pumping, grain milling, and sawing timber.

Compared to the conventional power systems, biomass gasifiers are relatively benign to the environment and have some other advantages:

• They create jobs in rural regions;
• Small-scale heat biomass-gasifiers are technically reliable and economically viable;
• Cost-reduction potential is high.

Biochemical conversion

Biochemical conversion of biomass into a fuel can be achieved either by anaerobic digestion or by alcohol fermentation.

Anaerobic digestion

This conversion system is now considered state-of-the-art and is one of the most economical and easily obtained energy sources for small communities. It is an option for feedstock with high moisture content that cannot be burned directly. The technology is available commercially but the cost-reduction potential is low. The biogas obtained can be used for multiple applications: cooking, lighting, refrigerating and space heating for domestic and commercial needs; heat for industrial processing; running pump sets and other agricultural machinery; internal combustion engines for motive power; and for generating electricity.

Biogas technology is known in most developing countries, where it has gained wide use, especially in China and India. Industrialized countries have built larger and more elaborately controlled digesters (Dobelmann and Müller, 2000). Landfill gas has been also gaining importance, especially in Austria, Finland, France, the United Kingdom and the USA, where some power plants are now operating.

Biogas production through anaerobic digestion guarantees a reliable and cleaner renewable source that reduces water pollution, requires a small area, increases hygienic conditions, reduces the annoyance caused by odour and helps mitigate climate change. It is an easily recoverable feedstock, economically viable, that also provides a residual sludge useful as animal fodder or fertilizer.

Alcohol production

The production of alcohol from biomass is now state-of-the-art. Although production costs have decreased over the last decades, energy costs are still high and cost-reduction potential is low. Liquid biomass fuels have particular promise for replacing fossil fuels for transportation in an economically competitive way. Ethanol can be easily used in the transportation sector instead of gasoline or as an admixture. Bio-energy could largely contribute to the energy supply in growing cities where air pollution has become a serious environmental and health problem.

Global interest in ethanol fuels has increased considerably over the last few decades. Many countries have pioneered both small- and large-scale ethanol fuel programmes, especially Brazil and the USA. Besides other environmental advantages, the production of alcohol for energy use helps revitalize rural communities because it creates a large number of jobs and enhances national energy security.

Physico-chemical conversion

This conversion system produces a liquid biofuel obtained by pressing or extracting biomass that contains vegetable oil. The technology has been state-of-the-art for decades, but the energy costs are still high and the cost-reduction potential is low. The oil produced is simple to use as a fuel. Depending on the type of burner, it can be used either pure or in mixtures for heating systems. It can also be substituted for diesel or added to diesel without problems (BMFT, 1992).

The use of bio-diesel is not yet common, but it has been extensively tested both in the USA and Europe. There are no significant projects in developing countries, but some progress has taken place in Malaysia, India, Nepal and Thailand (Bhattacharya, 2004).

Energy plantations

The concept of growing biomass specifically for energy purposes is young and experience is still limited. Its use is rapidly increasing, however, and modern wood-energy applications are becoming more competitive with conventional applications.

Some industrialized countries, such as Finland, Sweden, the United Kingdom and the United States, have implemented several research- and development programmes. Developing countries are also implementing programmes on sustainable biomass for energy purposes. For example, farmers in India, Kenya and Rwanda are turning to agro-forestry to respond to local demand for wood and to improve the environment. Other effective experiences can be found in Brazil, China, Ethiopia, Pakistan, the Philippines, Sri Lanka, Turkey and Uruguay, which have remedied some of the environmental damage caused by earlier deforestation (World Bank, 1996; Saraçoğlu, 1998).

Modern bio-energy has many significant socio-economic benefits. It helps revitalize rural communities, creates a great number of jobs, diversifies production, reduces migration to urban areas, saves money, strengthens the local economy and increases income stability. It also diversifies fuel supply, enhances national energy security, saves on foreign exchange and provides economic security (FAO, 1997; Börjesson, 1998; UCSUSA, 1999; ABA, 2000).

Energy plantation costs are already favourable in some developing countries. For example, eucalyptus plantations in north-east Brazil supply wood chips at US$ 1.5-2.0 per gigajoule, whereas costs are higher in industrialized countries— as much as US$ 4 per gigajoule in some parts of north-west Europe (UNDP-WEC, 2005). Co-generation systems, such as natural gas and coal with biomass, can achieve...
lower costs. If biomass integrated gasification/combined cycle (BIG/CC) technology becomes available commercially, production costs could drop further to about US$ 0.04 kWh (UNDP-WEC, 2005).

Wind energy

Wind energy is a form of solar energy that has been used since ancient times for sailing, pumping water and grinding grain. Currently, it can either be used directly or converted into a higher-value, highly flexible and useful form of energy: electricity (AWEA, 2005).

Mechanical energy has limited applications. Windmills are less widely used today, but they still provide energy for pumping water and milling grain in many rural areas, especially in developing countries. Modern wind-energy converters constitute a maturing technology that has started to supply electricity on a small scale to remote sites, where it is frequently used for pumping water, charging batteries and for communication systems. It may also reduce the electric bills of home-owners. On a larger scale, windfarms with many large generators provide electricity to utility grids and, from integrated systems with other generators (photovoltaic, biomass, or diesel), provide electricity to small grids.

Wind economics depend on the distribution of the wind resource, electricity costs and the system chosen. The world’s total wind-power generating capacity accounts for approximately 0.5 per cent of the world’s power generation. The world’s largest wind power installed capacity is found in Germany (38 per cent), Spain (16 per cent), the USA (16 per cent) and Denmark (8 per cent). Some other countries are India, Italy, Japan, the Netherlands and the United Kingdom (British Petroleum, 2004).

Wind-energy technology has continuously improved; it is more reliable and costs have fallen around 90 per cent during the last 20 years. Wind power is one of the fastest growing renewable-energy technologies and is one of the most cost-effective methods of electricity generation available, even with the relatively low current cost of fossil fuels (Taylor, 2004). For instance, with average wind speeds at the hub height range of 5.6–7.5 m/s, the corresponding electricity production cost is about US$ 0.12 kWh (see table, page 41). Cost reductions of up to 45 per cent are feasible within 15 years and, eventually, wind electricity costs might come down to about US$ 0.03 kWh.

The use of wind energy has many advantages, it is environmentally friendly, creates jobs, revitalizes communities, uses local energy, eases the demand on the power grid, saves conventional fuels, diversifies a nation’s portfolio and helps reduce the energy shortage.

Requirements for climate information

Climate and weather play an important role in the availability of solar, wind and biomass-energy sources and in the demand for energy. They also have a significant effect on system performance.

Energy systems must be carefully designed to operate reliably, efficiently and at low-cost, thus the planning and design stages need detailed, historic climate information, which usually consists of average climate data to determine the availability of solar, wind and biomass resources; the selection of biomass feedstock; the appropriate orientation of buildings; the energy demand variations; icing risk; the site selection of solar, wind and biomass-energy systems and their optimal performance.

Once a renewable energy system is operating, it is unlikely to be affected by average weather and climate conditions, because these were considered during the design stages. The system may be affected by unusual weather and climate variability. For operation, current data, weather forecasts and advisories are mostly needed, especially for the daily performance of the renewable energy systems, decision-making, control of biomass growth and yield predictions.
Climate monitoring and prediction should be considered for energy applications, because they could largely assist in forward planning and adaptation for certain large-scale anomalies. Some of these requirements are already available from standard climatological summaries, but others need to be developed to satisfy the specific needs of solar-, wind- and biomass-energy users.

Conclusions

Energy sources such as solar, biomass and wind offer a renewable, clean and decentralized option that in the future could help both meet the world’s energy demand and reduce our current dependence on unreliable, finite and centralized energy sources. They would also lessen the environmental problems caused by consumption of the latter. The use of renewable energy can create jobs, possibilities for using local construction materials and provide attractive options for specific energy needs, especially in developing countries and rural areas.

A wider use of these renewable energy systems is a challenging technical and socio-economic process that requires the cooperation of diverse sectors. The participation of climatologists is essential to provide the information and advice that users require for the successful development and operation of these alternative energy systems.

References


Pisa is the capital city of the Province of Pisa in Tuscany, central Italy, renowned worldwide for its Leaning Tower, which attracts millions of tourists every year.

Construction of the Tower began in 1173. It was designed to be “vertical”, but acquired a lean owing to a poorly laid foundation and loose substrate that allowed the foundation to shift. Over the centuries, the Tower sank even further into the ground. A multinational task force met in 1964 to discuss stabilization methods and after over two decades of concertation, the Tower was closed to the public in January 1990. After a decade of reconstruction and stabilization efforts, the Tower was reopened to the public on 15 December 2001 and has been declared stable for at least another 300 years.

The public are now allowed to go up to the top of the Tower, where meteorologists might be surprised to find an automatic weather station. Recent studies on the interactions of the atmosphere and the Tower have demonstrated that the columns and capitals are subject to the greatest damage as a result of cycles of heating and cooling caused by their dimensional structure and by their direct exposure to the Sun. Major damage to the surfaces of the Tower is related to the impact of rainfall, while the area under the inclination is subject to greater particle deposits, which, being screened from the rainfall by the Tower itself, are not washed away. These impacts were demonstrated by an analysis of the microclimate around the Tower by Camuffo in 1996.

Need for greater awareness

Recent awareness of the impacts of climate on a number of ecosystem goods and services also helped turn the attention of climatologists to the issue of the impacts of climate on monuments.

Intense rainfall and changes in humidity cycles can cause damage due to faulty or inadequate water disposal systems. The porous nature of the building material allows the water from the ground to enter the structure and eventually escape into the environment through surface evaporation. From the point of view of archaeological remains or cultural artworks, the important aspect about heavy rain is how hot and dry the weather is afterwards, because it is the drying-out process that is damaging. Crystallization and dissolution of salts caused by wetting and drying affects standing structures, archaeological remains and wall paintings, frescoes and other decorated surfaces. Relative humidity cycles and shocks can causing splitting, cracking, flaking and dusting of materials and surfaces.

There are numerous examples of damage to monuments due to flooding due both to direct erosive impacts of flooding and to indirect impacts from the continuous and long period of growth of moulds.

In the case of temperature, it is not the absolute temperature that affects masonry, but the range of temperatures and the time period of their occurrence. Diurnal and seasonal changes in temperatures and extreme events such as heat waves and snow loading can cause deterioration of facades due to thermal stress. Cycles of freezing and thawing and overheating during heat waves can damage internal structures.

Growing populations close to heritage sites and lack of appropriate land-use planning have led to the destruction of natural vegetation barriers to wind. As a result, storms and wind gusts are showing greater impacts on historical monuments than before. Wind-driven rain and sand, especially in semi-arid regions, can cause structural damage and collapse, while surfaces of monuments can deteriorate under the erosive effects of both water and sand.

In many areas, climate and pollution can act together to cause immense damage to monuments through stone recession by dissolution of carbonates, blackening of materials, corrosion of metals, etc.
Cultural heritage is the legacy of physical artefacts and intangible attributes of a group or society that are inherited from past generations, maintained in the present and bestowed for the benefit of future generations. Our cultural and natural heritage are both irreplaceable sources of life and inspiration.

In August 2002, the historic city of Prague was devastated by a flood. Old theatres, libraries, churches, museums and synagogues suffered damage amounting to some 80 million euros. In the same year, the Cloth Hall, a World Heritage site in Cracow, Poland, was partially destroyed by a severe storm.

The United Nations Educational, Scientific and Cultural Organization (UNESCO) seeks to encourage the identification, protection and preservation of cultural and natural heritage considered to be of outstanding value to humanity. This is embodied in an international treaty called the Convention concerning the Protection of the World Cultural and Natural Heritage, adopted by UNESCO in 1972. The World Heritage List counts 830 properties which the World Heritage Committee considers as having outstanding universal value. These include 644 cultural, 162 natural and 24 mixed properties in 138 States Parties.

Climatologists around the world must take an active interest in World Heritage concerns, which is now receiving greater attention in the light of projected climate change.

Climate change and heritage

Climate change is high on the international agenda. Rising sea-levels are threatening coastal sites, such as the four World Heritage sites of London. Desertification is threatening others, such as the three Great Mosques of Timbuktu in Mali. So far, however, few governments have considered the effects of altered weather on important buildings and monuments.

UNESCO convened a Group of Experts on Climate Change and World Heritage, which met on 16 and 17 March 2006 at the request of the World Heritage Committee. The report “Predicting and managing the effects of climate change on World Heritage” presents an overview of climate change, the impacts of climate change on natural and cultural heritage and the implications for the World Heritage Convention, as well as a number of recommendations. Some of the recommendations relevant to WMO are as follows:

- The World Heritage Committee could collaborate with the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC) by presenting information at the Conference of the Parties (COP) and meetings in the context of the work programme of the Subsidiary Body for Scientific and Technological Advice and encouraging the exchange of experts and the use of UNFCCC guidelines. National Focal Points of both Conventions could also work together on climate change issues;

- Wetlands are vulnerable to climate change and have limited adaptive capacity. Innovative solutions are therefore required. Management plans need to consider impacts of climate change and other pressures, minimize changes in hydrology from other human activities, reduce non-climate pressures and monitor the changes. Monitoring is essential to evaluate the effectiveness of adaptation options and steps to rectify any adverse effects should be part of the adaptive management strategy. A key limitation to implementing adaptation and mitigation options for wetlands is the lack of knowledge of wetland hydrology, their functioning, their uses and past and present management;

- Rigorous monitoring and maintenance are essential to ensure a continuous redefinition of adaptation strategies as climate projections are refined. Training in the various problems and possible responses to climate change in all aspects of conservation activity,
namely, development of traditional skills, monitoring, management and emergency preparedness, is equally important;

- **Strengthening of existing networks** is necessary, together with ensuring that climate change issues become a part of the exchange of information within those networks. Environmental effects are transboundary. At the very least, regional networks need to be strengthened and focused on climate change adaptation;

- More research is needed on the effects of climate change on both the physical heritage and on the social and cultural processes of which they are a part;

- UNESCO’s World Heritage Centre could engage with key climate change researchers of the Intergovernmental Panel on Climate Change to encourage them to address cultural heritage issues more directly. This would ensure that climate data of direct relevance to World Heritage are given the necessary attention;

- Strengthened capacity-building is important for dealing with the effects of climate change, as well as for good communication and awareness programmes. There is a need to ensure improved gathering and analysis of information to identify evolving conditions related to climate change. Developing adequate monitoring systems where they do not exist and strengthening existing ones will be an important aspect of this effort;

- Not only extreme events should be documented but also short cycles of change that can make significant changes to cultural heritage. Records of short cycle changes will gradually expand the notion of climate change impacts on cultural heritage and enrich understanding.

- **Information needs to be disseminated in the following specific areas:**
  - Climate-change modelling and monitoring geared to cultural heritage;
  - Prediction of subsidence and heave caused by extreme weather;
  - Understanding of damage mechanisms and remediation due to extreme weather;
  - Understanding the effect of wind-driven rain, leading to severe damp penetration;
  - Understanding the effect of wind-driven dust and pollutants, leading to erosion and weathering;
  - Environmental performance of historic buildings under extreme weather;
  - Mobilizing public and political support for climate change adaptation and mitigation inside and outside World Heritage sites is essential. This could be achieved by a variety of measures—workshops, exhibitions, media campaigns, audiovisual material and popular publications—which link the global phenomenon of climate change to the local and regional context;

- **Specific World Heritage sites to be used as demonstration models for countries and other stakeholders to design adaptation and mitigation strategies for sites facing climate change challenges:**

  - Assess the vulnerability of natural World Heritage sites in terms of their exposure, sensitivity and adaptive capacity to the present and potential future impacts of climate change and develop strategies for those at most risk;

  - Specific site-level mitigation and adaptation strategies should be designed and implemented in partnership with relevant stakeholders. States Parties and site managers need to look beyond the individual site level and develop and implement regional and/or transboundary mitigation and adaptation strategies that reduce the vulnerability of natural World Heritage sites in a broader context;

  - Assess future climate change scenarios through appropriate tools and guidelines;

  - Monitoring climate, climate impacts and management responses is critical. There should be a focus on professional monitoring strategies. Remote-sensing such as satellite technology, non-destructive techniques and bio-sensing to assess biological damage to materials and the use of simulation tools to predict the impact of climate change on the behaviour of cultural heritage materials are needed;

  - A strategy for dealing with disasters arising from climate change should be linked with wider disaster risk planning and strategy efforts including the “Strategy for reducing risks from disaster at World Heritage properties” prepared by ICOMOS,

The World Heritage Committee endorsed the recommendations and requested States Parties and all partners concerned to implement the Strategy so as to protect the universal value, integrity and authenticity of World Heritage sites from the adverse effects of climate change. It decided that sites affected by climate change could be registered on the List of World Heritage in Danger.

Furthermore, the Committee requested the World Heritage Centre to prepare a policy document on the impact of climate change on World Heritage properties. The draft policy document should include considerations of the synergies between conventions dealing with this topic, identify research needs, and address legal questions on the role of the World Heritage Convention with regard to suitable responses to climate change. It should also define links with other United Nations and international bodies dealing with this issue.

Studies of climate and monuments

A project called NOAH’S ARK is studying how climate change might affect European cultural heritage. The project is mapping areas where built heritage and cultural landscapes are at greater risk of future damage, for example due to rainfall changes or extreme climatic events. It will offer advice on how to protect different types of monument against these new threats.

NOAH’S ARK brings world-class climatologists together with specialists in the protection and conservation of cultural heritage. In its first year, the project used the Hadley Centre (Met Office, UK) climate models to provide information relevant to the effects of weather on buildings and monuments.

The partners have now generated the crucial variables, which include relative humidity, the number of days with high wind speed and predictions of heavy rainfall and storm events for three time periods: the present (1961-1990), the near future (2010-2039) and the far future (2070-2099). These databases will form the basis of a vulnerability atlas of Europe, showing areas where changes in conditions will pose a threat to cultural heritage.

The team is also modelling future levels of air pollution, long understood to have an adverse impact on buildings and monuments. The outcome of all this research will be a set of mitigation and adaptation guidelines, targeted by monument type and building material, which will be made available for public use at the end of the project in 2007.

A new report The Atlas of Climate Change: Mapping the World’s Greatest Challenge compiled by researchers with the Stockholm Environment Institute with assistance from the United Nations Environment Programme, was unveiled at the 12th Conference of the Parties to the UNFCCC and the second Meeting of the Parties to the Kyoto Protocol held in Nairobi, Kenya. The report describes impacts such as rising sea-levels, flooding and storms. Mosques, cathedrals, monuments and artefacts at ancient sites are threatened by changes in climatic conditions, which in turn may lead to damaging shifts in moisture levels affecting structures directly, or the chemistry and stability of soils on which they are found.
Weather forecasting in West Africa over the last 25 years

by Ernest A. Afiesimama*

Brief historical background

Meteorological Services were first established in different countries of West Africa in order to make observations of meteorological parameters at a few stations, particularly in capital cities. With the era of commercial flights, aeronautical weather forecasting became a major activity of the National Meteorological Services (NMSs). These NMSs have developed and now have the responsibility of providing basic and specific weather and climate information/data for commercial, industrial and agricultural purposes for private/public agencies and individuals. The overall aim is to contribute to sustainable development in all socio-economic activities.

Weather forecasting methods

From the 1980s, when unprecedented advances in technology and know-how occurred, until the mid-1990s, weather forecasting in West Africa was done mainly by the conventional method, i.e. obtaining synoptic data from the WMO Global Telecommunication System (GTS), plotting the data on weather maps and analysing them, with weather forecasters making deductions from them.

In the last 10 years, with the availability of the METEOSAT meteorological data distribution (MDD) system, analysed and forecast maps are retrieved to supplement the conventional method. With the dearth of synoptic data from stations in West Africa due to changes in telecommunication facilities, dwindling economies and social instability, reliance on numerical maps (analysed and forecast fields) from world modelling centres became preponderant. At present, there are few forecasting centres that still use conventional methods.

Conventional methods

Essential to the preparation of successful forecast charts are careful analyses and consideration of a series of surface and upper-level charts. Analyses do not end with the construction of suitable isopleths which fit the available observations and are reasonable from the aspect of continuity. It is most important that the latest charts and the preceding series are meticulously examined so that the weather forecaster obtains an appreciation of movement and development in time and space. The weather forecaster also studies the charts to obtain an understanding of the situation which is satisfactory from the geometrical, kinematical, statistical, dynamical and physical viewpoints. This is an exacting task, which can seldom be completed in its entirety on the forecast table, even when much time is devoted to the analysis.

With experience and good judgement, forecasters find that it is usually possible to apportion the time available for consideration of the analysis in a reasonably satisfactory manner. The proportions are not, of course, fixed. In situations with a well-established and dominant synoptic-scale system, the forecaster often proceeds to a consideration of mesoscale systems and developments, because these are the systems (disturbance/squall lines, mesoscale convective systems, etc.) that are responsible for the weather situation in the northern hemisphere summer.

When the synoptic- and mesoscale systems interact in a complex manner, which sometimes occurs during a change of season, the greater part of the time for consideration may be profitably spent on synoptic-scale developments. The forecaster’s ability to identify the important areas or any particular chart is obtained by a combination of theoretical knowledge, practical experience and wise judgement. This is a great asset in the preparation of forecast charts if they are to achieve a continuing high standard of accuracy.

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Problems associated with conventional methods

A number of difficulties are associated with this method in West Africa. Synoptic chart analyses cannot give accurate forecasts of meteorological elements over a part of any country. This is because:

- The synoptic chart analysis method cannot take into account the meso- and convective-scale systems and orographic forcings, which have a great impact on the weather of the region;

- The conventional synoptic analysis method is time-consuming and largely dependent on the space-time availability of the weather records from the synoptic stations;

- Upper-air and surface data are usually inadequate either because of telecommunication problems or internal disturbances. This means that the region is not well resolved in space and the atmospheric situation structure and physical process operating in the atmosphere are not well understood;

- Pressure and temperature tendencies are ill-defined and difficult to detect on synoptic charts. Most synoptic systems are quasi-stationary, yet small fluctuations can cause considerable change in weather parameters, especially rainfall.

Because of these shortcomings, and the availability of the meteorological data distribution system, weather forecasting in the region gradually shifted to numerical methods in the 1990s.

Numerical weather prediction (NWP)

This approach to weather forecasting is the development of mathematical models based on physical laws, which describe the complex behaviour of the atmosphere. Such models are used with success on time-scales of a few days to months. The world of the future will be dominated by numerical weather forecasting models and guidance based on the output of those models. Numerical models are currently being employed in many parts of the world to simulate observed phenomena such as the development of fog, clouds, flash floods, storm surges, environmental pollution and degradation, ozone layer depletion, climate change, etc.

There may have been only one or two complete numerical modelling activities over West Africa to date. Forecast offices use model output products from world modelling centres such as Météo-France, the European Centre for Medium-Range Weather Forecasts (ECMWF) and the Met Office, UK, as part of the preparation of weather forecasts in the region. The weather forecaster receives printed weather maps from modelling centres on a daily basis through the meteorological data distribution system or the Internet. These maps contain analysed and forecast fields.

The success of the forecast depends on how the physical processes have been represented during the model simulation and not necessarily the features seen on the weather maps. The approach used by some forecasters to improve forecasts based on the models or to “add value” to model output is that of statistics techniques. These include model output statistics, the perfect prognosis method and the Kalman Filter method. The idea is to draw up an observed field and compare it with the forecast field and make appropriate error adjustments to obtain a new forecast field.

Problems associated with NWP in the region

Although the method has advantages in terms of the speed of providing model output products, there are certain challenges in the region. Numerical models are currently limited by our incomplete understanding of the weather systems and how the various atmospheric, land-surface and oceanic components interact. In addition, we are unable to transform this incomplete understanding into mathematical representations. For example, parameterization schemes such as the convection scheme used
in the model which provides output products in West Africa do not adequately represent the sub-grid weather systems.

One major challenge requiring a solution is in the area of capacity building. Scientists in this specialized field are lacking and young students should be encouraged to study mathematics and physics, which are foundation courses for numerical modelling. Also, visits to world modelling centres are important to acquire skills, as the field is very dynamic.

**Ensemble forecasting**

Forecasters in West Africa have always understood the value of examining multiple NWP forecasts to help produce a more reliable forecast. However, this depends on the NWP products available from the different global and regional modelling centres. West African forecasters are familiar with two types of ensemble forecasts. These are forecasts from different models and forecasts from one model but with different initial conditions. What are available to the West African forecasters are the former. The forecast products common to the region are those from centres such as ECMWF, Météo-France, the Met Office, UK, and, most recently, the Global Forecast System.

Ensemble prediction is a relatively new tool for operational forecasting that allows for more rapid and scientifically based comparisons of multiple model forecasts. A more complex approach is to use various statistical and graphical methods to combine multiple model runs, each based on slightly different initial conditions or using slightly different model configurations and/ or parameterizations. In this way, they can include information about the level of uncertainty, the most likely forecast outcomes and probabilities of those outcomes. With ensemble prediction products added to their NWP toolkit, forecasters in the region now have another level of information that will help them enhance the use of NWP guidance in their forecast process.

**Communication infrastructure for weather forecasting in West Africa**

Accurate weather forecasting is impossible without a fairly sophisticated level of technological development. The development of sensors to detect the present state of the atmosphere and a communication system to collect and disseminate the data rapidly are essential. Meteorological equipment has evolved and satellite-based meteorological telecommunication systems have replaced the old analogue ones.

**Socio-economic benefits of weather forecasting in the region**

Weather forecasts in West Africa play an important role in the enhancement of socio-economic activities by providing accurate weather and seasonal information, especially rainfall and temperature. These vital meteorological variables contribute to agricultural productivity and water-resources management in the form of early warnings. This is a region whose population of more 200 million depends on agriculture. The seasonal forecasts made annually at the African Centre of Meteorological Application for Development have helped in no small measure to provide information to farmers for improved agricultural productivity. The forecasts obtained from numerical models have also been useful for impact assessment so as to provide adaptation strategies and mitigation options for extreme weather events.

Another critical aspect is that of reducing human casualties from hazardous weather. Aviation, although adjudged the safest mode of travel, is still subject to the vagaries of weather. From thunderstorms/lightning and downbursts, to wind shear and fog, clear air turbulence and dust haze, as well as temperature and pressure extremes, every phase of flight has the potential to be impacted by weather. Commercial aviation in West Africa deals with these adverse types of weather regularly and the cost implication is significant, aside from the discomfort and anxiety caused to travellers. Casualty mitigation has a substantial economic impact. In the last couple of years, a considerable reduction in accidents and incidents in air travel has been recorded.

**Acknowledgment**

This work was prepared with support from START International under the START/PACOM Award 2005 through a grant from the US NSF (GEO-0203288). It was carried out at the Regional Meteorological Training Centre, Lagos, Nigeria.

**References**


Without the basic meteorological data, the hydrologists, agriculturists, aviation authorities, transport officials and economic planners—to mention only a few—are unable to tackle their problems on a sound basis. Priority in WMO technical assistance has always been given to building up meteorological services in countries where there is no service at all or only a very rudimentary service ... the cover photograph shows a WMO expert giving instruction to some Afghan trainees in Kabul.

Contents

Fifty years ago, the main items in the January Bulletin were technical assistance, climatology, agrometeorology, radiation and radiosonde comparisons, the second session of the Commission for Maritime Meteorology, the International Radiation Conference and the International Geophysical Year 1957-1958. A few highlights are given below. (A full account of the January Bulletin 50 years ago will be available in the February 2007 edition of MeteoWorld on the Web: http://www.wmo.int/meteoworld/en/

Weather and potato blight in Chile

By P.M. Austin Bourke, Irish Meteorological Service

[This disease is caused by the fungus Phytophthora infestans.] Since no effective way to eradicate the disease was known, the Chilean authorities adopted the introduction of more resistant varieties of potato and the use of fungicides to hinder the spread of the disease ... Spraying was a costly business ... machinery for spraying was sparse and transport of equipment and materials was not easy in a country where the potato growing regions stretched for over a thousand miles of often difficult terrain.

The life cycle of Phytophthora infestans is controlled by environmental conditions ... In certain humid conditions, the fungus forms spores outside the plant surface and it is at this stage that the disease is vulnerable to protective measures ... the meteorologist can help considerably to make fungicide applications less costly and more effective by indicating to farmers the optimum times to spray—neither too late, when the damage is already done ... nor too early, when the protective layer on the plants is apt to be washed off by rains and a substantial amount of new unprotected foliage will have grown before the disease is again on the move.

The criteria [were] ... a minimum period of 12 hours with relative humidity not below 90 per cent and temperature not below 90 per cent and temperature not below 10°C, followed by at least four hours during which the foliage of the plants is wet owing to rain, drizzle, dew or wet fog. In the rainy area, these conditions are, as in Ireland, mostly associated with low pressure systems and often with the influx of maritime tropical air masses. In the coastal areas of north Chile where rainfall is sparse and where crops must be irrigated, the humid conditions favouring blight come from the frequent fogs which are caused by the cold coastal Humboldt current and which are often accompanied by morning drizzle, too light to make any measurable contribution to the recorded precipitation.

Weather ... favourable to blight ... is to be expected on an average of about one year in eight. In between
the seasons of widespread epidemic blight, local conditions in almost every year will lead to losses of yield in sheltered and humid locations. Even in seasons of comparatively little disease on the foliage there is a risk of appreciable loss of crop due to washing down of the spores by rainfall to infect the tubers.

In order to provide data for a potato blight forecasting service, the Chilean authorities proposed to set up a network of agrometeorological stations at their agricultural experimental farms. The observations will also be applied to investigations into the environmental aspects of other plant diseases of economic importance to Chile, such as wheat rusts, apple scab and sunflower rust. They will further be of value in planning and introduction of new crops and plant varieties, in determining the water requirements of crops as a prelude to scientifically planned irrigation and in the many other aspects of Chilean agriculture in which weather plays an important part.

Many other interests in the nation’s expanding economy—forestry, fisheries, tourism, building, sanitation, medicine, aviation, hydroelectric work, water boards, etc.—stand to gain considerable benefit [from the application of modern meteorological methods]. There is a growing realization that the climate of Chile is as much a part of her natural wealth as are her copper mines and nitrate deposits, and could be far more efficiently utilized than at present in the drive to heighten living standards.

**The task ahead in climatology**

By C.W. Thornthwaite

... climates are not simple latitude belts. They [are] highly irregular areas exhibiting contrasts in moisture supply and in wind movements as well as solar heat, which are reflections of the general circulation of the atmosphere and which, in turn, are strongly affected by the distribution, orientation and configuration of the great land masses and water bodies over the Earth’s surface.

... early investigators devoted much effort to developing standards of instrumentation and exposure. At the same time, the basic geographic quality of climatology was gradually lost from view. To many people, the content and scope of climatology is only this—the measuring, recording and averaging of standard meteorological elements. ... climatology, when circumscribed in this way, is sterile and unrewarding.

The fault lies, at least in part, with the climatologists who are responsible for the collection and compilation of the basic data.

... proper field for study in climatology is not limited to the atmosphere alone but must include the land surface as well. ... any region is a composite of innumerable local climates; the climate of the ravine, of the south-facing slope, of the hill top, of the meadow, of the corn field, of the woods, of the bare rocky ledge.

In recent years there have been numerous examples of the application of climatological principles in the solution of practical problems in agriculture, industry and defence. I regard this as a wholesome and thoroughly desirable development. However, in order for our science to advance we must continually add to the store of basic climatological knowledge. Applied and fundamental research in climatology must go forward side by side ... Only by diligent effort can we hold for climatology its newly won respect.

**Membership of WMO**

Sudan became a WMO Member State on 2 January 1957. WMO thus had 70 Member States and 25 Member Territories.

**Postage stamps in honour of WMO**

The United Nations would be issuing a set of two postage stamps in honour of WMO on 28 January 1957. The stamps would be for denominations of 3 and 8 US cents and would be of the same design except that the name of WMO would be in English on the 3 c stamp and in French on the 8 c stamp. The stamps could be used for mail posted in the UN post office in New York. The stamps depicted a radiosonde balloon symbolizing the globe and the worldwide range of WMO’s activities.

**News and notes**

**Presentation of first IMO Prize to Dr Hesselberg**

The first IMO Prize was presented to Dr Th. Hesselberg, former director of the Norwegian Meteorological Institute, at Oslo on 21 September 1956. The presentation was made by the President of WMO, Mr André Viaut, at a ceremony in the meteorological institute at Blindern.
Review

The Asian Monsoon
Bin Wang (Ed.)
ISBN 3-540-40610-7
Price £ 154/US$ 259.

Research into the Asian monsoon has a long history but substantial progress has been made since the 1960s through a number of international and regional monsoon projects and field experiments.

Understanding of the monsoon climate and its changes represents one of the most difficult challenges to climate science because of the complexity of its interactions over a wide range of atmospheric processes, as well as associated interactions between the atmosphere, ocean and land. The Asian monsoon can have not only significant regional implications, but also important impacts on the global climate system and global climate prediction.

The Asian Monsoon is the first comprehensive book to bring together the knowledge gained over the past two decades. Unlike traditional monsoon meteorology, this book describes the Asian monsoon system as an interdisciplinary scientific theme incorporating the atmosphere, the ocean and the land surface, all of which interact through physical, chemical and biological processes.

The book makes an important contribution to the understanding of the monsoon environment by including analyses of paleoclimatic records, human influences and impacts of the monsoon on the economy and human health. It also contains new ideas that are expected to markedly improve predictions of monsoon climate variations and anthropogenic changes. A distinctive feature is that it combines modern observations with explanations of the physical principles governing monsoon climate variations on all time-scales, ranging from intraseasonal to tectonic. Most chapters contain an authoritative review of the subject and highlight conceptual breakthroughs, as well as frontier research issues.

An overview describes the coupled atmosphere-ocean-land dynamic system that interacts with other components of the Earth’s climate system. The powerful boreal winter monsoon and AustraV summer monsoon over the maritime continent and Australia are considered, providing a comprehensive overview of the monsoon in general and the Asian-Australian monsoon in particular.

Monsoon variability is considered over a broad range of time-scales, from days to decades, and on various spatial scales, from the smallest mesoscale to continental and global scales. The great variety of monsoon weather is described and a comprehensive review of current knowledge and issues of the monsoon’s intraseasonal variations is presented. A summary is given of the main features of interannual variability and possible causes. Variability on the decadal to interdecadal time-scale is also addressed. Several chapters are devoted to improving the understanding of the monsoon system’s physical processes and its roles associated with the Earth’s climate system. They look at atmospheric internal dynamical processes on the mesoscale and on large and planetary-scales. Hydrological processes are also discussed, as well as interactions of the monsoon system with land-surface processes, El Niño/Southern Oscillation-Asian monsoon interactions and the role of the Tibetan Plateau. A firm basis for understanding the complex monsoon physics is thus laid.

Numerical modelling and prediction of monsoon activity is addressed. The governing dynamical controls and physical representations that determine the potential predictability of monsoons are explored. Although
the dynamical models of the coupled ocean-atmosphere-land system still have considerable difficulty in capturing the predictability, the discussions offer new ideas that are expected to contribute to noticeable improvements in monsoon climate prediction in the coming decades.

With regard to enhancing understanding of the monsoon environment and its societal influences, evidence from palaeorecord studies shows that the Asian monsoon system has undergone remarkable changes on geological time-scales. A detailed account is given of past monsoon cycles according to geological, orbital and millennial and centennial time-scales. In the future, anthropogenic influences, including land-use/cover changes and atmospheric composition changes on regional and global scales, may considerably affect the future of the Asian monsoon. Possible human influences on the Asian monsoon are discussed, with focus on agriculture and the economy.

This book can be used as a comprehensive interdisciplinary text for students, both undergraduate and graduate. It can also serve as a professional reference for research scientists and professionals in many fields. Most of the material in this book will also be of great value to non-specialists.

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New book received

The Equations of Oceanic Motions

P. Müller.  
x + 291 pp.  
Price: £45/US$ 80

Modelling and prediction of oceanographic phenomena and climate are based on the integration of dynamic equations. The Equations of Oceanic Motions derives and systematically classifies the most common dynamic equations used in physical oceanography, from those describing large-scale thermohaline circulations to those describing small-scale motions and turbulence.

After establishing the basic dynamical equations that describe all oceanic motions, Müller then derives approximate equations, emphasizing the assumptions made and physical processes eliminated. He distinguishes geometric, thermodynamic and dynamic approximations and the acoustic, gravity, vortical and temperature-salinity modes of motion. Basic concepts and formulae of equilibrium thermodynamics, vector and tensor calculus, curvilinear coordinate systems and the kinematics of fluid motion and wave propagation are covered in appendices.

Recent WMO publications

Technical regulations (WMO-No. 49)  
Volume III—Hydrology  
Loose-leaf; updated by supplements when necessary  
2006 edition  
ISBN: 92-63-15049-4  
Price: CHF 71

Guidelines for the education and training of personnel in meteorology and operational hydrology (WMO-No. 258)  
2006; Volume 1, Supplement No. 1  
(F, R and S in preparation)  
24 pp.

Guide on meteorological observing and information distribution systems for aviation weather services (WMO-No. 731)  
(F, R, S in preparation)

Guide on the quality management system for the provision of meteorological service for international air navigation (WMO-No. 1001)  
2006; v + 54 pp.  
(F, R, S in preparation)  
ISBN: 92-63-11001-8  
Price: CHF 25

Guidelines on the role, operation and management of National Hydrological Services (WMO-No. 1003)  
2006; viii + 74 pp.  
ISBN: 92-63-11003-4  
Price: CHF 18

Drought monitoring and early warning: concepts, progress and future challenges (WMO-No. 1006)  
2006; 24 pp.  
(F) (S in preparation)  
Price: CHF 15

Legal and Institutional aspects of Integrated Flood Management—Case Studies (WMO-No. 1004)  
2006; iv + 97 pp.  
[E]  
Price: CHF 20

2006; CD-ROM  
ISBN: 92-63-11007-7  
Price: CHF 20
Visits of the Secretary-General

The Secretary-General, Mr Michel Jarraud, recently made official visits to a number of Member countries as briefly reported below. He wishes to place on record his gratitude to those Members for the kindness and hospitality extended to him.

Cyprus

On 15 September 2006, the Secretary-General participated in the event marking the official launching of the WMO cartoon booklet “We care for our climate”, which was translated into Greek and published by the National Meteorological Service of Cyprus. During the ceremony, which was organized by the Meteorological Service and the Ministry of Education, Mr Jarraud thanked the Permanent Representative of Cyprus with WMO, Mr Kyriakos Theophilou, for an important contribution that has now been made available to all Members, through its publication on the WMO Website (Info showcase).

Slovenia

On 4 September 2006, the Secretary-General visited Ljubljana, Slovenia, on the occasion of the Sixth Annual Meeting of the European Meteorological Society (EMS) and the Sixth European Conference on Applied Climatology. At the opening ceremony, Mr Jarraud made a presentation entitled “Climate information and services: leveraging opportunities and risk management”. The Conference, which drew on experience presented by scientists and experts from European National Meteorological Services, research institutes, universities and private organizations, is one of the major regular events in European meteorology.

During his visit, the Secretary-General met with Mr Janez Podobnik, Minister of Environment and Spatial Planning of Slovenia, as well as with Dr David Burridge, President of EMS, Mr Silvo Žlebir, Director General of the Environment Agency of the Republic of Slovenia, and Mr Jožef Roškar, Director of the Meteorology Office and Permanent Representative of Slovenia with WMO.

Peru

The Secretary-General visited Lima, Peru on the occasion of the 14th session of Regional Association III (South America), which was held in Lima from 7 to 13 September 2006. Mr Jarraud visited the Ministry of Defence and met with the Minister, HE Ambassador Allan Wagner Tizón.
The opening ceremony took place in the presence of Mr Renzo Chiri Márquez, Secretary-General of the Ministry of Defence; Mr Raúl Micheliní, Acting President of RA III; and Mr Edison Díaz Villalta, Chief of the National Meteorological and Hydrological Service and Permanent Representative of Peru with WMO. Also present at the ceremony were Mr Pablo Cisneros Andrade and Mr Roberto Briceño Gordillo representing the Peruvian Ministry of Foreign Affairs and the General Commander of the Air Force, respectively.

The Secretary-General met with the permanent representatives of Members present in Lima for discussions on weather, climate and water issues, technical cooperation and the strengthening of the National Meteorological and Hydrological Services.

Least Developed Countries meeting, New York

On 13 September, the Secretary-General visited the United Nations Office in New York, on the occasion of the WMO special event on Weather, Climate and Water Services for Development and Disaster Mitigation in Least-Developed Countries (LDCs). The event was organized as part of the mid-term comprehensive global review of the Barbados Programme of Action (BPoA) for the LDCs for the decade 2001–2010. In his presentation, Mr Jarraud highlighted the role of National Meteorological and Hydrological Services and stressed the important relationships between weather, climate and water and the development constraints and challenges of LDCs, in the context of the seven commitments of the Barbados Programme of Action for the LDCs.

Attending the event were HE Ms Maria Mutagamba, Minister for Water and Environment of Uganda and Chairperson of the African Ministers’ Council on Water; HE Ambassador Filipe Chidumo, Permanent Representative of Mozambique to the United Nations; Mr Oussou Edouard Aho-Glele, Minister Counsellor of the Permanent Mission of Benin to the United Nations and Chairman of the LDCs Group; and Mr Om Pradhan, representing the High Representative of UN Office of the High Representative for the Least Developed Countries.

China

On 18 September, the Secretary-General visited Nanjing, China, to participate in the opening ceremony of the Tenth WMO Symposium on Education and Training, which was held at Nanjing University of Information Science and Technology (NUIST). Mr Jarraud delivered an opening address and met with HE Mr Liang Baohua, Governor of Jiangsu Provincial People’s Government; HE Ms Huang Lixin, Vice Governor of Jiangsu; Mr Qin Dahe, Administrator of the China Meteorological Administration and Permanent Representative of China with WMO, and Mr Li Lianshui, President of NUIST.

The general theme for the Symposium was “Meteorological and hydrological education and training for disaster prevention and mitigation”. The event covered three main topics, namely: “Preparedness—prevention and early warning”; Mitigation—emergency relief and rehabilitation”; and “Interdisciplinary training”. The Symposium reviewed the most recent developments and emerging trends in the field. Mr Jarraud was awarded honorary membership of the Chinese Meteorological Society.
Russian Federation

On 26 September, the Secretary-General addressed the opening of the International Conference on the Problems of Hydrometeorological Security, which was organized in Moscow by the Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet). The Conference provided a comprehensive discussion forum focused on the problems related to monitoring and prediction of severe hydrometeorological phenomena, aimed at reducing the vulnerability of populations and economic losses. Representatives of academic and applied science institutions, universities, experts from Hydrometeorological Services, regional users of hydrometeorological information and representatives of various economic sectors of more than 30 countries took part in the Conference.

Mr A.I. Bedritsky, head of Roshydromet and President of the WMO, opened the Conference. The First Deputy of the Chairman of the Government of the Russian Federation, D.A. Medvedev, and the President of the Federation Council, S.M. Mironov, addressed the Conference. Other distinguished speakers included A.N. Chilingarov, Plenipotentiary Representative of the President of the Russian Federation for the International Polar Year 2007-2008; V.N. Lipinsky, Chairman of the Intergovernmental Council for Hydrometeorology of the Commonwealth of Independent States; and Vice-Admiral C. Lautenbacher, Undersecretary of Commerce for Oceans and Atmosphere and Administrator of NOAA (USA).

Sweden

On 2 October, the Secretary-General travelled to Sweden to join the President of WMO, Mr Alexander Bedritsky, in presenting the 51st International Meteorological Organization (IMO) Prize to Lennart Bengtsson for his outstanding and lasting contributions to the science of meteorology. The ceremony was held in Norrköping City Hall, in the presence of Ms Maria Agren, Director-General of the Swedish Meteorological and Hydrological Institute and Permanent Representative of Sweden with WMO, as well as other national and municipal authorities.

Management Oversight Board for the Strengthened International Strategy for Disaster Reduction System, New York

On 10 October, at the invitation of the UN Undersecretary-General for Humanitarian Affairs, Emergency Relief Coordinator and Chairperson of the Management Oversight Board (MOB) for the Strengthened International Strategy for Disaster Reduction (ISDR) System, the Secretary-General of WMO participated in the second pre-Management Oversight Board, meeting. WMO is a member of the ISDR System Management Oversight Board, together with the World Bank, the International Federation of Red Cross and Red Crescent Societies, the United Nations Environment Programme and the United Nations Development Programme. The meeting was attended by representatives of missions in New York, as well as the media, the private sector and foundations. Mr Jarraud delivered a statement on the commitment of WMO to the implementation of the Hyogo Framework For Action and stressed the critical role of National Meteorological and Hydrological Services (NMHSs) in relation to hazard monitoring, risk assessment and early warning systems. The event included a press conference, in which Mr Jarraud further elaborated on the critical role of WMO and NMHSs in disaster risk management.

Mozambique

The Secretary-General visited Mozambique on the occasion of the Seventh EUMETSAT Users Forum, which was held in Maputo from 16 to 20 October 2006. At the opening of the Forum, the Secretary-General made a keynote address in the presence of the President, HE Mr Armando Guebuza.

The Forum focused on the cooperation between EUMETSAT and its African user community. In particular, the forum reviewed the Preparation for the Use of METEOSAT Second Generation in Africa (PUMA) project and noted that lessons learnt should be used
Maputo, Mozambique, October 2006 — Mr Jarraud with Mr António Francisco Munguambe, Minister of Transport and Communications

to reinforce the proposed African Monitoring of the Environment for Sustainable Development (AMESD) project. The Forum also recognized the important roles of WMO and the NMHSs in the implementation of AMESD, and made recommendations for their enhanced involvement in the project.

The Secretary-General met with the African Union Commissioner for Rural Economy and Agriculture, Mrs Rosebud Kurwijila, and Mr Babagana Ahmadu, Director for Rural Economy and Agriculture. Mr Jarraud also met with Mr F. Lucio, permanent representative of Mozambique with WMO, and with other permanent representatives of Members participating in the Forum. They exchanged views on preparations for the 14th session of Regional Association I (Africa), to be held in Burkina Faso, in February 2007.

**United Nations System Chief Executives Board for Coordination, New York**

On 27 October, the Secretary-General participated in the second regular session of the United Nations System Chief Executives Board for Coordination (CEB), which was chaired by the UN Secretary-General and held at UN headquarters in New York. The session addressed a number of high-priority programme and management issues, including employment and migration, the Least-Developed Countries (LDCs), relations with parliamentarians, gender mainstreaming, the UN System Staff College and results-based management. Following the session, a CEB retreat took place at Greentree Estate in Manhasset (New York), during which UN Executive Heads had discussions on system-wide coherence and reform issues.

**India**

On 30 October the Secretary-General visited New Delhi, India, to participate in the opening ceremony of the 14th session of the WMO Commission for Agricultural Meteorology (CAgM). Present on the occasion were HE Mr K. Sibal, Minister of Science and Technology and Earth Sciences; Mr P. S. Goel, Secretary, Ministry of Earth Sciences; Mr S. Nair, Joint Secretary, Department of Science and Technology and Permanent Representative of India with WMO, and Mr B. Lal, Director General of the India Meteorological Department (IMD), and Mr R.P. Motha, president of CAgM.

The Secretary-General presented the 20th Professor Dr Vilho Vaisala Award for an Outstanding Research Paper on Instruments and Methods of Observation to Mr J.P. Pichamuthu (India), for his paper entitled...
“Directional variation of visual range due to anisotropic atmospheric brightness”.

While in New Delhi, Mr Jarraud met with HE Mr Sharad Pawar, Minister of Agriculture, for discussions on weather, climate and sustainable agriculture in India. He also visited Mr N.C. Vij, Vice-Chairman of the National Disaster Management Authority.

Staff Matters

Appointments

Leonard BARRIE:
Director,
Atmospheric Research and Environment Programme Department, on 15 September

Jérôme D. LAFEUILLE: Chief, Satellite-based Observing System Division, WMO Space Programme Office, on 21 September 2006

Christophe JACOB:
Chief, Joint WMO/EUMETNET Office (Brussels) on 1 October 2006

Samuel W. MUCHEMI:
Scientific Officer, Public Weather Services Division, Applications Programme Department, on 23 September 2006

Anushia D. MANOHARAN:
Internal Auditor, Internal Oversight Office, Office of the Secretary-General, on 28 September 2006

Victoria HANSON:
Administrative Assistant to the Director, Cabinet and External Relations, on 1 November 2006

Alice BLUNT:
Administrative Assistant, Satellite Programme Office, on 27 November 2006

Guillaume SÉVERIN:
Information Technology Assistant, Information Technology Division, Resource Management Department, on 1 May 2006

Miguel CASAS GARATE:
Information Technology Applications Manager, Information Technology Division, Resource Management Department, on 30 October 2006

Departures

Virginia GUERRERO, Head, Recruitment and Staff Development Unit, Human Resources Division, Resource Management Department: seconded to UNAIDS (Geneva) as Learning Adviser, on 1 October 2006

Didier VAN DE VYVERE, Programme Manager with responsibility for Europe and the Newly Independent States, Development Cooperation and Regional Activities Department: retired on 30 November 2006

Valentin ANITCHKINE, Russian Translator, Linguistic Services and Publications Department: retired on 31 August 2006

Valerie CLÉMENT, Administrative Assistant, Satellite Programme Office: retired on 30 November 2006
### Calendar

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Place</th>
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<tbody>
<tr>
<td>22–24 January</td>
<td>Regional Workshop on the project “Preparedness for Climate Variability and Change, Natural Disaster mitigation and Enhanced Food Security in Africa</td>
<td>Livingstone, Zambia</td>
</tr>
<tr>
<td>23–26 January</td>
<td>Fifty-seventh session of the WMO Bureau</td>
<td>Moscow, Russian Federation</td>
</tr>
<tr>
<td>24–26 January</td>
<td>Joint Task Force on Hemispheric Transport of Air Pollution (TF-HTAP) and WMO Workshop on Integrated Observations for Assessing Hemispheric Air Pollution</td>
<td>Geneva</td>
</tr>
<tr>
<td>24–27 January</td>
<td>JCOMM Expert Team on Maritime Safety Services - Second session (ET-MSS-2)</td>
<td>Angra dos Reis, Brazil</td>
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<tr>
<td>25 January</td>
<td>NGGIP—18th session of the Task Force Bureau</td>
<td>Geneva</td>
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<tr>
<td>26 January</td>
<td>Meeting of WMO Bureau and IOC Officers</td>
<td>Moscow, Russian Federation</td>
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<tr>
<td>26–28 January</td>
<td>Pre-session Meeting of the AR4 WG I and Fifth Lead Author’s Meeting</td>
<td>Paris, France</td>
</tr>
<tr>
<td>29–31 January</td>
<td>JCOMM Expert Team on Marine Accident Emergency Support – first session (ET-MAES-1)</td>
<td>Angra dos Reis, Brazil</td>
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<tr>
<td>29 January</td>
<td>Second meeting of the EC Advisory Group on Disaster Prevention and Mitigation</td>
<td>Geneva</td>
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<tr>
<td>29 January–1 February</td>
<td>Tenth session of IPCC WG I</td>
<td>Paris, France</td>
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<tr>
<td>29 January–2 February</td>
<td>Third International Verification Methods Workshop Emphasizing Training Aspect (co-sponsored by WMO)</td>
<td>Reading, United Kingdom</td>
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<tr>
<td>29 January–9 February</td>
<td>Training on Operational Tropical Cyclone Forecasting</td>
<td>New Delhi, India</td>
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<tr>
<td>31 January–2 February</td>
<td>EC Task Team on WMO Integrated Observing System (EC-TT/WIGOS)</td>
<td>Geneva</td>
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<tr>
<td>2–3 February</td>
<td>2007 Meeting of Presidents of Technical Commissions</td>
<td>Geneva</td>
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<tr>
<td>5–6 February</td>
<td>CAS International Core Steering Committee for THORPEX —sixth session (THORPEX ICSC-6)</td>
<td>Geneva</td>
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<tr>
<td>12–13 February</td>
<td>African Regional Seminar on African Meteorological Services, Media and Development</td>
<td>Ouagadougou, Burkina Faso</td>
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<tr>
<td>14–23 February</td>
<td>Regional Association I (Africa)—Fourteenth session</td>
<td>Ouagadougou, Burkina Faso</td>
</tr>
<tr>
<td>13–15 March</td>
<td>CBS Steering Group on Radio Frequency Coordination</td>
<td>Geneva</td>
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<tr>
<td>19–22 March</td>
<td>WMO International Conference on “Secure and Sustainable Living: Social and Economic Benefits of Weather, Climate and Water Services”</td>
<td>Madrid, Spain</td>
</tr>
<tr>
<td>19–30 March</td>
<td>CAS Joint Scientific Steering Committee of Open Programme Area Group on Environmental Pollution and Atmospheric Chemistry</td>
<td>Geneva</td>
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<tr>
<td>20–24 March</td>
<td>JCOMM Expert Team on Wind Waves and Storm Surge —second session (ET-WWSS-2)</td>
<td>Geneva</td>
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<tr>
<td>26–27 March</td>
<td>JCOMM Expert Team on Marine Climatology—second session</td>
<td>Geneva</td>
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<tr>
<td>26–29 March</td>
<td>Expert Meeting on Gender Mainstreaming</td>
<td>Geneva</td>
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<tr>
<td>26–31 March</td>
<td>Twenty-eighth session of the WMO/ICSU/IOC Joint Scientific Committee</td>
<td>Zanzibar, United Republic of Tanzania</td>
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<tr>
<td>28–31 March</td>
<td>JCOMM Expert Team on Sea Ice—third session</td>
<td>Geneva</td>
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</table>
The World Meteorological Organization

WMO is a specialized agency of the United Nations. Its purposes are:

- To facilitate worldwide cooperation in the establishment of networks of stations for the making of meteorological observations as well as hydrological and other geophysical observations related to meteorology, and to promote the establishment and maintenance of centres charged with the provision of meteorological and related services;
- To promote the establishment and maintenance of systems for the rapid exchange of meteorological and related information;
- To promote standardization of meteorological and related observations and to ensure the uniform publication of observations and statistics;
- To further the application of meteorology to aviation, shipping, water problems, agriculture and other human activities;
- To promote activities in operational hydrology and to further close cooperation between Meteorological and Hydrological Services;
- To encourage research and training in meteorology and, as appropriate, in related fields, and to assist in coordinating the international aspects of such research and training.

The World Meteorological Congress is the supreme body of the Organization. It brings together delegates of all Members once every four years to determine general policies for the fulfilment of the purposes of the Organization.

The Executive Council is composed of 37 directors of National Meteorological or Hydrometeorological Services serving in an individual capacity; it meets once a year to supervise the programmes approved by Congress.

The six regional associations are each composed of Members whose task it is to coordinate meteorological, hydrological and related activities within their respective Regions.

The eight technical commissions are composed of experts designated by Members and are responsible for studying meteorological and hydrological operational systems, applications and research.

Executive Council

President
A.I. Bedritsky (Russian Federation)
First Vice-President
A.M. Noorinan (Islamic Republic of Iran)
Second Vice-President
T.W. Sutherland (British Caribbean Territories)
Third Vice-President
M.A. Rabiolio (Argentina)

Ex officio members of the Executive Council (presidents of regional associations)

Africa (Region I)
M.S. Mhita (United Republic of Tanzania)

Asia (Region II)
A.M.H. Isa (Bahrain)

South America (Region III)
R.J. Viñas García (Venezuela)

North America, Central America and the Caribbean (Region IV)
C. Fuller (Belize)

South-West Pacific (Region V)
A. Ngari (Cook Islands)

Europe (Region VI)
D.K. Keuerleber-Burk (Switzerland)

Selected members of the Executive Council

M.L. Bah Guinea
P.-E. Bisch France (acting)
F. Cadarso González Spain (acting)
M. Capaldo Italy (acting)
Q.-uz-Z. Chaudhry Pakistan
J.J. Kelly United States of America
T. Hiraki Japan (acting)
M. Konaté Mali (acting)
W. Kusch Germany (acting)
G.B. Love Australia (acting)
F.D. Freires Lúcio Mozambique (acting)
J. Lumsden New Zealand
P. Manso Costa Rica (acting)
J. Mitchell United Kingdom (acting)
A.D. Moura Brazil (acting)
J.R. Mukabana Kenya
D. Musoni Rwanda (acting)
S. Nair India (acting)
I. Obrusnik Czech Republic (acting)
H.H. Oliva Chile
Qin Dahe China
J.K. Rabadi Jordan (acting)
B.T. Sekoli Lesotho
Yap Kok Seng Malaysia (acting)

Presidents of technical commissions

Aeronautical Meteorology
C. McLeod

Agricultural Meteorology
J. Salinger

Atmospheric Sciences
M. Béland

Basic Systems
A.I. Gusev

Climatology
P. Bessemoulin

Hydrology
B. Stewart

Instruments and Methods of Observation
J. Nash

Oceanography and Marine Meteorology
P. Dexter and J.-L. Fellous

(Three seats vacant)
Members of WMO

At 31 December 2006

States (181)

Afghanistan  Dominican Republic  Mali
Albania  Ecuador  Malta
Algeria  Egypt  Mauritania
Antigua and Barbuda  El Salvador  Mauritius
Argentina  Eritrea  Mexico
Argentina  Estonia  Micronesia, Federated States of
Australia  Ethiopia  Monaco
Austria  Fiji  Mongolia
Azerbaijan  Finland  Morocco
Bahamas  France  Mozambique
Bahrain  Gabon  Myanmar
Bangladesh  Gambia  Namibia
Barbados  Georgia  Nepal
Belarus  Germany  Netherlands
Belgium  Ghana  New Zealand
Belize  Greece  Nicaragua
Benin  Guatemala  Niger
Bhutan  Guinea  Nigeria
Bolivia  Guinea-Bissau  Niue
Bosnia and Herzegovina  Guyana  Norway
Botswana  Haiti  Oman
Brazil  Honduras  Pakistan
Brunei Darussalam  Hungary  Panama
Bulgaria  Iceland  Papua New Guinea
Burkina Faso  Indonesia  Paraguay
Burundi  Iran, Islamic Republic of Iraq  Peru
Cambodia  Israel  Philippines
Cameroon  Italy  Poland
Canada  Jamaica  Portugal
Cape Verde  Japan  Qatar
Central African Republic  Jordan  Republic of Korea
Chad  Kazakhstan  Republic of Moldova
Chile  Kenya  Romania
China  Kiribati  Russian Federation
Colombia  Kuwait  Rwanda
Cook Islands  Kyrgyzstan  Saint Lucia
Costa Rica  Lao People’s Democratic Republic  Sao Tome and Principe
Côte d’Ivoire  Latvia  Saudi Arabia
Croatia  Lebanon  Senegal
Cuba  Lesotho  Serbia
Cyprus  Liberia  Seychelles
Czech Republic  Libyan Arab Jamahiriya  Sierra Leone
Democratic People’s Republic of Korea  Lithuania  Singapore
Democratic Republic of the Congo  Luxembourg  Slovakia
Denmark  Madagascar  Slovenia
Djibouti  Malawi  Solomon Islands
Dominica  Malaysia  Somalia
Sudan
Suriname
Sweden
Switzerland
Syrian Arab Republic
Tajikistan
Thailand
The former Yugoslav Republic of Macedonia
Togo
Tonga
Trinidad and Tobago
Tunisia
Turkey
Turkmenistan
Uganda
Ukraine
United Arab Emirates
United Kingdom of Great Britain and Northern Ireland
United Republic of Tanzania
United States of America
Uruguay
Uzbekistan
Vanuatu
Venezuela
Viet Nam
Yemen
Zambia
Zimbabwe

Territories (6)

British Caribbean Territories
French Polynesia
Hong Kong, China
Macao, China
Netherlands Antilles and Aruba
New Caledonia
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<th>Item</th>
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<tr>
<td>Ceiling Balloons</td>
<td>PR-30, PR-45</td>
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<tr>
<td>Pilot Balloons</td>
<td>PR-30, PR-45, PR-100, PR-200, PR-300, PR-350</td>
</tr>
<tr>
<td>Sounding Balloons</td>
<td>PR-200, PR-300, PR-350, PR-500, PR-600, PR-750, PR-850</td>
</tr>
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</table>

(b) METEOROLOGICAL INSTRUMENTS:

Various Sensors like Temperature, Humidity, Pressure, Raingauge etc., Mechanical Recording Instruments such as Thermograph, Hygrograph and Automatic Weather Station (i.e. Datalogger) from 4 channel to 32 channels.

(c) METEOROLOGICAL CONSUMABLES:

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- World Meteorological Day 2007 – Polar meteorology: understanding global impacts brochure (WMO No. 1073) and poster
- MeteoWorld – October 2006 and December 2006
- World Climate News No. 30 – January 2007