WORLD METEOROLOGICAL ORGANIZATION

Secretary-General	G.O.P. OBASI
Deputy Secretary-General	M. JARRAUD
Assistant Secretary-General	A.S. ZAITSEV

Vol. 50 No. 3 July 2001

BULLETIN

The official journal of the World Meteorological Organization

Subscription rates:

Surface mail		
1 year:	SFR	60
2 years:	SFR	110
3 years:	SFR	145
Airmail		
1 year:	SFR	85
2 years:	SFR	150
3 years:	SFR	195

Published quarterly (January, April, July, October) in English, French, Russian and Spanish editions.

Remittances and all correspondence about the WMO Bulletin should be addressed to the Secretary-General.

World Meteorological Organization
Case postale 2300, CH-1211 Geneva 2, Switzerland
Tel.: (+41.22) 730.84.78
Fax: (+41.22) 730.80.24
e-mail: bulletin@gateway.wmo.ch

The front cover, table of contents and a summary of the feature articles in the *Bulletin* are posted on the WMO homepage: http://www.wmo.ch (Hot topics)

Editor: A. S. ZAITSEV
Associate Editor: Judith C. C. TORRES

In this issue

"Costs and benefits of weather and climate services"

John Hickman developed an interest in meteorology when, as a young apprentice, he experienced the impact of weather on everyday work at a construction site and came to appreciate the value of weather forecasts. His interest grew and the post from which he retired, more than 40 years later, was that of Director of the New Zealand Meteorological Service. Mr Hickman traces the progression of his career in his interview with Dr Taba.

A review of the global climate in 2000 reveals that the year was again warmer than normal, although more so in the northern than in the southern hemisphere. There were more named storms in the Atlantic but fewer tropical cyclones than normal in the Pacific region. Heavy rainfall and flooding were dominating events in disparate parts of the world.

Meteorological and related services are defined by J.W. Zillman and J.W. Freebairn as public goods whose benefits to society are maximized the more widely they are consumed. Their article outlines the elements of an economic framework for assessing the benefits of such services and for evaluating options for their funding and pricing. Although basic public safety and welfare will continue to be the principal motors behind the provision of these services, scope remains for the development and application of economic valuation methodologies and pricing and charging models for a range of services, users, sectors and countries.

Y. Boodhoo identifies some of the visible benefits of weather and climate services in, for example, the aviation, agriculture, marine, environment, insurance, transport and tourism sectors. Some benefits are less visible but no less important in other sectors such as water management, urban planning and building and human health. The marketing of climate and weather products and services is a prime factor both for the public and for NMHSs. The author points out that the public tends to appreciate a service more when it has to pay for it!

In the socio-economic development of contemporary Russia, say A.I. Bedritsky and L.A. Khandozko, the role of hydrometeorological information is more important than ever before. Public awareness of that role is increasing, while the savings made from the use of hydrometeorological information are three to four times the total expenditure of the NMS. The authors outline five objectives which need to be met to determine the optimal use of hydrometeorological information and associated economic benefits.

In many countries, the profitability of meteorological services is clear and more and more products are being offered in response to demand. Météo-France offers special services for various activities, from feasibility studies using climate data to ready-to-use products. M. Le Quentrec presents some examples illustrating the importance and value of such services for a wide range of users, including organizers of international sporting events, railway companies, road transport controllers, central heating engineers and wine-growers.

Forecast value is a measure of the benefit achieved when forecasts are used to change actions. A difficulty in assessing the value has been in developing analytical links between quality measure and value. M.S.J. Harrison and N.E. Graham describe a new approach to linking forecast quality and forecast value, which has already been applied with positive results in southern Africa.

W.A. Mutuli presents a holistic framework for considering the problems facing NMSs in an environment which is dynamic and complex and also demands immediate solutions. She concludes her article with recommendations for action by WMO Members.

S.G. Cornford states the case for the standardized and mandatory reporting of the impacts of abnormal weather events. Thus, he says, NMHSs would be able to provide more valuable information to governments, thereby demonstrating their effectiveness, and might also develop improved methodologies for forecasting impacts, as well as the weather itself.

J. Purdom presents the structure, goals and timetable of a virtual laboratory for education and training in satellite matters for the years to come.

Cover: Thanks to accurate meteorological information during the planning and construction phases, the Stade de France was completed ahead of schedule for the Football World Cup in 1998 and without incident. (Photo: Le square des photographes)

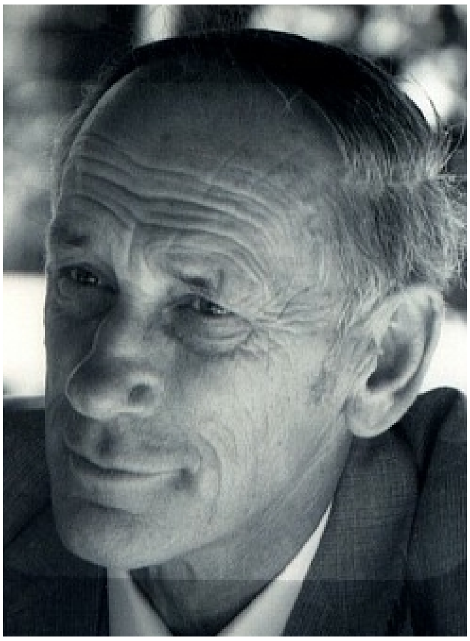
The Bulletin interviews

John S. Hickman

Dr Taba recounts:

In terms of both geology and human settlement, New Zealand is a young country. Its total area of some 270 500 km^2 is similar to that of Japan or the British Isles. The two main islands lie roughly north-east/south-west along the junction of the Indo-Australian and Pacific tectonic plates between latitudes 33° and 47°S and longitudes 166° to 178°E. Although there are a few areas of plains, the landscape is mostly rolling countryside, hilly or mountainous (the highest peak, Mt. Cook, is 3 754 m).

Archaeological studies indicate that the Maori people have inhabited the islands for the past 700-800 years. The first European explorers visited New Zealand in 1642. Formal European settlement commenced in 1840 when representatives of the British Crown and a number of chiefs of Maori tribes signed the Treaty of Waitangi.



John Hickman

The present-day population is about 3.8 million. Auckland, in the north, is the largest city with almost 1 million inhabitants. Wellington, the capital, has about 335 000 inhabitants. It is a city of brightly coloured houses perched on the hills surrounding a stunning harbour.

Our interviewee of this issue, John Sedgley Hickman, was born at Wanganui, New Zealand. He became an apprentice in the building industry after obtaining the school certificate and attended night classes to prepare himself for university entrance subjects and vocational courses. He completed his B.Sc. degree with mathematics and geology as his major fields. He began a career with the Meteorological Service, first as trainee meteorologist and forecaster, then becoming Superintendent of Training, Assistant Director for Research and, in 1977, Director—a position he held until his retirement in 1988.

During his 12 years as Director, John revolutionized meteorological practice in New Zealand. He obtained the first computer to be used for operational numerical weather prediction (NWP) and the first high-resolution meteorological satellite receiving station, resulting in a dramatic improvement in the quality and the quantity of the information provided to the public, as well as to international users. As a result of his work in the field of meteorological research, the Meteorological Service achieved international recognition, attracting visits from many of the world's leading meteorologists. John demonstrated immense practical skills and foresight and power of strategic judgement during his association with the Service; these qualities were highly appreciated in international scientific circles.

As president of WMO Region Association V (South Pacific), as a member of the WMO Executive Council and as chairman of several of its subcommittees and working groups, John made important contributions to science on the international level. His retirement did not interrupt his work: in 1989, he was invited to participate in preparing WMO's Long-term Plan. He was invited to join, in a personal capacity, the tripartite intergovernmental Programme on Climate Change involving New Zealand, Australia and the United Kingdom, and he chaired the Climate Committee of the Royal Society of New Zealand.

John was a vigorous promoter of closer links between the Meteorological Service and the university. He strengthened and widened contact with the academic community and strongly supported meteorology as an academic discipline in the Victoria University of Wellington. Close research links, the renewal of a senior lectureship and a fellowship in meteorology were fruits of these efforts. John showed great interest in the protection of the atmospheric environment and ensured better national organization of, and support for, monitoring programmes for ozone and greenhouse gases.

In 1989, he was made a Companion of the Queen's Service Order (QSO) for public services; in 1990, he was awarded an honorary D.Sc. by Victoria University, Wellington, and the Commemoration Medal for services in the field of science. In 1998, he was made an honorary member of the Meteorological Society of New Zealand.

He and his wife, Joyce, now live on the outskirts of a provincial town 100 km north of Wellington. Care of the property keeps them busy; they have a garden and a small orchard and John has a workshop. In 1997, John had heart surgery and has now withdrawn from regular involvement in committee and similar work but maintains a close interest in the work of the Meteorological and Royal Societies of New Zealand and, from time to time, contributes to discussion documents and submissions on matters concerning atmospheric science.

Three Directors of the New Zealand Meteorological Service (from left to right): John Hickman (1977-1988); John de Lisle (1975-1977) and John Gabites (1965-1973) (photo taken in 1988)

I met John for the first time in Melbourne, Australia, in 1968, on the occasion of a Satellite Training Seminar organized by WMO. We have maintained contact ever since. John is shy but friendly. He is also modest. When I asked him to accord me an interview for the WMO Bulletin, he said:

> *The more I look back at my career and the more I look at your interviews with the giants of meteorology of the last 5O years, the more I realize how insignificant a pygmy I am. I will fully appreciate your decision if you decide not to proceed with the interview.*

This interview took place in Wellington in February 2001.

H.T. — Please tell us the date and place of your birth, your parents and something about your childhood.

J.S.H. — I was born on 9 September 1927 in Wanganui, a provincial town, some 200 km north of Wellington. When I was about six months old, the family moved to the far north of New Zealand. I was the second in a family of five children. My father had been a carpenter, and in the army during wartime, but about two years before I was born he became a trainee minister in the Church, studying and working at the same time. We were far from wealthy, but families helped each other through sharing, giving and lending at a time of global economic depression. We children had a loving and caring home and we always had holidays together, even if this meant walking our house cow the whole way with us so that we had a milk supply! Our parents taught us their high personal values, largely by example. We remained in various small rural settlements in the far north until 1941, when we went to Auckland, the largest city in New Zealand.

H.T. — Your primary and secondary schooling?

J.S.H. — I first attended school in the last quarter of 1933. Commencement of primary schooling was, for all children of my age at the time, delayed by one year because of the economic depression and lack of government funding. The two primary schools I attended were quite small, and each teacher was responsible for pupils in three or four different grades. Although tuition was to a national curriculum, the reality was that, in many small country schools, some of the standards did not equate with those in some schools in the larger cities. I felt this on commencing secondary school at a technical college in Auckland. Whilst the basis of each course at the College was academic, there was strong emphasis on producing students who would take their place in industry—accounting, agriculture, building, engineering, printing, etc. I was on a woodwork course. It was wartime and there was a shortage of teachers as most of military age were in the armed forces. Many of our teachers were older people, who tended to digress on all topics of life. This was challenging and quite an inspiration and, on reflection, I think it helped many of us.

H.T. — Did you go to university immediately after secondary school?

J.S.H. — After secondary school, I was apprenticed to a builder for five years and took night classes at the tech-

nical college for three years in building and structural engineering; for the university entrance examination; for further study in mathematics and physics; and then two years part-time study in mathematics and geology at Auckland University. I commenced work at 07h15 each day, finished at 16h15 on days that I had lectures, and then would cycle or, if I could afford it, take a tramcar to the technical college or university, some 10 km away. Some laboratory classes finished at 21h00 and others occupied most of my Saturday mornings. My family moved to Dunedin, in the south of New Zealand, but I remained in Auckland to finish my apprenticeship. This was divided roughly into two years on construction sites, two years in workshops, and one year in the office doing draughting, costing and negotiating contracts.

H.T. — How did you become interested in meteorology?

J.S.H. — My interest in meteorology was first aroused during my apprenticeship! Every builder has experienced the vagaries of weather on a construction site. During the war years, there were no public radio forecasts but immediately after the war, in 1945, public forecasts were reinstated. These seemed to be useful—if only they could be more accurate! I had read something about air masses and fronts in science books and thought that making weather forecasts might not only be challenging, but would also prevent me from tramping around in mud on a construction site. I asked my mathematics tutor what sort of background and qualifications were necessary to study weather forecasting. His answer was brief: "Far more mathematics than you will ever be able to understand. Forget about being a weather forecaster." So I did.

H.T. — Then how, why and when did you join the New Zealand Meteorological Service?

J.S.H. — At the end of my apprenticeship I followed my family to Dunedin and completed a basic degree at Otago University, in pure and applied mathematics and geology. I read an advertisement in the newspaper for weather observers and immediately saw a possible future for the next year or two. Why not sit in a lighthouse making the occasional weather observation and studying mathematics in what must be a lot of spare time? I could not afford to go back to University full-time but I hoped to have the opportunity for at least part-time study. I applied for a post as a weather observer and was interviewed by the late Dr Ritchie Simmers. When he asked "What did you have in mind when going through university?" I could only, in all honesty, reply "getting through". I could see that he thought "no meteorological ambitions here!" Then he asked if I was prepared to serve overseas, in Fiji, and I casually asked "How about the Antarctic?" Unbeknown to me, Dr Simmers had made two Antarctic voyages with Sir Douglas Mawson (1929-1931) and from that point on, I was accepted as a kindred spirit and the outcome of the interview was never in doubt. I joined the New Zealand Meteorological Service in early 1951.

H.T. — What was the structure of the Meteorological Service in those days? Who was the Director?

J.S.H. — The Director was the late Dr Miles Barnett. He became Director in 1939 and was active in international meteorology during the change from IMO to WMO. He served on the committee which prepared the WMO Convention and was Permanent Representative of New Zealand with WMO from 1951 to 1962, He was also at various times First Vice-President of WMO, president of RA V and a member of the Executive Committee. He was consequently away from New Zealand for long periods and I was in the Service for several months before I met him.

Until the outbreak of war in 1939 the New Zealand Meteorological Service had been a part of the Department of Scientific and Industrial Research (DSIR). The Service was transferred to the Royal New Zealand Air Force for the duration of the war and grew to a relatively large unit that served aviation. When hostilities ceased the Government decided that the Service would remain administratively allied to aviation. This was disappointing for Dr Barnett and made it particularly difficult for the Service to attract good science graduates at a time of a widespread shortage in all sectors of the national work force. When I joined in 1951, most of the effort in the Service was towards making weather observations, compiling climatological records and providing weather forecasts for the general public and for aviation. There was only a small amount of research, mainly in climatology and the upper atmosphere and the measurement of total ozone was in the early stages Meteorologists employed in weather forecasting were expected to spend about 25 per cent of their time away from shift work, doing research/investigations. In practice, because of staffing difficulties, time was seldom available for any substantial off-shift studies.

H.T. — What training did you receive?

J.S.H. — There was no meteorology at universities in New Zealand. On joining the Meteorological Service, graduate staff were given practical and theoretical training within the Service, lasting about one year. The first part was a weather observing course, followed by a graduate-level course in meteorology and weather analysis and forecasting. I did additional study in mathematics at *the university at the same time and at the end of the course worked as a forecaster.*

H.T. — How long did you work as a forecaster? What changes did you see?

J.S.H. — I spent about 12 years as a forecaster; four on short-period domestic aviation; four in Nadi, Fiji, on domestic and international aviation and general and tropical cyclone forecasting for the South-west Pacific; and four on general forecasting for the public and specialized industry at the National Weather Forecast Centre in Wellington. The standard path for young meteorologists was to be posted to a domestic aviation forecast office after formal training in order to gain first-hand knowledge and to learn about what goes on in the real world of weather. The air crews—in an era when personal briefing by a meteorologist was the norm and when neither aircraft nor navigational aids were as advanced as they are now, and domestic flights in New Zealand were generally in mountainous areas and below about 3 000 m—made certain of that!

Those years were particularly interesting. The first meteorological satellite information and the first operational NWP products became available, jet aircraft were introduced onto South-west Pacific air routes, atmospheric nuclear bomb tests were still being conducted, and manned orbital flight was in its infancy. The first two of these were aids to the forecaster; the last three a strong challenge to forecasters in the data-sparse South-west Pacific. They all gave the opportunity and the incentive to learn much more about the behaviour of the atmosphere and, in particular, the interactions between low- and mid-latitude dynamics. The four years at Nadi were highly stimulating and particularly satisfying. They also gave the opportunity to visit other forecasting centres, for example, Sydney and Honolulu.

H.T. — What did you do next?

J.S.H. — After my time as a forecaster, I transferred to the research section. It was still quite small, just a handful of graduate staff and a few assistants. The work was varied and included the training and development of meteorologists; ad hoc work such as forecasts for a high altitude turbulence study, and analysing the results; and the construction of trajectories to trace the transport of debris from atmospheric nuclear bomb tests in the South Pacific. Applications of boundary-layer meteorology and the design and conduct of field studies to determine chimney height, and thus minimize ground-level pollution, was a growing area of study in view of industrial development. Of course, keeping abreast of developments in NWP and the meaning and use of meteorological satellite information were also high priorities.

H.T. — Tell us about your activities in training.

J.S.H. — My training activities started in the Meteorological Service, but cooperation with the university grew over nearly 20 years. One of my tasks in the research section was to conduct the theoretical and practical training course for new graduate recruits. Some specialist lectures were given by other staff members. The course was at graduate level and similar to the type of course given professional meteorologists at the United Kingdom Meteorological Office. It also took cognizance of the four "levels" of meteorological training proposed by WMO. However, the attitude of the Service was that they did not employ forecasters but had meteorologists employed on forecasting. Training for meteorological observers was separate from that for meteorologists and carried out within another section of the Service.

H.T. — You were subsequently successful in extending meteorological studies to the University. How did you achieve this and why was it so important to do so?

J.S.H. — After my first one or two courses for meteorologists, the University in Wellington appointed a senior lecturer in meteorology within the Mathematics Department. We made use of this theoretical course as part of training in subsequent years. Some years later, when the lecturer retired, the University was under considerable pressure to reduce costs and there was a high risk of the position being eliminated. The Service managed to lobby successfully for its continuation and, in addition, later funded a Fellowship in Meteorology to make for a more viable meteorology unit within the University's Research School of Earth Sciences.

This was a satisfying outcome and entirely consistent with our overall aim of shifting basic teaching in meteorology as a science to the universities. In a small country like ours, we were acutely conscious of the dangers of having only one centre of expertise in meteorology. The subject was becoming mature as a science, while still presenting some great intellectual challenges, and serious debate was warranted within the country, rather than simply between one centre in the country and scientists and institutions overseas.

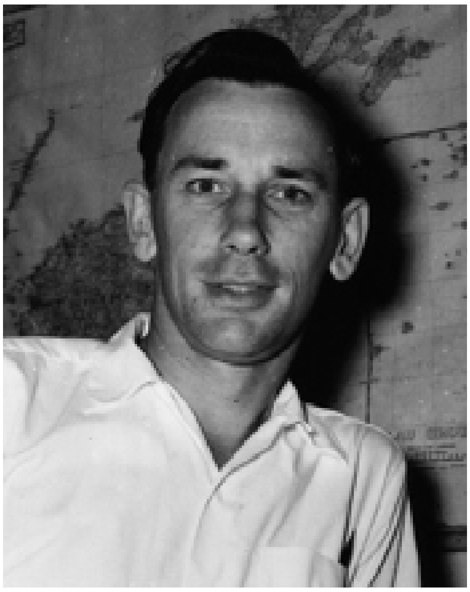
H.T. — You went on to develop a new training organization?

J.S.H. — In addition to fostering education and training at university level within New Zealand, we pursued a policy of always having one or two staff studying at doctorate level at established overseas universities or research institutions.

During 1972-1973, I had the task of bringing together all the training programmes within the Service *and establishing and putting into operation a better, integrated total training system. We also provided a large amount of training for staff from Meteorological Services of South-west Pacific countries. Working with the people from the Pacific was especially rewarding and many courses were provided especially for them.*

H.T. — You then became Assistant Director for Research. What was your task?

J.S.H. — There were four Assistant Directors—one each for Climatology, Forecasting, Research, and common Facilities. The task I took up in late 1973 was to look after the research staff and help them develop research within the Service and, at the same time, play a part in the overall management of the Service. The Service had three principal functions set out in an Act of Parliament: one, to provide meteorological services for the benefit of all sections of the community; another to promote the advancement of meteorology; and the third to advise the Government on all matters relating to meteorology. In order to carry out these functions, it was necessary to broaden the spectrum of research.



John Hickman in Nadi, Fiji, in 1960

H.T. — How did the research programme evolve?

J.S.H. — The environmental movement gained momentum, following the UN meeting in Stockholm in 1972, and meteorologists were broadening their horizons. A section of the research unit that had been developing for several years addressed potential problems of air pollution from planned industrial installations. This work increased and we were able to recruit scientists from other disciplines, such as chemistry. The depth and extent of circulation studies in the South-west Pacific, including those of El Niño, increased, and more qualified staff joined to work in the field of NWP. The Service started to recruit skilled staff directly into specialist research positions, rather than pursuing the earlier practice of training all graduate staff as meteorologists and giving them general experience before having them specialize. The overall aim of the research programme was not only to conduct studies that helped improve the meteorological services regularly provided but also to enable the Service to "provide advice ... on all matters relating to meteorology". The underlying actions were thus to put meteorology in the Service on a sounder and broader scientific basis. There is no doubt that some of the major WMO programmes and the work of the WMO Commissions helped Services such as ours organize their work on a much better scientific foundation.

H.T. — What was the situation at the Meteorological Service when you took over as Director?

J.S.H. — I was Director from early 1977 to late 1988 and I was fortunate. Former directors had put in place programmes to enhance the overall scientific and technological basis of the Service. In particular, Dr John Gabites had, almost single-handedly at first and from about the time I joined, set up a regular series of seminars and conferences, greatly enhanced the content and use of the meteorological library, and broadened everyone's concept of the scope of meteorology. He was Director from 1965 to 1973. Dr John de Lisle, Director from 1973 to 1977. vigorously maintained the momentum built up by Dr Gabites.

From another perspective, I was unfortunate. Because of the recruitment pattern into the Meteorological Service to meet the needs of the growing aviation industry in the late 1930s, and the 1939-1945 wartime needs, a large number of senior staff reached retiring age in 1977. Still more retired during the next one to two years. The loss of experience was quite serious. However, a growing group of young and able meteorologists were also beginning to make their presence felt.

H.T. — What were your major preoccupations during the period you were Director?

J.S.H. — My overarching aim for the Service was to ensure a balance between basic observation; study and research of the observations and related concepts; and useful servicing. The observing network consisted of a core of well-distributed stations staffed by Meteorological Service personnel, supplemented by a large number of other stations staffed by volunteers (often in other *government departments). Cost-cutting programmes and reorganizations in other departments were always reducing the network and the use of automatic weather stations became essential. The difficulties in making or acquiring reliable stations and installing them in isolated coastal locations or mountainous terrain, where communications were unreliable or non-existent, were immense. Early use was made of satellite interrogation.*

The question of what was relevant research was continually being asked by various review committees. Clearly, anything that "makes the forecast better" is "relevant". The maxim "do what you are good at" was oft-repeated. But relevant research in a Meteorological Service is more than making the forecast better—although this is, of course one facet. It seemed to me that the Service should pursue a broad programme of meteorological research but have within that programme a few particular strengths. Only in this way would it be possible to make sensible judgements on developments across most of the field and to decide on the need for changes in emphasis. This approach served the Service, the public and the Government well. The growth in teaching and research in meteorology in most New Zealand universities over these years allowed good cooperation to develop between the Service and the universities.

H.T. — What were some of the tangible results of your efforts?

J.S.H. — The Service's first dedicated mainframe computer was installed in 1978, allowing operational automated data handling and NWP systems. Prior to 1978, NWP in New Zealand had been semi-operational and carried out on various machines in various other government departments. When the Service changed to fully operational NWP, the errors in upper-level wind forecasts for aviation in the New Zealand area were immediately reduced by about one-third. We also acquired a high-resolution meteorological satellite receiving terminal and derived our own temperature-sounding input for the numerical model from the raw data. These developments allowed the office in Wellington to fulfil the roles of a Regional Telecommunications Hub, and Regional Meteorological Centre, within the World Weather Watch, and to be one of the early Regional Aviation Forecasting Centres in the World Area Forecast System.

H.T. — Political changes in the region must have had an impact on the way meteorological services were organized?

J.S.H. — From the late 1940s to the late 1970s, a large part of the meteorological observing network, and associated meteorological services in the South-west Pacific had been supported by a consortium of governments, mainly to meet the needs of trunk-route aviation. In the late 1970s, as costs were passed from governments to the aviation industry, the question of support for the wider observing network and the wide range of local meteorological services that had been developed for some island communities—including tropical cyclone forecasts—became urgent since these costs could not fairly be charged to the industry. The New Zealand Meteorological Service eventually accepted these not insignificant costs. Since the early 1940s, Meteorological Service staff had carried out various meteorological activities in the South-west Pacific and developed a good understanding of peoples' needs. These staff had built up a tremendous amount of goodwill with the various governments over the years and especially as many countries became independent. These countries seemed to trust the Meteorological Service as an organization that would always attempt to help them, not only with the provision of services but also in developing education and training programmes while working entirely within the framework of their country's Public Service. Ours was an excellent example of how meteorology can help promote understanding and goodwill among nations.

H.T. — Tell us about your initial contacts with WMO.

J.S.H. — My initial direct experience of a WMO event was the Tropical Meteorology Symposium in Rotorua, New Zealand in 1963. The introduction to an international conference and the opportunity to meet and hear some of the world's leading meteorologists was particularly valuable to a young meteorologist half a world away from the main centres of activity. Attendance at a Meteorological Satellite Training Seminar, Melbourne in 1968—arranged by you—in which Vince Oliver, Ralph Anderson and T. Fujita were the main presenters was equally valuable. For me, the Melbourne seminar was a turning point in my career. It helped me to sort out all sorts of ideas that were floating around in my head after practical forecasting for low, middle and high latitudes and gave direction to ways of thinking about the development and decay of weather systems. My position was probably similar to that of hundreds of others in smaller countries. I was deeply aware of my lack of formal advanced university education in meteorology and literally hungered for anything that would break me out of the cloistered walls of in-house training and self-tuition. In my mind there is no doubt that WMO training seminars give this opportunity.

It was not until about the last 10 years of my career that I became deeply involved with WMO through the sessions and work of RA V, CAS, Congress and later EC.

H.T. — What were the major events during the period you were president of RA V?

J.S.H. — I was vice-president from 1982 to 1986 and president from 1986 to 1988. Ho Tong Yuen (Malaysia), president from 1978 to 1986, ensured that as vice-president I was closely involved in the work of the Association and I attended a number of meetings on his behalf. From 1986 to 1988, two projects received most attention. One was the development of an Association of South-East Asian Nations (ASEAN) Meteorological Centre having especial expertise in numerical modelling in the low-latitude region. We were aided immensely in this work by a study and report prepared by Prof. J Smagorinsky[1]. It was most rewarding working with him. The other project was the development of a Regional Specialized Meteorological Centre at Nadi, Fiji, with responsibility for tropical storm warnings for the South-west Pacific.

At Vanda Stations (Dry Valley), Antarctic, November 1985

H.T. — What was your main involvement with the WMO Executive Council?

J.S.H. — I was involved in financial matters much of the time. The establishment of the Financial Advisory Committee was an important additional element in financial planning for the Organization and helped to bring additional credibility in the eyes of many Members. Much of the work of EC is internal to WMO. Perhaps the most important external items were the discussions and negotiations leading to the establishment of the Intergovernmental Panel on Climate Change (IPCC). The IPCC has had, and is still having, a global impact.

H.T. — You participated in the preparation of the WMO Long-term Plan. Can you tell us about it?

J.S.H. — Although I participated in discussions of the planning process, I did not join the EC Panel on Long-term Planning until after the Congress of 1987. The Panel had not formally met by the time I retired but the Third Long-term Plan caught up with me and I assisted with drafting Part One—Overall Policy and Strategy. Dr John Zillman[2] was Chairman of the Panel, as he had been for the Second Plan and was for the Fourth. I was also asked to draft Part One of the Fourth Long-term Plan. The work included attending a few of the EC Panel discussions and attempting to encapsulate their decisions, and the directions of EC and Congress, in the draft.

H.T. — You were involved in some climate change activities. What were they?

J.S.H. — In 1988, New Zealand established a national programme on climate change, whose structure was similar to that of the IPCC. There were three working groups: on the science of climate change; on likely impacts; and on responses. The climate science working group, of which I was convenor, was under the umbrella of the Royal Society of New Zealand. We published a popular-level report, a fuller scientific report and a supplement updating the earlier scientific report.

H.T. — What have you been doing since retirement?

J.S.H. — After my retirement in 1988, I did not seek any full- or near-full-time employment. I was convenor of the Science working group of the New Zealand Climate Change Programme; a member of the Steering Group for the Programme; a member of the International Geosphere-Biosphere Programme committee; chairman of the Clean Air Council; convenor of the physical sciences group in the national Antarctic Research Programme and I was involved in some ad hoc committees concerned with changes in science structures and envi-

1 Interviewed *WMO Bulletin* 32 (4)

2 President of WMO since 1995

ronmental law. All these activities were voluntary. Moreover, I was tired and in need of some rest after a trying period of rapid change in government structures. For relaxation, I resumed work on some long-delayed improvements to our house in Wellington—I returned to being a carpenter and joiner!

H.T. — Apart from WMO, what sort of consultancy positions did you have?

J.S.H. — Most were as a commissioner at public hearings, evaluating proposals for, and public submissions concerning, industrial development, or continued use of existing and rather old installations—especially thermal electricity generating stations. The atmospheric factors of potential chemical pollution, noise, dust and contribution to climate change were always prominent concerns of citizens. In the earlier cases, general air pollution was the main concern but later the question of greenhouse gases and climate change became the main issue. It was interesting to see concerns about climate change grow in the eyes of the public and developers, but necessary to temper many extreme statements made by all parties! Another consulting task involved specifying atmospheric parameters and the observation programmes required to aid the design of a long-lasting, very large public building in a coastal location subject to strong winds and a salt-laden atmosphere.

John Hickman with W. Gibbs (Australia (centre)) and J.W. Wilkins (New Zealand) during the eighth session of RA V in Melbourne, 1982

H.T. — Tell us about the Antarctic programme.

J.S.H. — New Zealand has maintained a year-round Antarctic base, on Ross Island, and an Antarctic research programme since the International Geophysical Year (1957/1958). From the beginning, the atmospheric component has included the usual climate elements, such as radiation balance, and, in later years, total ozone and other high-altitude trace gases. Other studies include measurement and composition of particulates, low-level dispersion, micrometeorology and the climate and weather of the "Dry Valley" region—a large ice-free area north-west of Ross Island. For about two years, the New Zealand Meteorological Service also maintained the weather observing programme at the Amundsen-Scott South Pole station on behalf of the US National Science Foundation. I was associated with the New Zealand Programme for over 20 years, a member of the Research Committee for about 12 years and convenor of the physical sciences part of the Programme for several years. The work included visits to the Antarctic, including the South Pole station, in connection with both Meteorological Service studies and the wider national programme.

H.T. — Tell us about your activities in connection with the protection of the environment.

J.S.H. — In the late 1950s/early 1960s Parliament passed legislation setting out air-pollution control measures and establishing a quasi-autonomous Clean Air Council charged with assessing matters related to air pollution and making recommendations to the Government. One member of the Council was required to have a meteorological background. At the same time, there was a growing trend to establish larger industrial plants and to move away from an almost total reliance on hydro-electricity generation towards thermal stations, particularly for peak loads. The Meteorological Service, air pollution control, and planning authorities developed a close working relationship and the Service was involved in both site selection and detailed design, particularly with respect to building orientation and stack height. The field studies were rather crude in comparison with today's standards but developed rapidly along with numerical modelling and a well-respected and authoritative group soon gained recognition. It continues today, albeit within a changed organizational structure. I was able to take part in many of the early studies, and later foster further development of the group. I was a member of the Clean Air Council for about 15 years and chairman for nearly ten.

H.T. — Since your departure from the Meteorological Service, there have been some structural changes in the Service. Could you please tell us the reasons?

J.S.H. — In 1984 there was a change of government and, as part of its response to serious national financial problems, it brought about rapid and wholesale change *in the public sector. All government-supported activities were restructured to conform to a "business" model. Some remained as advisory units to the Government, some were privatized and others remained a State Owned Enterprise (SOE). The SOE is a government-owned business, with the emphasis on its being a business rather than its being government-owned. The Meteorological Service escaped the initial wave of major restructuring but was caught up in the next in 1988. A strict business model was imposed, involving a massive reduction in staff. I was unhappy with the overall aims being pursued and the direction being taken. Since I was already past my optional retirement date, but had not yet reached the mandatory date, I elected to retire. This was a difficult decision—was I walking away from a challenge I should have accepted? With the benefit of hindsight, my decision was probably the only one to make.*

A further change of government in 1990 accelerated more change, especially within the science sector of Government and the Meteorological Service was cut in half. From 1992, forecasting activities became the responsibility of Meteorological Service of New Zealand Limited, an SOE and fully commercial business. The SOE also carries out work in data collection to provide national severe weather warnings, issue basic forecasts and to fulfil obligations to contribute to the Global Observing System, and other WMO activities, under contract to the Government. The method of funding is quite different from that for government departments and staff of the SOE are no longer "public servants" within the usually accepted meaning of the term. Research, including climatology, part of the former Meteorological Service, became part of the National Institute for Water and Atmospheric Research. The alliance of water and atmosphere was something that many of us had been seeking for many years—but not at the expense of separating forecasting activities.

H.T. — What are some of the most unforgettable events in your professional life?

J.S.H. — Pilots of aircraft often say that no matter how many landings they may have made, they always experience a glow of satisfaction when they make a near-perfect landing. I think that weather forecasters have a similar feeling when they make a good forecast. At least, they did in the pre-NWP, pre-meteorological satellite era in small meteorological offices, where the synoptic and mesoscale analyst and the forecaster were all the same person! Operational weather forecasting provided me not only with more than my fair share of headaches but also a few glows of satisfaction with respect to forecasting particularly severe or damaging weather. To be able, in later years, to take part in discussions of current analyses and forecasts, even when my other duties were centred elsewhere, was a particular pleasure.

In a different context, international meteorology has been thoroughly unforgettable. To meet the heads of almost all the Meteorological Services in the world at a WMO Congress, and to have the opportunity for discussions with them and receive invitations to visit them was an amazing opportunity. Perhaps those who live in parts of the world closer to the main centres of activity do not feel the same way. But for somebody from the Antipodes, at a time when international travel and communications were not as developed as they are now, it was an experience in friendly and willing global cooperation and understanding that could only hasten both personal and national development. I will for ever remain thankful that that was my privilege.

H.T. — John, I would like to congratulate you, on behalf of the readers of the WMO Bulletin and on my own behalf, for such a distinguished and successful career.

The global climate system in 2000

Global temperatures during 2000

The global mean annual combined land-surface air and sea-surface temperature for 2000 was 0.29°C above the 1961–1990 climatological normal. However, this warmth was not evenly distributed. The northern hemisphere north of 30°N experienced considerably greater anomalous warmth in 2000 (+0.65°C) than did the tropics and the southern hemisphere south of 30°S (+0.15°C and +0.19°C, respectively). The southern hemisphere south of the tropics was approximately 0.1°C cooler than in 1999. Since mid-1998, the temperatures in the tropics have been greatly influenced by prevailing tropical eastern Pacific cool water (La Niña) conditions.

Regional temperature anomalies

Severe cold conditions coupled with snow affected large parts of China and Mongolia from January to February. Over one million people were affected, with economic loss estimated at over US$ 30 million. In

THE GLOBAL CLIMATE SYSTEM IN 2000—SUMMARY

The year 2000 was the 22nd consecutive year with a global mean surface temperature above the 1961-1990 normal, and the seventh warmest year in the past 140, despite the persistent cooling influence of the La Niña event. The warmer years were 1998, 1997, 1995, 1990, 1999 and 1991.

Most of the non-tropical northern hemisphere experienced above-average temperatures throughout the year, except during the September-November period, when much of Asia and west-central parts of North America were colder than normal. With La Niña conditions persisting, the eastern tropical Pacific was colder than usual through most of the year. The remainder of the tropics and the non-tropical southern hemisphere had a variety of anomalies, with predominant warmth.

The number of named storms in the Atlantic was above normal, but there were fewer tropical cyclones than normal in the Pacific region. Hurricanes from the Atlantic caused extensive damage in Central America, while typhoons in the western Pacific brought record-breaking rainfall over Japan and flooding to the Korean Peninsula and Viet Nam. A tropical cyclone over north-western Australia in December caused flooding and damage. Successive tropical cyclones that struck southern Africa early in the year caused severe flooding which led to hundreds of casualties and considerable human suffering.

Heavy rain and flooding with loss of life and extensive property damage also occurred in several other areas of the world. The most notable events were severe flooding in the European southern Alps in October, in the United Kingdom and France from September to December, in Colombia from June to August and, during the summer monsoon, across Bangladesh, Cambodia, India, the Lao People's Democratic Republic, Thailand and Viet Nam. More than 10 million people were affected in India alone with over 650 deaths. Torrential rains and deadly mudslides wreaked havoc in Central and South America in May and June. Over western Australia, extensive areas experienced one of their wettest-ever January–April periods, with record rainfall and flooding in many locations.

January and February, severe cold conditions in parts of India resulted in over 300 deaths. In May, much of the western part of the Russian Federation, centred on the Volga region, experienced a severe cold spell with temperatures 4-5°C below normal. In South America, Paraguay experienced the lowest minimum temperatures ever recorded at nearly all stations during June and July.

In contrast, a scorching heat wave gripped much of southern Europe during June and July, breaking many records and claiming numerous lives as temperatures exceeded 43°C in locations across Greece, Italy, Romania and Turkey. In Bulgaria, new absolute maximum air temperature records (for more than 100 years of observation) were established at more than 75 per cent of meteorological stations on 5 July. Overall warmer than normal temperatures prevailed over many regions during the year.

In England, 2000 was the 15th warmest year in the past 342 years of observations. In France, 2000 tied with 1994 as the warmest year since 1948, and in the Netherlands, it tied with 1999 and 1990 as the warmest year since 1900. Norway recorded the third warmest year since measurements started in 1866, and the maximum temperature of 11°C on 5 October on Bear Island in the Barents Sea broke the earlier record high for that month, set in 1924. In the USA, the January–October period was the warmest on record, but November-December was the coldest two-month period on record, and the year ranked 13th warmest since 1895. In Canada, 2000 was the seventh warmest year since 1948. Japan recorded its fifth warmest year in its 103-year record. After six months of generally cooler-than-average temperatures, unusual warmth developed across parts of Australia in July and continued into the southern hemisphere spring. Visitors to the Olympic Games in Sydney experienced unusually warm conditions as maximum temperatures in September averaged 4-5°C above normal over a broad belt in central and eastern Australia. But, despite this September warmth, annual temperatures were below the 1961-1990 average in Australia for the first time since 1984. New Zealand experienced a cool beginning of the year, in contrast to its winter (June-August) period, which was the second warmest in the past 140 years.

Drought and fires

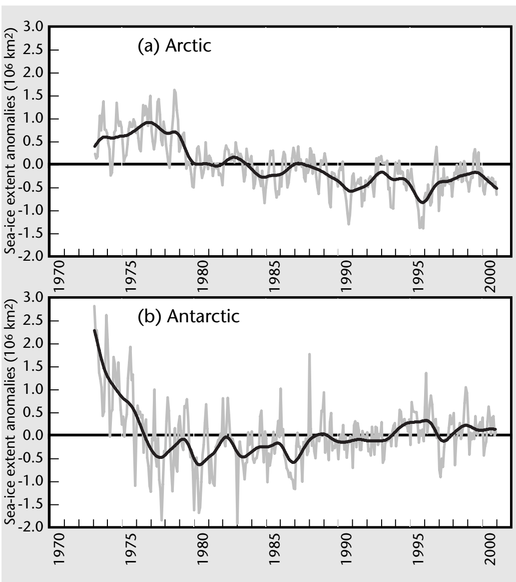
Major droughts affected much of south-eastern Europe, the Middle East, and the area through central

Asia to northern China. Especially hard hit were Afghanistan, Bulgaria, Iraq, the Islamic Republic of Iran and parts of China. This was the worst drought in over 30 years in the Islamic Republic of Iran, destroying crops and killing livestock. Parts of northwestern India experienced a second consecutive year of deficient monsoon rainfall. In Bulgaria, the warm and dry conditions led to 1 400 wildfires that consumed more than 58 000 hectares, destroying 73 homes. Greece also suffered from hundreds of fires during the height of the heat wave, particularly on Samos, where fire consumed one-fifth of the island. In North America, months of above-average temperature coincided with below-normal precipitation through northern Mexico and much of the southern and western regions of the USA, leading to one of the worst wildfire seasons in the past 50 years. Severe-to-extreme drought covered 36 per cent of the USA by the end of August.

The third consecutive year of below-normal rainfall in the greater Horn of Africa aggravated existing drought conditions over much of the area, resulting in severe food shortages. Tens of millions of people were affected by this drought. Especially hard hit were Ethiopia, and parts of Djibouti, Eritrea, Kenya, Somalia and the United Republic of Tanzania.

Hurricanes and typhoons

During 2000, the Atlantic experienced 15 hurricanes and tropical storms, well above the long-term average of 10. The Pacific experienced only 22 storms, which is below the annual average of 28. Many such storms produced extreme amounts of precipitation, flooding and damage. For example, hurricane *Keith* caused severe damage in Central America in October. In the Pacific, typhoon *Prapiroon* struck the west coast of the Korean Peninsula, bringing relentless rainfall and flash floods in August/September, and typhoon *Saomai* caused record-breaking rainfall over parts of Japan in September. A tropical storm hit Viet Nam in early September, exacerbating the monsoon flooding in the Mekong delta area and contributing to great hardship there. Cyclone *Steve* followed an unusually long track across Australia in February and March, causing severe flooding in some locations. Typhoon *Xangsane* struck the Philippines in late October, causing death and considerable damage. One major cyclone (03B) formed over the Bay of Bengal and struck the southern Indian peninsula in late November, causing severe property damage from rainfall and wind. Arguably the most devastating cyclones of the year were *Leon-Eline*, *Gloria* and *Hudah,* which struck Madagascar, Mozambique and parts of southern Africa, causing severe flooding and loss of life in the February-April period.



Monthly anomalies (millions of km^2) of Arctic (a) and Antarctic (b) sea-ice extent for the period 1973-2000, derived from satellite passive microwave sounder data. The data source is the HadISST1 dataset. Anomalies are with respect to the 1973–2000 period. (Source: Hadley Centre, The Met Office)

Flooding and other precipitation anomalies

Severe flooding from excessive summer monsoon rainfall in parts of southern India, and in Bangladesh, Cambodia, Thailand, the Lao People's Democratic Republic and Viet Nam resulted in loss of life and extensive property damage. More than 10 million people were affected in India alone with over 650 deaths.

Flooding and mudslides took a heavy toll in Central and South America in May and June. Torrential rains triggered mudslides killing 13 people in Guatemala. In Nicaragua, the Rama River rose 4.5 m and spilled over its banks on 21 June, flooding most of Rama City, a town of 10 000 inhabitants. Severe flooding affected Colombia from June to August. Parts of central Chile experienced the wettest June in 80 years, in contrast to a significant rainfall deficit that characterized the rest of the wet season (May–August).

In Australia, extensive areas experienced one of their wettest-ever January-April periods, with record rainfall and flooding in many locations, particularly in western Queensland. Heavy rain in November caused widespread flooding in parts of New South Wales and Queensland. Total rainfall in Australia in 2000 was the second highest since 1900. The annual total of 12 461 mm of rainfall recorded for 2000 at Bellenden Ker in northern Queensland was a new Australian record for rainfall at an individual observing station.

April was the wettest April, and the three-month October–December period was the wettest on record in the 235-year monthly England and Wales precipitation series. October and November each had the highest ever daily precipitation recorded over England and Wales in that calendar month in a 70-year record. Sustained above-average rainfall from September to December led to major flooding in many parts of England, Wales and France. North-eastern Italy and southern Switzerland experienced severe floods and mudslides in October. South-eastern parts of Norway experienced the wettest year since measurements began in 1895 and some stations had more than five times the normal precipitation in November. In contrast, November was the driest in Reykjavik, Iceland, since records began in 1920.

In July, Canada experienced its first deadly tornado in over 14 years and, in a rare incident, a hurricane made landfall in Newfoundland in October. In another rare event, a thunderstorm moved through Barrow, Alaska on 20 June. In early November, 692 mm of rain fell in one 24-hour period at Hilo, Hawaii, breaking the previous 24-hour record of 566 millimetres.

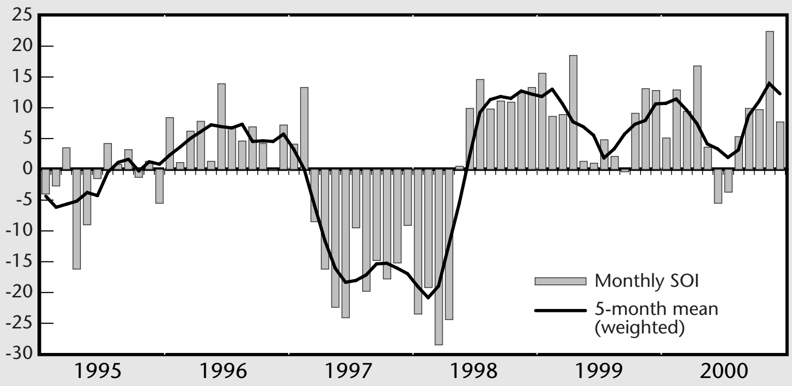
Stratospheric ozone

The stratospheric abundance of manufactured chlorine compounds is now stable at around 4 ppbv as a consequence of measures implemented by countries in support of the Montreal Protocol. Such concentrations are capable of severe stratospheric ozone destruction given the right meteorological conditions. Due to the long lifetimes of the chlorine compounds, their effect on ozone levels will likely continue for the next several decades.

In the Arctic lower stratosphere (10–22 km), significant ozone losses occurred in upper-middle and polar latitudes during 2000. These were at their greatest extent in March, when deviations of -20 to -30 per cent (against the 1964-1976 averages) could be found in an area poleward of 65°N, stretching from northern Scandinavia across the Russian Federation to about 130°E. Elsewhere in the northern hemisphere, during the same period, there were negative deviations of 10–12 per cent from Spain to Ukraine and 6 to 10 per cent over North America.

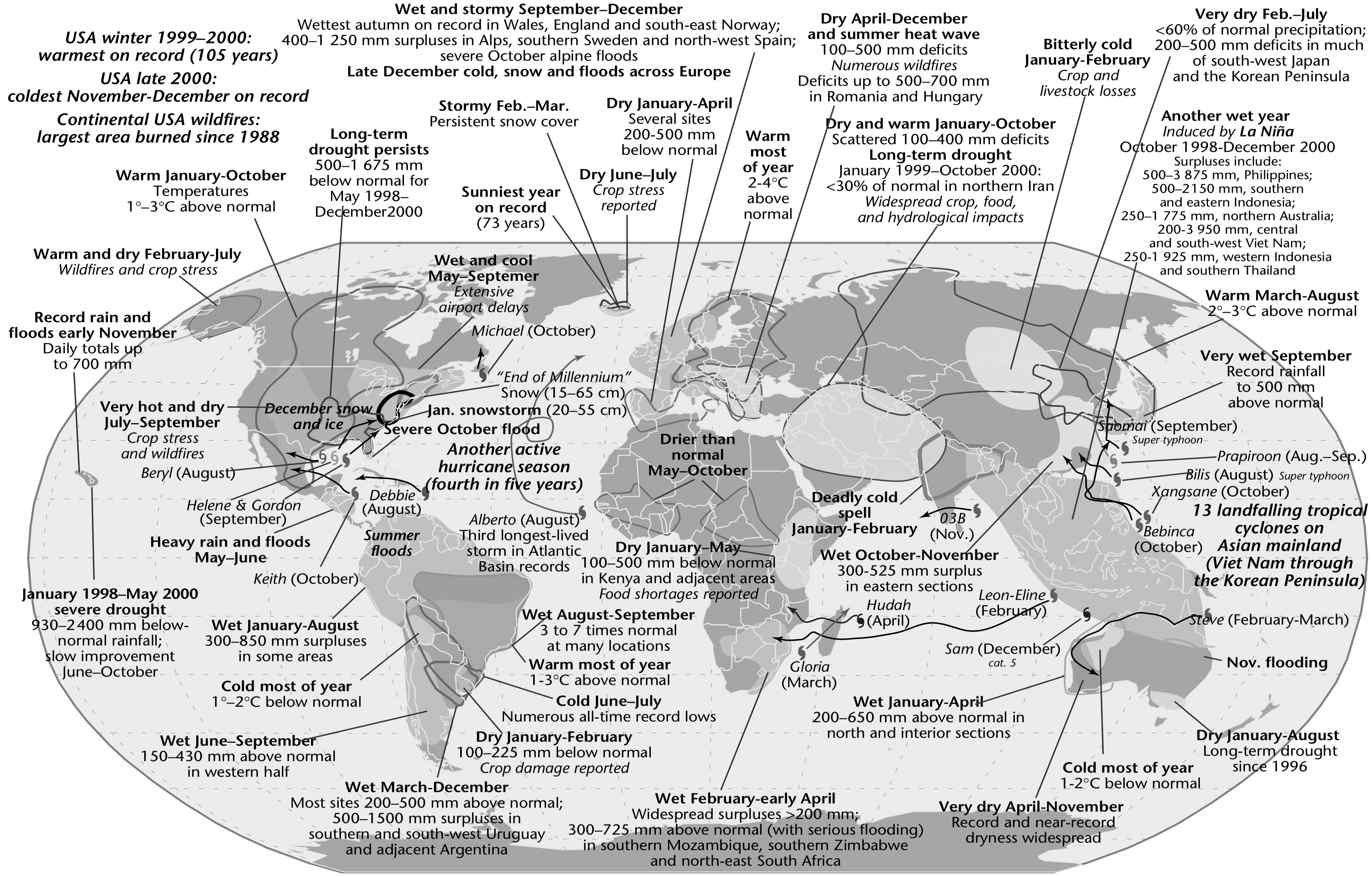
LA NIÑA

Cold El Niño/Southern Oscillation (ENSO) conditions prevailed for most of the year in the eastern Pacific as the long-running La Niña event, which began in mid-1998, weakened to near normal during June–August but then re-intensified later in the year. Precipitation patterns throughout the Tropics reflected typical La Niña conditions during the first half and towards the end of the year. Southern Asia was affected by enhanced precipitation during the summer monsoon. The tropical Indian Ocean, Indonesia and the western tropical Pacific also experienced greatly enhanced precipitation, while the central tropical Pacific experienced virtually no rainfall. Other regions that experienced enhanced precipitation under the influence of La Niña during the period included north-east South America and southern Africa. Conversely, the La Niña event was a factor that contributed to below-normal precipitation over equatorial east Africa and along the Gulf Coast of the USA.



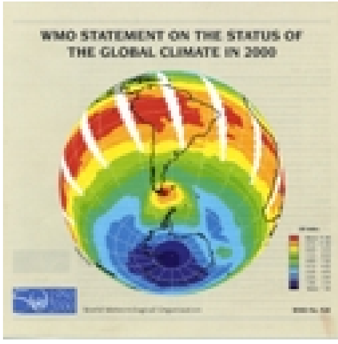
Monthly values of the Southern Oscillation Index (the normalized difference in surface air pressure between Darwin and Tahiti) and smoothed values using a five-point binomial filter (Source: National Climate Centre, Bureau of Meteorology, Australia)

SIGNIFICANT CLIMATE ANOMALIES AND EPISODIC EVENTS IN 2000



Source: Climate Prediction Center, NOAA, USA

In the southern hemisphere, the behaviour of the ozone hole was most unusual. Already in early August, an exceptionally large area of very low stratospheric temperatures—as low as -93°C—was noted over the Antarctic. By early September, the ozone hole was the largest on record, and in late September and early October it was also the deepest with losses of total atmospheric ozone exceeding 50 per cent from pre-hole days, within most of the area of the ozone hole. However, by late October, the ozone hole had rapidly dissipated and it became one of the smallest and weakest of the past decade.



The WMO Statement on the Status of the Global Climate in 2000, a 12-page colour booklet, is now available (WMO-No. 920) from the Secretariat. It may also be found in pdf format under "Hot topics" on the WMO homepage.

Sea ice

The area of ocean covered by sea ice is mainly observed by satellite and this limits the length of record of both Arctic and Antarctic sea-ice extent. The nearly 30 years of satellite data, and longer direct measurements from specific locations, indicate considerable year-to-year variability of sea-ice extent and characteristics. Overall, there has been a decline in Arctic sea-ice extent of nearly 3 per cent per decade since the 1970s.

The Arctic waters are covered by an essentially solid ice pack throughout winter and the ice begins to break up in July. Some coastal zones become completely ice-free during August and September and the constant motion of the ice pack causes it to open and close in polynyas and leads at random. The observation of open water at the North Pole during the 2000 summer, while rare, is not in itself evidence of global warming. However, it is consistent with the regional trends and observations of local warming (e.g. 1.3°C increase over the past three decades at Resolute, Canada) and submarine observations of ice thickness reduction.

Sea-ice extent in the Arctic in 2000 was below the long-term mean throughout the year, while, in the Antarctic, values were somewhat above the long-term average for much of the year.

Economic framework for the provision of meteorological services

By J.W. Zillman[1] and J.W. Freebairn[2]

Introduction

The role of meteorological and related services in supporting the safety, security and general wellbeing of society, in contributing to increased economic welfare of individuals, businesses, industries and nations and in providing a more informed scientific basis for protecting the quality of the natural environment, has been described in a vast array of publications through the 20th century (e.g. Moore, 1910; Brunt, 1928; Berry, Bollay and Beers, 1945; Meteorological Office, 1967; Maunder, 1970, 1986; Taylor, 1972; Houghton, 1985; WMO, 1993; Harris, 1995; Cartwright and Sprinkle, 1995; Munn *et al.*, 1996; Katz and Murphy, 1997; Burroughs, 1997; Stern and Easterling, 1999; McBean, 2000) and is recognized and understood, to varying degrees, by most members of the community in both developing countries and the industrialized world. The special role played by the National Meteorological Services (NMSs) of the 185 WMO Member States and Territories and their relationships with other service providers and with the academic research and teaching communities have recently been summarized by Zillman (1999).

Historically, the availability of at least a minimum level of state-of-the-art meteorological services has been seen as a basic community necessity and right, the satisfaction of which self-evidently justified a significant level of government expenditure. In recent times, however, the greatly increased pressure on public funding in most countries has extended to

1 Commonwealth Bureau of Meteorology, Melbourne, Australia

2 Department of Economics, University of Melbourne, Melbourne, Australia

public meteorological services and governments have begun to look for alternative delivery mechanisms and new funding sources to replace or supplement the long-established taxpayer funding of their NMSs (WMO, 1999(*a*)).

The pressure for revenue generation and the extension of market forces into the provision of meteorological services, where the tradition of international cooperation and mutual assistance between publicly funded NMSs has long provided the basis for a highly efficient international system of meteorological data collection and exchange under the WMO World Weather Watch, have introduced several new sources of tension and instability into international meteorology (Bautista Pérez, 1996; WMO, 1996). Concern at the potential impacts of these developments moved WMO Members to issue the Geneva Declaration of the Thirteenth World Meteorological Congress (WMO, 1999(*b*)).

These pressures have, in turn, increased the need for a more comprehensive, more rigorous and more widely understood economic framework through which to assess the benefits and meet the costs of meteorological service provision at the national level. We have recently attempted to elaborate the elements of a framework for assessing the economic benefits of both basic and specialized meteorological services (Freebairn and Zillman, 2001(*a*)) and for establishing the economic basis for their funding and pricing (Freebairn and Zillman, 2001(*b*)). The purpose of this article is to outline the essential features of this framework and to summarize our key conclusions as an introduction and guide to the more detailed papers.

This article outlines the elements of an economic framework for assessing the benefits of meteorological and related services and for evaluating options for their funding and pricing. The non-rival and non-excludable properties of most meteorological infrastructure and public services identify them as classic public goods, whose benefits to society are maximized the more widely they are consumed. Direct government funding and free provision to all are favoured with their contribution to national welfare maximized at the point where social marginal benefits equal social marginal costs. Value-added special services for use by individuals or small groups of specialized users have private or mixed good properties, their benefits accrue to only a limited number of people and they are appropriately funded by user fees. Depending on the institutional structures adopted, options exist for pricing of these special services slightly above marginal cost.

The national meteorological service system

In its most generalized conceptual form, the national meteorological service system operating in most countries can be represented, as shown in Figure 1, in terms of the:

- Basic infrastructure, data and products: the basic data collection and processing infrastructure which underpins the provision of the full range of services (and may itself be recognized as the provision of a basic service to present and future generations);
- Basic service; those services provided by an NMS in discharging its government's sovereign responsibilities to protect the life and property of its citizens, to contribute to their general welfare and the quality of their environment, and to meet its international obligations under the Convention of the World Meteorological Organization and other relevant international agreements;
- Special services; those services beyond the basic service (which) may include the provision of special data and products, their interpretation, distribution and dissemination, and consultative advice.

It has long been widely accepted that provision of the basic national meteorological infrastructure, data and products (usually referred to as the "basic systems") is a responsibility of government. There would be little gained and much additional cost and confusion incurred through the establishment of duplicative and competing observational and communication networks; and the data from the basic networks may be used by all of a wide range of service providers without reducing their value to others.

The basic weather and climate service to the community at large (the "basic service" (WMO, 1990(*a*)) sometimes, also, referred to as the "national meteorological service" or the "national weather service") is usually made widely available to the public through the mass media. It may include a range of services directed to the needs of major community sectors, such as farming, fishing, sailing, etc.

The third category of activities shown in Figure 1 is what has been defined by the World Meteorological Organization (WMO, 1990(*a*)) as special

Figure 1 — A schematic representation of the essential components of a national system for provision of meteorological services. The basic infrastructure, data and products (sometimes referred to as "basic systems") underpin the provision of both the basic service to the community at large and special value added services to individual users.

meteorological services, consisting of those services, additional to the freely available basic service, which are provided to meet the particular and special purpose decision needs of individuals or major identifiable user sectors. Examples include weather services tailored to the needs of remote offshore oil and gas operators and aviation weather services tailored to meet the needs for safe, regular and economic operation by the aviation sector.

Economic characterization of meteorological services

While the formulation of public policy on the provision of meteorological services has historically been based more on social considerations (especially those related to the safety of life and property) than on economic considerations, meteorological information and service provision have increasingly become amenable to the discipline and techniques of economic analysis, especially following the introduction of the concept of public goods (Samuelson, 1954) and the development of a comprehensive body of literature on the theory of public expenditure, public sector economics and the role of government in a digital age (e.g. Heald, 1983; Musgrave and Musgrave, 1991; Bailey, 1995; Cornes and Sandler, 1996; Stiglitz, 2000; Stiglitz *et al.*, 2000).

Within this framework, and as for other economic goods and services, assessment of the benefits of meteorological services, identification of appropriate options for their funding and pricing, and the achievement of an efficient allocation of scarce resources to the different categories of service depend importantly on the rivalry and excludability properties of the different services as summarized schematically in Figure 2.

Much meteorological information, like information more generally, has the property of non-rival consumption. Use of this information (say a general weather forecast for the following day or a warning of an approaching storm) by one decision-maker (deciding, for example, whether to irrigate a crop or whether to put the car under cover) does not reduce its availability to others. In effect, once such information is produced and made available to one user, the marginal cost of meeting the needs of other users is zero, or close to zero. Many such services are also characterized by high costs of exclusion. Once the information is available (say through a radio broadcast), it is available to all and it would be impossible, or very costly, to exclude potential users from accessing the information and using it for their own benefit. Non-rival consumption and high costs of exclusion mean that many meteorological services are classic public goods, whose provision is widely accepted as the responsibility of governments (Heilbroner and Thurow, 1994; Cornes and Sandler, 1996).

Many value-added meteorological services (such as site-specific rainfall forecasts for hay-making or forecast flight conditions for individual aircraft) are of value to only a small number of easily identified specialized users. Although non-rivalrous in character, the costs of exclusion may be low (the information can

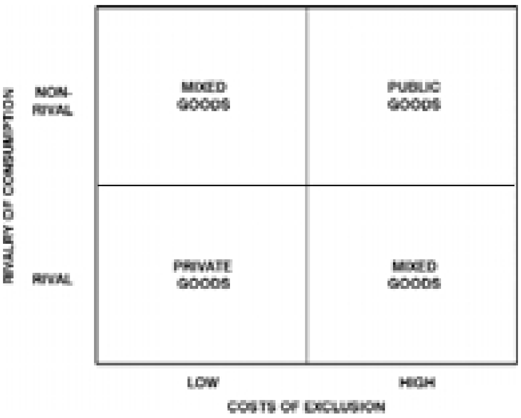


Figure 2 — Economic framework for the categorization of meteorological services according to rivalry of consumption and costs of exclusion. According to Samuelson (1954), a pure public good is one which exhibits both: non rivalry of consumption (one person's consumption does not reduce the amount available to others); and non excludability (it is impossible or extremely expensive to exclude from benefit a person who refuses to contribute to the cost).

easily be provided electronically on a confidential one-to-one basis). Such value-added specialized meteorological services thus have mixed good properties of non-rival consumption and low costs of exclusion. Where the specialized user effectively is a single entity, either literally or as a result of the small group of users combining as a club, then the value- added meteorological service can be analysed as a private good with properties of rivalry and excludability.

The extent of rivalry and excludability of consumption are important considerations in determining the basis on which different meteorological services should be provided and how they should be funded and charged for. With private goods, competitive markets and prices provide the coordinating mechanism. In the case of public goods, markets fail and government funding and zero pricing become important strategies.

Benefits and costs of meteorological services

An economic model for evaluating the benefits of meteorological services (public or private; and for individual users or the community at large) and for determining the most economically efficient allocation of resources to their provision can be formulated in terms of the dependence of total benefits and costs on the volume of service as shown in the top part of Figure 3 or the dependence of marginal benefits and costs on volume of service as shown in the bottom part of Figure 3.

The volume (or level) of meteorological services can be measured as units of historical or current data on rainfall, wind, temperature etc., or in terms of temporal or spatial resolution of numerical prediction model output, or as measures of forecast accuracy and lead time or effectiveness of communication or tailoring to specific user needs or, more generally, as the quantity and quality of information provided on weather, climate and the state of the atmosphere.

The total benefits function (TB) provides a measure of the increase in well-being of decision-makers as they use more and better meteorological information to make choices which lead to the avoidance of losses and/or the achievement of gains that would not otherwise have occurred. There will usually be a threshold volume/level of service (as measured in terms of information content, skill, accessibility, credibility etc.), OB in Figure 3, which must be reached before decision-makers will gain the confidence to make use of the information to alter their weather- or climate-sensitive decisions. The total benefits will then rise fairly steeply as skill and confidence in the use of the increasing volume (quantity

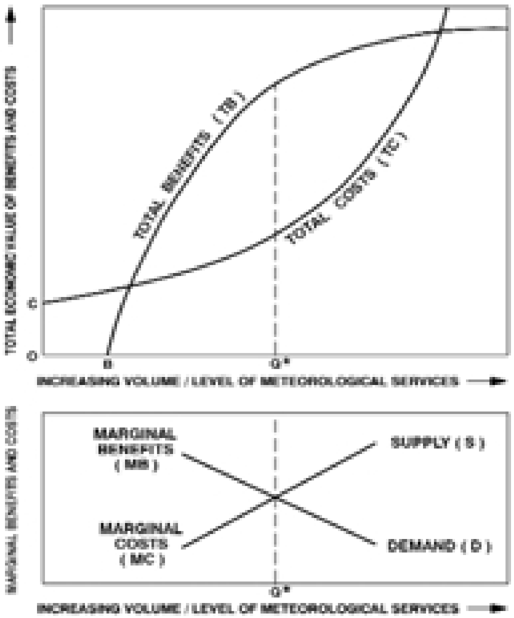


Figure 3 — The total (top) and marginal (bottom) benefits and costs of meteorological services as a function of the volume (or level) of service. The demand for meteorological service (D) is given by the marginal benefits curve (MB) and the supply (S) by the marginal costs curve (MC). Societal well-being is maximized at the volume of service Q at which the demand and supply curves intersect. This is also the volume of service for which the excess of total benefits (TB) over total costs (TC) is greatest.*

and quality) of meteorological information yields increasing payoffs. The total benefits function will, however, eventually plateau as further increasing volumes of meteorological information lead to smaller and smaller additional benefits in terms of better decisions. The total costs function (TC) involves an upfront cost component OC (for establishment of an essential minimum level of meteorological data collection and processing infrastructure), plus an increasing cost component as the more sophisticated and more expensive infrastructure and service provision facilities required to deliver more and better services are brought on line. The total cost function becomes convex downward as more and more resources become necessary to deliver smaller and smaller improvements in the service.

The bottom part of Figure 3 shows the more conventional economic model of the demand for, and supply of, meteorological services. The demand for meteorological services, D, is in fact the marginal benefits (MB) curve (the first derivative of the total benefits curve immediately above). The supply of meteorological services, S, is the marginal cost (MC) curve (the first derivative of the total cost curve above).

The information on total and marginal benefits and costs in Figure 3 provides a conceptual basis for determination of the economically optimum level of resources to allocate to the production and use of meteorological services. Basic supply and demand analysis indicates that the volume of meteorological service Q* which maximizes social well-being is given by the volume at which the supply and demand curves intersect; this is also the volume for which the difference between the total benefits and total costs in the upper part of Figure 3 is a maximum. To the left of Q*, too few resources are allocated to meteorological service provision in the sense that marginal benefits exceed marginal costs and net gains can be had by expansion. To the right of Q*, additional resources used to increase the volume of meteorological services will add more to costs than to benefits and, in so doing, will detract from overall national welfare.

The decision faced by governments or by private-sector purchasers of meteorological services in identifying the optimum level of investment to make in meteorological service provision boils down to establishing the marginal benefits and cost curves in Figure 3. Freebairn and Zillman (2001(*a*)) outline the available methodologies for establishing the form of the marginal benefits curve (MB), while Freebairn and Zillman (2001(*b*)) examine the issues involved in determining and meeting the costs (through funding and pricing models for the different categories of service) involved in provision of the services in terms of the marginal cost curve (MC).

Evaluating the benefits

The last 40 years have seen the development of a substantial body of literature on methodologies for evaluation of the benefits of both basic and special meteorological services and their application in a wide range of case-studies at individual, business, sectoral and national levels (e.g. Maunder, 1970; Freebairn, 1979; Anaman *et al.,* 1995; Katz and Murphy, 1997). WMO has played a particularly important role in documenting and synthesising the results of this work (WMO, 1990(*b*); 1994).

In proceeding to construct the total or marginal benefits curves of Figure 3 for a locality, region or country, it is essential to take account of a very important difference between services which are rivalrous and those which are non-rivalrous in consumption. In the case of rivalrous services, the societal value (or benefit) of the service is essentially its value to the highest bidder in the market for the service. In the case of non-rivalrous consumption, on the other hand, the value of the service to society is the sum of its value to all the individual users as shown schematically for the simple case of just two users in Figure 4.

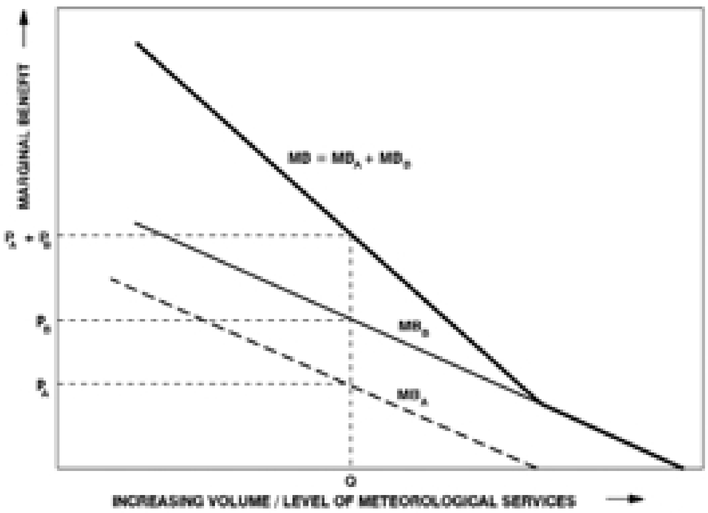


Figure 4 — The marginal benefits of non-rival meteorological services as a function of the volume (or level) of service. The marginal benefit function (derived, as in Figure 3, as the derivative of the total benefit function) for User A is MB_A and that for User B is MB_B . For a given volume of service Q, User A values the last unit of service at P_A and User B values it at P_B. The benefit to society (consisting of just Users A and B in this illustration) is then given as the sum $P_A + P_B$.

There are essentially four different approaches that can be employed to estimate the form of the total benefits (TB) and marginal benefits (MB) curves for a particular user or group of users or for society as a whole. In summary these are:

- *Market prices*. The use of market prices as a measure of marginal benefits is straightforward for those special services which are characterized by private good characteristics of rival consumption and ease of exclusion. This results from the market reality that customers will purchase the services up to a point where the marginal value to them equals the price and the recorded price and volume for a sample of purchases will then determine the marginal benefit (MB) or demand curve D. The advantage of market prices is that they explicitly reveal the value that the users place on, and are willing to pay for, the service;

- *Normative or prescriptive decision making models.* This is the most widely used approach to estimate the benefits of meteorological services. The models formulated for individual decision-makers seek to identify the expected payoffs in terms of higher profits, lower costs or greater utility resulting from management decisions based on different volumes or levels of meteorological information. The results from individual decision-making models can be extended to represent an industry, region or other aggregate of users. They can also be developed to capture important market responses and feedbacks. Prescriptive models have a number of advantages and disadvantages. The most significant challenge is that of realistically representing the impact of the meteorological information on improved decision-making;
- *Descriptive behavioural response studies.* These are essentially complementary to prescriptive studies and involve estimation of the value of meteorological services from observation of the actual behaviour of individuals, businesses and governments. They include user surveys of decision-making, natural experiments, potential laboratory experiments and regression studies. They, too, have a range of advantages and disadvantages;
- *Contingent valuation studies.* The contingent valuation method, although controversial, is useful in estimating the benefits of services with strong public good characteristics. Users of the services are asked to nominate the sum they would be willing to pay for a particular level of the public good service and the results are summarized to find a measure of society's willingness to pay. Although contingent valuation studies must be very carefully designed, they have proved particularly useful in obtaining at least lower bound estimates of the value of public weather services on a city, region or national basis.

Many hundreds of individual studies have been reported and evaluated in the literature (e.g. Katz and Murphy, 1997) but, while especially revealing in respect of the benefits of particular categories of services (e.g. for agricultural users, aviation, energy supply, etc.), the conclusions remain fragmentary and there is as yet no comprehensive understanding of the location or shape of the total or marginal benefits curves for the totality of meteorological services for a nation as a whole. In attempting to assess the benefits to a national economy as a whole, it is important to take account of a range of interactions in the market situation (Freebairn and Zillman, 2001(*a*)). Perhaps most important, however, in attempting to construct the benefits curve for an entire national community, is the recognition that, for public good services, the aggregate benefits will be the sum of the benefits of all those individuals in the community who are making beneficial use of the service for decision purposes. In terms of the schematic representation in Figure 4, the situation is that, at present, we have value estimates for only some users of meteorological services, say the MB_A curve, but we do not have information for the MB_B curve or, hence, for the aggregate benefits curve $MB = MB_A + MB_B$.

Establishing the costs

In principle, at least, the establishment of the total and marginal cost curves as a function of the volume or level of service in Figure 3 is more straightforward than for the benefits curves. Not only is there a fairly wide spread of "levels of service" represented amongst the NMSs of the world, the costs of which are more or less accurately known, there is also a gradually accumulating database linking the costs of the infrastructural investment (e.g. in storm-tracking radars, airport meso-networks, satellite read-out systems, numerical prediction models, etc.) needed to upgrade particular individual services (e.g. severe storm warning, airport windshear detection, maximum temperature forecasting, tropical cyclone tracking, etc.) to specific levels of performance as indicated by service-specific skill scores, user-community satisfaction indicators, etc.

In practice, however, the task is far from straightforward, except in the case of very simple, geographically restricted and user-specific services such as, say, monitoring of ground temperature to specified accuracy and reliability standards at a particular location for alerting the community to the imminence of water-pipe freeze up or the like. On the larger scene, there are at least three major impediments:

- No local, regional or national meteorological service system can be operated or evaluated as a closed system without allowance for the high level of dependence on data, information and technology transfer from adjacent localities, regions or countries;
- The costs of supporting a specific volume or level of meteorological service for a particular country are heavily dependent on the area of the country over which it is necessary to establish and operate observing networks;
- The costs are heavily dependent on the nature of the prevailing meteorological regime and the

weather and climate phenomena to be observed, tracked, and predicted.

Given the lack, or prospect, of ever developing, any single generally applicable and generally acceptable overall measure of service level, the establishment of the form of the cost curves of Figure 3 is necessarily approached on a case-study and pragmatic basis as an aid to, rather than any form of objective substitute for, informed judgement.

Benefit-cost analysis

One technique often used in determining whether significant projects for the upgrading of meteorological infrastructure and services should proceed, and in choosing between alternative approaches for achieving such an upgrade, which may now be set in the overall framework of Figure 3, is benefit-cost analysis (Layard and Glaister, 1994). As normally used in meteorology, it involves a systematic appraisal of the projects' likely impact on both the benefit and cost curves of Figure 3, but one in which an attempt is made to quantify the full range of social, economic and environmental benefits and costs in money terms.

While benefit-cost studies of meteorological service improvement projects often prove controversial because of the inherent subjectivity in the quantification of both costs and benefits and the difficulty of associating expected benefits uniquely with a particular project (e.g. Chapman, 1992), the overall concepts and planning discipline involved may be seen as a useful element of an overall economic framework for the provision of meteorological services.

Funding, pricing and charging

Given a general understanding of the benefits and costs of operation of a national meteorological service system and, with the caveats explained above, of the benefits and costs attributable to individual components of the service and individual users and customers, the challenge is clearly to identify appropriate policies and mechanisms for funding, pricing and charging for these services. Economic theory and a century of experience in meteorological and related service provision suggest that the options include:

- Government funding from taxation revenue and zero pricing;
- Marginal cost pricing for specialized value adding services;
- Marginal cost pricing plus a loading on value-added services with the loading being a contribution to overall costs; and
- Two-part tariffs for value-added services involving a contribution to the costs of the basic infrastructure.

Comparison of the different funding and pricing options depends importantly on the rivalry and excludability properties of the different stages or components of meteorological service provision. The various options are evaluated from the perspective of economic efficiency by Freebairn and Zillman (2001(*b*)), separately for public good, private good and mixed public and private good services. They are evaluated in terms of revenue collected and fees paid; guidelines for the efficient allocation of resources to the production and use of meteorological services; incentives for suppliers and users to adopt cost-saving technology and to innovate; and feasibility and simplicity.

On the basis of this assessment, some general conclusions emerge which suggest an overall strategy for funding the provision of meteorological services to meet the basic criteria of economic efficiency and practical feasibility in a situation where the services which enable individuals, businesses and governments to make better higher-pay-off decisions span the full spectrum of public, private and mixed goods, and the lines of demarcation between the different types of goods are poorly defined and changeable over time.

Basic infrastructure, data and products for national and international use, and basic public weather and climate forecasts and warnings, primarily have public good properties. The information is non-rival in consumption, there are many actual and potential users from most sectors of the economy, and costs of exclusion are high. Other than for the identifiable costs of their distribution to individual users, economic efficiency and practicality considerations suggest that these public good services should be provided free of charge to actual and potential users. General taxation revenue should provide most of the funds for public good meteorological services.

Specialized value-added meteorological services provide extra information which enhances decision-making by smaller groups of individuals and especially businesses. Here, many of the specialized services have mixed good properties of non-rival consumption and low costs of exclusion. In some cases with one user, or effectively one user, the non-rival consumption property can be ignored, leaving a private good situation. The value-added services use both the basic infrastructure information as an input plus relatively easily identifiable additional inputs for production. User charges for the value-added meteorological services, such as for aviation (WMO, 1999(*c*)), set at the marginal cost of the additional inputs result in economic efficiency.

Options to include in the price or user fee for value-added specialized meteorological services an extra charge to contribute to the funding of the public good infrastructure are controversial. In terms of the criteria of efficiency and extra revenue collected, a two-part tariff is preferred to a tax on the value-added outputs or on the extra inputs used in producing them. Monopoly power is, however, necessary to ensure sustainability of a two-part tariff. Unfortunately, decisions by the monopoly supplier are likely to involve static and dynamic efficiency losses. These efficiency losses or costs have to be compared with the social costs of using tax revenue to fund the basic infrastructure.

Institutional options for service provision

One of the key current public policy issues on which economic analysis throws considerable light relates to the institutional structural options for delivery of service and, in particular, the relative roles of the NMS and the national and international private sectors.

One possible service provision structure is to restrict the NMS to providing public good meteorological services, including the basic infrastructure and general forecasts, with full government funding, and leave the production of value-added specialized meteorological services with private good and mixed good properties to private firms. Private firms would use the readily available public good services at zero charge, then employ, and pay market prices for, extra resources to produce value-added services, and charge what the market will pay. The forces of competition would provide effective incentives and rewards for private firms for developing and adopting innovations in both the production of value-added meteorological services and in the uses made of the information. With the NMS effectively excluded and all having equal access to the public good meteorological information, different private sector firms can compete amongst each other on level terms.

However, in addition to the safety considerations which may make it highly undesirable that a major user sector (e.g. aviation) base its decisions on information which could be inconsistent with the widely available public forecasts and warnings, at least three sets of arguments against excluding the NMS from involvement in the production of value-added services need to be considered. First, there may be economies of scope which result in cost savings in using skilled forecasters, computers and other NMS resources in joint production of value-added services, as well as the basic infrastructure and public services. Second, the delineation of public good meteorological services as the limit of the domain of the NMS is a vague and somewhat arbitrary exercise. Further, the demarcation will change with rapid technological change, and is likely to be subject to inefficient strategic and political gamesmanship. Third, for many, and maybe most, value-added services, it is likely that economies of size will mean that it is cost effective to have just one supplier, although the importance and extent of the economies is an empirical issue and one which may have different answers for different value-added services. Where economies of size are such as to favour a natural monopoly, it may be necessary to choose between a regulated public supplier, the NMS, or regulation of a private firm monopoly supplier and, in this situation, there is no clear answer.

Alternatively, the supply of value-added meteorological services could be structured to achieve a close-to-level playing field for fair competition between the NMS and actual and potential private sector suppliers. The public good meteorological services used as an input for producing value-added services would be made available to all producers on exactly the same terms, of which a zero price is one option, and the NMS sets prices for the value-added services it produces to at least cover the incremental production costs, as would a commercial private business competitor. While the delineation of what is a public good to be funded by the government and provided free of charge to all, from what is a value-added meteorological service, will be arbitrary, so long as the distinction is clear and explicit, it has a limited impact on achieving competition in the value-added specialized meteorological services market.

An overall framework

Given the ongoing international debate within both the meteorological and economics communities on the extension of market forces to hitherto non-market spheres of activity and especially on the scope for interfacing of the fundamentally different paradigms of meteorology (cooperation) and economics (competition), it is not yet possible to present any generally agreed overall economic framework for the provision of meteorological services at either the national or the international levels. On the basis of the various concepts discussed above, and with significant over simplification, it is, however, possible to indicate some approximate interrelationships and alignments in terms of the simple conceptual model of service provision shown in Figure 1.

Figure 5 offers a schematic summary of these relativities and relationships on the basis of the usual subdivisions by:

- Service category;
- Economic classification;

- Valuation methodology;
- Charging regime; and
- International exchange;

and with the caution that the horizontal alignments are, in almost all cases, suggestive rather than definitive but may be considered useful as a point of departure for further development of an overall economic framework for the provision of meteorological services.

Conclusions

The 20th century has provided governments and national communities with a great deal of experience and insight into the social, economic and environmental benefits of meteorological services and the most appropriate funding, charging and institutional arrangements for their provision and ongoing improvement in line with community needs and continuing progress in the enabling science and technology.

Historically, such services have been widely seen as a basic community necessity and right in both the developing and developed world and their benefits as self-evidently justifying the substantial public and private expenditure involved, which, in some countries, is as much as 0.03 per cent of GDP (Zillman, 1999), and of the order of US$ 10 billion in global aggregate.

The parallel progress of general economic theory, and especially the growth of a body of theory and practice in the analysis of public expenditure, has provided the tools to look in more depth at the economics of meteorological service provision and begin to assemble a general economic framework for the provision of meteorological services at the national level. While many of the underlying considerations remain highly subjective, value laden and beholden to the lessons of history and practical experience, the conclusions reached so far are strongly supportive of the international framework which has built up through the 20th century, based on the unique model of international cooperation under the World Weather Watch framework of the World Meteorological Organization.

An important conclusion is that, although market theory can provide useful insights into many aspects of the arrangements for the provision of meteorological services, by far the largest part of meteorological service provision is not appropriate for the application of market forces or competitive supply. Other public policy and international considerations suggest the advantages of public provision as well as public funding of most nonrival meteorological services and economies of scope and scale argue strongly for the integrated provision of serv-

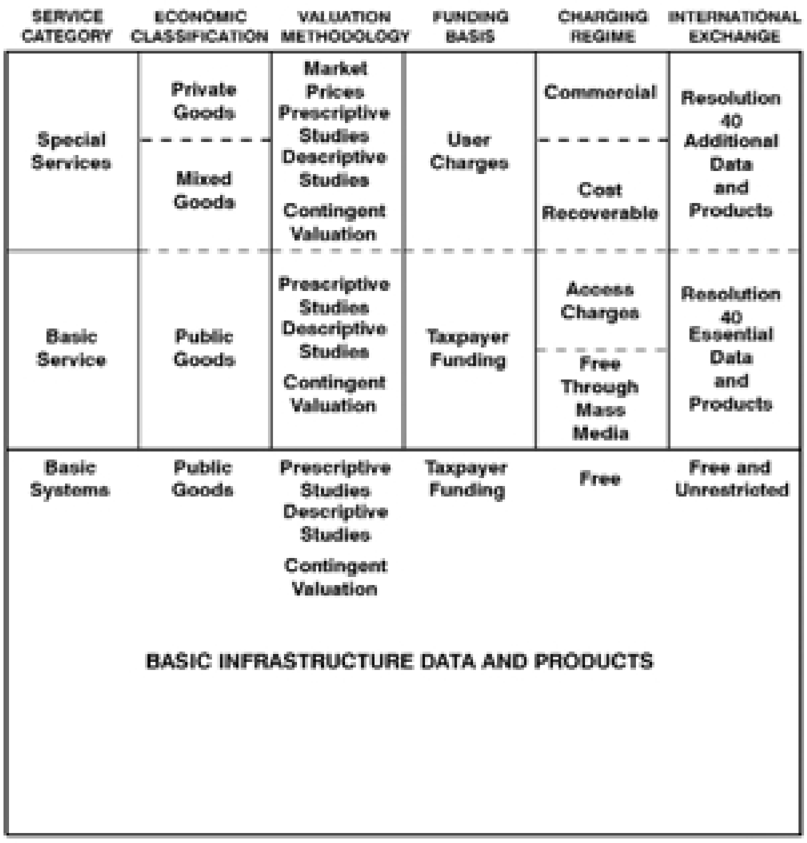


Figure 5 — A schematic representation of the approximate relationships between the basic underpinning national meteorological infrastructure and the outputs (basic and special services; and essential and additional data for international exchange under Resolution 40 of the World Meteorological Organization (1996)) based on it, in terms of economic classification, valuation methodology, funding basis and charging regime. It is important to note that the horizontal alignment of boundaries (broken lines) is approximate only and is, at present, highly variable from service to service, country to country and time to time.

ices to certain major user groups such as aviation and shipping.

In combination, these considerations suggest a continuing fundamental role for the State-funded NMS in the provision of essential meteorological services at the national level.

While the basic public safety and welfare considerations, which have historically shaped the provision of meteorological services at the national level, will continue as the primary basis for decision-making by governments, there is considerable scope for increased effort on the development and application of economic valuation methodologies and pricing and charging models for a range of services, user sectors and countries. The two papers by Freebairn and Zillman (2001(*a*) and (*b*)) are intended to help stimulate and assist that process.

References

ANAMAN, K.A., J.J. THAMPAPILLAI, , A. HENDERSON-SELLERS, P.F. NOAR and P.J. SULLIVAN, 1995: Methods for assessing the benefits of meteorological services in Australia. *Meteorol. Appl.* 2: 17-29.

BAILEY, S.J., 1995: *Public Sector Economics*. Macmillan Press Ltd., London, 406 pp.

BAUTISTA PÉREZ, M., 1996: New WMO regulations on the international exchange of meteorological data and products. *WMO Bulletin*, 45, 20-29.

BERRY, F.A., E. BOLLAY and N.R. BEERS (Eds), 1945: *Handbook of Meteorology*. McGraw-Hill Book Company Inc. NY, London, 1 068 pp.

BRUNT, D., 1928: *Meteorology*. Oxford University Press, London, 111 pp.

BURROUGHS, W.J., 1997: *Does the Weather Really Matter?* Cambridge University Press, 230 pp.

CARTWRIGHT, G.D. and C.H. SPRINKLE, 1995: A history of aeronautical meteorology. In: *Historical Essays on Meteorology 1919-1995* (J.R. Flemming, Ed.). American Meteorological Society, 443-480.

CHAPMAN, R., 1992: *Benefit-cost Analysis for the Modernisation and Associated Restructuring of the National Weather Service*. National Institute of Standards and Technology, US Department of Commerce, Washington DC, 105 pp.

CORNES, R. and T. SANDLER, 1996: *The Theory of Externalities*, Public Goods and Club Goods. Cambridge University Press, 590 pp.

FREEBAIRN, J.W., 1979: Estimating the benefits of meteorological services: some methodological questions. *Proceedings of the Value of Meteorological Services Conference*, Bureau of Meteorology, Melbourne, Australia, 117-123.

FREEBAIRN, J.W. and J.W. ZILLMAN, 2001(*a*): Economic benefits of meteorological services, *Meteorol. Appl.* (in press).

FREEBAIRN, J.W. and J.W. ZILLMAN, 2001(*b*): Funding meteorological services, *Meteorol. Appl.* (in press).

HARRIS, S., 1995: *International Public Goods, the Climate and Meteorological Services*. World Meteorological Day Address, Bureau of Meteorology, Melbourne, 11 pp.

HEALD, D., 1983: *Public Expenditure: Its Defence and Reform*. Martin Robertson and Company Oxford, 376 pp.

HEILBRONER, R. and L. THUROW, 1994: *Economics Explained*. Simon and Schuster, New York, 285 pp.

HOUGHTON, D., 1985: *Handbook of Applied Meteorology*. John Wiley and Sons, 1 461 pp.

KATZ, R.W. and A.H. MURPHY (Eds.), 1997: *Economic Value of Weather and Climate Forecasts*. Cambridge University Press, 217 pp.

LAYARD, R. and S. GLAISTER, 1994: *Cost-Benefit Analysis*. Cambridge University Press, 497 pp.

MCBEAN, G.A., 2000: *Forecasting in the 21st Century*. WMO-No. 916, Geneva, 18 pp.

MAUNDER, W.J., 1970: *The Value of Weather*. Methuen, London, 388 pp.

MAUNDER, W.J., 1986: *The Uncertainty Business: Risks and Opportunities in Weather and Climate*. Methuen, 420 pp.

METEOROLOGICAL OFFICE, 1967: *Meteorology for Mariners*. Her Majesty's Stationery Office, 304 pp.

MOORE, J., 1910: *Meteorology, Practical and Applied*. Rebman Limited, London, 492 pp.

MUNN, R.E., J.W.M. LA RIVIÈRE and N. van LOOKEREN CAMPAGNE, 1996: *Policy Making in an Era of Global Environmental Change*. Kluwer Academic Publishers, 225 pp.

MUSGRAVE, R. and P. MUSGRAVE, 1991: *Public Finance in Theory and Practice* (Fifth Edition), McGraw Hill, 627 pp.

SAMUELSON, P.A., 1954: *The pure theory of public expenditure. Review of Economics and Statistics*, 36, 387-389.

STERN, P. and W. EASTERLING, 1999: *Making Climate Forecasts Matter*. National Academy Press, Washington DC, 175 pp.

STIGLITZ, J., 2000: *Economics of the Public Sector*, 3rd Edition. Norton, New York, 823 pp.

STIGLITZ, J.E., P.R. ORSAG and J.M. ORSAG, 2000: *The Role of Government in a Digital Age*. US Computer and Communications Industry Association, 151 pp.

TAYLOR, J.A., 1972: *Weather Forecasting for Agriculture and Industry.* David & Charles Publishers, Devon, 250 pp.

WMO, 1990(*a*): Forty-second Session of the Executive Council: Abridged Report with Resolutions, WMO-No 739, Geneva.

WMO, 1990(*b*): *Economic and Social Benefits of Meteorological and Hydrological Services. Proceedings of the Technical Conference*, Geneva, 26-30 March 1990. WMO-No 733, Geneva.

WMO, 1993: Guidelines on the Role of National Meteorological and Hydrometeorological Services in the Implementation of Agenda 21 and the Framework Convention on Climate Change. WMO, Geneva.

WMO, 1994: Proceedings of the International Conference on the Economic and Social Benefits of Meteorological and Hydrological Services. WMO/TD-No 630, Geneva.

WMO, 1996: *Exchanging Meteorological Data: Guidelines on Relationships in Commercial Meteorological Activities: WMO Policy and Practice*. WMO-No. 837, Geneva, 24 pp.

WMO, 1999(*a*): The National Meteorological Service and Alternative Service Delivery (A Statement by the Executive Council of the World Meteorological Organization on the future role and operation of national Meteorological Services), Geneva.

WMO, 1999(*b*): Geneva Declaration of the Thirteenth World Meteorological Congress. *Thirteenth World Meteorological Congress, Abridged Report with Resolutions*. WMO-No. 902, Geneva, 146.

WMO, 1999(*c*): *Guide on Aeronautical Meteorological Services Cost Recovery: Principles and Guidance*, WMO-No. 904, Geneva, 17 pp.

Zillman, J.W., 1999: The National Meteorological Service. *WMO Bulletin*, 48, 129-159.

❀ ❀ ❀

Costs and benefits of weather and climate services

By Yadowsun BOODHOO*

Introduction

Cost recovery by National Meteorological and Hydrological Services (NMHSs) has been a popular theme for some time now. While some aspects have been dealt with, not all has been said. With globalization and fast developments in communication and methods of dealing in international affairs and trading, climate products have, albeit to a lesser extent than other commodities, and after lengthy debate, become an object of trade. One will recall the importance of Resolution 40 (Cg-XII), the "negotiation" of which started well before its endorsement.

Pricing of products

The cost of any product of any enterprise depends on the following: investment cost to set up the enterprise, its production capacity, cost of operation, estimated lifetime, size of the market, etc. In the case of NMHSs, investments have been made in a gradual way and for most of them it will be difficult to evaluate their magnitude. It will also be difficult to foresee any future investment need as the technology is evolving fast and cannot be foreseen by most, especially the developing ones.

It is not always easy to put a price tag on each and every product and service provided by an NMHS. Because most NMHSs are government owned, termed as essential Services and have adequate budget allocations, they have, therefore, not felt the need to embark on cost-recovery exercises. Until, perhaps, very recently some of these services were explicitly not allowed to claim any fee for services provided. This attitude is gradually changing with the new trend and as governments ardently try to reassess and prioritize their goals.

Another difficulty in evaluating the cost of climate products emanates from the fact that meteorological and climate products are not finite commodities. For example, a farmer, when estimating his crop-related income, knows that he needs to sell each of his products at a certain price to recover his expenses and ascertain adequate profit. In this case, once the product leaves the compound of the farmer, the latter has no control over it. In the case of climate products, the same basic data, and even the finished product, can be copied and sold over and over again, provided there is sufficient demand for it. At the time of data collection and processing by the NMHS, however, little is known about the marketability, let alone the market value of the data and product. The field of commercialization of meteorological and climate products is still in its infancy and in full evolution.

The other difficulty in cost recovery is that potential users are not sufficiently aware of the need for climate data. Either they consider the purchase of climate information or products as a sheer waste of resources or they are simply not alert to the long-term profitability of using such information. In either case, NMHSs need to embark on user-education programmes. In some countries, central governments have had to legislate in order to make the utilization of climate data compulsory for planning and implementing projects. Some of these are given as examples below.

Potential customers

Apart from national Government, the foremost and best known customer is the aviation sector. The service rendered through the provision of forecasts of weather elements en route of the craft and at the different aerodromes concerned, is a *sine qua non* of safe flying. Due to the high commercial visibility and exigencies of airline companies, most NMHSs do have cost recovery formulae in this field. In some cases, this exercise is performed by the central government or the airport authorities which levy a certain airport landing tax inclusive of the cost for the provision of meteorological information. In other cases, separate organizations (e.g. ASECNA) cater for the sole need of the aviation sector and operate on a distinctly commercial basis.

The agricultural sector is definitely an important partner of the NMHS. The farmer needs to make use not only of day-to-day weather forecasts but also of climate data and forecasts from weeks to months and—even better—seasons in advance. Although this latter lead-time may, to many, seem a new con-

* Head, Operations, Mauritius Meteorological Services, and president, WMO Commission for Climatology

Figure 1 — The spraying of sugar-cane with ripener (Photo: Y. Boodhoo)

cept, it is already in practice within several NMHSs. In fact, climate prediction, even a single season in advance, allows not only for advanced planning involving storage and harvest time but also the crucial question of strategic price negotiation with customers and investment or reinvestment and developmental planning.

Even a climate forecast with a lead-time of weeks may enable the margin profit to be increased considerably. For the sugar-cane sector, as for several others, pesticide or ripener spraying at the appropriate moment may boost output and thus entail non-marginal increase in revenue. Here, the profit is tangible. For example, the sprayer has a definite cost of operation (manpower, chemical and engine running and depreciation cost), all of which is wasted if spraying is performed under improper climatic conditions. Hence, NMHSs can negotiate to recover at least part of the otherwise lost income and even a small percentage of the accrued income to the farmer through increased yield, thanks to correct weather/climate forecasts.

The marine sector relies heavily on meteorological information, mainly because of safety at sea resulting from correct forecast and timely warnings about hazardous weather. On the other hand, the accurate temperature forecast for tankers, for example, is highly significant. High temperatures will require larger tanker storage capacity as a result of thermal expansion of the liquid. Fluctuating and elevated temperatures are again detrimental for perishable goods being conveyed over long distances. Port authorities levy charges to ships bunkering in their harbours, but no system has been devised to enable the collection of fees for the provision of weather information to ships plying in the open sea.

Environment ministries, while evaluating development project proposals, rely on climatic factors for decision-making. These may, for example, justify the rejection of the setting-up of polluting enterprises upwind of, or close to, agglomerations. Environmental impact assessments—in most cases having legal significance—are formalized through the careful consideration of the site's climate.

The insurance sector has a positive attitude towards cost-recovery manoeuvres by NMHSs. In the case of accidents, whether on land, air or at sea, whether under a slight rain or under gusty conditions and heavy downpours, insurance companies feel it more appropriate to apply a benefit-sharing fee in return for climate data. Figure 2 shows a giant crane left through—what the insurance company, in a court of claim, terms—negligence. If backed by climate data, it will entail savings for the insurance sector by tens of millions in most currencies of the world.

Over large land masses, road transport is an important and often economical means for conveying goods. Weather elements play an important role for maintaining these goods in healthy condition. NMHSs can agree to recover part of the cost while providing the appropriate forecast.

The climate change issue is greatly exacerbated by the often uncontrolled utilization of fossil fuel. In a cold climate, economy in fuel consumption is enhanced through the concept of degree-days, which itself is devised by the use of climate data and weather forecasts. The other important factor in energy-meteorology matters is to welcome a potential new breed of clientele for NMHSs: renewable energy. Climate data are in high demand for the application of projects related to wind- and solar-energy forms.

One acquired and dedicated customer of the Weather and Climate Department is invariably the tourist industry. Tourists need to be well nurtured and looked after, as they form the pillars of one of the most important industries on the planet. The health and safety of the tourist become important from the moment he/she steps into the office of the travel agent where brochures boast of the "sun, sea and climate" of the different destinations. NMHSs provide abundant data to hotels about the correct amount of time to spend on the beach (to avoid excessive UV-B radiation), ideal sites to visit (weather dependent), the need to avoid dehydration (because of the climate again). The safety, good humour and well-being of the tourist become of prime importance during adverse weather about which hotels and other stake-holders need to be notified in advance. This is a sure and guaranteed revenue for most NMHSs.

Figure 2 — Giant crane damaged by a tropical cyclone (Photo: Y. Boodhoo)

Invisible benefits

One of the reasons for governments to have decreed that NMHSs were essential services is probably the difficulty for NMHSs to compute the definite cost of products provided to customers. The timely provision of weather and climate services to the public is as essential as the provision of medical care and the maintenance of law and order by the competent bodies free of charge. These services, required urgently in most cases, do not allow for time to negotiate price and revenue.

In the face of impending storms, flash floods and other weather extremes, the provision of appropriate warnings to the public becomes mandatory. The value of these warnings and forecasts can be estimated only with difficulty but let it be noted that it is immense. A single life thus saved (it could well be yours or mine) by the timely issue of warnings has a tremendous impact on the public. These same warnings, when provided in advance, enable the farmer, for example, to save part of his crop or the fisherman to secure his fishing gear, including his boat.

Hence the concept of invisible benefits: it is probably this concept which exerts a heavy weight in the set-up of NMHSs. Some examples of sectors which yield invisible benefits, through the proper application of climate and weather products to the nation, are given below.

The water-management sector relies heavily on climate forecasts for deciding planning strategies. Prediction of abundant rainfall may permit the water sector to effect a continued supply to the consumer (increased revenue), while an expected drought or deficit in rainfall may force the water sector to curtail supply. Although, in real terms, this implies reduced income, it may in fact translate into important long-term benefits through proper planning. In the end, such strategies become a question of life and death to the nation at large.

The role of NMHSs in providing climate data for planners and builders is paramount: the very comfort and well-being of the people are at stake. Cities planned without climate data may become health hazards if, for example, the siting of buildings and layout of streets do not allow for adequate ventilation or sufficient green space, especially in hot and humid climates. The undesired effect of heat islands in such regions can be offset only through sound planning, which itself is enabled by the judicious use of climate data.

Within the city, individual buildings may turn out to be uncomfortable and unhealthy if climate data and products are not taken into consideration during the planning stage. The size and shape of openings, orientation of building-fronts, thickness of walls, shape of roofs and, last but not least, the choice of building materials, must all be made after a careful study of the climatic parameters in the area. Otherwise, the result is what is termed sick-building syndrome. This is due not only to the use of hazardous materials, but also to the unhealthy atmosphere created inside by inadequate openings, poor ventilation and insufficient light penetration. Whole apartment blocks have been pulled down and rebuilt recently according to new building norms based on climatic parameters of the site.

The heat-wave warning project actually being carried out by experts of the Commission for Climatology rests entirely on weather forecasts. The project itself was launched after the realization that climatic parameters negatively impacted on human health. The project was so devised as to provide warnings and advice to those who may be vulnerable to extreme heat. The value of such forecasts cannot be equated indisputably in monetary terms.

Conclusion

Several NMHSs have implemented programmes of cost recovery. A few claim to be self-financing. In some cases, this independence is only achieved through generous government grants for services provided to the nation as a whole. While this is a plausible attempt at becoming "independent", much remains to be achieved in devising and implementing techniques for the marketing and sale of weather and climate products. WMO has organized major conferences and conducted seminars on the topic. However, each nation has its own specificity, requirements and traditions. It is not always feasible to transfer such techniques from one country to another. Besides, there must be an appreciation of commercialization and aptitude for marketing within the NMHS, as well as a legal framework that supports its commercial operation.

Nevertheless, it is important to recognize the concept of scientific marketing of climate and weather products, which is a prime factor both for the public and for motivating the staff of NMHSs. The public has a psychological frame which does not always permit it to value that which it receives free of charge. The staff of NMHSs will need to carefully prepare products for which charges are levied.

The economic benefits of hydrometeorological services

By A.I. Bedritsky[1] and L.A. Khandozko[2]

Background

The history of sciences and their application is an unbroken chain of quests, discoveries and consolidated achievements in a great flow of contemporary events which have either promoted or hindered scientific knowledge, as can be seen in the case of hydrometeorology in all countries of the world.

The Hydrometeorological Service of Russia is now 167 years old. Throughout these years, meteoro-

1 Head, Russian Federal Service for Hydrometeorology and Environmental Monitoring (ROSHYDROMET)

2 Hydrometeorological University, St Petersburg, Russian Federation

logical science worldwide has developed and grown, thanks to the work of eminent Russian scientists, whose achievements in this field are well known. Examples are the fundamental research carried out by A.Y. Kupfer, M.A. Rykachev, A.I. Voeikov, L.S. Berg, N.E. Kochin, I.A. Kibel, N.A. Bagrov, G.V. Gruza, A.S. Monin and many others, who laid the foundations of Russian meteorology, establishing the scientific and practical basis for the use of a wide range of hydrometeorological information in the economy and in other spheres of activity. In the 1930s, M. A. Omshansky was the first to establish and formulate the economic content of forecasts.

Without this background, modern Russian hydrometeorological science and practice would be impossible.

Hydrometeorological products and society

Clearly, society has to use natural resources to meet its vital needs. In practice, any form of production constantly requires the use not only of resources which are limited in quantity and are not renewable. For that reason, mechanisms involved for the use of additional resources occurring in nature which are permanently renewable, are always used in human activity, and are by their very nature inexhaustible. The atmosphere is one such resource, as is information on its current and forecast state, which has a direct impact on all water bodies. The importance of hydrometeorological information as a resource in the economy of a country manifests itself in two ways. Firstly, hydrometeorological conditions are essential in conducting the production process in sectors such as agriculture, transport and energy. Secondly, the expected state of the hydrometeorological environment known through forecasts plays a role of warning function in this process. Of particular importance are weather forecasts and warning of especially dangerous hydrometeorological events, which help prevent damge to valuable societal assets.

With the current economic renewal in Russia, hydrometeorological information is more important than ever. This importance can be felt in such areas as commerce, production and transport, the harnessing of natural resources (including the country's continental shelf), the development and adaptation of new techniques and technologies, sports, tourism and insurance activities.

Weather forecasts play an absolutely vital role in the lives of Russia's major cities, and public awareness of the importance of this unique resource is constantly rising. Municipal, regional and federal development programmes include increasingly complete hydrometeorological information, as do the sectoral programmes of the various ministries. For example, the Ministry of Emergency Situations in its everyday work relies heavily on hydrometeorological information.

Meteorological forecasts in the economy and in commerce

Ernest Gold was Assistant Director (Forecast Service) of the United Kingdom Met. Office from 1919 to 1947. In a lecture to entrepreneurs he said:

> *In the light of the current criticism of forecasts, before beginning my lecture, I would like to propose the following wager: I promise to pay one guinea every time: (a) the BBC forecast broadcast at 5.55 p.m. for south-eastern England announces rain, but there is no rain until the next day, or (b) the forecast does not give rain, but rain does fall before 6 p.m. the following day. I promise to pay it to anyone who agrees, for his part, to pay me half a guinea every time the forecast gives rain and it does indeed rain, or the forecast gives no rain and there is indeed no rain. The agreement will be for one year, and we can settle accounts monthly.*

We can only assume that Mr Gold was aware of the scientific work of M.A. Omshansky, who translated forecast information into the language of the rouble. Just the same, when we consider the skill scores of weather forecasts at the time, Mr Gold was taking a risk. But we must give him his due. His "credo" is still convincing today.

There have been two major historical eras in the development of Russian meteorological services. The first involved extensive development aimed at increasing the skill scores of hydrometeorological forecasts; the benefits of such forecasts were taken for granted. The second phase involved the intensive development of meteorological services, with increasing importance placed on providing specialized hydrometeorological forecasts and other types of information for users. In 1974, Academician V.A. Bugaev wrote: "science must pay attention not only to the proper compilation of forecasts, but also to their appropriate application in practice". As early as the 1960s and 1970s, Academician E.K. Fyodorov took the initiative of collecting and summarizing information on the economic benefits which forecasts should produce.

At present, the savings realized thanks to the use of all types of hydrometeorological information amount to some 3 or 4 billion roubles, while the total expenditure on the Hydrometeorological Service comes to about 1 billion roubles.

Specialized services for users have become increasingly varied according to the productive sector in question. The introduction of the use of agrometeorological and meteorological forecasts in agriculture has been advantageous. For example, the economic impact in 1983 amounted to 383.2 million roubles.

Economic benefits

The overwhelming majority of the users of meteorological information give the provider certain data which make it possible to evaluate the economic benefit of forecasts. This calls for a constant search for new forecasting techniques (including technical services, more modern forecasting methods and the adaptation of the frequency and type of forecast to the location and territory covered). The user's organizational and financial infrastructure enables the identification of such factors as the average cost of measures of protection against dangerous weather events or meteorological conditions (C) and residual losses which for the time being cannot be prevented (εL), and the maximum possible loss (L) if the event is missed in the forecast.

According to one well-known conventional approach to assessing the usefulness of forecasts, the user (provided he acts responsibly and has a real interest in forecasts) must have a table (or matrix), S_{ij}, of losses, as follows:

	$d(\Pi)$	$d(\bar{\Pi})$
ϕ	$C+\varepsilon L$	L
$\bar{\Phi}$	C	0

where: $d(\Pi)$ and $d(\bar{\Pi})$ respectively mean that the user is oriented towards forecast Π—"a phenomenon is expected" or to forecast $\bar{\Pi}$—"a phenomenon is not expected";
ϕ and $\bar{\Phi}$ respectively mean the phenomenon was actually observed or not observed;
ε is the coefficient of unavoidable losses.

In this matrix, such convincing information may be included as to make it possible to carry out a number of simple operations showing the benefit of weather forecasts for a given user who has full confidence in the provider of the forecasts.

Thus, in the first approximation, the benefit of forecasts if Π is predicted and ϕ has been observed, is defined as:

$$W = (L - \varepsilon L)-(C + \varepsilon L) = L(1 - 2\varepsilon) - C$$

Taking into consideration the consequences of all the user's operational decisions, it is possible to define his adaptability to adverse weather conditions. The numeric indicator of adaptation can be described as follows:

$$G = n_{11}\, L(1 - \varepsilon)/n_{01}\, C + L\,(n_{12} + \varepsilon n_{11})$$

In this expression, the frequencies n_{ij} are the essential part for preparing the text of forecasts Π and $\bar{\Pi}$, while n_{01} is the sum of texts in the matrix of corresponding occurrence of short-range alternative forecasts. The indicator $G \geq 1$ characterizes the successful use of forecast data by a given user. A complete picture of the economic benefits of weather forecasts can be obtained by assessing the economic effect (absolute value) and economic effectiveness (relative value) of the use of such forecasts. Such an assessment is done by calculating the average losses when using methodic (operational) forecasts, then comparing them with the average losses if the user only referred to the actual (present) weather. Such an assessment must be carried out jointly with the users. In recent years, such assessments have been increasingly introduced into synoptic practice in Russia. In 1996, for instance, the total economic effect of specialized hydrometeorological services was evaluated at approximately 2 trillion roubles (about 2 billion roubles in current money). The main users are presented below:

Economic effect of specialized hydrometeorological services by economic sector

Economic sector	*Economic effect (million roubles)*
Fuel and energy	462.6
Agriculture	277.5
Maritime activities	259.7
Construction	221.0
Civil aviation	174.6
Inland navigation	150.6
Urban administration	150.5
Rail transport	41.1
Road transport	15.8

Commercialization: choosing the path

Throughout the world, there is a continuing trend to cut the budgets of the National Meteorological Services (NMSs). Without dwelling on the reasons for this, we would like to note that, in many countries, the need has emerged for NMSs to provide for part of their own development resources through the commercialization of hydrometeorological products and services for various users. In Russia too, beginning in 1992, under the provisions of a Government Order, ROSHYDROMET switched to the provision of specialized information for users on a remunerated, contractual basis, while continuing to provide free information on weather events which threatened life or property. The specialized hydrometeorological services thus began to be marketed, with Meteorological Agencies representing ROSHYDROMET and directly interacting with the users. This system has been a success. A legal and standard-setting basis has been drawn up for specialized hydrometeorological services. Market surveys are carried out to determine users' needs, and new forms of information are drawn up in response to them. Pricing policy is formulated on the basis of a number of principles. The Meteorological Agencies have brought an increasing number of users to understand the need to take hydrometeorological information into account in their economic activities. The importance of hydrometeorological information in various spheres of Russian society is becoming plain to see.

It takes a dynamic approach to sell forecasting products. The following play especially important roles when such products are sold: the interest of the user and the possible benefit derived from the use of the information; the way in which highly effective information is developed and processed before it can meet the final user's needs; a rational (optimal) pricing policy which can ensure the improvement of the hydrometeorological information; and financing capable of ensuring that the very best specialists take part. Commercialization in a Hydrometeorological Service differs in many ways from typical marketing, as the product in this case is information on the natural environment. This information product is demanded by society itself. Society's needs are simple—to ensure that losses from environmental dangers are kept to a minimum and that benefits are maximized, whenever possible. Commercialization should foster the complete satisfaction of such needs. Its most vital role is to make the information more effective.

Yet there is a risk (and not only in Russia) that specialized hydrometeorological services may develop in a more negative sense. This risk applies not only to those NMSs with State-funded basic infrastructures and which sell forecasts to cover some costs, but also to NMSs which function entirely according to market economics. In the latter case, the development of international cooperation among NMSs working exclusively on the basis of the rules of the market would eventually lead to the termination of the free and unlimited exchange of meteorological data and related products. When we take into consideration the fact that the information exchanged relates to the natural circulation patterns of the atmosphere, any reduction or elimination of such exchanges would leave NMSs completely incapable of carrying out the work assigned to them at the national level.

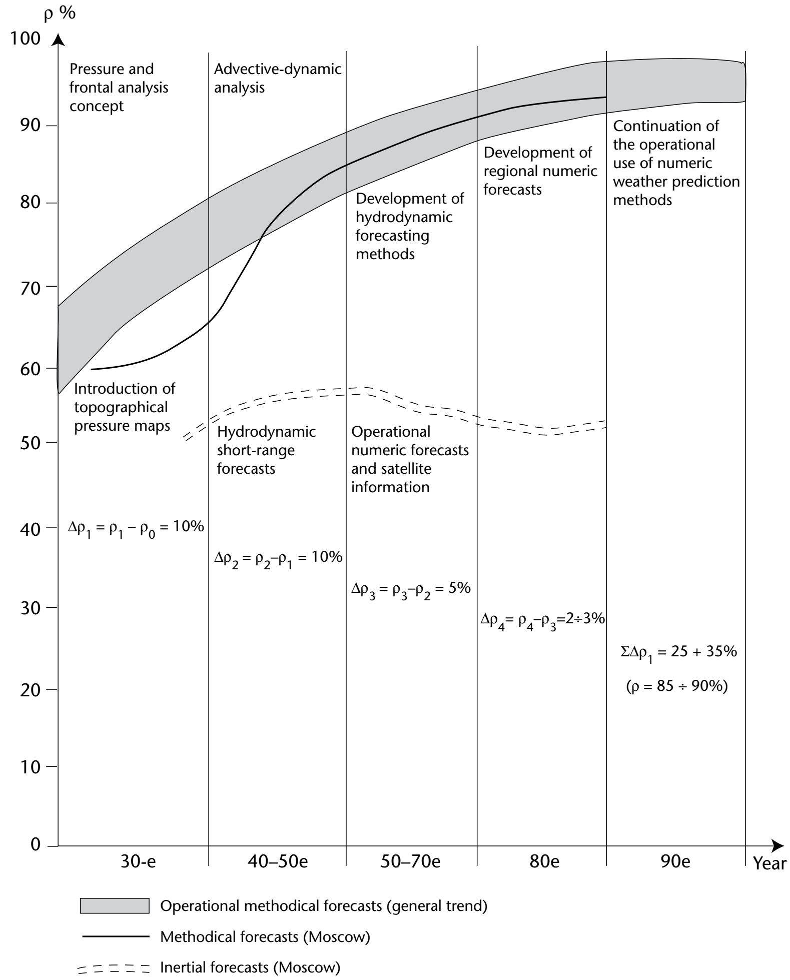
This danger was foreseen even as early as 1991, when the WMO Executive Council established a Working Group (WGCOM) on the Commercialization of Meteorological and Hydrological Services, of which a representative of ROSHYDROMET was a member. Concern was expressed about the violation of the rules of free and unlimited exchange of information, and about the quality of products, in particular forecasts.

Of course, any reduction in the quantity or quality of hydrometeorological information or the confidence of the public and of the Government in the NMS would be inadmissible; for development, any such scenario must be avoided. WGCOM therefore drew up certain recommendations which led to the adoption at Cg-XII (1995) of Resolution 40. These recommendations could have been supplemented with the following: To ensure that hydrometeorology is effective in society, NMSs must be able to consider commercial activities in this field as their prerogative, to exercise full control over the benefits they produce, the way they are organized and the way they are funded. In principle, the atmosphere should not be subjected to unbridled commercialization. This is essential if we are to avoid a stratification of NMSs, a loss of the scientific basis for specialized hydrometeorological services and the demise of international meteorological cooperation. Commercialization must follow the lead of science and benefit from its achievements so as to make possible more effective specialized services for the economy. What users acquire or purchase is not so much the forecasts, but their benefits. This means that commercialization must correspond to the following "credo": the user does not need the meteorological products or information *per se*, but rather their ability to achieve an objective. The provider (the NMS) earns its due only if this is the case.

The development of a network of Meteorological Agencies at the territorial administrations of the Hydrometeorological Service has ensured the success of NMS commercialization in Russia. To a certain extent these administrations put con do the "dirty work" of commercialization.

Prospects

The economic and social importance of hydrometeorological forecasts and of specialized hydrometeorological services is so great that it is not only in certain economic sectors that there is interest, but also the entire State. A number of tasks must be carried out in the framework of "economic meteorology". In each situation, the full meteorological and economic content of the problem must be reflected, failing which the solution proposed will be incomplete or a simple half-measure. The system of tasks outlined below sets out principles which can help us gain an understanding of how hydrometeorological information can be used to tackle problems, and how its economic benefits can be assessed.



Trends in skill scores of short-range weather forecasts in Russia

Task No. 1

The system for the assessment of forecast skill scores should be based entirely on the matrix approach. This relates to both alternative and multi-phase forecasts. General reliability rates are not sufficiently effective to serve as a measure of "forecast-fact" correspondence. It is necessary to draw up a conjugation matrix seasonally, and a database of such information must be set up. A basis must be established for an unbiased, objective and balanced view to the forecasting results, that must be considered the necessary condition for the development of new methods and techniques.

Task No. 2

The experience of the post-war years in synoptic practice has shown that skill scores are approaching a kind of "saturation" point. Despite the well-known discrepancies of information on forecast skill scores in various years,we can see, using a general reliability rate, a dynamic trend in forecasting (see figure above). In the period from the 1960s to the 1980s, effectiveness was defined to a great extent by an increase in the forecasting skill score. In general terms, this approach will, in future, be exhausted. There is now a need to introduce new technologies for the use of forecasts capable of ensuring increased benefits. This will inevitably involve the structure of weather-related economic management. Consequently, this problem will have to be tackled jointly with the users.

Task No. 3

In the final analysis, the task of a user who employs a wide range of forecasts boils down to adapting as well as possible to expected adverse weather conditions. That consists in choosing the appropriate organizational, technical or financial protective measures capable of ensuring a maximum of prevented losses, i.e. of lowering the coefficient of unavoided losses. Its threshold value depends on the type of adaptation selected.

Task No. 4

Historically, the overwhelming majority of users have seen forecasts as a simple yes/no proposition, according to which they decide on the basis of weather-related economics to take one of two possible paths: either they carry out activities assuming that there will be favourable weather conditions, or they invoke protective measures if dangerous weather events are predicted. This results in a relatively low benefit derived from weather forecasts. There are good prospects for the joint development with users of a finer loss matrix. The calculation of average (in statistical terms) losses for all discrete groups, with a confidence strategy and a best-case scenario, will make it possible to increase the economic benefit of the forecasts. Experience has shown that an optimum approach might involve between three and five weather-related economic decisions.

Task No. 5

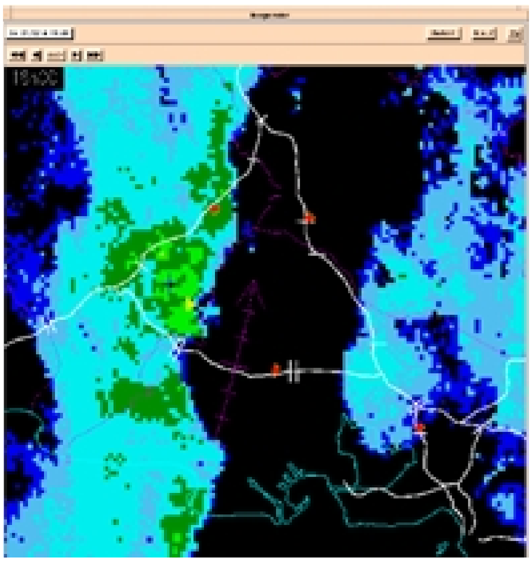
The success of specialized hydrometeorological services is defined not only by the volume of the information provided, the number of users or the amount paid for the forecasts. Confidence in the specialized hydrometeorological services is directly related to their final results. The approaches to assessing the economic effect and effectiveness currently in use in Russia now can be proven at the international level.

Tackling the above tasks will make it possible in the long term to increase the profits of specialized hydrometeorological services and will help to extend the circle of users of such products in all economic sectors.

Benefits of meteorology and climatology for companies and communities

By Michel Le Quentrec*

The savings realized and losses avoided thanks to weather forecasts play an important role in the economy, be it in providing for the safety of air transport, people and property or in ensuring optimum economic performance. For several years now, Météo-France has offered special services for various activities, from feasibility studies using climate data to ready-to-use products. In this article, I will present some examples illustrating the importance and the value attached to such services by a wide range of users. These have for the most part been drawn from the quarterly magazine *meteo.fr*, which, since September 1997, has been issued by Météo-France's marketing and communication directorate.



Snowfall on the motorways of southern France forecast with the nowcast system, Aspic (Source: Météo-France)

On 12 July 1998, the French national football team won the World Cup. Despite the public scepticism and criticism aired in the press, the new *Stade de France* was completed ahead of plan, the pitch was green and the fans filed in and out without a hitch. This was no accident. From the very beginning, the builders took the weather into consideration when erecting the 180 000 m^3 of concrete and 6 ha of roof, costing nearly 300 million euros. The roof is composed of 18 sections, each weighing some 350 tonnes, which had to be raised to a height of over 40 m during con-

* Commercial and Communication Director, Météo-France
E-mail: michel.lequentrec@meteo.fr

Meteorological advice for the choice of tyres for the 24-hour Le Mans car race
(Source: Météo-France)

struction. For each one, that would take several hours and could not be done in winds of over 27 km h^{-1}. Mr Touzet, the engineer responsible for the stadium's roofing and perimeter, had ordered wind records going back 10 years, and had noted that the wind exceeded the limit 275 days per year. The scheduling was going to be tight. To find weather windows, the builders subscribed to a tailor-made service provided by forecasters briefed on the special problems of the construction site. Despite numerous winds and storms which twice forced the team to take down the enormous crane, there were no accidents, and the work on this all-important part of the building was completed ahead of schedule. The feasibility study and construction of the stadium benefited from other forms of meteorological assistance, for example for the planning of the works and to ensure worker safety and the integrity of the equipment. All possible weather conditions were considered when plans were made to bring 80 000 fans to each match and to transport them home safely afterwards. Fortunately, no extreme conditions were encountered. The security chief, Prefect Jacques Lambert, naturally used the services of Météo-France; he had seen firsthand the importance of climate data and forecasts during the 1992 Winter Olympics in Albertville.

Other major construction projects, including the graceful, massive Normandy Bridge over the Seine estuary, have also benefited or will soon benefit from the same kind of meteorological support as did the Stade de France. Some Meteorological Services can do still more, by making available their expertise in fluid mechanics. In about 2004, a highway viaduct will cross the River Tarn near the French city of Millau. At 2.5 km long and with a height of 300 m over the river, this will be one of the largest land-based public works projects in Europe. It has already been the subject of a host of meteorological studies. Georges Gillet of the Ministry of Public Works, Transport and Housing asked Météo-France's national weather research centre for a scale study of the fluid mechanics of the viaduct. This would help to model its behaviour when subjected to various possible wind scenarios, to understand the influence of the terrain roughness on airflow and to determine the size of eddies produced near the structure's ends. The results, which were corroborated with studies on other infrastructure in the area, made it possible to validate and define specifications for the calls to tender. This is crucial to the design tolerances of the structure's parts and, therefore, is also of the utmost importance to controlling costs. The estimated cost of the viaduct is 250 million euros. Meteorological costs are infinitesimal in comparison with the financial repercussions of oversizing the structure, not to mention the possibility of an enormous disaster if the specifications are underestimated! Construction begins in a few months. As would be expected, the appropriate meteorological support will be provided both throughout the works

A day-care centre participated in an experiment to regulate heating according to short-step weather forecasts. (Source: Météo-France)

and once the viaduct is completed, so as to ensure safe operation.

In another application related to road transport, the *Autoroutes du Sud de la France* motorway company recently purchased a precipitation nowcasting system designed by Météo-France. According to Jean-Marie Bérier, the assistant director for customer relations and traffic:

> *We were looking for something to supplement our own information collection system from stations and patrols. We decided on the Aspic (nowcast) system. It gives a very precise on-screen image of rain as it arrives over a given motorway segment, with a lead-time of half an hour or an hour, and can estimate intensity and duration. Tailored to our needs, Aspic can act as a warning system; ... it can help us detect the risk of freezing rain permit us to issue a warning immediately over the radio.*

For a few thousand euros, the company has purchased a tool which not only ensures safety; it also makes the going easier for drivers, enhances the company's image and improves the use of the road. The savings alone would justify the investment.

Seen from another perspective, the performance of many companies is strongly influenced by the weather. To keep the risks of their businesses down, energy market traders in the USA have developed a new tool: weather derivatives. Weather derivatives can also be used for agriculture, the food industry, transport and recreational activities sectors. They require years of precisely kept meteorological records, which must be maintained with the utmost care. Any changes in the environment of the measuring apparatus, differences in instrumentation or even the slightest shift in location which might affect the measurements must be noted. With a great deal of statistical skill and comparative measurements, it is possible to draw up homogeneous climate series, which can then be used as a basis for the weather derivatives. Just four years after they emerged, weather derivatives already represent a market of several billion dollars in the USA. They are speculative financial tools that make it possible for companies to take insurance against the vicissitudes of an excessively warm winter or a too-wet summer, without which the health—if not the very survival—of such companies could hang in the balance. In Europe and elsewhere, several insurance companies and financial groups have joined NMSs to insure companies against such adverse weather conditions.

The previous night it was cold out, and in the morning the temperature had quickly risen; in the fine mist the train was nowhere to be seen. The railroad workers were not, however, on strike. Finally, an announcement came over the public address system reporting that the train had been cancelled. It was not the only one cancelled that day; thousands of workers and employees would clock in late. Why? The locomotives which were left outside first cooled, and then with the arrival of warm, humid air later in the night, their metal masses heated up more slowly than the surrounding atmosphere, producing heavy condensation. When the engineers switched them on, they shorted out. Worse still, the back-up locomotives sometimes fared no better. While this does not happen often, hundreds of engines in a big city can be knocked out of action, requiring 40 000 euros of repairs each and causing problems for commuters for days on end. To avoid this problem, the weather centre now issues special evening advisories to let the railroad company know whether it has to leave its locomotives running overnight and keep a watch over them if they cannot be garaged. This special service costs just a few hundred euros, but it can save the city's economy hundreds of thousands of hours of workers' time and can spare the railroad hundreds of thousands of euros in repairs (or possibly in garage construction and heating costs). And that is without even considering the benefits reaped by the company''s reputation for on-time performance.

Is there going to be a shortage of citrus fruits? Will the shipments be late? These questions are vital to fruit and vegetable importers. In the words of a market researcher at the biggest French wholesale produce importer: "If a cyclone hits the banana producers in the Caribbean or the grapefruit orchards in Florida, or if the asparagus freezes in Greece or heavy rain affects the spring strawberry harvest in Spain, we need to know about it ... We have to keep up with all the weather phenomena to better understand availability in production regions and to help us find our produce". Every morning, he receives a weather report on the Mediterranean basin, Florida and California, together with a cyclone report. "For us, all this information is both strategic and vital. It can help us bargain for purchases and discern fact from fiction."

Most of the time, buildings' heating systems are regulated directly as a function of the outside temperature. This has its limits, though, as it does not take into account the thermal mass of the buildings and the heating systems themselves. Fuzzy logic and short time-step weather forecasts of a few hours can be put to good use adjusting such systems. In the winter of 1996/1997, at a day-care centre and at another building, the city of Rennes, the Agency for the Environment and Energy Management (ADEME), the National Institute of Applied Sciences, a major heating corporation and the local weather service conducted a joint experiment in actual conditions. Christine Hainry, the director of the Louis Bodin day-care centre, was pleased with the results, as the system did away with overheating problems and made for a healthier environment with less risk of bacteria. Jean-Marc Berthet, whose unit services the building where the day-care centre is located, says the experiment resulted in energy savings of 25-30 per cent. For Jean-Luc Joan, a technician working for *Elyo Ouest Bretagne*, of the *Lyonnaise des Eaux* group, the building fared well in the test. A company has begun working on an electronic system that will automatically consult updated weather forecasts from the local weather centre, combine them with the building's parameters, apply fuzzy logic and regulate the heat on its own. It might take some time before such systems enter into general use, but a saving of just a few percent in electricity consumption can significantly reduce reliance on nuclear fuel or can mean one less tankerload of imported oil. With no loss in comfort or even improved performance, that can be a real boon to a country which imports energy. It also means less CO_2 contributing to the greenhouse effect, which in the case of coal- or oil-fired plants will make it easier to meet the objectives of the Kyoto Protocol.

While the greenhouse effect and energy use are of interest to everyone, few people have savoured a Château D'Yquem. Annual output of this fine wine never exceeds 90 000 bottles, and some years there is no yield at all. Francis Mayeur, who is in charge of production of the precious vintage in Sauternes, near Bordeaux, explains how he uses radar images:

> *Our average yield is 800 litres per hectare, which is not very high, because we have extremely strict harvesting requirements. We will only pick the grapes if they have noble rot permitting them to reach a potential alcohol content of 20 percent. If there is the least bit of water on the grapes, we cannot pick them. As a result, the grape harvest must be done in just 20 days, between mid-September and mid-November. We are slaves to the weather; we simply devour weather reports. With the Internet, we have access every 20 minutes to four sequential weather radar images of the Bor-*

Artist's impression of the future highway viaduct over the Tarn valley near the French city of Millau (Source: Météo-France)

deaux region, so we can see where the rains are and can figure out very precisely when they will reach the vineyard. If we see that a few clouds will pass, we keep the pickers in the fields, but if an area of precipitation is heading in from the Atlantic we have to stop picking; cutting a bunch in the rain is out of the question. In April and May, too, the fact that we can keep track of precipitation as it moves across the region means that we do not run the risk of spraying chemicals only to have them wash off in a downpour. We have access to practical and directly usable information which doesn't leave us out in the rain.

Other great vintages too are now using weather forecasts and radar images. Champagne is world renowned. The Champagne producers, who very often have to deal with the risk of spring frosts, have for years been extremely demanding when it comes to weather forecasts. They are generally happy with the results.

Label from a bottle of Château d'Yquem (Source: Météo-France)

There are numerous other examples. Meteorologists throughout the world are of course familiar with applications in agriculture, activities at sea and tourism. For television stations, weather reports are often the slots with the greatest viewer ratings, and the advertizing time around them consequently commands the highest rates. In performance sports such as car racing, the most subtle weather information can make a big difference in bringing victory to a car company or a driver, and thus in increasing the sales of the cars, motors, lubricants and tyres that are seen as winners too.

At this stage, the profitability of meteorological services is extremely clear. The question does not even arise anymore. In developed countries, the Meteorological Services are offering more and more products for which there is clearly a demand. While the market is growing fast, it is, of course, limited. Meteorological forecasting remains mainly a State-run, safety-oriented service. Nonetheless, much more than 10 years ago, it is now able to show how it can produce sizeable benefits for the market economy.

Forecast quality, forecast applications and forecast value: cases from southern African seasonal forecasts

By M.S.J. Harrison[1] and N.E. Graham[2,3]

Forecast quality is any measure that assesses the error of forecasts when compared to observations: well-known quality measures include root mean square (rms) error and percentage correct. Forecast value, on the other hand, is a measure of the benefit achieved when forecasts are used to change actions—if a forecast is not used to change actions, then it has no value. One of the difficulties in assessing the value of forecasts, and any changes in value as forecast quality improves, has been in developing analytical links between quality measures and value. A new approach to linking quality and value is described in this paper.

Quality and costs/losses (defined later) are both measured using a 2 x 2 contingency table. For quality, an approach referred to as Relative Operating Characteristics (ROC) is used, full details of which can be found in Stanski *et al.* (1989; cf. Swets and Pickett, 1982). For any event, where the event can be a yes/no

1 United Kingdom Met. Office
2 Hydrologic Research Center, San Diego, California, USA
3 Scripps Institute of Oceanography, La Jolla, California, USA

situation (such as rain/no rain; temperatures above/not above average; or drought/no drought), quality can be measured using:

		FORECAST	
		Yes	No
OBSERVED	Yes	*Hit*	*Miss*
	No	*False alarm*	*Correct rejection*

Four outcomes are possible, depending on whether the event is predicted or not and whether it occurs or not. If it occurs and is predicted, then that specific forecast is called a hit. If the event is not predicted but occurs, then the forecast is called a miss, and so on. By totalling the counts in each box of the table over many forecasts, it becomes possible to calculate the hit rate as the proportion of observed events that were predicted (i.e. hits/(hits + misses)) and the false alarm rate as the proportion of occasions on which the event did not occur but was predicted to occur (i.e. false alarms/(false alarms + correct rejections)). The two rates together fully characterize the forecast system in terms of the event; any guessing strategy produces equality of hit and false alarm rates and the forecast system has skill if the hit rate exceeds the false alarm rate. Calculation of hit and false alarm rates for deterministic predictions is straightforward, given a sufficiently large forecast archive. What is particularly attractive about using ROC from a meteorological perspective is that hit and false alarm rates can also be calculated from probability forecasts (including those from ensemble systems), although full details cannot be given here. Nevertheless, one important result that emerges from such calculations is that, except at time ranges shorter than perhaps 48 hours, probability forecasts almost always provide more value to applications than the corresponding deterministic predictions.

A 2 x 2 contingency table is also used in the cost-loss model of forecast value estimation (Murphy, 1994). If an event likely to cause losses is not predicted, then the user will not take any protective action, and will not incur any financial cost to undertake that action. Should the event not happen, then the user is happy, but if it does, then the user sustains a loss. On the other hand, the user can protect, at a cost, should the event be predicted. If the event does not happen, then the user has to bear the costs of unnecessary protection but, if the event happens as predicted, then the user will benefit from reduced losses. The position is summarized in the table below.

Users of forecast information need to fill in the boxes of this table using an appropriate response variable, whether it is money, crop yield, patient numbers, etc. Once that is done and the ROC calculations have been made for the forecast system using the same event, then it is straightforward to calculate the value of that forecast system for the specific application (in general, the exercise will need to be repeated for each event and each application). It is easily demonstrated that, for any particular application, value increases linearly with forecast quality as measured by this system. In practice, the calculation may not be straightforward, as users may have difficulty in producing data on losses through meteorological events and protection costs. Nevertheless, the system provides a consistent method by which forecasters and users can discuss, within a common framework, the value of forecasts in a given application and adjustments in value as quality changes.

		FORECAST	
		Yes	No
OBSERVED	Yes	Losses occur but are mitigated through taking appropriate protective action	Full losses occur which are not mitigated by protective action
	No	Costs of protection are borne but no losses occur	No losses; no costs; outcome is that expected from normal activities without the event

The initial test of this method was made at the first Southern Africa Regional Climate Outlook Forum (SARCOF), held during the October 1997-May 1998 period. At the final Forum meeting, a variety of users were interviewed in order that forecasters might understand user requirements in greater detail; that users might gain insight into the limitations of forecasts; and that preliminary estimates of potential value might be gained. Forecasts used in the exercise were hindcasts covering 25 years calculated using a global circulation model. The model was used in such a manner that the forecasts would have been obtained in real time had the model been available throughout that 25-year period. The overall estimate obtained across all users interviewed was that the average annual value of these forecasts in the southern African region is of the order of US$ 10^8-10^9 at a cost/benefit ratio of order 20-200 based on the marginal costs of providing climate services in the region. In this article, only results from a single interviewee representing an international aid organization will be discussed, although these results are typical. It should be noted, however, that the cost/loss values are somewhat artificial and, although realistic, should only be taken as indicative.

Users were asked four questions.

Question 1—What event do you require to be predicted?

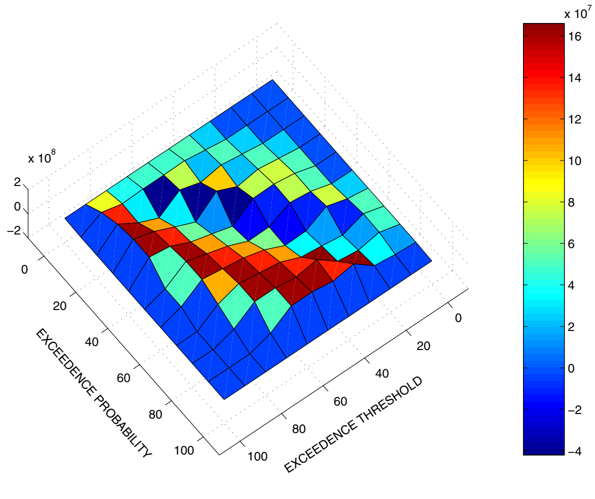
Experience both at SARCOF and elsewhere is that users are normally challenged by this question. Users do not always appear to have thought through the detail of their meteorological prediction requirements, relying on knowledge that meteorological events do impact their applications but without objective definition. Many SARCOF users, for example, requested predictions of drought, but most initially could not define drought in such a manner as to permit prediction (one definition received was when the US Ambassador in a country declared drought!). Through facilitating discussion, all users ultimately provided objective definitions of their chosen events, an exercise that not only provided forecasters with improved insight into user requirements but also focused user attention on forecast issues relevant to their particular application.

Question 2—What forecast quality is required in your application?

Users were asked to define subjectively what they considered to be the minimum hit rate and the maximum false alarm rate of the event that would be useful in their applications. The question focused user attention on practical limitations of forecast quality and also permitted discussion of contingency options in the event of forecast failure.

Question 3—What are the costs and losses involved in your application?

In other words, users were asked to fill in the figures in the second table to the best of their abilities.



Cost reductions: the example of international disaster management

Forecast value was estimated in three ways. First, by asking:

Question 4—given forecasts of the event with your desired quality, what value do you expect the forecasts to have?

Second, by direct calculation of value from the responses to the second and third questions. Third by inputting values from the cost/loss table directly into probability forecast results from the global circulation model's historical seasonal predictions for a region between approximately 23°S and 36°S latitude and between 15°E and 32°E longitude. This region covers southern Namibia, southern Botswana, the extreme southern tip of Mozambique and all of South Africa, Swaziland and Lesotho. Over the hindcast period, the correlation between the forecast and observed December-January rainfall over this region is 0.61.

In the case of the international aid organization application, the event of concern was a drought (Question 1). After extended discussion, the term "drought" was initially interpreted as the driest 10 per cent of historical events. However, after it was shown that the forecast systems had insufficient quality to provide positive value using that definition, the definition was changed to the driest 20 per cent of historical events, a figure at which value was obtained. In response to Question 2, the user felt that a minimum hit rate of 80 per cent was necessary, and that a maximum false alarm rate of 25 per cent could be tolerated. The cost/loss table (Question 3) was given values of US$ 5.6 billion, US$ 7 billion, US$ 1 billion and US$ 350 million, reading clockwise from top left. Based on these inputs, the value of a system giving the user's requested hit and false alarm rates was US$ 90 million as an annual average. The user personally estimated potential annual value at US$ 40 million (Question 4). Using the model hindcasts, annual value was assessed at US$ 8 million, or US$ 167 million if the definition of drought was further modified to the driest 30 per cent of years.

It is also possible to calculate a value surface for the hindcasts that covers all the options for any specific application using this particular forecast system. These options include the forecast probability of the event at which the user takes protective action (alongside the left-hand side in the diagram—this refers to the international aid example) and the threshold value of drought in the model climate, although the threshold value in the real climate is kept constant at the 30 per cent driest years (right-hand side). The surface itself represents the difference (as savings) between the annual average operating costs that accrue between: (*a*) the least expensive fixed action strategy (i.e. always assuming that there will be a drought and preparing for that contingency, or never doing so); and (*b*) the retrospective climate forecasts. In this scenario, the least expensive fixed-action strategy is to assume there is never a drought, which has an associated average annual operating cost to the organization of US$ 2.47 billion. In comparison, the annual average costs using a perfect forecast system would be US$ 1.79 billion, giving a potential maximum value of US$ 0.68 billion. In the diagram using the "real" forecasts, the region of maximum achievable savings runs in a diagonal. Thus, as is typical in such calculations, there are a number of different ways in which the forecast system can be used to obtain maximum value. In this case, the minimum net cost using the climate forecasts is US$ 2.3 billion, giving an annual savings (a value) of US$ 167 million or 24.6 per cent of the value achievable with a perfect forecast system. However, it is important to note from the diagram that it is quite possible to gain less than the maximum potential value, or even to lose money, through inappropriate use of the forecasts in this specific application. In certain circumstances, therefore, users may conceivably criticize a forecast system for not providing value, whereas it is their use of the system that is incorrectly calibrated.

Across all users interviewed, it was encouraging to note reasonable consistency between value estimates by the users and those from the more objective methods. Nevertheless, these results also indicated that either forecast quality given current prediction technology was insufficient or user requirements were too tightly drawn for value to be obtained in all applications. In these cases, it is necessary that either (or both): (*a*) the quality of the forecast information be improved; or (*b*) users consider whether alternate strategies for responding to forecast information might make more effective use of currently available climate predictions.

This system of estimating value in an objective manner has its limitations in its present form. Included amongst these is the fact that general use of forecasts may affect the macroeconomic structure within which an application sits, which in turn affects value. For example, if a single farmer correctly turns to drought-resistant crops then he may benefit. But if all farmers do the same they may produce a crop glut that reduces prices. A second limitation is that the links between predicted values and outcomes in applications might not be linear. Keeping to the agricultural example, there is no simple link between crop yield and rainfall. Although yield increases in a general sense with rainfall, higher yields can be obtained in dry years, provided the distribution of rainfall in time is favourable, and low yields in years of above-average rains that lead to flooding.

Other limitations exist too, but as a first step to producing an analytical approach to linking forecast quality with value this method is now being adopted in a number of NMHSs and is proving beneficial in assessing forecast value for specific applications. In particular, the approach was used successfully in the CLIPS Food Chain Showcase Project, the report for which is available through the CLIPS Web Page (from the WMO homepage). The basis of the approach is also built into the new experimental WMO Standardised Verification system for Long-Range Forecasts (see WMO homepage—link to WWW—for details).

References

MURPHY, A.H., 1994: Assessing the economic value of forecasts: an overview of methods, results and issues. *Met. Apps*. 1, 69-73

SWETS, J.A. and R.M. PICKETT, 1982: *Evaluation of Diagnostic Systems—Methods from Signal Detection Theory*. Academic Press.

STANSKI, H.R. *et al.,* 1989: Survey of common verification methods in meteorology. WMO/TD No. 358, 114 pp.

Acknowledgements

The authors wish to thank all those who kindly offered information in the development of this study.

❀ ❀ ❀

A systems approach to weather forecasting and the impact of meteorological products on society

By Winnifred A. MUTULI*

Introduction

Because of its central role in the national economies of developing countries, the farming community is an important user group of meteorological information. The understanding and interpretation of climate information has a direct impact on agricultural productivity and food security, yet there is little or no exchange of information between NMSs and the agricultural sector. Weather related disasters continue to disrupt the economies of most developing countries and often find governments unprepared.

This analysis conceptualizes the National Meteorological Centre (NMC) as the focal system and focuses on the impact of meteorological products to end-users by analysing the flow of information from the system and into the environment. The coupling with user organizations and groups is observed by analysing the interactions within the system's environment, relates them to the feedback systems and controls resulting from the interactions, and monitors the information flow back into the system. It provides the "big picture" or holistic view of the tasks involved in addressing problems facing individual NMSs in the provision of services.

A systems approach to weather prediction by National Meteorological Services (NMSs)

The systems approach is a problem-solving tool which takes a broad look at problems when offering solutions. A system is defined as a whole that cannot be taken apart without loss of its essential characteristics and must be studied as a whole. Its parts are explained in terms of the whole but never the reverse. The whole is always greater than the sum of the individual parts.

Schoderbek *et al.* (1975) define a system as a set of objects together with relationships between the objects and their attributes related to each other and to their environment in such a manner as to form an entirety or whole. He describes organizations as complex hierarchical systems with certain common characteristics.

Mintzberg (1979) describes the structure of an organization as the aggregation of the way labour is divided into distinct tasks while, at the same time, bringing the parts together by coordination for goal realization.

The NMC : a dynamic system in constant interaction with its environment

NMSs of WMO Members can be described as complex organizational systems with subsystems constantly interacting with the environment, structured in a hierarchical manner with specific tasks and functions designed to realize specific goals. The NMC of an NMS is conceptualized as the core operating system in the analysis. The goals of the NMC are precisely the goals of an NMS and what impacts on the NMC subsystem from the environment automatically impacts on the NMS system.

Figure 1 conceptualizes the operating core of an NMS which is the NMC where the vital process of weather forecasting takes place. The NMC is really a subsystem of the whole system of an NMS, but will be viewed as a system on its own with specified inputs, processes and outputs. The analysis will look at the work processes of an NMC and analyse the interactions that result when the weather products from the NMC are disseminated to user organizations in the environment. WMO sets standards and specifications for NMSs and defines the inputs, processes and outputs through the World Weather Watch Programme.

Mintzberg's Logo (1979) analyses the structure and design of an NMS organization and concludes that the NMC's functions and tasks are critical in the realization of the NMS's goals. All other tasks and functions of the subsystems of an NMS directly or indirectly support the functions of an NMC.

The increase in complexity and sophistication of user demands dictate NMC's task as going beyond the issue of weather forecasts and it becomes necessary to package the weather information to target specific user-groups. The information must be interpreted correctly by users for the effectiveness of the NMS system. The WMO Public Weather Services Programme pres-

*NOAA/NWS/IA

ents the interface between NMSs' products and their assimilation by users. The degree of effectiveness of an NMS system through goal realization translates to the degree of its visibility in the eyes of the community it serves. It is critical to the survival of an NMS system as it evolves and attempts to adapt to its environment in a systems perspective. The environment of an NMS itself is dynamic and constantly changing with new demands, while increasing in complexity. How well an NMS copes with the demands of its environment will increase its visibility and effectiveness through goal-realization and prompt increases in budgetary allocations to function effectively.

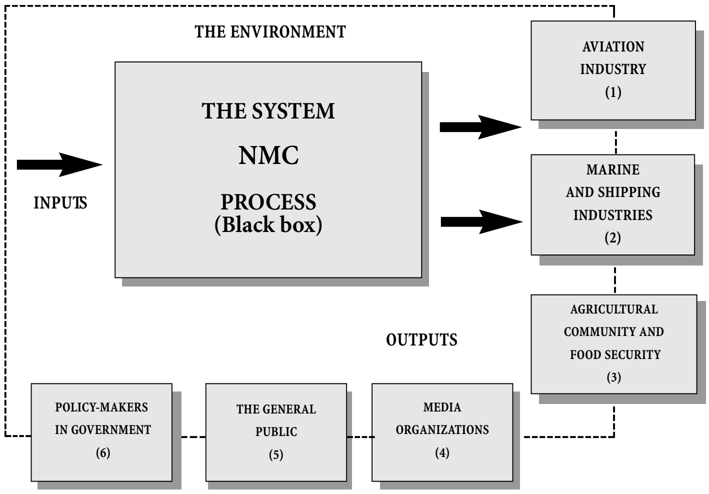


Figure 1 — Diagrammatic presentation of an NMC as a system and the interaction with user organizations in the environment (information flow from the system): outputs 1-4 are loosely coupled; outputs 5 and 6 are tightly coupled.

NMC system components and the setting of boundaries for problem-solving

Since organizations' tasks and functions attempt to meet organizational goals, the subsystem's components will set boundaries to distinguish what is in and what is out of the organization. Schoderbek *et al.* (1975) elaborate on the boundary of a system as being arbitrarily drawn, depending on the variables under focus, and is adjustable in the determination of what is relevant or irrelevant within the environment or without. He adds that problem-identification often dictates the boundaries implicitly accepted by the researcher.

Figure 2 is a presentation of an NMC's system boundary, distinguishing which subsystems are in the NMC and those outside. The work processes are described as near-real-time coded meteorological data as the input to the system, the process of decoding the meteorological data and plotting it onto weather charts, the analysis of charts followed by the decision-making for the forecast as products as the output of the system. The process is treated as a "black box" because of the variations of methods employed by different NMCs in the level of sophistication of methodologies and technology, including skills used in the work processes of the NMC.

In the immediate environment of an NMC are the end-user organizations, namely:

- The aviation industry;
- The marine and shipping industry;
- The agricultural community;
- The general public;
- The media organizations;
- The policy makers and planners in government;
- Non-governmental organizations and relief groups.

The NMC is in continuous interaction with these user organizations with a two-way information flow from the system and into the environment and vice versa. However, the current status of interactions between NMSs and user organizations are ineffective and denote a gap between the highly scientific and technical products from NMCs and the low level of comprehension of these products by most user organizations and groups.

The environment of NMCs and the impact of meteorological products

An organization is a product of its physical and cultural environment, and is in constant two-way exchange with its environment. Its survival depends upon its ability to extract from the physical environment the elements that make it necessary to sustain its operations. The environment pertaining to an organizational system constitutes all the subsystems outside the organization; these are beyond the system's control, yet exert some determination on the organization's system's performance.

Looking at the interactions between NMCs and end-user organizations in Figure 1, the coupling between the NMC system with end-user organizations in the environment is displayed by monitoring the two-way flow of information and analysing the resulting interactions. An analysis of the interactions between the NMC system and its environment suggest

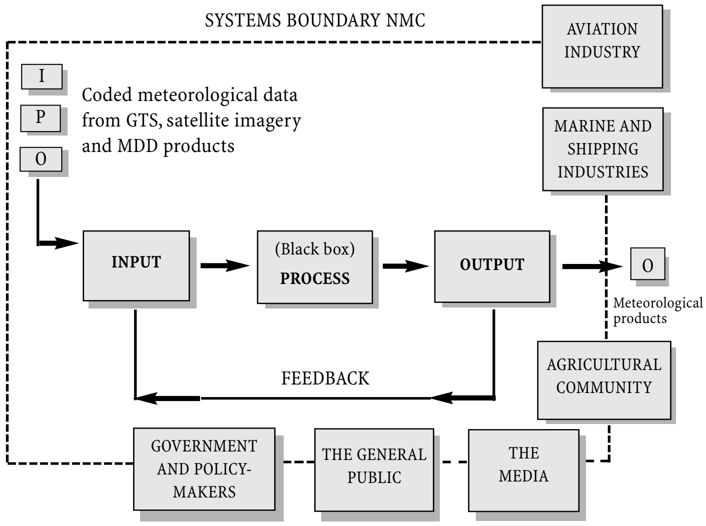


Figure 2 — Diagrammatic presentation of an NMC system, showing parameters, boundary and environment

that the aviation industry is tightly coupled with NMCs and is the biggest end-user group of weather products. The industry exhibits high levels of comprehension of weather and climate products by NMSs.

The analysis further indicates the marine and shipping industry as being tightly-coupled to the NMCs because of its high level of comprehension and use of meteorological products in its tasks. However, the agricultural sectors, media organizations, policy-makers and planners in governments, and the general public are loosely coupled to NMCs. This is reflected in the feedback control system (the backflow of information to the NMC system), which includes newspaper reports, editorials and commentaries on both the print and broadcast media indicating that weather products are neither understood nor correctly interpreted resulting in the low visibility of NMSs.

Agricultural sectors in developing countries are vital to the survival of communities yet are loosely coupled to NMCs. Most countries have sound infrastructures in their agricultural departments and sectors which routinely advise farmers through the agricultural extension officers; yet no establishment of formal methodologies of interactions between NMSs and the agricultural sectors exist or else are weak. The lack of adequate and formal information flow and exchange between NMSs and the agricultural community is demonstrated via feedback systems such as crop failure and economies disrupted by droughts, floods, pest infestations and health issues. Since the economies of governments of developing countries are agriculturally dependent, the tight coupling of NMCs of developing countries and their respective agricultural communities is imperative. NMSs could target agricultural extension officers who are in direct communication with farmers for effective decision-making in agricultural activities and result in direct economic benefit.

Policy-makers in governments lack knowledge of the role played by NMSs and the potential benefits to national economies. The policies and decisions made by this top echelon group in government affect the smooth running of NMSs in terms of budgetary allocations. The analysis suggests that the current status of information flow between NMSs and this important decision-making group is loosely-coupled. The need to sensitize policy-makers to the role of NMSs to the community and the potential benefits in national economies cannot be over-emphasized.

The cybernetic function of an NMC's environment

Stafford Beer (1959), describes cybernetics as natural laws governing the behaviour of large interactive systems, whether in the flesh, metal, or social and economic fabric. He goes on to say that the laws are closely related with self-regulation and self-organization and that they constitute the management principle by which systems grow and are stable, learn and adjust, adapt and evolve; that all these diverse systems are really the same in the cybernetic perspective ,because they manifest viable behaviour conducive to survival.

Schoderbek *et al.* (1975) describe the feedback control system as characterized by its closed-loop structure, which tends to maintain a prescribed relationship of one system variable to another by comparing functions of these variables, the difference of which it uses as a means of control. In this analysis, the control object chosen from the system's output variables is:

- The accuracy and reliability of forecasts and warning advisories issued by NMCs.

The accuracy and reliability of the systems outputs are derived by comparing the issued forecast to the observed weather occurrence. With the desirable outcome, they will be the same with minor deviations (d = 0). Specifically, issued forecasts are verified with actual weather occurrence and the difference 'd' used as a means of control to the NMC system. Figure 3 is a presentation of an NMC's environment showing the closed-loop structure of the feedback control system, including the output variables.

The environmental variables considered and defined by the public weather services interface are:

- Comprehensibility of forecasts by users;
- Usability of meteorological products;
- Benefits of meteorological products.

The deviation variable 'd' and the environmental variables in the feedback control function influence each other in such a manner as to control the NMC system by reducing the magnitude of 'd'. The variables influence the magnitude of the corrective action from the activator system and is input back to the NMC system. It can be argued that 'd' is always a factor of the environmental variables and displays the impact of NMC products to the environment, given the environmental variables, and the counter-impact the environmental variables have on the work processes of NMC via the feedback controls. For maximum control of the NMC, it is desirable for 'd' to be close to zero (d = 0). Then and only then is the NMC system in perfect equilibrium or stable with its environment in a systems perspective.

NMSs are surrounded by a dynamic environment demanding products at the prescribed level of accuracy and reliability to make critical decisions. This "hostile" environment is sensitive to 'd' through the environmental variables and will transmit 'd' back to the NMC system via the feedback loop. Consequently, the laws of cybernetics take effect and the NMC being unstable will, by self-regulation, attempt to adjust either one or all, or a combination of its inputs, processes and outputs and strive to take corrective measures to be in equilibrium with its environment by meeting environmental demands. NMSs will achieve corrective measures by improving meteorological data coverage; increasing the number of upper-air stations in their networks; incorporating satellite information in the forecasts to complement data sparse regions such as the oceans; initiating further training of meteorological personnel, and numerous other activities that the NMSs or WMO will deem necessary to incorporate in NMCs' work processes to achieve the prescribed level of product accuracy for survival in a systems perspective.

When either one or all the environmental variables diminish and/or when the difference parameter 'd' increases, then the NMC system and subsequently the NMS is regarded as being out of control in a systems perspective. The ideal is for environmental variables to be maximum and the output deviation variable 'd' to be close to zero for the NMC and subsequently, the NMS to be in control and in equilibrium with the environment for survival in a systems perspective. The environmental variables (comprehensibility, usability and benefits of NMC products) are tasks and functions to be designed and formulated by the Public Weather Service interface with the NMC system for the overall effectiveness of NMSs in the provision of services.

Functions of media organizations in the cybernetic function: the Detector System

Figure 3 suggests the Detector System in the cybernetic function as being the media organizations in the environment of an NMC where information is selectively acquired, evaluated and transmitted. Media news on weather and climate issues become the output of the Detector System and input to the comparator system of the cybernetic function. Media organizations are extremely sensitive to the variable 'd' and will transmit information to the Comparator System often with exaggerations. Thus the comprehensibility of weather and climate information by the media is important.

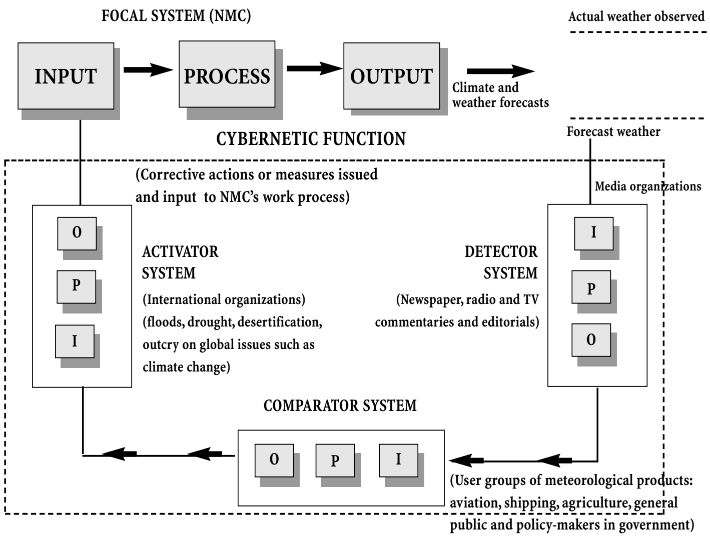


Figure 3 — Diagrammatic presentation of the cybernetic functions of the NMC system and the role of WMO and other organizations in the environment in the improvement of services

Functions of user groups in the cybernetic function: the Comparator System

Figure 3 suggests the Comparator System in the cybernetic function are user-groups. Concerns at the global, regional and local scales regarding the negative impacts of anomalies in weather and climate is the output of the Comparator System, which becomes the input to the Activator System. The Comparator System automatically transmits 'd' to the Activator System.

Functions of WMO in the cybernetic function: the Activating System

The Activator System in the cybernetic function is WMO and other international organizations, including donors and relief NGOs which evaluate alternative courses of corrective action based on the significance of the deviation variable 'd'. The output of the Activator System is the corrective action aimed at investigating the controllability and stability of the NMC and strives to achieve the ideal where d = 0. Corrective action almost always translates to financial implications. Martin Yerg (1996) stresses collaborative efforts in funding WMO's Technical Cooperation Programme. The bulk of these obligations are mostly borne by United Nations Development Programme (UNDP), WMO Trust Funds, WMO's Voluntary Cooperation Programme (VCP), and WMO's regular budget.

Conclusion

This article has aimed to provide a holistic framework of looking at problems that face individual NMSs in today's dynamic and complex environment which demand immediate solutions. How the problems are analysed not in isolation but include other related issues in the "big picture" for solutions. How NMSs should not view their organizations in isolation but consider user organizations in their immediate environment as being part of the solution, and the necessity for NMSs to be in equilibrium with the communities they serve by meeting their demands.

Recommendations

- WMO Members are encouraged to establish public weather services units to interface with the NMC and user organizations;
- In addition to defining standards for the inputs, processes and outputs for NMSs of its Members, WMO should set standards for the management of NMCs where decision-making will consider the holistic view for the provision of effective services;
- Members are encouraged to form partnerships with user organizations and programme them in their problem-solving frameworks.

References

BEER, M., 1980: *Organization Change and Development: A Systems View*, Goodyear Publishing Co. Inc., California.

BEER, S., 1975: *Platform For Change.* John Wiley and Sons, London.

WMO, 1999: *Guide To Public Weather Services Practices*, WMO-No. 834 (second edition).

KAST and ROSENZWEIG, 1970: *Organization and Management: A Systems Approach*. McGraw Hill Book Co, New York.

KASTELEIN, J., 1988: *Meteorology in the Service of Aviation*, WMO-No. 706, Geneva.

Kenya Times, 5 October 1991: "Challenge To Kenya's Weather Forecasters", Editorial, 6.

AMERICAN METEOROLOGICAL SOCIETY, 1997: Meteorological Drought: Policy Statement , *Bulletin* Vol. 78, No. 5, 847-849.

MINTZBERG, H., 1979: *The Structuring Of Organizations.* Prentice-Hall Inc., Englewood Cliffs, New Jersey.

SCHODERBEK *et al.* 1975: *Management Systems: Conceptual Considerations*. Business Publication Inc., Dallas, Texas.

YERG, M., July 1996: New Approaches To Technical Cooperation, WMO *Bulletin* 45 (3), 250-253.

Acknowledgment

The graphics were prepared by Jeffrey D. Baum.

Impacts of weather events: standardized reporting?

By S.G. CORNFORD*

Introduction

Each year, as a result of abnormal weather events, thousands of people die prematurely and national economies suffer losses which quite frequently exceed 1 per cent of Gross National Product (GNP) and occasionally amount to a substantial fraction of it. (In Honduras, in 1998, the amount was one-third of the GNP. The only upper limits are the destruction of a Member's whole population and complete economic

* Former Director (Special duties), Office of the Secretary-General, WMO. E-mail: meteorology@ntlworld.com

Member's response to the Secretary-General's annual request for information on socio-economic impacts of weather events: structural/cultural damage caused by a typhoon in Japan in 1999

infrastructure. These extreme limits are much more likely to be approached in WMO Members with small populations and small economies.) A survey of the impacts of the previous year's weather appears in the October issue of the *WMO Bulletin* every year. In what follows, references are to page numbers in the *Bulletin* for the year given, unless otherwise stated.

The absolute value of weather to national economies is hard to ascertain and depends almost entirely on the set of definitions which are chosen. It is often (as with crops, for example) easier to compare the weather-related impacts of one year with those of one or more earlier years. By and large, societies adapt their way of life, density of occupation of land, architecture and system of agriculture to the local climate; it is departures from the norms in abnormal weather events (AWEs) which cause trouble.

Need for standardized (and mandatory) reporting

The need for standardized (and mandatory) reporting of the impacts of AWEs arose initially out of a need to produce more authoritative (and comprehensive) annual surveys for the *WMO Bulletin*, (see 1996, 363; 1997, 368). More broadly, however, the applications of comprehensive authoritative data would allow National Meteorological and Hydrological Services (NMHSs) to be of much wider value to governments. Not only would NMHSs amass the data to demonstrate their growing effectiveness in alleviating the worst impacts and increasing the value of more positive ones, they might well also be able to evolve improved methodologies for forecasting impacts (on human behaviour, the location and timing of floods, crop failure and so on), as well as just the weather.

Each year, the Secretary-General of WMO requests information from Member countries (currently totalling 185) on the effects of AWEs in the previous year. Typically, between 70 and 80 Members respond. It is not clear whether or not some regard making no report as being equivalent to a report of no AWE. Indeed, it sometimes seems as though it is the abnormal weather which is being reported, whether it has abnormal impacts or not. At other times, it seems as though some Members report only when the impacts are abnormal. Typically, the Members which report comprise some two-thirds of the world's population but this means that impacts on some 2 000 million people are not reported. Only occasionally are reports received concerning events at sea or in the Antarctic, so that, coupled with the unreported land areas, more than 70 per cent of the Earth's surface is not covered. Consequently, not only is a standardized way of reporting needed, but so also is a network of reports to ensure that the impacts worldwide are sampled adequately and consistently.

What needs to be negotiated

The network described in the previous paragraph might be agreed within WMO's Commission for Basic Systems and might include not only WMO Members but also international bodies (particularly WMO technical commissions on behalf of their Members) with responsibility for the oceans (e.g. shipping and oil exploration interests) and the air (e.g. international and transoceanic air travel interests).

Similarly, it might be agreed that reports on abnormal weather alone should be seen as contributions to the survey of the year's "climate", which appears in the July issues of the *Bulletin,* and that the October survey should concentrate on impacts. This paper concentrates on standardizing the reporting of impacts.

What should be reported? This depends very much on how the data are to be used. As with surface observations of the weather collected for synoptic purposes a century ago, however, some future applications cannot be foreseen. It is important, therefore, to make reports as comprehensive as is consistent with achieving high standards of accuracy and timeliness of reporting.

Authoritative data

At present, when summarizing impacts, insurance companies and NMHSs rely mostly on reports in the public media. These are based on individual reporters' quick assessments (rarely subsequently revised), made when unfavourable impacts, such as floods and storm damage, are making assessment and its reporting difficult. NMHSs represent governments, but only a few States have governmental machinery for collating authoritative data on weather impacts. If decision-makers in governments are to regard NMHS assessments as authoritative, then NMHSs should engage other departments of their government on an ongoing basis and stimulate them to gather relevant data on impacts. NMHSs should then collate the data and inform the whole system, national and international. Any agreement on methodology should make it clear that the national reports of impacts are intended to have the authority of the national government.

Member's response to the Secretary-General's annual request for information on socio-economic impacts of weather events: transportation infrastructure damage caused by heavy rainfall in Latvia in 1998 (photo: Ulda Brieza)

Methodologies

The possible methodologies for reporting, storing and disseminating the data, should take account of the realities of availability, and what can be achieved by cooperation, as well as a wide range of needs, some of them unknown, but should take the best out of present practice and allow for future improvements.

Types of impact to be reported

Classes of impact arise from:

(*a*) Different types of weather (e.g. rain, snow, hail, fog, sandstorm, haze, low sun, cold, heat, thaw, gusts and squalls, wind, tidal surge, lightning, freezing rain, lack of rain, lack of snow, lack of warmth, lack of cold) and combinations of weather (especially in thunderstorms with lightning plus gusts and hail, but also rain and thaw, lack of snow plus cold). Standardized lists of types of weather to be included for international use need to be negotiated;

(*b*) Different types of weather system (often crossing national boundaries) (deep extratropical depressions, fronts, troughs, upper troughs, easterly waves, tornadoes, cyclones, hurricanes, typhoons, severe tropical storms, cold-air outbreaks, monsoons, squall lines). Standardized lists of types of weather system for international use need to be defined and negotiated;

(*c*) Different types of impact (rain-fed flood, thaw flood, flash flood, wind damage, hail damage, avalanche, mud and land slides, debris flow, drought, river flow, agricultural pests such as desert locusts and army worms, human diseases, loss of aircraft and ships). Many of these impacts are not confined within national frontiers (e.g. locusts, 1996, 363—365). Standardized lists of types of impact for international use need to be defined and negotiated;

(*d*) Different sectors of the economy affected (agriculture, livestock, market gardening, fruit crops, forestry, roads, bridges, river embankments, irrigation systems, reservoirs, distribution systems (for electricity, sewage, telecommunications and clean water), factories, offices, education, housing, railways, air transport, canal transport, sea transport, fisheries, tourism). With some sectors, it is not only the direct and consequential (see (*f*) below) economic effects which are important. In agriculture, for example, the weather-related loss of a crop in a developing country can have devastating human effects. Standardized lists of weather-related economic sectors need to be defined and negotiated;

(*e*) Differing extents to which weather was the only factor leading to the impact (see July 1999 *Bulletin*, 286-291). A standardized scale of weather-relatedness needs to be defined and negotiated;

(*f*) Differing extents to which losses which are not directly attributable to the weather events but which are consequent upon it are evaluated (e.g. losses as a result of work not done—but consequent gains from fuel saved—when snow prevents people attending their offices and schools; increase in some crime in temperate climates during hot weather; effects on the police, rescue and weather (and hydrological) precaution services). The possible need for a standardized list of consequential losses needs to be considered internationally;

(*g*) Differing scales on which impacts may be studied (see 1996, 366-368, for example, for a detailed study of the impact on aviation in one country in one year); impacts may also be different when viewed over different periods (see July 1999, 287-288). Suitable time-scales need to be agreed internationally;

(*h*) Differing units to describe the impacts, in order to allow them to be compared. With shipping, for example, impacts expressed as numbers of vessels sunk will be quite different from tonnage sunk, or the percentages of national marine population or marine tonnage lost. It may be these losses need to be expressed in all four ways. If it could be agreed internationally that the Member provides the first two, internationally available data will allow the third and fourth to be calculated by the editor of the annual survey. Similar international agreements are needed for units to be used in other sectors;

(*i*) Numbers of dead, missing and injured. In a comprehensive system, many of these terms need to be defined and agreed internationally. There is usually little doubt about the number of dead bodies found (though errors may arise in reporting and there may sometimes be doubt as to whether the weather (e.g. lightning) or its effect (e.g. a flood) was the main cause of death), but in most disasters there is some uncertainty about the number of people missing, and the greater the disaster the greater the uncertainty. Injuries, too, can range from minor to nearly fatal, yet they are rarely categorized;

(j) Numbers of people made homeless. Usually these fall into three categories: (*i*) people evacuated for their own safety who subsequently return home, even though there is work to do to make the home habitable again ("evacuees"); (*ii*) people whose homes are destroyed and are likely to be homeless for a period comparable with a year ("temporarily homeless"); and (*iii*) people whose homes are destroyed and are unlikely to be rebuilt, for example because the site is now seen to be unsuitable ("internally displaced").

How to handle benefits

Benefits are, in general, harder to measure than losses, though assessments may be possible in sectors such as agriculture and tourism, by comparison of one year's "output" with that of a few previous years. Factors other than weather will almost always also have to be allowed for.

Individual case histories

Tables of raw statistics can be used to produce indices and diagrams (see 2000, 358-372 for recent examples), which allow generalized conclusions to be drawn and can form the basis of action. However, in addition, some real case histories are needed if the subject is to remain alive and articles on it are to interest individual decision-makers and others. So, the summaries under the ten headings ((*a*)-(*j*) above) need to be supplemented with interesting case histories of the major events of each year in each country. Only when all the returns are in from all countries is it possible to sort out the events which are of greatest absolute impact (usually in the most populous countries for totals of premature human deaths and in the richest for the greatest absolute economic losses—see 1999, 391, 394 and 401), of the greatest impact relative to the size of the population or of the national economy (usually amongst the smallest communities) or of sufficient novelty.

Benefits of such a reporting scheme

Although there is bound to be variation from year to year, an overall steady reduction in the value of the relative indices of weather impact on a country is a mark of an increasingly effective NMHS.

A reduction in indices of both absolute and relative economic losses is most difficult to achieve in the many Members of WMO with a primarily agricultural economy (see 1996, 348). A reduction in absolute losses will also, however, be difficult to achieve in relatively rich countries with much ever-increasingly expensive infrastructure at risk. Such Members find a measure of the effectiveness of the NMHS in a reduction in losses relative to the national investment in infrastructure.

A steady reduction in the indices of weather-related premature fatalities would be a reliable index of an increasingly effective NMHS if accurate information on the numbers of fatalities (deaths plus missing) were available. Members of WMO with an increasingly effective NMHS, large populations and large surface areas, may expect the decline in the annual numbers of weather-related fatalities to be fairly steady, whilst equally effective NMHSs in smaller countries will inevitably find much greater variability from year to year, because individual storms may sometimes affect the whole area of the country and the whole of its population, and sometimes leave them completely unaffected.

Engagement with other government departments

As for abnormal weather events, so some material on significant hydrological events from all Members would allow some to be chosen which seemed likely to generate wide interest or have potential application (see, for example, 1996, 360; 1998, 373; and 2000, 363). In the United Kingdom in autumn 2000, it was the state of the catchments following rain over an extended period which chiefly led to rain-fed floods, coupled on some occasions with spring astronomical tides. Thus, just as they need to consult other ministries for authoritative figures for impacts on agriculture, shipping, aviation, etc. (if surveys are to be authoritative and not derive from immediate national and international press reports), permanent representatives need to consult their hydrological advisers when compiling the annual reports.

Miscellany

Scale of impacts to be considered

One of the findings over the past few years has been that the combined impacts of a few major events exceed the total of all the many smaller ones taken together (1998, 385). It is not known whether this would still be the case if the many millions of small unreported weather-related impacts could be taken into account and all impacts corrected for their degree of weather-relatedness (July 1999, 286-296). This is probably best examined as a separate localized study. For the time being, it seems best that Members should report impacts that seem major to them, either in absolute terms, or in relation to their population or the size of their economy, and having seen the annual survey and the coverage it gives to impacts of differing degrees of severity. Similarly, although attention has been drawn to the impact of ordinary day-to-day variability on the financial markets ("weather derivatives", 2000, 357), this should not form part of the application of the mandatory standardized reporting system advocated here.

Computer-based returns

Whilst it has been the custom for reports to be made in hard copy, almost all NMHSs now have computers. A reporting regime based on a computer program in widespread international use (such as Microsoft Excel)—or one devised especially for the purpose, perhaps under the guidance of the WMO Commission for Basic Systems (and if so, the provision of special workshops and Secretariat support)—could probably, after a teething period, ease and then speed up the production of annual surveys. More importantly, perhaps, the effort of producing the survey will ensure its application within each submitting country and lead to an enhanced capacity and contribution to national life of the NMHS.

Given modern telecommunications and possible computer handling of data, it may be that annual reporting could be replaced by routine reporting soon after the occurrence of an impact as is possible, consistent with the report being an authoritative one, based on reliable information coming from the relevant government departmental sources. Such information could be disseminated via the GTS, as agreed. This would not preclude the writing of annual summaries, but would allow Members to produce their own summaries of incidents relevant to their own particular needs. Coordinated summaries of events occurring within a broadly similar climatic zone consisting of several Members might well be convenient for application anywhere in the zone.

Virtual Laboratory for Education and Training in Satellite Matters

By James PURDOM*

Background

Today, operational meteorological satellites provide essential data for meteorological and hydrological services to WMO Members across the globe. New instruments on research satellites have provided insights into future satellite systems, such that a variety of environmental applications are growing vigorously. We should expect great strides forward during the next decade with planned improvements to the space-based component of the Global Observing System, and strive for full exploitation of that component. Updated and improved methods must be developed for preparing products for distribution to an increasingly sophisticated and diverse user community in order to accommodate the rapid-paced development cycle that informed users will demand. Maximum utilization of satellite data for environmental applications requires a strong training component. Meeting the demands of this challenge is only possible because of the combined efforts of WMO and the world's producers of operational meteorological satellite data as represented through the Coordination Group for Meteorological Satellites (CGMS) in the formation of the Virtual Laboratory for Satellite Data Utilization.

The Virtual Laboratory for Satellite Data Utilization (VL) is a collaborative effort joining the major satellite operators across the globe with WMO "centres of excellence" in satellite meteorology. Those centres of excellence serve as the satellite-focused training resource for WMO worldwide. A schematic of the VL is shown in Figure 1. The centres of excellence are five WMO Regional Meteorological Training Centres (RMTCs) and the Australian Bureau of Meteorology Training Centre, while the four satellite operators are the USA (NESDIS), Europe (EUMETSAT), China (NSMC) and Japan (JMA). The various centres of excellence are sponsored by one of the major satellite operators.

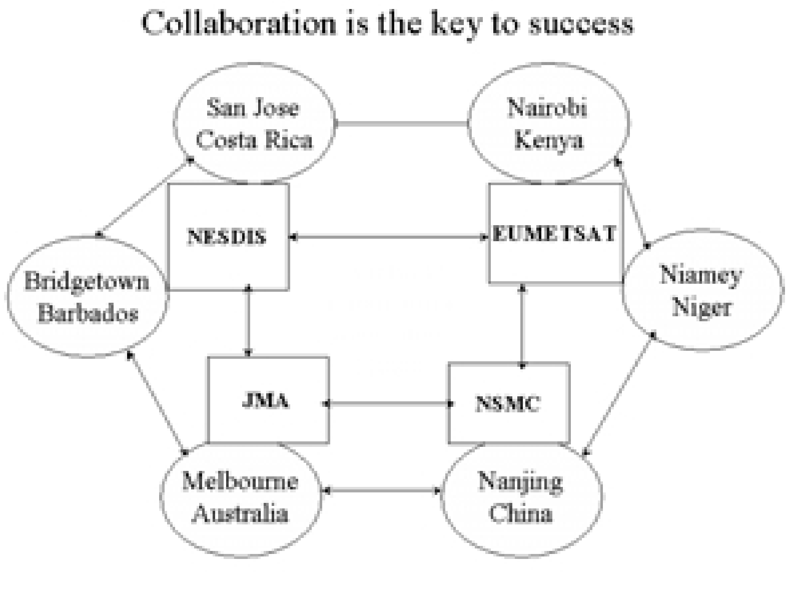


Figure 1 — Schematic illustration of the Virtual Laboratory as of May 2001

* Director, Office of Research and Applications (NOAA/NESDIS), and Chairman of the CBS OPAG/IOS

The Virtual Laboratory for Satellite Meteorology traces it origins back to work done by the Cooperative Institute for Research in the Atmosphere (CIRA), at Colorado State University in the mid-1990s. Initially aimed at providing online case-study data for training US National Weather Service (NWS) offices staff to fully utilize GOES data, it soon expanded to providing online case-study and near-real-time data to the WMO RMTCs in Barbados and Costa Rica. As with the NWS effort, RAMSDIS systems, software and data were provided to those RMTCs. Using common software and hardware has allowed work done on algorithm research at CIRA and other institutes to be used by RMTC and NMS staff in Barbados and Costa Rica on real-time satellite data and imagery. This cooperative arrangement has benefited the two countries and the researchers through new products and real-time ground-truthing and made more use of existing satellite resources[1]. Thus, much of the functionality of what is currently proposed for the Virtual Laboratory for Satellite Data Utilization (training in basic and advanced topics, access to tested and proven software/research and access to expertise) is borrowed from and builds upon the work done by the CIRA. Recognizing the importance of a coordinated, worldwide approach to improving satellite data utilization, the WMO's CBS OPAG IOS Expert Team (ET) on Satellite Systems Utilization and Products has discussed the VL concept at each of its three meetings to date. Initial discussions began in Locarno[2] (Switzerland) in June 1999. The next meeting of the group, held in Melbourne[3] noted that satellite training institutions and their sponsoring satellite agencies must utilize modern technology to provide a range of training opportunities and materials to WMO Members. The meeting noted that a key ingredient of the VL would be to build strong links with science groups. Annex IV of the Melbourne meeting summarizes the ET's discussion on the background, objectives, status and guidelines for the VLatory. The most recent meeting of the ET, in Lannion (France) in July 2000, identified the need for two streams of learning skills (basic and specialist) and a virtual resource library within the VL. A schematic representation of the relationships between the various components of the VL is shown in Figure 2[4].

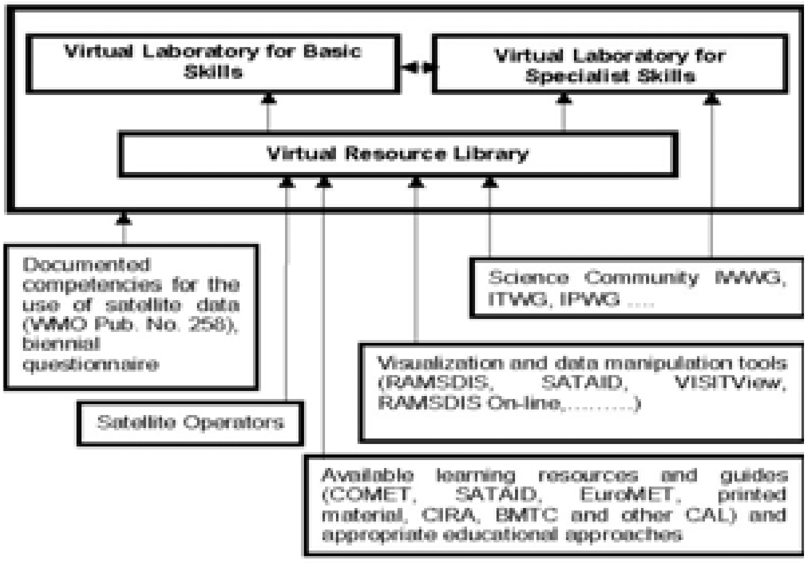


Figure 2 — Schematic of the Virtual Laboratory

Subsequent to the Lannion meeting, the concept of the VL was brought before CGMS in October 2000. CGMS and WMO agreed to establish a focus group on satellite data utilization and training within the VL framework and report back to CGMS and the WMO OPAG IOS on its findings and the need for future activities in this area. A major function of the focus group was to help foster the VL to realize the challenges set forth by the WMO Executive Council Panel on Education and Training and in support of the WMO Strategy for Education and Training in Satellite

1 For detailed discussion of the use of the RAMSDIS system and RAMSDIS online see the Report of the ET Meeting on Satellite Systems Utilization and Products, second session, Melbourne, Australia, 25-29 October 1999, available att http://www.wmo.ch/hinsman/Publications.html.

2 ET Meeting on Satellite Systems Utilization and Products, first session, Locarno, Switzerland, 2-4 June 1999, available at http://www.wmo.ch/hinsman/Publications.html.

3 See Footnote 1.

4 This figure and parts of the text from the latter portion of this abstract were taken from material provided by Mr Jeff Wilson, Australia Bureau of Meteorology, at the May 2001 VL Focus Group meeting.

Matters. The meeting of the focus group occurred during mid-May, 2001, and defined the various roles and responsibilities of participants, as well as the relationships between various components of the VL, as shown in Figure 2. This brief article is intended to bring WMO Members up to date on the current status of the VL and how it plans to move into the future.

SOME ACRONYMS

ASMET: African Satellite Meteorological Education and Training
CGMS: Coordinated Group for Meteorological Satellites
CIMSS: Cooperative Institute for Meteorological Satellite Studies
CIRA: Cooperative Institute for Research in the Atmosphere
COMET: Cooperative Programme for Operational Meteorology Education and Training
EUMETNET: European Meteorological Network
EUMETSAT: European Organization for the Exploitation of Meteorological Satellites
EuroMET: European Meteorological Education and Training
IOS: Integrated Observing Systems
NESDIS: National Environmental Satellite, Data and Information Service
OPAG: Open Programme Area Group (CBS)
PUMA: (Task Team on the) Preparation for the Use of METEOSAT Second Generation Satellites in Africa
RAMSDIS: Regional and Mesoscale Meteorology Advanced MeteorologicalSatellite Demonstration Interpretation System
SAFs: Satellite Application Facilities (EUMETSAT)
SATAID: Satellite Animation and interactive Diagnosis
TOVS: TIROS operational vertical sounder
VISIT: Virtual Institute for Satellite Integration Training

Virtual Laboratory Focus Group

The first session of the CGMS/WMO Virtual Laboratory Focus Group to discuss coordination and oversight requirements for the Virtual Laboratory for Education and Training in Satellite Matters was held at the EUMETSAT Headquarters in Darmstadt, Germany, 16-18 May 2001. This first meeting of the Focus Group led to several important and far-reaching accomplishments. The Focus Group agreed upon:

- A management structure;
- Immediate and strategic goals;
- Goals relating to implementation which included connectivity, a Virtual Resource Library (VRL), and utilization and evaluation of the VL;
- Specific action items and time tables for 0-1 year, 1-2 years, and 5 years. Each of these areas is discussed below.

Management structure

It was agreed that VL management would the responsibility of the VL Focus Group, which would be co-chaired by one satellite operator and one representative from the centres of excellence, with the WMO Satellite Activities Office serving as the Secretariat. The two co-chairs have the responsibility for day-to-day management, and will report to the VL Focus Group. Mr R. Francis (EUMETSAT) and Mr J. Wilson (BMTC) agreed to serve as the first two co-chairs. Membership of the VL Focus Group will include:

- A permanent core composed of the two co-chairs and representatives from each of the remaining satellite operators and centres of excellence (see Figure 1);
- Representatives of science teams as appropriate (see Figure 2); and
- Other interested parties as appropriate.

With regard to management, the VL Focus Group will review progress, assimilate inputs/feedback and assign actions. As appropriate, the Focus Group will address relevant training programmes, e.g. within PUMA, EUMETNET and Project Mitch, to assure synergy and consistency with VL goals. There will be regular and extensive use of teleconferencing (initially at least every three months) for coordination of the various activities under way within the VL, and to review progress with respect to action items and timetables, and to discuss other matters of relevance to the VL.

Immediate and strategic goals

The immediate goal set by the Focus Group was to implement a baseline VL and to foster its logical growth. Challenges that will be met in implementing this immediate goal are set forth in the section below that addresses 0-1 year actions. Strategically, the Focus Group emphasized the need to provide high-quality and up-to-date training resources on current and future meteorological and other environmental satellite systems, data, products and applications to improve utilization among Members; and to enable the centres of excellence to facilitate and foster research and the development of socio-economic applications at the local level by the NMHS through the provision of effective training and links to relevant science groups.

A component of immense strategic importance to the VL will be a virtual resource library (addressed in a separate section below). The virtual resource library supports all three cornerstones of the WMO strategy to improve satellite system utilization:

- Providing access to training and educational material;
- Providing software and expertise on how to utilize the data; and
- Providing case-study and near-real-time data.

Baseline activities toward the establishment of the virtual resource library include the establishment of Web servers by EUMETSAT at their Darmstadt facility as an initial site for training resources and materials (end of September 2001) and NESDIS at CIRA for an initial set of near-real-time data and products (end of November 2001). To facilitate this, by the end of July 2001, each member of the focus group agreed to prepare an inventory of which training resources and materials were currently available for the core virtual resource library, and each satellite operator would identify what data and products could be linked into it. While it was realized that, in the baseline VL, servers would be at only selected locations, a strategic goal was to have servers, with many mirrored capabilities, located at all nodes of the VL.

Goals to aid implementation

Connectivity

The components of the VL must be able to communicate with one another from their home facility. In addition, each component must have access to resources available within the VL. To address those issues, a near-term goal is to establish Internet links with a minimum data rate of 56 kbs at the six centres of excellence and supporting satellite operators. The main purpose of those links would be to support communications (e-mail, voice) as well as the exchange of software and selected image datasets. Those selected image datasets would include both case-studies and some near-real-time datasets. It was recognized that data are of fundamental importance to the centres of excellence, and that a preferred method for receipt of data, in the short-term, would be the direct insertion of data from a ground receiving station at each site for possible insertion into

EUMETSAT Headquarters, Darmstadt, Germany, May 2001 — Participants in the first session of the CGMS/WMO Virtual Laboratory Focus Group to discuss coordination and oversight requirements for the Virtual Laboratory for Education and Training in Satellite Matters their VL servers. To enhance the exchange of training materials, including real-time lectures and classroom participation between nodes of the VL, the centres of excellence would consider means to increase link capacity to a minimum of T-1 within five years;

Virtual Resource Library

It was pointed out one strategic goal was to have servers, with many mirrored capabilities, located at all nodes of the VL. Those servers are at the heart of the Virtual Resource Library (VRL). The VRL will have two components: a core of baseline information to be exchanged (mirrored as appropriate) to all centres of excellence and a repository of data and specialized information for local use. Local use distribution will be the responsibility of the data provider, and could range from complete distribution to all centres of excellence, to restricted distribution to only the local centre of excellence. Included within the baseline information at the VRL (see Figure 2) will be a suite of standard software packages and applications for use with those software packages. Used in combination with the case-study data, it will provide capabilities for adapting algorithms and software to those data in a variety of standard formats. The data will be linked to training sessions, and may be used independently for activities such as application development and testing. Visualization and data manipulation tools such as RAMSDIS, SATAID, VISITView, and RAMSDIS online will be important components of the VRL core, as will learning resources and guides (COMET, SATAID, EuroMET, printed material, CIRA, BMTC and other computer-aided learning (CAL)) and appropriate educational approaches.

A number of important issues are being addressed by the Focus Group as the VRL is in its formative stage. These include:

- Establishing a list of usable training resources (includes image datasets, software, tools);
- Implementing a structure for the depository of training resources which will allow easy access by the centres of excellence trainers; and
- Populating this structure with a core set of material from the training resources list.

To assure scientific integrity, the VL and VRL will have strong links to specialized science groups such as the International TOVS Working Group (ITWG) and the International Wind Workshops (IWW).

It is envisaged that remote training will become an important part of the VL in the years to come. The VISITView program, in which an instructor in a remote location utilizes modern computer and communications technology to train forecasters at different locations is expected to become an important resource within the core VRL. VISITview (http://www.ssec.wisc.edu/visitview/) is a platform-independent distance-learning and collaboration software program. It allows multiple users located in different offices across a wide geographic region to view the same series of images containing graphics and text. VISITview provides a large number of features, including annotation, colour enhancements, zooming, animations, multi-panel displays, image fading, quiz questions, etc. To avoid problems with limited Internet bandwidth, files used for the real-time presentations are acquired by the offices in advance. The files for each training session contain all the information needed for the training. This allows each training office the opportunity to view the session in advance and to use the session to conduct on-station training. Standard voice phones are used during the session. However, for those remote offices with limited phone access, alternative voice options using Internet phone software can be used.

Utilization: user requirements and VL assessment

Addressing user needs and ensuring that those needs are being met were important items of discussion by the Focus Group. Effective use of publication WMO-No. 258 and the biennial satellite data utilization questionnaire are central to the success of the VL. It was agreed that analysis of user responses focused on education and training, taken from the biennial questionnaire, would be carried out by the relevant centre of excellence. From their analyses, results would be reported to the VL Focus Group. This analysis and reporting serves a number of important purposes, such as identifying areas of common training needs and areas where development activities are required to address unmet user requirements. Thus, establishment of a VL user-tracking and feedback mechanism from the outset was recognized as an important activity. Another matter discussed with respect to training was the use of real-time data. For a number of applications (such as nowcasting) training meteorological students to an operational level of expertise near real-time data and products are a strong requirement. It was pointed out that, while case-studies are important, the atmosphere, as revealed through daily weather discussions using real-time data during training events, is rarely so neatly packaged as a specific case-study. In addition, near-real-time data are needed to train forecasters on the effective use of new satellite reception and processing systems. It was also recognized that, depending on the application, the need for near-real-time data availability may not be as stringent. This need will be one of the items addressed during the VL's evolution over the next five years, at which time a comprehensive review of the VL was suggested by the Focus Group.

Typical activities to be undertaken as the VL develops

The Focus Group discussed a number of generic activities that would be undertaken as the VL takes shape, as well as specific actions that must be undertaken during the next five years. The generic-type activities are given in bullet form immediately below, and are then followed by specifics for the next five years. No doubt some actions will change as the VL becomes a reality, but the basic intent of improving satellite data utilization will remain unchanged.

- Consolidate documentation of the range of skills/competencies for operational meteorologists and specialists;
- Examine which online (Web-based learning), CAL, CDs and hardcopy learning materials are currently available for use in the VL. This activity will include contacting groups such as ASMET, COMET, CIRA, EUROMET, BMTC and CIMSS, which have complementary projects under way and relevant science groups (such as the EUMETSAT SAFs, the ITWG, the IWW and the proposed quantitative precipitation working group);
- Negotiate with the copyright holders of the training material rights either to link to their material and/or to acquire the rights to use their material at the designated centres of satellite training expertise (this includes the centres making the material available to on- and off-site users);
- Work with groups such as ASMET, COMET or EuroMET, to design and test possible user interfaces, educational approaches for delivering the material, and examine methods for online tracking of student participation;
- Evaluate, on a trial basis, the proposed VL material in conjunction with one of the WMO satellite training workshops for more user feedback;
- Incorporate user feedback into the educational approach and review the content of the VL;
- Move to a wider implementation of the material;
- Undertake a periodic review of the VL sites in conjunction with reviews of the skills and competencies of the operational meteorologists and specialists;
- Prepare sample datasets for the various data streams now being provided or planned for in the near future. The datasets would be used within the VL concept;
- Provide for continuous monitoring of user requirements for education and training, as well as the effectiveness of the VL.

Implementation schedule

The agreed-upon implementation schedule for the VL with corresponding action items is as follows:

0 to 1 year

- During the next six months, all centres of excellence to evaluate content, and how and what can be maintained on a server at the centre;
- Train satellite operators and centres of excellence on the use of RAMSDIS, using VISITview;
- Increase training event effectiveness through the use of VISITview;
- Add the SATAID training resource to the VRL and utilize VISITview on the use of that tool.

1 to 2 years

- Within 1-2 years, all satellite operators to strive to have a server online and connected to the VL;
- Each centre of excellence to strive to have a server online and connected to the VL;
- To establish a voice channel capability within VISITview;
- To evaluate ways to improve the VRL;
- To evaluate the quality of submitted materials by the centres of excellence, completeness (e.g. speaker notes), appropriate deletion dates, compatibility issues and virus protection.

5 years

- Conduct a comprehensive review.

Summary

The first session of the CGMS/WMO Virtual Laboratory Focus Group to discuss coordination and oversight requirements for the Virtual Laboratory for Education and Training in Satellite Matters was most successful.

The VL represents a vehicle through which the WMO and CGMS will work to improve the utilization of satellite data worldwide. Effective Member interaction with their respective centre of excellence is required for Members to fully realize this benefit.

Exciting times with great opportunities await us!

❀ ❀ ❀

WMO programme news

WORLD WEATHER WATCH PROGRAMME

BASIC SYSTEMS

Working Group on Planning and Implementation of the World Weather Watch in RA I (Africa)

The fourth session of the Working Group was hosted by the Egyptian Meteorological Authority in Cairo from 19 to 23 March 2001. It was attended by representatives of Regional Telecommunication Hubs in Africa (Algiers, Cairo, Dakar, Nairobi and Pretoria), ACMAD, ASECNA and WMO, as well as members of the Working Group.

The meeting was officially opened by Mr A.M. Rebba, Chairman of the Board of Directors, Egyptian Meteorological Authority and Permanent Representative of Egypt with WMO, and was subsequently chaired by Mr W. Nyakwada (Kenya). Speakers emphasized the need for improved data availability from the Region, especially as the provision of meteorological services was assuming a global dimension.

The following observations were formulated by the session:

- The 2000 Annual Global Monitoring of the WWW indicated the low availability of observational data and Members were urged to take urgent measures to enhance and re-activate their observing activities;
- Within the Global Telecommunication System, many main regional circuits and regional circuits either were not operating or required improvement. Further, some serious gaps persisted in terms of data collection at the national level, due mainly to a lack of operational equipment;
- Many upper-air stations were silent, occasioning large gaps in various areas of the region. This was attributed to deficient operations of Radiosonde Observing System (RAOB) stations and the high cost of consumables.

The meeting developed a strategic plan for the implementation and improvement of basic systems in RA I to address, *inter alia*:

- Improvement of the Global Observing System to focus on support for acquisition of automatic stations, satellite ground stations and the promotion of marine observing projects;
- Enhancement of regional meteorological data exchange through promotion and implementation of modern technology, such as the Internet and satellites;
- Enhancement of the Global Data-processing System to contribute to building capacity and implementation of data-processing and forecasting systems and overcome the digital divide in Africa.

Cairo, Egypt, March 2001 — Participants in the fourth session of the Working Group on Planning and Implementation of the World Weather Watch in RA I (Africa)

The strategy was subsequently considered by the RA I Advisory Working Group and approved thereafter on behalf of the Association by the president.

The report of the session and the strategy are available on the WMO Website: http://www.wmo.ch/web/www/reports.html#RegionalWG

INSTRUMENTS AND METHODS OF OBSERVATION PROGRAMME

Fifteenth Professor Dr Vilho Vaisala Award

Albuquerque, New Mexico, USA, 16 January 2001 — Presentation of the 15th Vaisala Award (from left to right): Prof. G.O.P. Obasi, Secretary-General of WMO; Mr P. Ketonen, Vaisala Inc.: Dr E.R. Westwater, Project Leader and Lead Author of the winning paper; General John J. Kelly, Permanent Representative of the USA with WMO

Following the decision of the fifty-second session of the Executive Council in 2000, the fifteenth Professor Dr Vilho Vaisala Award was presented by Prof. G.O.P. Obasi, Secretary-General of WMO, on 16 January 2001 in Albuquerque, New Mexico, USA, at the Annual Conference of the American Meteorological Society (AMS). Eleven US scientists received the Award, namely Dr Edgeworth Westwater, Dr Yong Han, Mr Jack Sinder, Dr James Churnside, Dr Joseph Shaw, Mr Michael Falls, Dr Charles Long, Dr Thomas Ackerman, Dr Kenneth Gage, Mr Warner Acklund and Dr Anthony Riddle for their paper entitled "Ground-based remote sensor observations during PROBE in the tropical western Pacific". The paper, which was published in the *Bulletin* of the American Meteorological Society, Vol. 80, No. 2, February 1999, presents the results of the Pilot Radiation Observation Experiment (PROBE).

The authors describe the deployment of a suite of state-of-the-art research instruments over the tropical western Pacific, including the dual-frequency microwave water substance radiometer (MWSR) to determine the quality of radiosonde humidity observations, and the unique Fourier transform infrared radiometer (FTIR). The area covered is approximately between 10°N and 10°S and from Indonesia to near Christmas Island. Data with high vertical resolution are obtained from radiosondes, while the MWSR provides the required temporal structure of the atmosphere. The MWSR identifies liquid clouds and the FTIR ice clouds. In this respect, the Experiment yielded numerous important advances in calibration and measurement methodology, especially relating to synergistic use of data from multiple sensors. As a result, two long-term climate observing stations are currently operating in the tropical western Pacific and as many as three others may be deployed in this important, but data-sparse, region of the world, referred to as the Pacific "warm pool".

The award ceremony was attended by General John J. Kelly, Assistant Administrator for Weather Services of the National Oceanographic and Atmospheric Administration and Permanent Representative of the USA with WMO, and Mr Pekka Ketonen, Chief Executive Officer of Vaisala Inc.. A large number of meteorologists and other scientists participating as delegates at the Annual Conference of the AMS also attended.

Expert Meeting on Rainfall Intensity Measurement

At its twelfth session (Casablanca, Morocco, 1998), the Commission for Instruments and Methods of Observation underlined the need to standardize measurement of rainfall intensity and raised the possibility of organizing a Rainfall Intensity Measurement Intercomparison (global, regional, or national).

The results of a WMO questionnaire distributed in 2000 revealed a great interest by Members to address this matter in more detail. An Expert Meeting on Rainfall Intensity Measurements was therefore organized at the Slovak Hydrometeorological Institute in Bratislava from 23 to 25 April 2001. Fourteen experts from nine Member countries participated. The meeting reviewed the needs of various users of precipitation data, especially in relation to rainfall intensity and developed proposals to cover common needs for the future, such as minimum time resolution, measuring range and related accuracy/uncer-

Slovakia, April 2001 — The participants in the Expert Meeting on Rainfall Intensity Measurements visited with great interest the Research and Test Station in Jaslovske Bohunice, where an intercomparison of relevant instruments had recently begun.

tainty of these observations. The recommendations developed will be discussed and reviewed by the CIMO Working Group on Surface Measurements with the objective to submit the refined versions to CIMO-XIII and other interested WMO technical commissions for consideration and approval.

The meeting discussed the need for, and feasibility of, organizing a WMO Rainfall Intensity Intercomparison and considered the various options available for acquiring reliable information on the performance characteristics of raingauges and related equipment. It was agreed to recommend, as a first step, calibrations of suitable types of raingauges to be carried out in at least two independent certified laboratories. Field tests might be carried out under the required climatological conditions if considered urgent and feasible.

TROPICAL CYCLONE PROGRAMME

WMO/ESCAP Panel on Tropical Cyclones

The 28th annual session of the WMO/ESCAP Panel on Tropical Cyclones was held in Bangkok, Thailand, from 14 to 20 March 2001 and was attended by representatives of seven Member countries (Bangladesh, Maldives, Myanmar, Oman, Pakistan, Sri Lanka and Thailand). The meeting elected Mr Wanchai Sarathulthat (Thailand) and Dr Qamar-uz-Zaman Chaudhry (Pakistan) as Chairman and Vice-Chairman of the Panel, respectively, until the next session.

The Chairman of the Local Organizing Committee, Mr Dusadee Sarigabutr, Deputy Director General of the Thai Meteorological Department (TMD), welcomed the 25 participants and highlighted a number of WMO activities which the TMD would be organizing during the year.

The session was opened by Mr Wanchai Sarathulthat, Director-General of TMD, who stressed that Thailand had actively participated in the Panel's activities since its establishment in 1973 and would continue to do so in the years ahead.

The representative of the Secretary-General of WMO, the Director of the WMO Regional Office for Asia and the South-West Pacific, highlighted the recent activities of WMO's Tropical Cyclone Programme (TCP) and stressed the need of Panel Members for more effective warnings with increased reliability and lead time, and closer interaction with National Meteorological and Hydrological Services (NMHSs) and national agencies concerned with disaster prevention and preparedness.

The meeting carried out a detailed review of the Coordinated Technical Plan. It was recommended

Bangkok, Thailand, March 2001 — Participants in the 28th annual session of the WMO/ESCAP Panel on Tropical Cyclones

that, in future meetings, the national delegation should include representation from the hydrological service, which would strengthen discussions on the hydrological component. The Panel also urged the Secretariats of WMO and ESCAP to provide technical cooperation for flood-forecasting projects related to tropical cyclones. In line with this, the Panel requested WMO and ESCAP to support this activity through the organization of a one-day workshop in conjunction with the next Panel session in order to highlight state-of-the-art scientific and applications-oriented developments and to promote progress in the development and implementation of the hydrological component of the TCP.

With the aim of attracting donor assistance for the Storm Surge Disaster Reduction Project in the northern part of the Indian Ocean, the Panel recommended that the project proposal be submitted for a peer review to update figures and strengthen its technical content, develop national storm-surge projects and include aspects of storm-surge probabilities and risk vulnerability.

The Panel further emphasized the need for human resource development in Member countries and urged WMO to provide additional assistance in this endeavour, especially in relation to tropical cyclone training activities.

RA IV Hurricane Committee

The 23rd session of the RA IV Hurricane Committee was held in Maracay, Venezuela, from 23 to 27 March 2001. There were 36 participants from 23 Members of the Association and six from regional and international organizations.

Highlights of the outcome of the session

Numbering and headings of subtropical depressions
The Committee discussed the submission by France concerning difficulties being experienced with the numbering system and the heading for subtropical depressions (WWNT) compared to those for tropical

depressions (WTNT), as indicated in the Hurricane Operational Plan. The Chairman pointed out that there was an error in the Plan and that the heading had been changed some time ago. WTNT is the heading now used for both subtropical and tropical depressions. The Chairman alluded to the difficulties in determining the true tropical or extratropical characteristics of many systems which might become classified as subtropical. However, the Committee decided that one numbering system should be used for both systems.

NMHSs were urged to consult with the hydrological community in their countries when compiling the rainfall information.

The Committee made amendments and changes to the RA IV Hurricane Operational Plan. It recommended to the thirteenth session of RA IV (XIII-RA IV) the approval of the amendments to the text of the Plan. The Committee urged WMO to publish a new 2001 edition in English and Spanish, as soon as possible.

A detailed review of all components of the Technical Plan and its Implementation Programme was carried out, taking into account the development and progress made by Members since the 22nd session of the Committee. The Committee recommended to XIII-RA IV the approval of the updated RA IV Hurricane Committee's Technical Plan and its Implementation Programme.

Maracay, Venezuela, March 2001 — Participants in the 23rd session of the RA IV Hurricane Committee

Dropwindsondes over land areas

It was pointed out that pilots would not take the responsibility of releasing dropwindsondes over land because of the possibility of injury on the ground. The importance of upper-air soundings from land stations, including special soundings, was emphasized.

Attachment of hurricane forecasters to RSMC Miami

The programme of assigning bilingual (English/Spanish) forecasters from NMHSs in the Region to the RSMC had been beneficial to all concerned. NMHSs were urged to make their bilingual forecasters available during the hurricane season, whenever possible.

Post-tropical-cyclone report

The Committee discussed the use of the guide to report on heavy rainfall events, which had been devised by the RA IV Working Group on Hydrology. The guide had been presented to the Committee in full detail at its last session. The Committee decided that the Chairman and the two Vice-Chairmen would work on producing a format based on the guide for post tropical cyclone report for inclusion in the Operational Plan. The modified version would be prepared as a document for consideration and adoption by the twenty-fourth session of the Committee in 2002.

The USA offered to host the 24th session of the RA IV Hurricane Committee in Orlando, Florida, from 3 to 10 April 2002, in conjunction with the US National Hurricane Conference (1-5 April 2002).

Workshop on Hurricane Forecasting and Warning, including topics related to Public Weather Services

This workshop was organized and hosted by the NWS/NOAA Tropical Prediction Center, National Hurricane Center, in Miami, Florida, USA, from 23 April to 5 May 2001, in cooperation with WMO. The training facilities, resource persons and lecturers were provided by RSMC Miami. Training included practical and hands-on exercises.

The purpose was to assist invited Members in their efforts to improve their tropical cyclone warning systems and related public weather services, by providing refresher training for, and updating the knowledge of, forecasters. It was designed for Class II and Class I meteorological personnel who had had practical experience in operational hurricane or tropical cyclone forecasting. Special attention was given to the training of tropical cyclone forecasters of small island States in the Caribbean region in support of sustainable development within the framework of the International Strategy for Disaster Reduction.

The following WMO Technical Documents were distributed to the trainees:

- Global Perspectives on Tropical Cyclones (available in English only);
- Estimating the Amount of Rainfall Associated with Tropical Cyclones Using Satellite Techniques (available in English and Spanish).

The workshop was attended by 17 meteorologists from 16 countries: Barbados; Bermuda; Canada; Colombia; Costa Rica; Dominican Republic; El Salvador; Guatemala; Honduras; India; Mexico; Pakistan; Panama; Saint Lucia; Thailand; and Venezuela. WMO funded one participant from each of 12 Hurricane Committee Members and three tropical cyclone forecasters from the Bay of Bengal and Arabian Sea area.

WORLD CLIMATE PROGRAMME

WORLD CLIMATE APPLICATIONS AND SERVICES PROGRAMME

Climate Information and Prediction Services (CLIPS)

The CLIPS Food Chain Showcase Project has been successfully completed in the United Kingdom,with the participation of the United Kingdom Met. Office, the ECMWF, a number of universities, and research and commercial organizations involved in all stages of the food supply chain. The project was designed to examine the potential benefits of seasonal forecasts within this particular sector. Working groups for field vegetables, sugar beet, apples and tomatoes examined all aspects of the potential use of seasonal forecasts from production to final retailing (the apples group reviewed international aspects whereas the others addressed national considerations only). The approach used to tackle some of the technical issues within a context of seasonal forecast applications in southern Africa is discussed in a separate article in this edition of the *Bulletin* (see pages 228-231).

One industry participant in the Food Chain Project described the potential for seasonal forecasts as "phenomenal". The project chairman commented:

> *There is no doubt in my mind of the potential benefits of seasonal weather forecasting for food chain businesses. This special [...] study has shown the benefits that can be realized through scientists and food chain businesses working in partnership.*

Through the project, the importance and benefits of close coordination and cooperation between forecast producers and users were clearly demonstrated. The benefits potentially available, even in a region of relatively low predictability such as Europe, were also illustrated. Outcomes from this project will be used to guide future CLIPS demonstration and pilot projects.

The CLIPS Project Office participated in the first meeting of the CLIVAR-GOALS VACS (Variability of the African Climate System) Project, aimed at improving knowledge, understanding and predictability of seasonal-to-interannual climate variations over the continent. CLIPS activities will benefit from the outcomes of this project.

WORLD CLIMATE DATA AND MONITORING PROGRAMME

The first regional workshop under the Action Plan of the CCl/CLIVAR Joint Working Group on Climate Change Detection was hosted by the University of the West Indies in Kingston, Jamaica, 8-12 January 2001. It brought together data managers from 18 NMHSs in the Caribbean region and representatives of four regional entities with interest in Caribbean climate.

Participants were introduced to the science of data management, including quality control and homogeneity, as well as to climate indices as a mechanism for extracting climate change information. The participants processed regional data to determine their suitability for climate-change analysis, calculated 15 climate-change indices and presented the new results as indicative of regional trends.

The second regional workshop was hosted by the National Meteorological Research Centre, Casablanca,

Geneva, February 2001 — CCl Task Team on Data Management Systems

Morocco, 18-23 February 2001. The workshop was attended by 28 participants from 23 African countries.

A feature of the Workshop that contributed to its success was the structure of the agenda that included preparatory activities:

- A tele-forum of an intensive exchange of e-mails, faxes and letters to inform, send examples and explain the work to be done during the Workshop;
- Pre-forum training of the participants; and
- A forum where each participant made an analysis using national and local data, prepared a report and made a presentation.

The participants processed regional data from 23 locations and calculated a total of 18 relevant indices for each location. African maps of six of the indices were also prepared and the complete results will be published as scientific reports.

Next generation client/server Climate Data Management Systems for the CLICOM project

The final version (3.1) of the current software of the CLICOM project was released in January 2000. Météo-France has financed and, jointly with ACMAD, translated CLICOM 3.1, its reference manual and the migration guide for use in the French language. The French version of CLICOM 3.1 is available on both the WMO and ACMAD Websites and can be downloaded by anonymous ftp. CLICOM project software will not be developed further in its present form because of the many advantages of new generation database management systems.

Several Member countries which are developing (or have developed) next-generation, client/server climate data management systems (CDMSs) have offered to share them with other Members. A CCl Task Group has developed CDMS evaluation criteria and specifications for a test dataset (data of a variety of types) in order that Members wishing to take advantage of these offers can assess the systems for their particular situations. The WMO Secretariat has sent a questionnaire on system evaluation criteria and a set of self-testing materials, comprising datasets (both hard copy and digital) and a task list, to the 14 Members which had offered to share their systems with other Members.

A small CCl Task Team met at the WMO Secretariat in Geneva from 5 to 9 February 2001 to analyse the self-testing results so far received and to plan the on-going evaluation process. Seven Members (Australia, Brazil, the Czech Republic, Jordan, the Russian Federation, Tunisia and Zimbabwe) submitted responses to the criteria questionnaire and six of them also submitted self-testing results. The evaluation for each system identifies which functions comply with requirements, which only partially comply, and which do not. An iteration stage is now taking place with some of the self-testing results being re-submitted and re-evaluated until the evaluation fairly describes the system and can be made available to Members. Descriptions of the offered systems and results of the assessments will be made available to Members via a password-restricted WMO Web page. Members will be encouraged to move to one of these next-generation client/server CDMSs that are being offered for sharing. They will be able to consult the "evaluation" Web page to see which, of the offered systems best meets their needs. VCP aid will be sought to help facilitate this transition from the previous CLICOM project software.

ATMOSPHERIC RESEARCH AND ENVIRONMENT PROGRAMME

GLOBAL ATMOSPHERE WATCH

Installation of Dobson spectrophotometer in Armenia

Since 1999, the Meteorological Observatory Hohenpeissenberg (MOHp) of the German Weather Service has served as the GAW Dobson spectrophotometer calibration centre for Regional Association VI, in collaboration with the Solar and Ozone Observatory, Hradec Kralove (SOO-HK), of the Czech Hydrometeorological Institute. In this role, the MOHp received Dobson instrument No. 44 from the University of Cologne in 1998 in order to repair and calibrate the instrument prior to its deployment in the GAW global ozone monitoring network. The work was undertaken by experts from MOHP, SOO-HK and the USA. Subsequently, Armenia was selected as the permanent site for ozone observations using this instrument. Dobson operator train-

A Dobson spectrophotometer has been installed in Armenia as part of the GAW global ozone monitoring network.

ing was provided to scientists from the Armenian Hydrometeorological Service at both MOHp and SOO-HK during 2000 with the instrument being sited at Nor Amberd (40°23'N, 44°15'E; elevation 2 070 m).

The Global Atmosphere Watch continually looks for ways to improve the global coverage of ozone observations and is highly appreciative of the individual efforts of Messrs Matthias Lugauer (MOHp) and Martin Stanek (SOO-HK) in this initiative. The cooperation and enthusiasm of the Armenian hosts are important factors in the continuing success of this project.

Workshop on Understanding Ozone Trends

In recent years, continued observations and analyses have raised a number of questions about how well past ozone changes can be explained in quantitative terms. In particular, the roles of changes in atmospheric dynamics, stratospheric aerosol loading and halogen loading have been assessed in a number of ways. However, there is no general consensus on the relative contributions of these factors or how to assess them in a consistent manner.

In an attempt to address these matters, a Workshop on Understanding Ozone Trends was organized at the initiative of SPARC and the International Ozone Commission in close conjunction with the co-chairs of the Montreal Protocol Science Assessment Panel and WMO's Global Atmosphere Watch programme. The meeting took place at the University of Maryland, USA, from 7 to 9 March 2001. The results of the workshop will feed directly in to the quadrennial ozone assessment process involving WMO, UNEP, the European Commission and NASA and NOAA of the USA. The assessment will be released in 2002 and serves the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer.

APPLICATIONS OF METEOROLOGY PROGRAMME

AGRICULTURAL METEOROLOGY PROGRAMME

Scientific Advisory Committee (SACOM) of the African Centre of Meteorological Applications for Development (ACMAD)

WMO was represented at the fifth session of SACOM at the National Meteorological Service, Casablanca, Morocco, from 1 to 3 February 2001. A number of important aspects of ACMAD's scientific programme

Casablanca, Morocco, February 2001—Participants in the fifth session of the Scientific Advisory Committee of the African Centre of Meteorological Applications for Development

were discussed. These included: scientific and technical matters raised by the eighth and ninth sessions of the Board of Governers; nomination of senior professional staff; evaluation of the current programmes of ACMAD; independent evaluation of the ACMAD programme by ECA, WMO and other partners; implementation plan for 2001-2002 and the main features of long-term planning.

Governing Council of the International Fund for Agricultural Development

WMO was represented at the twenty-fourth session of the Governing Council of IFAD in Rome from 20 to 22 February 2001. The President, Mr Fawzi Hamad Al-Sultan presented a progress report. The President of Egypt, HE Hasni Mubarak, addressed the session.

Important issues discussed included the appointment of the President of IFAD; reports on the fourth and fifth replenishment of IFAD's resources; the proposed budget for 2001; progress reports on the process re-engineering programme, the popular coalition to eradicate hunger and poverty, and the global mechanism for the United Nations Convention to Combat Desertification.

The Governing Council appointed Mr Lennart Båge of Sweden as President of IFAD for a term of office of four years with effect from 1 April 2001.

RA VI Working Group on Agricultural Meteorology

A meeting of the RA VI Working Group on Agricultural Meteorology was held at the Headquarters of the Hungarian Meteorological Service in Budapest from 26 to 28 February 2001.

The meeting was opened by Dr Zoltan Dunkel, Chairman of the Working Group. Dr Ray Motha, president of the Commission for Agricultural Meteorology gave the opening remarks.

Budapest, Hungary, February 2001 — Participants in the RA VI Working Group on Agricultural Meteorology assembled around a sculpture at the Hungarian Meteorological Service

Members reviewed the terms of reference of the Working Group. Following a short report from the chairman, members reported on a range of topics, including effect of climate and weather on quality and storage capacity of grapes, spring barley and tomatoes; conservation aspects of environmental resources and agricultural methodologies that describe quantitatively the pollution of water and air resources; recent developments in remote-sensing as a tool for detection of droughts, forest fires, frost risks etc.; cost/benefit ratios of the provision of agrometeorological information; information campaigns and training of farmers' associations and water-resource managers regarding the use of agrometeorological forecasts and products; review of the state-of-the-art of education in agrometeorology in Europe; and the status in Europe of weather-dependent agrometeorological growth simulation models with potential for operational crop-state monitoring and yield forecasting.

Members discussed the contents of the reports of the chairman and the final technical report of the Group which will be submitted to the thirteenth session of RA VI in 2002. A timetable for submission of the final report was discussed and adopted. A number of recommendations, especially regarding the issues to be tackled by the next session of the Working Group were made.

Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) of the Convention on Biological Diversity

WMO was represented at the sixth meeting of SBSTTA in Montreal, Canada from 12 to 16 March 2001. The plenary session considered progress reports on ad hoc technical expert groups, assessment processes, marine and coastal biodiversity, and inland water ecosystems.

Delegates met in two working groups. Working Group I focused on invasive alien species (IAS). It also produced recommendations regarding options for future work and reconsidered the Guiding Principles. Working Group II considered scientific assessments, the Global Taxonomy Initiative, climate change and biodiversity (including cooperation with the UN Framework Convention on Climate Change (UNFCCC)), and migratory species. The recommendations from SBSTTA-6 will be forwarded to the sixth meeting of the Conference of the Parties to be held in The Hague, the Netherlands, 8-19 April 2002.

Dr Robert Watson, Chair of the Intergovernmental Panel on Climate Change (IPCC), presented a summary report of key climate and biodiversity interactions and scientific data relevant to climate change.

SBSTTA underlined the urgent need to address climate change as a major cause of biodiversity loss, and recommended immediate action under the CBD and UNFCCC to mitigate the impacts. It initiated a pilot assessment of the linkages between climate change and biodiversity, established terms of reference for the ad hoc technical expert group, and invited the IPCC to contribute to this assessment process by preparing a technical paper and identifying experts. It suggested assessments be made on the basis of the ecosystem approach and invited other relevant organizations to contribute. It requested formation of a joint liaison group between the Bureaux of the subsidiary bodies of the CBD and UNFCCC.

The subject of marine and coastal biological diversity received considerable attention from the delegates. Many highlighted the climatic interference with coral reef habitats and the need for cooperation with relevant organizations. In the framework of the ongoing dialogue between the CBD and IPCC regarding the impacts of climate change on coral reefs, the following activities are included as possible elements of a work plan on physical degradation and destruction thereof: assessment and indicators, management, capacity building, financing, education and public awareness.

Under the agenda item on IAS, delegates called for consideration of species shifts resulting from climate change. SBSTTA urged Parties, multilateral organizations and others to consider the potential effects of global change on the risks of IAS.

CAgM reports

- WMO/CAgM Related Achievements in Agricultural Meteorology, by W. Baier (No. 83);
- Report of the RA I Working Group on Agricultural Meteorology, by A.L. du Pisani, G. Goroza,

J.G. Kabira, M.V. Laing, R. Lekhal, M.F. Lukando, A. Makarau and E. Mersha (No. 84);

- Agrometeorological Information Needs in Agricultural Production, Report of the Working Group on Validation of Information Requirements for Agricultural Crops, by P.D. Jamieson, A.D. Agbangla, P. Diemer, S.S. Jagtap, F. Lansigan, J.F. Strand, V.N. Strashny and S. Wang (No. 85).

HYDROLOGY AND WATER RESOURCES PROGRAMME

International Conference on Freshwater

The year 2002 will see the 10th anniversary of the United Nations Commission on Environment and Development which was held in Rio de Janeiro, Brazil, in June 1992. A major event is being organized for the later part of 2002 in Johannesburg, South Africa, to commemorate the event and review progress in the implementation of the recommendations adopted.

An extensive series of regional and sectorial meetings will be held in preparation for the Johannesburg Conference. Of particular importance to the freshwater community will be the International Conference on Freshwater in Bonn, Germany, from 3 to 7 December 2001. Participants will include representatives from national governments, international organizations and non-governmental organizations. The aim is to go beyond a review of past achievements and failures to deliver clear, forward-looking messages and encourage concrete action. A review of the progress achieved in the implementation of freshwater-related objectives set out in Agenda 21 (Chapter 18) will serve to identify remaining obstacles and define necessary action.

Issues to be highlighted will include:

- Innovative strategies for water and sanitation for the poor: access and affordability;
- Competing water uses: water for food/agriculture, and water for nature;
- Transboundary water issues: lessons learned;
- Protecting water resources: sanitation and pollution prevention (industry, agriculture, human settlements);
- Floods and droughts: prevention and management;
- Governance, management, stakeholder participation;
- New partnerships between public sector, private sector, civil society, science;
- Mobilizing financial resources;
- Technology transfer;
- Capacity building;
- Gender perspective.

The Conference is being organized and hosted by Germany. WMO is represented on the Conference Steering Committee and the Conference Secretariat is provided by German Technical Cooperation (GTZ). Further and more detailed information can be found on the Conference Website: http://www.water-2001.de

The new World Assessment Programme of the UN system

Acceptance of the need for a more people-oriented and integrated approach to water management and development has gradually evolved as a result of a number of major conferences and forums. The Mar del Plata Action Plan of the UN Water Conference (1977), the Dublin Conference on Water and the Environment (1992) and the Rio Earth Summit (1992), with its Agenda 21 document, and the World Water Vision exercises of 1999-2000 have successfully reinforced the need for comprehensive assessment of the world's freshwater as the basis for more integrated water management. As urged by the Commission on Sustainable Development and endorsed by the Ministerial Conference at The Hague in March 2000, the UN Administrative Committee on Coordination Subcommittee on Water Resources (ACC/SWR) has undertaken a collective UN system-wide continuing assessment process—the World Water Assessment Programme (WWAP).

The UN system, through the ACC/SWR, has the mandate, credibility and capacity to take on the task of systematically marshalling global water knowledge and expertise to develop over time the necessary assessment of the global water situation, as the basis for action to resolve water crises.

The WWAP, building on the achievements of many previous endeavours, focuses on assessing the developments as regards freshwater throughout the world. The primary output of the WWAP will be the biennial World Water Development Report (WWDR). The Programme will evolve with the WWDR at its core. Thus there will be a need to include data compilation (geo-referenced meta-databases), supporting information technologies, data interpretation, comparative trend analyses, data dissemination, methodology development and modelling. The recommendations from the WWDR will include capacity building to improve country-level assessment, with emphasis on developing countries. This will include the building of capacity in education and training, in monitoring and database science and technology and in assessment-related institutional management. The

Programme will identify water crises and will thus provide guidance for donor agencies, as well as the knowledge and understanding necessary for further capacity building.

The Programme focuses on terrestrial freshwater, but will link with the marine near-shore environments and coastal zone regions as principal sinks for land-based sources of pollution and sedimentation and as areas where the threat of flooding and the impact of sea-level rise on freshwater resources would be particularly acute.

The Programme, including the new WWDR, is undertaken by the UN agencies concerned, aided by a Trust Fund, donors providing support in cash and in kind, either through specific agencies or through the Trust Fund. UNESCO currently provides and manages the Trust Fund and hosts the WWAP Secretariat at its Headquarters in Paris.

The WWDR will be a periodic review, continuously updated, designed to give an authoritative picture of the state of the world's freshwater resources and our stewardship of them. It will contain indicators and analyses that will identify, diagnose and assess:

- The effectiveness of societal stewardship of global freshwater resources, including the broad institutional and socio-economic context of water resource utilization;
- The supply, demand and uses for water and the challenges of extreme events;
- Current critical problems and emerging threats to freshwater ecosystems and their management.

The WWDR will target all those involved in the formulation and implementation of water-related policies and investments and will aim to influence strategies and practices at the local, national and international levels. While a broad, global picture will be given, particular emphasis will be placed on developing countries, where management capacities are likely to be weaker, with the aim of identifying areas in particular need of attention. It will help lay the foundations for efficient and effective capacity building in areas where stewardship challenges are great.

The involvement of national governments, as the prime beneficiaries of the process, will be actively sought. This is considered a pre-condition for the high-quality continuation of data collection and analysis, and for the subsequent credibility and sustainability of the report.

The preparation of the WWDR will be a joint effort of the UN and its member States to collect and prepare reliable data in a harmonized and meaningful manner, while promoting capacity-building and national ownership. The data and information used in the report will come from official sources such as national authorities and basin agencies. National and local governments, institutions and universities, user associations, the private sector, NGOs and national consultants will be involved.

The first edition of the World Water Development Report will lay the foundation for subsequent editions. It will concentrate on an inaugural assessment of progress since the Rio Summit and on developing appropriate assessment methodologies.

A first draft of the WWDR will be presented for discussion at the International Conference on Freshwater that will be held in Bonn in December 2001. A first full edition will then be presented in Johannesburg at the Rio +10 Conference, with the final version being launched at the Third World Water Forum in Kyoto in March 2003.

EDUCATION AND TRAINING PROGRAMME

Publications

Lecture Notes for Training Agricultural Meteorological Personnel

The 1980 edition of WMO-No. 511—*Lecture Notes for Training Class II and Class III Agricultural Meteorological Personnel*—based on a draft by Dr J. Lomas and completed and finalized by Dr W. R. Gloyne has been revised and updated as a second edition entitled *Lecture Notes for Training Agricultural Meteorological Personnel* by Prof. Jon Wieringa, from the Wageningen Agricultural University (Netherlands) with the assistance of Dr Lomas.

Given the importance of small-scale exchange of various forms of energy when dealing with agrometeorological subjects, the publication includes several chapters on boundary-layer physics and surface- energy balance. Since wind provides transport for surface-energy exchange, one chapter presents and discusses small-scale wind dependence on local terrain. Other subjects are the possibilities of managing small-scale agricultural climate, a review of weather hazards threatening crops (such as drought, hail, fire and pollution), some general aspects of agrometeorological operations (such as forecasting), and special observational agrometeorological needs. The appendices include lists of references and recommended publications, unit conversion factors and other parameters in use.

Notes for the training of instructors in meteorology and operational hydrology

Part I of "Notes for the training of instructors in meteorology and operational hydrology" has been released as

WMO/TD No. 1058 (Education and Training Programme ETR-16).

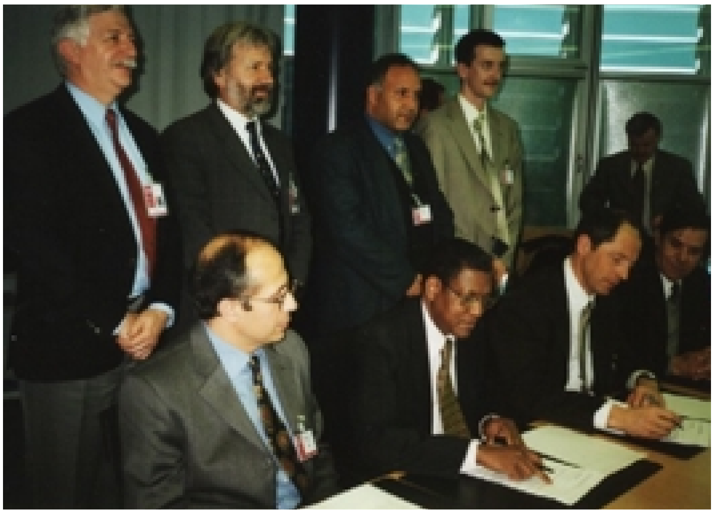
Prepared under the guidance of Geoffrey M. Rudder as main editor, this publication includes chapters dealing with instructional design, training delivery, the use of educational technology in training and putting theory into practice, and an annex containing references to materials for training the trainer.

It aims at helping meteorological and hydrological instructors update their know-how on teaching methods, strategies and technologies. It is hoped that the text will serve as a guide and reference to both new and experienced instructors. The publication is available for downloading from the Education and Training Web page.

TECHNICAL COOPERATION PROGRAMME

Libyan Arab Jamahiriya

The Libyan and UNDP authorities have approved the large-scale project entitled "Modernizing the Libyan Meteorological Services". The project aims to enhance the capability of the Libyan Meteorological Department (LMD) to contribute effectively to the socio-economic development activities of the country. This will be achieved through upgrading and expanding the national observing meteorological network of stations, as well as specialized observing stations, establishing an automatic data-processing system, upgrading the telecommunication facilities, improving public awareness through the set-up of a TV weather presentation studio, enhancing the weather forecasting through the provision of satellite ground-receiving and imaging systems, and flood and marine warnings, as well as management of water resources. The duration of the project is for three years with total allocations of US$ 7 million



Geneva, 16 March 2001 — Signing of the contract between WMO and Météo-France on implementation of the project "Modernizing the Libyan Meteorological Services": (from left to right (seated)) Messrs Claudio Caldarone, Deputy Resident Representative, UNDP Tripoli; H.M. Diallo, Director, Technical Cooperation Department (WMO); Patrick Bénichou, Export Manager, Météo-France; Abdurrahman Sherif, National Project Manager (LMD), Chairman of Project Committee; (standing) Messrs G. Necco, Dictor, Education and Training Department (WMO), J.-M. Rainer, Chief, Telecommunication and Monitoring, World Weather Watch Department-Basic Systems (WMO); Ahmed Elhaj, Technical Director (LMD); and Hervé Grimaud, Project Manager (Sofréavia)

In implementing the project, familiarization tours were organized for Libyan specialists in some developing and developed Services to update their knowledge with new technologies being used by these Services. As a result, a contract was signed between WMO and Météo-France in the presence of Libyan and UNDP representatives on 16 March 2001 for implementing some of the components.

Manpower development constitutes a large part of the allocations made for the project, including academic training in the field of meteorology and its application, which is foreseen in the United Kingdom and other training institutions. In addition, technical training for Libyan specialists is being provided within the contract concluded with Météo-France.

United Arab Emirates

Taking into consideration the growing high-level concern in certain countries and regions at the inability to meet demands for freshwater within the limited resources available, the Office of the President of the United Arab Emirates established a Department for the Studies of Water Resources. The Department has signed a contract with the University Corporation for Atmospheric Research (UCAR), Colorado, USA, to carry out studies and field experiments on the cloud characteristics over the country and the possibilities for rain enhancement.

In order to assist in conducting the studies, a large-scale project aimed at the collection of meteorological information through a network of weather radars and automatic weather observing stations covering all climatological regions of the country was approved in October 2000. Implementation of the project commenced with the procurement of 30 automatic weather stations and a number of weather radars. Calibration of installed weather radars was also completed. The project is foreseen to be completed by the end of 2001 or early next year with a total input from the Government of almost US$ 6 million covering provisions for equipment, consultancy missions, subcontracts and manpower development.

Tripartite review meetings on the UNDP/WMO government cost-sharing projects entitled "Strengthening of meteorological services to the armed forces" and "Strengthening of the meteorological services in the United Arab Emirates" were carried out in January 2001. Satisfactory progress has been reported on the implementation of the first project. During the last year, in addition to consultancy services, the military forecasting centre was equipped with the required facilities, including a climatological database and satellite-receiving equipment. The completion of the project is scheduled for December 2001.

Concerning the second project, it was successfully completed in December 2000, following the build-up of the National Meteorological Service with its various sections, including the Central Forecasting Office, the Meteorological Data National Bank, the Repair and Maintenance Workshop, Meteorological Communication Centre and Ozone Measurement Station.

Seventh Climate Outlook Forum for the Greater Horn of Africa

The seventh Climate Outlook Forum for the Greater Horn of Africa (GHACOF-7) was held in Morogoro, United Republic of Tanzania, from 14 to 16 February 2001. It was organized by the Drought Monitoring Centre, Nairobi, under the framework of the USAID/WMO trust fund project "Applications of meteorology to the reduction of climate and weather related risks to food security, water resources, and health for sustainable development in the Greater Horn of Africa sub-region" . The main objective was to formulate a consensus forecast for the March-May 2001 rainfall season in the Greater Horn of Africa. This region is sometimes referred to as the Eastern Africa subregion, comprising Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, Sudan, the United Republic of Tanzania and Uganda. Participants came from Meteorological Services of the 10 GHA countries, the Democratic Republic of Congo and climate scientists and other experts from national, regional and international institutions and organizations. More than 140 participants attended the meeting. The European Centre for Medium-Range Weather Forecasts, the United Kingdom Met Office, and the National Centre for Environmental Prediction supplied additional inputs for the Forum.

The Forum reviewed the state of the global climate system and its implications for the subregion. It examined the evolution of the 1998-2000 La Niña episode and the SSTs over the Pacific Ocean, as well as the SST anomalies over the Indian and Atlantic Oceans and other factors that affect the climate of the subregion. These factors were assessed using coupled ocean-atmosphere models, statistical models and expert interpretation. The Forum established probability distributions to indicate the likelihood of above-, near- or below-normal rainfall for each zone. The Forum also concluded that there was increased likelihood of near-normal rainfall occurring over most of the Greater Horn of Africa subregion for the period March-May 2001. However, probabilities favoured above-normal rainfall to occur over Burundi, Rwanda, and most of the United Republc of Tanzania. Considering that some parts of the subregion had experienced drought conditions for the past several seasons, it was felt that the accumulated rainfall deficits in some of these areas might not be offset, even if normal rainfall conditions were realized. Users were, therefore, strongly advised to keep in contact with their respective National Meteorological Services for interpretation of this outlook, updates and additional guidance.

Support to the Implementation of the Regional Haze Action Plan of ASEAN Member Countries

A Memorandum of Understanding between WMO and the UN Economic and Social Commission for Asia and the Pacific was concluded in November 2000 for the implementation of a joint project entitled "Support to the Implementation of the Regional Haze Action Plan of ASEAN Member Countries", with total financing (US$ 250 000) from the Government of Australia. The participating countries in the project are Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore and Thailand.

Within the framework of the project, WMO will undertake a number of activities, including:

- Organization of two training workshops in Jakarta and Singapore; in Jakarta to review the needs of monitoring/modelling activities and training; and in Singapore to finalize actions and to coordinate with other ongoing programmes;
- Procurement of aerosol mass measuring equipment to be installed in the participating countries, if knowledgeable personnel are available such as at the University; and

- Review of existing monitoring methodology, and consultation with the ASEAN Specialized Meteorological Centre in this respect.

The project implementation started by appointing a principal consultant and preparing the workshops. The duration of the project is 18 months.

IN THE REGIONS

Russian-Belarusian scientific conference

Results of the 1998-2000 implementation of the joint Russian-Belarusian Programme for the "perfection and development of a common technique for the reception, collection, analysis and forecasting, storage and dissemination of hydrometeorological information and data about environmental pollution" and long-term prospects of cooperation between Goskomgidromet (Belarus) and Roshydromet (Russian Federation) between 2001 and 2005.

The conference took place in Kuchino, Russian Federation, from 15 to 17 November 2000. The 48 participants included scientists and specialists from Roshydromet and Gosgidromet, the Permanent Committee of the Union State and the Hydrometeorological Services of Kazakhstan and Tajikistan. The conference examined the results and implementation of the Programme and its basic orientation in the future.

The objectives of the programme had basically been fulfilled and the application of the results had facilitated the more efficient use of hydrometeorological information on environmental pollution, to the benefit of the populations and economies of Russia and Belarus.

Some important outcomes of the Programme, 1998-2001

- Operational techniques had been developed for hydrometeorological forecasting, including a global model for the forecasting of meteorological fields for five to seven days; a hydrodynamic model of short-term weather forecasting with high spatial resolution; and a technique for aviation meteorological forecasting;
- A common technique had been developed and introduced for collecting and processing information, managing databases and forecasting pollution in the environment; the automatic exchange of data for the monitoring of radioactivity had been established;
- New upper-air equipment, soil thermometers, automatic weather stations, cloud-height and visibility-distance measuring instruments, level meters, etc., had been produced and an image-processing technique developed for stand-alone centres receiving satellite data and remote-sensing information on the surface layer of the atmosphere;
- New techniques for the routine processing on a PC of meteorological, hydrological and solar measurement information had been developed and applied, as had a common approach to the compilation of databases, permitting more information to be accessed.

Basic orientation of the Programme, 2001-2005

- The perfection of methods and techniques for the long-term forecasting of natural phenomena for various sectors of the economy; further development of the joint Russian-Belarusian system of meteorological telecommunications with the use of modern information technology, including Internet
- The development of strategies to help various sectors of the economy adapt to climatic changes;
- An assessment forecast of the expected changes to be carried out first of all for temperature and precipitation; climate-change monitoring must be ensured;
- Work to continue on the creation of a common system for monitoring radiation and the development of monitoring methods and techniques for chemical pollution and accidents. Efforts also to continue to focus on the development and use of integrated pollution indices as an objective basis for comprehensive environmental assessments;
- New measurement systems and equipment to continue to be developed for environmental observations;
- Standards to be introduced for measurement-related matters such as calibration techniques and equipment for comparison of instruments;
- New techniques for processing environmental information to be introduced, with a view to unifying databases and ensuring access to information sources;
- The legal conditions to be established for the effective functioning of a Union State

Hydrometeorological Service, as well as a common basis of laws and standards for its activities;

- Skill-enhancement courses, internships, joint seminars, scientific and production-related meetings to be planned; experience acquired by, *inter alia*, the Intergovernmental Council for Hydrometeorology of the Commonwealth of Independent States, WMO and UNESCO to be studied and applied.

Madagascar's National Meteorological and Hydrological Service reaches a century

The National Meteorological and Hydrological Service of Madagascar celebrated its 100th anniversary on 16 February 2001.

The history of meteorology in Madagascar is, however, much longer, being pioneered by Alfred Grandidier in the early 1870s. Unfortunately, the registers containing his observations perished in a fire at Saint-Denis (La Réunion). Only those concerning the period 28 May to 15 July 1870 at Antananarivo survived.

Some landmarks are the following:

- Early 1870s: climatological observations implemented at Sainte-Marie and Nosy Be;
- Early 1880s: the meteorological stations at Farafangana, Mahajanga and Toamasina begin operations;
- 1889: first observations at Antananarivo carried out from the Observatory at Ambohidempona;
- 1889: tropical cyclones in Madgascar and the Mozambique Channel first recorded;
- 16 February 1901: a decree of General Galliéni establishes a national meteorological organization (Agricultural Meteorology Service);
- 1950: Madagascar Meteorological Service installed at Ampadrianomby Antananarivo (present-day headquarters of the Meteorological and Hydrological Administration);
- 19-30 January 1953: first session of RA I (Africa) at Antananarivo;
- 1962: inception of the Madagascar National Meteorological Service;
- 23 March 1986: first celebration in Madagascar of World Meteorological Day;
- 1987: inception of the National Madagascar Meteorological Administration;
- 1989: inception of the Meteorological and Hydrological Administration.

Throughout the year, various activities have been planned to celebrate this anniversary at home and abroad. These include the organization of events for the public, such as tree-planting, lectures and open days; press conferences and briefings, newspaper articles, TV and radio programmes; a video-clip; and a competition for the design of a commemorative logo or stamp.

News & notes

United Kingdom qualifications in meteorology

The Royal Meteorological Society has launched, on behalf of the meteorological services sector, new National Vocational Qualifications in weather forecasting and weather observing. These complement the existing Chartered Meteorologist (CMet) qualification that the Society offers as the ultimate professional qualification for meteorologists. They have been developed with the support of most of the major employers in the meteorological services industry and both the Qualifications and Curriculum Authority and the Scottish Qualifications Authority, which have approved the National Occupational Standards that underpin the qualifications.

At the launch ceremony at The Meteorological Office College, Peter Ewins, Chief Executive of the Met. Office, welcomed the new qualifications on behalf of all the major employers in the sector. He said: "It is important for employers to offer their employees the opportunity for continuing professional development with the chance to gain a nationally recognized qualification and to support them in achieving it".

Dr Richard Pettifer, Executive Secretary of the Society, said:

> *As more and more independent companies appear in the field, there is a need for customers and potential customers to be offered reassurance that professional standards are being maintained. These national qualifica-*

tions and the Chartered status offered by the Society provide this for the first time at every level of the profession.

WMO Professor Mariolopoulos Fund Award

The Mariolopoulos-Kanaginis Foundation is a non-profit-making body, established by an initial grant from Mrs Ekaterini-Nina E. Mariolopoulos in memory of her husband and of her parents, Petros and Eugenia Kanaginis. Its main objectives are the development of the environmental sciences and the preservation of the environment and humanity's cultural heritage.

In 1996, a WMO trust fund was established by the Foundation under the title "WMO Professor Mariolopoulos Fund Award". The award was created in memory of the exceptional contribution of Prof. Mariolopoulos to meteorology and climatology in Greece. It is given for an outstanding research paper in atmospheric sciences published or accepted during the previous two years in a refereed journal by a young scientist (age below 35 years by the date of publication). It is the first award of a UN organization in honour of a Greek scientist.

The Award Committee is composed of representatives of WMO, the European Commission and the Board of Trustees of the Foundation. The first Award was made in 1998 and was conferred on the winner by the Secretary-General of WMO, Prof. G.O.P. Obasi.

In 2000, the Foundation organized the Award ceremony on 2 November at the University of Athens. The first prize was awarded for the papers "New estimates of radiative forcing due to well mixed greenhouse gases" by G. Myhre (Norway) and "Study of the structure of the lower troposphere over Athens using a backscattering LIDAR during the MEDCAPHOT-TRACE experiment: Measurements over a suburban area" by D. Balis, (Greece). An honorary award was given for the paper "Role of lee waves in the formation of solid polar stratospheric clouds: Case studies from February 1997" by E.D. Rivière (France).

Athens, Greece, 2 November 2000 — WMO Professor Mariolopoulos Fund Award ceremony (from left to right): Mr E. Efthimiopoulos (Deputy Minister of Environment); Dr C. Patermann (European Commission); Prof. C. Zerefos (Vice-President of the Mariolopoulos-Kanaginis Foundation); Dr G. Myhre and Dr B. Balis, Award winners

The awards were presented by Mr E. Efthimiopoulos, Vice-Minister of Environment, and Dr Christian Patermann, European Commission.

News from the Secretariat

Secretary-General's visits

The Secretary-General, Professor G.O.P. Obasi, 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 offered to him.

Sir Gilbert Walker Memorial Lecture and Award Ceremony

At the kind invitation of the Government of India and the President of the Indian Meteorological Society, the Secretary-General visited India from 18 to 21 March 2001 on the occasion of the First Sir Gilbert Walker Memorial Lecture and Award Ceremony and the inauguration of the International Conference on Monsoon Forecasting. In his keynote lecture "WMO's contribution to the development of meteorology", the Secretary-General congratulated the Society on its initiative and for the close collaboration it maintains with the India Meteorological Department (IMD).

Prof. Obasi was received by HE Mr Bachi Singh Rawut, Minister of State for Science and Technology, and Prof. V.S. Ramamurthy, Secretary, Ministry of Science and Technology. They exchanged views on a wide range of issues concerning the strengthening of the excellent relationship between India and WMO and on the continued development of the IMD in support of socio-economic development.

The Secretary-General visited the National Centre for Medium Range Weather Forecasting (NCMRWF), the new telecommunication facilities, the New Delhi Regional Telecommunication Hub and the seismological data-processing facilities of the IMD. He was interviewed by the media on a number of subjects, including global warming and the accuracy of weather forecasts.

Prof. Obasi took the opportunity to hold extensive discussions with Dr R.R. Kelkar, Permanent Representative of India with WMO, on the development of the IMD and its relationship with WMO, and regional cooperation. He also met with senior staff and some of the scientists participating in the conference and the award ceremony, with whom he exchanged views on the development of meteorology and in particular on the research and prediction of monsoon.

Regional Association IV (North and Central America)—13th session

The Secretary-General visited Venezuela on the occasion of the 13th session of WMO Regional Association IV (North and Central America) which was held in Maracay from 28 March to 6 April 2001. In his address, Prof. Obasi highlighted some of the developments over the intersessional period that had implications for the activities of the Association and invited the delegates to ensure the effective implementation of regional components of the programmes and activities of the Organization. He assured them of WMO's continued support to the efforts of the NMHSs aimed at strengthening the sciences of meteorology and hydrology, promoting their image and status and in responding to the needs of their respective nations in socio-economic development. Prof. Obasi was decorated with the order of Saman de Aragua, First Class, State of Aragua, Venezuela.

The Secretary-General was received by Prof. Didalco B. Graterol, Governor of Aragua State, with whom he exchanged views on strengthening the excellent relationship between Venezuela and WMO. He also met with General A.J. García, Division of the Francisco de Miranda Air Base, with whom he had fruitful discussions on various matters, including education and training, climate change and mitigation of the impacts of natural disasters.

Prof. Obasi had discussions with Coronel F. Camargo Duque, Permanent Representative of Venezuela with WMO, on the further development of the National Meteorological Service and the participation of Venezuela in the programmes and activities of WMO. He also took the opportunity to discuss matters of mutual interest, including the development of the NMHSs, with the permanent representatives of WMO Members or their representatives, attending the session.

RA IV Hurricane Committee—23rd session

The Secretary-General took the opportunity of his visit to Venezuela to address the closing session of the Regional Association IV Hurricane Committee on 27 March 2001. He congratulated Mr Max Mayfield, Chairman of the Committee, and the members for their significant contributions to the work of the Committee.

He highlighted the contributions of the Committee since its establishment in 1978 in promoting and coordinating activities related to mitigation of the impact of hurricanes in North and Central America and the Caribbean, as well as to the International Decade for Natural Disaster Reduction during the 1990s and the succeeding International Strategy for Disaster Reduction. He urged the Committee to give particular attention to the improvement of the facilities and the capacity of developing countries in the Region and assured the Committee of WMO's continued support to its work.

Administrative Committee on Coordination (ACC)

The Secretary-General participated in the First Regular Session of the Administrative Committee on Coordination (ACC) for the year 2001 held at the UNEP Headquarters in Nairobi, Kenya, on 2 and 3 April 2001. The ACC focussed its discussions on the challenges of globalization in the context of the follow-up to the Millennium Summit, African development and the review of the ACC structure for increased effectiveness. As for the implementation of the Summit recommendations, the ACC agreed on a number of measures primarily addressed to the UN system organizations. In this regard, the ACC placed emphasis on the eradication of poverty.

The ACC agreed that support to Africa by the international community, including the UN system organizations, was necessary in order to facilitate full implementation of the existing international initiatives on Africa, reverse the resource outflows, and to promote and support capacity building and self-reliance of African countries. Particular attention should be paid to meeting Africa's basic needs such as water, food, security, rational use of land, peace and stability and combating natural disasters such as floods, droughts and tropical cyclones.

In the context of the review of the ACC structure, the Secretary-General emphasized the need for sustained cooperation among the UN system organizations in the fields of water and the oceans. It was essential for ACC to examine its subsidiary bodies, including the Interagency Committee on Sustainable Development related to the follow-up of Agenda 21, especially in the light of the forthcoming World Conference on Sustainable Development, and the Subcommittees on freshwater and on oceans and coastal areas.

Intergovernmental Panel on Climate Change (IPCC)—seventeenth session

The Secretary-General addressed the opening meeting of the seventeenth plenary session of the IPCC in Nairobi, Kenya, on 4 April 2001 and congratulated the Panel for completing the three parts of the Third Assessment Report. He outlined the challenges faced by the IPCC and expressed his satisfaction at the increasing participation in IPCC assessments of experts from developing countries and those with economy in transition and urged the Panel to pursue its efforts in this matter. He thanked donor governments and assured the session of WMO's continued support to the Panel. The Secretary-General took the opportunity to exchange views with Executive Director of UNEP, Dr K. Töpfer, on the strengthening of the fruitful cooperation between UNEP and WMO.

During his visit to Nairobi, the Secretary-General was received by the Hon. Musalia Mudavadi, Minister for Information, Transport and Communications, and exchanged views with him on matters related to the strengthening of the collaboration between Kenya and WMO. He also visited the Kenya Meteorological Department, the WMO Subregional Office for Eastern and Southern Africa and the Drought Monitoring Centre (DMC) and had discussions with Dr Joseph R. Mukabana, Permanent Representative of Kenya with WMO, and staff of the DMC and the Subregional Office.

International Symposium on Challenges of Water Resources Management in the Developing Countries in the 21st Century

At the kind invitation of Prof. R. Radhakrishna, Vice-Chancellor of Andhra University and of Prof. U. Aswathanarayana, Chairman of the Organizing Committee, the Secretary-General inaugurated the International Symposium on Challenges of Water Resources Management in the Developing Countries in the 21st Century (Visakhapatnam, India, 6-9 May 2001). In his opening statement, the Secretary-General expressed his appreciation to the University for its pioneering work in promoting the geophysical sciences in India. He also paid tribute to the late Prof. Mahadevan in whose honour the Mahadevan Centre for Water Resources Management was being inaugurated at the University. The Secretary-General welcomed the initiative and recalled the various programmes of the Organization from which the Centre could benefit through the Indian Meteorological Department.

At the kind invitation of Prof. A.R. Subramanian, President of the Visakhapatnam Chapter of the Indian Meteorological Society, the Secretary-General delivered the 2nd Koteswaram Memorial Lecture entitled "Addressing climate change—role of the World Meteorological Organization". He was honoured by the Association of Hydrologists of India and by the Visakhapatnam Chapters of the Meteorological and Agrometeorological Societies of India. The Secretary-General recalled the important contributions of Prof. Pancheti Koteswaram, a former Vice-President of WMO and a member of the WMO Executive Council, to the promotion of research and training, operational activities in meteorology and in international cooperation. The Secretary-General took the opportunity to exchange views with a number of scientists, as well as members of the academic community of Andhra University on the advancement of meteorology and hydrology and their applications to socio-economic development.

TWAS Officers' Meeting and Interacademy Panel on International Issues Workshop

At the kind invitation of Prof. M.H.A. Hassan, Executive Director of the Third World Academy of Sciences (TWAS), the Secretary-General participated in the TWAS Officers' Meeting, on 15 May 2001, and in an Interacademy Panel on International Issues Workshop on the theme "Capacity building for academies in Africa", Trieste, Italy, 16-18 May 2001. The TWAS considered a number of issues related to its development and in particular its Strategic Plan III: 2001-2004. The Secretary-General stressed the need for the Academy to promote meteorological, oceanographic and hydrological services in support of sustainable development. In particular, the Academy considered the project on promoting best practices for conservation, management and sustainable use of water resources in the south, which had been supported by WMO and UNESCO. The Academy will give priority to the issue of water in the Third World.

The Interacademy Workshop reviewed the status of African Academies in terms of their strengths, weaknesses and needs. It noted the experience of academies outside the Region, and discussed strategies and plans for strengthening existing national academies or establishing new ones so that progress in science and technology could be harnessed for the sustainable development of Africa. The Secretary-General chaired a Panel of Ministers of Science and Technology on capacity-building in Africa in support of science- and technology-based development.

African Millennium Science Initiative Task Force Meeting

At the kind invitation of Dr Philip A. Griffiths, Director of the Institute for Advanced Studies at the University of Princeton, USA, and Chairman of the Board of the Science Institutes Group, the Secretary-General participated in the follow-up meeting of the African Millennium Science Initiative ((MSI), Nairobi, Kenya, 26 May 2001). The Meeting considered a number of priority issues in the context of scientific fields that contribute to addressing the many challenges facing Africa to support its development. The Meeting reviewed a number of ongoing and proposed projects and identified priority areas to build a foundation for MSI in Africa. In this context, the MSI Task Force Meeting developed concrete proposals for the first phase, including an implementation plan and mechanisms for soliciting support from foundations and institutions and from various governments. The Meeting also agreed on a schedule for follow-up action.

The Secretary-General took the opportunity to discuss with participating scientists and policy-makers matters, in the context of the Initiative, relating to National Meteorological and Hydrological Services and regional centres such as the African Centre of Meteorological Applications for Development and Drought Monitoring Centres.

Staff changes

Appointments

On 26 February 2001, **Mrs Florence GROSFILLEY** was appointed Fellowship Clerk in the Fellowships Division of the Education and Training Department. Mrs Grosfilley is a graduate in business and management from the Institut Supérieur de Gestion in Paris. She also holds certificates in strategic planning and finance from the Manhattan Institute of Management, New York, and in Japanese economy from the


Florence Grosfilley

International Management University of Asia in Tokyo. Mrs Grosfilley's first position was that of part-time financial analyst in the Swiss private sector in 1988. In June 1991, she joined the International Organization for Migration in Geneva, initially as Personnel Clerk and, finally, as Secretary to the Fundraising Support Division. She obtained her first short-term appointment with WMO as secretary to the Building Management Team in 1998. Mrs Grosfilley was then selected for a temporary assignment as Fellowship Clerk with effect from 20 September 2000, which was then converted into a one-year fixed-term appointment .

On 1 March 2001, **Ms Haleh Yasrebi** was appointed Senior Data-processing Clerk in the Observing System Division of the World Weather Watch, Applications Department. Ms Yasrebi holds a Master's degree in Computer Science from the University of Geneva. Before joining WMO, she had worked in the Swiss private sector, first as a Developer and User Assistant, then as an Analyst-Programmer. Following her Master's degree, she worked as a Research Assistant at the University of Geneva. She also worked for an American civil engineering company until 1999, when she was hired as consultant and then as programmer analyst in the World Health Organization, where she stayed until her appointment with WMO.

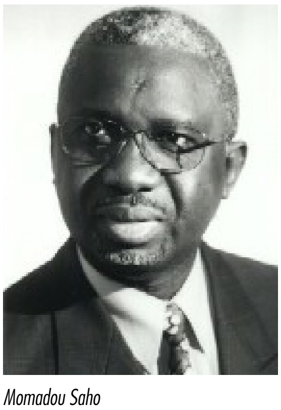

Haleh Yasrebi

On 1 March 2001, **Mr Tomiji MIZUTANI** was appointed Senior Budget Officer in the Finance and Budget Division, Resource Management Department. After a B.A. in Chinese Studies from the Tokyo Metropolitan University; Mr Mizutani obtained a bachelor of laws degree in Japanese and international law from Chuo University (Tokyo) and "Diplômes d'Etudes

Approfondies" in Philosophy from the Sorbonne (Paris) and in Canon law and the History of law from the University of Paris XI. He also holds several MBA-level certificates, including public sector management and performance management. Mr Mizutani is a registered student of the Chartered Institute of Management Accounting in London. His career began in April 1989 as an expert in Japanese law for the Swiss Institute of Comparative Law in Lausanne. He subsequently worked as Assistant Budget Officer at UNESCO, Paris, and as Programme Budget Coordinator at the Universal Postal Union in Berne. In 1995, he transferred to the United Nations International Drug Control Programme in Vienna as Programme Budget Officer. In 1999, he moved to Geneva as Research Officer in the Joint Inspection Unit of the United Nations system, from which post he was transferred to WMO.


Tomiji Mizutani

On 1 March 2001, **Mr Momadou M. SAHO** was appointed Scientific Officer in the Agricultural Meteorology Division of the World Climate Programme Department. Mr Saho holds an M.Sc. degree in Meteorology from Leningrad Hydrometeorological Institute and an M.Sc. in Agrometeorology from Reading University, United Kingdom. Mr Saho's first appointment in July 1976 was as Meteorologist in the Gambian Department of Hydrometeorological Services. He became Senior Meteorologist in 1979 and Assistant Director of the Water Resources Department in 1982. In October 1983, he became Director and Permanent Representative of the Gambia with WMO. As such, he contributed to the establishment and development of the WMO/CILSS Regional AGRHYMET Project and Regional Training Centre. He was technical adviser to the Gambia River Basin Organization, Secretary of the National Water Resources Council and a member of the WMO Executive Council. As of 1988, Mr Saho collaborated with WMO as a consultant on various national and regional projects aimed at the development of NMHSs. From 1995, until the date of his appointment, he was a consultant in the External Relations Office of the WMO Secretariat.


Momadou Saho

On 15 March 2001, **Mr Kuniyukji SHIDA** was appointed Programme Manager for Arab States, Asia and the South Pacific in the Technical Coooperation Department. Mr Shida holds a B.Sc. in Meteorology from the Japanese Meteorological College. In April 1984, he was appointed Scientific Officer in the Oceanographical Division of the Japan Meteorological Agency (JMA). He was promoted to International Affairs Officer in 1988 and to Senior Scientific Officer at the El Niño Monitoring Centre in 1994. Mr Shida's most recent post was that of Deputy Head of the Office of International Affairs (April 1996). Throughout his service in the JMA, he collaborated as a consultant on technical cooperation matters with WMO and various NMHSs and participated in meetings of a number of international bodies.


Kuniyukji Shida

Promotion

On 1 April 2001, **Dr Ion Draghici**, Programme Manager in the Education and Training Department, was appointed Chief of the Training Activities Division in the same Department. Dr Draghici entered WMO in June 1992 as Programme Manager in the Office for the Arab States and Europe of the Technical Cooperation Department. When this Department underwent restructuring in November 1994, he was reassigned to the ETR Department.

Transfers

With effect from 10 January 2001, **Mrs Ariella F. GLINNI**, Junior Professional Officer, was transferred from the Technical Cooperation Department to the World Climate Programme Department.

With effect from 19 February 2001, **Mrs Natasha BRUTSCH** was transferred from the post of Personal Assistant to the Secretary-General to the Secretariat of the Global Climate Observing System Office.

Also on 19 February 2001, **Mrs Lunaly ITH-NGUON**, Administrative Assistant in the Secretariat of the Global Climate Observing System Office, was transferred as Administrative Assistant to the newly appointed Director Coordinator for Scientific and Technical Programmes.

Departures

On 28 February 2001, **Mr Daniel GASPARINI** took early retirement from his post of Chief of the Printing Unit in the Publication and Distribution Services Department after just over 25 years of service in WMO. He started initially as an Assembler in June 1972, leaving in March 1973 to join WHO before returning in November 1975 as an Offset Operator and obtaining the position of Chief of the Unit in July 1978.

On 31 May 2001, **Mrs Odina CANTAMESSA** took early retirement from her post of Senior Data-processing Clerk in the Data Management Office of the World Weather Watch, Basic Systems Department. Mrs Cantamessa joined WMO in 1968 as Clerk in the Networks and Telecommunications Division, and obtained a first promotion in January 1974. In September 1980, she was promoted to the post of Data-processing Clerk and the post was upgraded to Data-processing Assistant in January 1990.

Also taking early retirement on 31 May 2001 was **Mrs Marie-Christine CHARRIÈRE**, Programme Assistant in the Atmospheric Research and Environment Programme Department. Mrs Charrière joined WMO in July 1968 as Secretary in the Applied Meteorology Division and was promoted to the post of Senior Secretary in the same Unit in March 1971. From December 1973 to September 1974, she was transferred to act as Administrative Assistant to the Acting Director, Meteorological Applications Department and the appointment was confirmed in October 1974. In January 1981, she was made Administrative Assistant of the newly created Research and Applications Department, combining the former Research and Meteorological Applications Departments. The post was upgraded to Programme Assistant in January 1990.

On 30 June 2001, **Mrs Valerie J. GERARD** retired from her post of Programmer/Analyst in the World Climate Programme Department. Mrs Gerard had worked for WMO under short-term appointments since October 1982 before finally obtaining a fixed-term position in July 1999 under the scheme designed to improve the conditions of service of temporary staff.

Also retiring on 30 June 2001 was **Mr Leontiy M. MIRIDONOV**, Translator in the Languages Division of the Conference and Languages Services Department. Mr Miridonov rejoined WMO as Translator in March 1984 after an absence of just over 4 years and obtained a promotion in May 1990 following the reclassification of his post.

We wish Messrs Gasparini and Miridonov and Mmes Cantamessa, Charrière and Gerard a long and happy retirement.

On 7 April 2001, **Mrs Irma RODENHUIS** (ex Morimoto) resigned from her position of Design/Layout Assistant in the Publications Division of the Publication and Distribution Services Department after nearly 11 years of service, first of all under temporary contracts and, more recently, as a fixed-term member of staff.

On 8 April 2001, **Mr Taysir Mustafa AL-GHANEM** returned to the International Fund for Agricultural Development (IFAD) in Rome after a two-year secondment as Chief of the Information and Public Affairs Office.

We wish Mrs Rodenhuis and Mr Al-Ghanem every success in their future endeavours.

Anniversaries

Mr Harouna M. DIALLO, Director, Technical Coooperation Department, completed 20 years of service on 2 April 2001.

Mrs Margaret J. ANDERSON, Administrative Assistant, World Climate Programme Department, completed 25 years of service on 26 April 2001.

Mr Abderrahmane QARBAL, Stockroom Clerk, Common Services Division of the Resource Management Department, completed 20 years of service on 1 May 2001.

Mr Antonio BELDA EGEA, Offset Operator, Printing Unit, Publication and Distribution Services Department, completed 20 years of service on 4 May 2001.

Mrs Gilda A. SOLAZZO, Documents Assistant, Documents Production Section, Conference and Language Services Department, completed 20 years of service on 25 June 2001.

❀ ❀ ❀

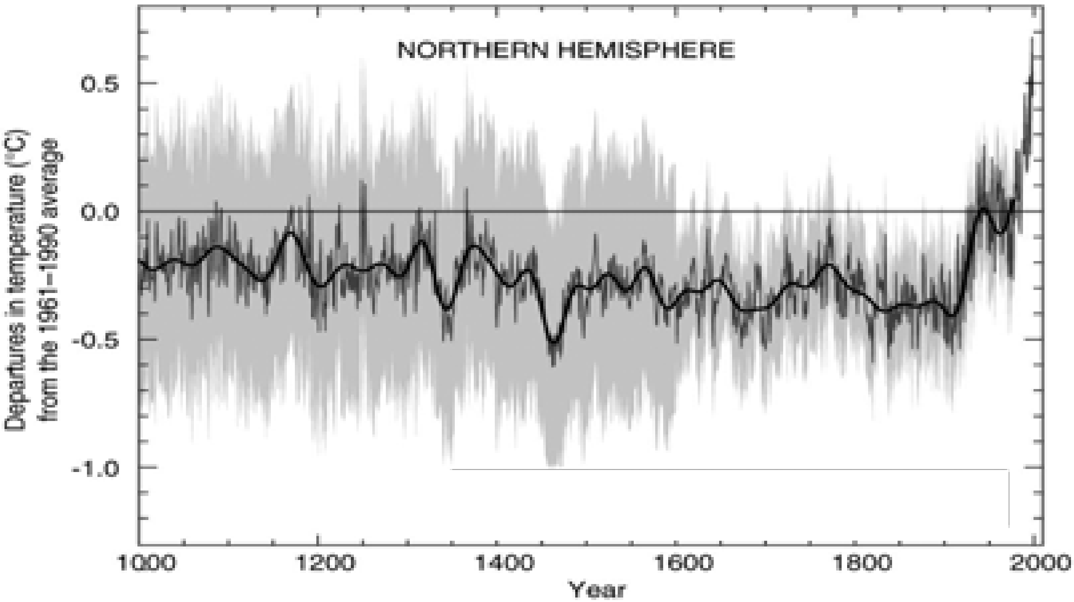
Reviews

Climatic Variability in Sixteenth-Century Europe and its Social Dimension

C. Pfister, R. Brázdil and R. Glaser (Eds.). Kluwer Academic Publishers, Dordrecht (1999). 351 pages; numerous figures. ISBN 0-7923-5934-8. Price: US$ 150.

In the context of the climate history of the last millennium, there has been intense interest in the cooling documented for the 19th century for the northern hemisphere. The figure below shows the trend of northern hemisphere temperatures for the last 1 000 years, with warming in the late 20th century. A key question of any future impacts of global warming concerns the impacts on human society and economics. History can provide valuable lessons on effects of climatic variability on human dimensions. Climatic variability in Sixteenth-Century Europe and its Social Dimension *provides an excellent integration of climate and history studies. It documents the multidecadal cooling of the late 16th century in Europe, resulting in one of the peak cooling excursions of the Little Ice Age epoch. This example of climate variability provides graphic examples of the impacts of a mere 0.5°C cooling in annual mean temperature on society.*

The volume commences with an overview of the documentary evidence and early daily weather observations available from Czechoslovakia, Germany, Hungary, Italy, Spain and Switzerland. This reviewer, who originates from Oceania, where such data are sparse, marvels at the resources that are available in Europe to assemble such a detailed climate history of the region. Evidence from 750 000 records of historical documentary sources is used to reconstruct decadal temperature and precipitation patterns over the region—one of annual temperatures 0.1 -0.3°C below the 1901-1960 average between 1500-1530 (due primarily to the cold decade of the 1510s), with 1530-1560 almost at 1901-1960 levels. From 1560 to 1600, climate cooled with particularly cool seasons in the 1580s and 1590s. Precipitation was above the 1901-1960 average, except in the 1540s. Coldness and wetness increased in Central Europe from 1560 in all seasons, culminating between 1587 and 1597. Tree-ring records from northern and southern Europe confirm these trends.



Northern hemisphere (NH) temperature variations over the last millennium from proxy, historical and instrumental observations (IPCC, 2001). Temperature reconstruction and instrumental data from AD 1000-1999 (data from thermometers and tree rings, corals, ice cores and historical records). Smoother version of NH series and two standard error limits (grey shaded) are shown.

The work then links the climate anomalies to likely circulation patterns, evidence pointing to more north-easterly patterns in winters in the 16th century, and a decreasing occurrence of anticyclonic ridging from the Azores "high" towards central Europe in summer. What is illuminating is that, although some patterns that caused warm and cold climatic anomalies in the 16th century are similar to 20th century patterns, some are not direct analogues, implying that forcing circumstances between the two periods are somewhat different. The late 20th century has greenhouse and aerosol forcing, which was not present during the late 16th century. The other difference is that volcanic forcing may have been a more prominent mechanism in the 16th century.

The strength of the volume comes in the later sections. The first group examines and documents glacial expansion in the late 16th century, flood events in European rivers, and storm surge damage on the Flanders coast. The climatic deterioration in the 1560s caused rapid advances of the alpine glaciers, while a more or less continuous increase in flood events occurred in Germany and Czechoslovakia during the entire 16th century and storm activity on the Flanders coast increased in the second half. These results show the impacts of small temperature, precipitation and circulation changes on glaciers and extreme events. Temperatures decreased by about 0.5°C only, with the climate becoming wetter as the 16th century progressed.

The final collection of papers documents the effects of these climatic variations on agricultural commodity prices, wine production—and witch-hunting! A clear link is made with grain price fluctuations. Wine yields and prices show a more dramatic response. The climatic deterioration from 1586 to 1587 decimated yields, with prices jumping and beer sales tripling in the 1590s. The last contribution links the climatic deterioration to the rise in witch-hunting in the early 1560s.

The quality of all the papers in this collection is excellent and shows the hours of scholarly effort that have been devoted to extracting the information. The authors have advanced the science and methodology of historical climatology to the point where useful information can be obtained through analysis of documentary records. For those interested in the course of the Little Ice Age in central Europe during the 16th century, this volume is a must. It is also an essential work for the bookshelves of those interested in pursuing analysis of documentary and early weather records, as it provides an excellent summary of practical methods in extracting useful climatic information.

Perhaps of more importance are the implications that arise from the multidecadal climate fluctuations. If climatic variability in the order of 0.5°C can cause such dramatic effects on glaciers, flood events and storm surges, agricultural commodity prices, wine yields and other societal effects, then what are the impacts of the projected increasing climatic variability and change during the 20th century? The latest IPCC projections (IPCC, 2001) place temperature increases in the range 1.4 -5.8°C by the end of the 21st century, with likely increases in heavy rainfall events. The lessons from the past tell us that these can only be dramatic.

Reference

IPCC, 2001: *Climate Change 2001 The scientific basis.* J.T. Houghton, Y. Ding, M. Nogua, D. Griggs, P. Van der Linden, K. Maskell (Eds.). Cambridge University Press,.Cambridge, United Kingdom (in press).

J. Salinger
j.salinger@niwa.cri.nz

On the Compatibility of Flexible Instruments

C.J. Jepma and W. van der Gaast (Eds.). Kluwer Academic Publishers, Dordrecht (1999). xii + 169 pages; numerous figures. ISBN 0-7923-5728-0. Price: £61/US$ 105.

The third meeting of the Conference of Parties to the United Nations Framework Convention on Climate Change adopted a protocol in Kyoto, Japan, on 10 December 1997. Article 3 of the Protocol includes a provision that aggregate emissions of greenhouse gases do not exceed their assigned amounts. Three flexible instruments were included to help Annex I Parties achieve this commitment :

- *Joint Implementation among Annex I (JI) Parties;*
- *Helping Non-Annex I parties develop a Clean Development Mechanism (CDM);*
- *International emissions trading (IET).*

A two-day workshop dealing with carbon credits was held in the Netherlands, 28-29 May 1998. Several issues were addressed concerning the flexibility mechanisms of the Kyoto Protocol. This book contains 12 papers delivered at the Workshop, divided into four sections.

The participants came from developed as well as developing countries and their presentations about the issues relating to the commitment towards containing greenhouse-gas emissions were basically driven by national/regional considerations. A wide spectrum of views, therefore, are reflected. Many speakers, including I. Bashmakov of the Russian Federation, talked about the slowness of action in this direction and the need for both private and public support for carbon emission reductions.

An overview of flexible instrument issues by the editors, Jepma and van der Gaast, is the opening piece and sets the stage for the reader to understand this complex subject. Four presentations on the CDM and the setting-up of a clean development fund are made by participants from developing countries (e.g. Pakistan) and developed countries (e.g. Germany). They also trace the similarities between JI and CDM, though one is a top-down mechanism, and the other a bottom-up approach. The system of accrual of credits from CDM projects is also described. The various aspects of a suggested mechanism for credit sharing, including uncertainties, are shown.

The third section deals with greenhouse-gas emissions trading and discusses the various emission trading models. These include intergovernmental emission trading and emission source to government trading. Several administrative, policy-related and monitoring-related issues are presented. This section also addresses the question of equity, which is a crucial area of negotiation in the climate-change issue.

The final section addresses the compatibility of flexibility mechanisms.

Overall, the papers are focused and of good quality. The common aim appears to be a workable environment, where development of CDM is funded and sustained in a manner which is acceptable and beneficial to both donor and recipient nations. This is a complex task because of the existing differences in the political, social and economic priorities of nations.

Though addressed to the specialist, the book is also useful to the general reader who has some knowledge of the Kyoto Protocol.

U.S. De
adgmrpune@hotmail.com

An Introduction to Atmospheric Physics

By D.G. Andrews. Cambridge University Press, London (2000). x + 229 pages; numerous equations and figures. ISBN 0-521-62958-6 (p/b). Price: £17.95/US$ 28.95. ISBN 0-521-62051-1 (h/b). Price: £50/US$ 80.

This textbook provides a concise, accurate and elegant introduction to scientific study of the Earth's atmosphere—its principal physical processes, and wave-motion phenomena. It shows how basic physical principles, together with advanced mathematical methods, can be utilized to understand, model and predict the occurrence and evolution of important weather and climate phenomena.

The book consists of eight chapters, three appendixes, a list of selected bibliographic references, and an index of topics. The conciseness of the text is largely facilitated by the assumption that the reader's knowledge of mathematics and physics is reasonably high, e.g. the level usually required in physical science faculties, upper-undergraduate classes. The accuracy and elegance of the presentation come from the author's scientific excellence and didactic skill—his outstanding knowledge and understanding of the subject, and his constant concern for clarity of communication.

Chapter 1— Introduction—gives an overview of the main topics treated in the book. Viewing the complex Earth-atmosphere system as a simple physical system in thermal equilibrium, the author presents two simple models revealing the crucial role of radiative forcing by the Sun; the second model allows simplified explanations of the so-called greenhouse effect, possible global warming, and stratospheric ozone depletion. The remainder of this chapter illustrates the vertical structure of the atmosphere and introduces two basic types of wave motions in the atmosphere-gravity and Rossby waves; the difficulty of accurately defining the weather and climate in simple physical terms is also touched upon.

Chapter 2—Atmospheric thermodynamics—deals with applications of basic thermodynamic principles to the atmosphere. Meteorologically important concepts and processes, such as the prevalence of the hydrostatic balance in the atmosphere, potential temperature conservation for the adiabatic flow, air parcel, buoyancy oscillations, static stability, and available potential energy are introduced in the first part of this chapter. The second part deals with the moisture in the atmosphere: phase changes of water, Clausius-Clapeyron equation, stability of a moist atmosphere, the tephigram, and cloud formation.

Chapter 3—Atmospheric radiation—is concerned with the transfer of energy within the atmosphere by electromagnetic waves. It starts with an outline of basic physical concepts, Plank's law for the spectral energy density of blackbody radiation, and the application of the local thermodynamic equilibrium concept to the atmosphere. It continues with the derivation of the radiative transfer equation; basics of molecular spectroscopy; infra-red and ultraviolet absorption by atmospheric gases; the principles of the calculation of short-wave heating and long-wave heating and cooling; and the calculation of the resulting net radiative-heating rates throughout the atmosphere. The last two sections are devoted to the greenhouse effect and to the scattering of solar radiation in the atmosphere.

Chapter 4—Basic fluid dynamics—starts with a simple derivation of the Navier-Stokes equation for fluid flow in inertial frame, and its formulation in a rotating frame. After expressing the equation of motion *in spherical coordinates, some fundamental meteorological notations, concepts and approximations are introduced: the Coriolis parameter; the f-plane, geostrophic and hydrostatic approximations; and thermal and gradient wind. The use of pressure rather than height as vertical coordinate, and the meteorological formulation of the first law of thermodynamics are discussed in the last section.*

Chapter 5—Further atmospheric fluid dynamics—provides a rigorous introduction to the theory of atmospheric dynamics. It starts with the fundamental concepts of vorticity and potential vorticity, and the derivation of Ertel's potential vorticity equation; and continues with the presentation of the Boussinesq and quasi-geostrophic approximations, including the derivation and elegant interpretation of the quasi-geostrophic potential vorticity equation. Next, internal gravity waves and planetary Rossby waves are discussed as plane-wave solutions of linearized Boussinesq equations, and of linearized (barotropic) quasi-geostrophic potential vorticity equations, respectively. The last two sections are devoted to the basic theory of the atmospheric boundary layer, and of baroclinic and barotropic instability, respectively.

Chapter 6—Stratospheric chemistry—starts with a presentation of basic physical and chemical principles relevant to the study of atmospheric chemistry: thermodynamics of chemical reactions, chemical kinetics, bimolecular reactions, and photo-dissociation. It continues with application of the various concepts and equations to the study of stratospheric ozone: Chapman chemistry, catalytic cycles, transport of chemicals, and the Antarctic ozone hole.

Chapter 7—Atmospheric remote sounding—provides a physical-mathematical introduction to the theory of atmospheric remote-sounding: remote-sounding from space: satellite measurements of the thermal radiation emitted from, and of the solar radiation backscattered by, the atmosphere; remote-sounding from the ground: spectrophotometer measurements of ultraviolet radiation and calculation of column ozone; radar measurements of the backscatter of radiowaves from water drops and ice crystals in the troposphere, to estimate precipitation rates; and Doppler techniques. Principles of radar and lidar measurements of the backscattering from inhomogeneities in the refractive index for radio propagation in the lower and middle atmosphere, and from molecules and aerosol particles are also discussed.

Chapter 8—Atmospheric modelling—provides a qualitative introduction to the mathematical (numerical solution of fundamental equations) and physical (laboratory analogues) modelling utilized in atmospheric research and forecasting. The author distinguishes three broad categories of physical processes that can be included in atmospheric models: dynamical, radiative and chemical. The complex interactions between the various processes are exemplified in connection with the role of the tropopause in the general circulation, the middle-atmosphere temperature field, and the Antarctic ozone hole.

Students intending a career in meteorology should seriously treat the problems provided at the end of each chapter, because it is through those problems that the book introduces a number of important meteorological applications not discussed in the main text. Solutions and hints for selected problems are given in an appendix; and annotated references given at the end of each chapter may assist the interested reader in further documenting relevant topics.

I.D.

Artificial Neural Networks in Hydrology

R.S. Govindaraju and A. Ramachandra Rao (Eds.). Kluwer Academic Publishers, Dordrecht (2000). xvi + 329 pages; numerous figures and equations. ISBN 0-7923-6226-8. Price: US$ 160.

Artificial neural networks (ANN) have already become a popular tool of researchers for the analysis and prediction of various hydrometeorological phenomena. ANNs are applied in almost all areas where traditional statistical methods were used for decades. The book is a contribution to the most popular application area of ANN in water-related areas. It is a collection of papers, based mainly on the authors' previous publications in peer-reviewed journals. The editors state that the book "gives a fairly accurate picture of the role of artificial neural network applications to hydrologic problems today". We agree with that.

The editors refer to individual contributions as chapters, but we would rather refer to them as papers, for the reasons mentioned below. The presented papers cover quite a wide area of applications: streamflow and precipitation forecasting, subsurface hydrology, subsurface spatial characterization. Papers by Gupta et al.*, Salas* et al. *and Deo and Thirumaliah deal with flow forecasting on various time-scales. Precipitation forecasting is the focus of the papers by Hsu* et al.*, and Dracup and Silverman. Maier and Dandy address the problem of water quality, whereas ANN-based adaptive regulation of river flows is covered by Reddy and Willamowski. Most of the papers, especially those devoted to the issue of subsurface flow modelling (Rizzo and Dougherty, Shin and Salas and others) also provide information about more traditional methods; this gives a practitioner a good basis for comparison.*

ANN is in fact a generic name for a family of connectionist data-driven models. In most of the reported experiments, the traditional model of a multilayer perceptron trained with the backpropagation algorithm is used. Practice shows indeed that this architecture in many cases allows the best results to be achieved. There are, however, cases when other methods are found beneficial. Several papers cover techniques such as self-organizing feature maps—spatial characterization of soil moisture (Islam and Kothari), rainfall estimation from satellite imagery (Hsu and Gupta), and modular neural networks (Zhang and R.S. Govindaraju)—used to perform spatial interpolation of saturated hydraulic conductivity. For practitioners it would be essential to read the paper of Maier and Dandy, where an important issue of data preparation is systematically covered: in many practical applications of statistical and data-driven methods, the problem of proper data analysis and pre-processing should be considered central. It might have been better to place this paper at the beginning of the book.

Concerning the composition of the book, the editors could have given more attention to balancing the description of ANN methodology and practical applications. Almost every paper repeats the general description of ANN architecture. It would have been better to cover the general descriptions of methodology and architecture in the first paper and allow authors to provide more material on the essence of experiments and applications in the subsequent papers. This was actually our motivation to speak of "papers" rather than "chapters" when we mentioned individual contributions.

The approach of classifying models by dividing them into two groups is especially relevant in the context of ANNs, i.e. physically based; and data-driven models. ANN is a representative of the second group, in which the models are based on the data-describing processes and much less on the descriptions of the underlying physical principles. Apart from ANN, other methods include various methods of machine learning such as classification and clustering techniques, association and decision trees, instance-based learning, fuzzy rule-based systems, etc. For example, the self-organizing feature map (Kohonen neural network) covered in this book is representative of a wider class of classification algorithms. In most papers, this positioning of ANNs among other data-driven methods and other modelling techniques in general is not really addressed (an exception is the paper of Maier and Dandy), and experiments sometimes lack proper comparison with other methods. This feature is, however, present in many other publications on ANNs and in many method-oriented publications in general.

The book consists of 12 papers from the USA (with the participation of a researcher from the Republic of Korea), one paper from Canada, one from India and one from Australia. There is an obvious and unfortunate omission of papers from other parts of the world (shall we mention Europe here?). The size of this publication does not allow reference to dozens and dozens of projects and publications of European researchers in this area; interested persons are invited to check European journals and conference proceedings, (particularly of the Hydroinformatics conference) or to perform a search on the Internet or read newsgroup comp.ai.neural. Authors and editors of the book may also find it interesting to get acquainted with the research and practical applications originating form many other countries.

To summarize, this book covers a wide area of various hydrological applications and a reasonably wide spectrum of ANN-related methods. Papers covering the used methodology are clearly and concisely written without unnecessary mathematical details. Applications are presented in most cases at a level that makes it possible to understand their main features. References cover most important works in hydrological applications of ANNs. The book can be recommended as an important (but not the only) source of information on applications of artificial neural networks to hydrological problems. It would be useful for graduate students, researchers and hydrologists.

D.P. Solomatine
sol@ihe.nl
http://www.ihe.nl/hi/sol

Natural Environmental Change

By A.M. Mannion. Routledge Introductions to Environment Series, London and New York (1999). xvi + 198 pages; numerous figures. ISBN 0-415-13933-3. Price: £12.99.

This book has 10 chapters, each of which discusses natural environmental change as evidenced in geology and ocean sediments, with case-studies. The emphasis is on natural, rather than anthropogenic, factors. The end of each chapter carries a box containing important information on methodology or principles for analysing or obtaining data. Also at the end of each chapter is a summary of the important points raised. There is an extensive bibliography.

The first two introductory chapters look at some important theories of famous scientists such as Brückner, Bertalanffy and Wegener, and the geological history of the Earth. We may conclude that earthquakes *and volcanic activity are the two major factor for environmental change in short-term and carbon dioxide and oxygen are key factors in long-term environmental change .*

The following four chapters discuss envionmental change as revealed by data from archives, such as ocean sediments, ice cores, terrestrial deposits (e.g. glacial moraines and lake sediments), tree rings and historical and meteorological records, and the next three chapters consider environmental change at different latitudes.

In Chapter 3 we read about significant advances in the elucidation of the natural environmental change of the last 3 million years from research on ocean sediments.

Chapter 4 looks at the data record of environmental change as contained in ice cores in the Arctic, Antarctic, at Vostok and Prue, and in Mongolia and Tibet. The presence of bubbles in the ice cores offers a unique opportunity to measure directly the composition of the atmosphere and its temporal change .

In Chapter 5, on the basis of physical, chemical and biological techniques, data on environmental change are presented. They cover lake sediments, peats, palaeosols, loess, carbonate deposits and packrat middens. Chapter 6 contains records of catastrophic droughts, floods and famines and their periodicity, which contribute to identifying both natural and anthropogenic climatic change .

Chapters 7, 8 and 9 are concerned with environmental change in high, low and middle latitudes. Most of the evidence for high-latitude environmental change derives from the northern hemisphere, where the direct impact of glacial advance has been experienced.

The last chapter presents conclusions and perspectives. My personal conclusion is that this is one of the most comprehensive books that has been written in this area.

Victoria Ezzatian

Books received for review

Introduction to Atmospheric Chemistry (a companion text to Basic Physical Chemistry for the Atmospheric Sciences)

By P. V. Hobbs. Cambridge University Press, London (2000). x + 262 pages; numerous figures and equations. ISBN 0-521-77800-X(p/b). Price: £15.95/US$ 24.95. ISBN 0-521-77143-9 (h/b). Price: £42.50/US$ 69.95,

Snow and Glacier Hydrology

By Pratap Singh and Vijay P. Singh. Kluwer Academic Publishers (2001). xvii + 742 pages; numerous figures and equations. ISBN 0-7923-6767-7. Price: US$ 265.

Snow Ecology—An Interdisciplinary Examination of Snow-Covered Ecosystems

H.G. Jone, J.W. Pomeroy, D.W. Walker and R.W. Hoham (Eds.). Cambridge University Press (2001). xx + 378 pages; numerous figures and illustrations. ISBN 0-521-58483-3. Price: £50/US$ 80.

Climate Change Impacts on the United States—The potential consequences of climate variability and change

Overview report by the National Assessment Synthesis Team. Cambridge University Press (2001). 154 pages; numerous illustrations in colour. ISBN 0-532-00074-2 (p/b). Price: £12.95/US$ 16.95.

Weather of the 90s—a decade of weather and climate in the UK

By Peter B. Wright. Westwind Services, Newport (2001). 76 pages; numerous figures. ISBN 0-9539710-0-7. Price: £12.95.

Some recent titles from WMO

Forecasting in the 20th Century

By Gordon A. McBean. Ninth IMO Lecture (1999) WMO-No. 916. (2000), English. ISBN 92-63-10916-8. v + 18 pp. Price: SFR 20.

Operational Provision for the Hydrometeorological Safety of the Transport Corridor Europe-Caucasus-Asia (TRACECA)

WMO-No. 917 (2000); English/Russian. ISBN 92-63-00917-1. 24 pp. Price: SFR 15.

Annual Report of the World Meteorological Organization 2000

WMO-No. 918 (2001); English, French, Russian and Spanish. ISBN 92-63-10918-1. iv + 52 pp. Price: SFR 26.

Volunteers for Weather, Climate and Water

WMO-No. 919 (2001). English, French, Russian and Spanish. ISBN 92-63-90919-2. 24 pp. Price: SFR 15.

Commission for Hydrology—eleventh session (2000): Abridged final report with resolutions and recommendations

WMO-No. 921 (2001); English, French, Russian and Spanish (Arabic and Chinese in preparation). ISBN 92-63-10921-4. v + 45 pp. Price: SFR 20.

Exchanging Hydrological Data and Information—WMO Policy and Practice

WMO-No. 925 (2001). English, French, Russian and Spanish. ISBN 92-63-10925-7. 36 pp. Price: SFR 15.

CALENDAR OF COMING EVENTS

Date	*Title*	*Place*
2001		
14-17 August	Air Quality Monitoring and Management	Abuja, Nigeria
27-31 August	Ocean Sciences at the Dawn of a New Millennium	Seoul, Republic of Korea
4-10 September	RA I Tropical Cyclone Committee for the South-West Indian Ocean—fifteenth session	Moroni, Comoros
10-14 September	Fourth International Conference on the Global Energy and Water Cycle	Paris, France
10-14 September	Emergency Response Activities Coordination Group	Washington, DC, USA
10-14 September	Fourth International Conference on the Global Energy and Water Cycle	Paris, France
17-20 September	A Changing Atmosphere	Turin, Italy
18-21 September	International Expert Workshop on Advances in the Use of Historical Marine Data	Boulder, Colorado, USA
19-26 September	Regional Association III (South America)—thirteenth session	Quito, Ecuador
24-28 September	Fifth European Conference on Applications of Meteorology and First European Meteorological Society Annual Meeting	Budapest, Hungary
24-29 September	Eighteenth session of the IPCC	London, United Kingdom
25-27 September	International Conference on Hydrological Challenges in Transboundary Water Resources Management	Koblenz, Germany
25-28 September	Workshop on Typhoon Forecasting Research	Seoul, Republic of Korea
25-28 September	Eleventh WMO Meeting of Experts on Carbon Dioxide Concentrations and Related Tracers Measurement Techniques	Tokyo, Japan
1-5 October	Sixth CO_2 Conference	Sendai, Japan
8-12 October	Inter-Regional Workshop on Improving Agrometeorological Bulletins	Barbados
22-26 October	CAeM Working Group on the Provision of Meteorological Information Required by Civil Aviation (PROMET)	Geneva
26-30 November	RA V Working Group on Hydrology—fifth session	Wellington, New Zealand
27 November	ESCAP/WMO Typhoon Committee—thirty-fourth session	Honolulu, Hawaii, USA
18-22 November	International Workshop on Operational Marine Forecasting	Halifax, Novia Scotia, Canada
5-8 December	Third International Symposium on Environmental Hydraulics	Tempe, Arizona, USA
2002		
13-17 January	American Meteorological Society—82nd Annual Meeting and Exhibition	Orlando, Florida, USA
21-23 January	Third International Symposium on Non-CO_2 Greenhouse Gases	Maastricht, The Netherlands
12-21 February	Commission for Atmospheric Sciences—thirteenth session	Oslo, Norway
6-17 May	Regional Association VI (Europe)—thirteenth session	Budapest, Hungary

*MEMBERS OF THE WORLD METEOROLOGICAL ORGANIZATION**

STATES (179)

Afghanistan
Albania
Algeria
Angola
Antigua and Barbuda
Argentina
Armenia
Australia
Austria
Azerbaijan
Bahamas
Bahrain
Bangladesh
Barbados
Belarus
Belgium
Belize
Benin
Bolivia
Bosnia and Herzegovina
Botswana
Brazil
Brunei Darussalam
Bulgaria
Burkina Faso
Burundi
Cambodia
Cameroon
Canada
Cape Verde
Central African Republic
Chad
Chile
China
Colombia
Comoros
Congo
Cook Islands
Costa Rica
Côte d'Ivoire
Croatia
Cuba
Cyprus
Czech Republic
Democratic People's Republic of Korea
Democratic Republic of the Congo
Denmark
Djibouti
Dominica
Dominican Republic
Ecuador
Egypt
El Salvador
Eritrea
Estonia
Ethiopia
Fiji
Finland
France
Gabon
Gambia
Georgia
Germany
Ghana
Greece
Guatemala
Guinea
Guinea-Bissau
Guyana
Haiti
Honduras
Hungary
Iceland
India
Indonesia
Iran, Islamic Republic of
Iraq
Ireland
Israel
Italy
Jamaica
Japan
Jordan
Kazakhstan
Kenya
Kuwait
Kyrgyzstan
Lao People's Democratic Republic
Latvia
Lebanon
Lesotho
Liberia
Libyan Arab Jamahiriya
Lithuania
Luxembourg
Madagascar
Malawi
Malaysia
Maldives
Mali
Malta
Mauritania
Mauritius
Mexico
Micronesia, Federated States of
Monaco
Mongolia
Morocco
Mozambique
Myanmar
Namibia
Nepal
Netherlands
New Zealand
Nicaragua
Niger
Nigeria
Niue
Norway
Oman
Pakistan
Panama
Papua New Guinea
Paraguay
Peru
Philippines
Poland
Portugal
Qatar
Republic of Korea
Republic of Moldova
Romania
Russian Federation
Rwanda
Saint Lucia
Samoa
Sao Tome and Principe
Saudi Arabia
Senegal
Seychelles
Sierra Leone
Singapore
Slovakia
Slovenia
Solomon Islands
Somalia
South Africa
Spain
Sri Lanka
Sudan
Suriname
Swaziland
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
Yugoslavia
Zambia
Zimbabwe

TERRITORIES (6)

British Caribbean Territories
French Polynesia
Hong Kong, China
Macao, China
Netherlands Antilles and Aruba
New Caledonia

* As of 31 May 2001