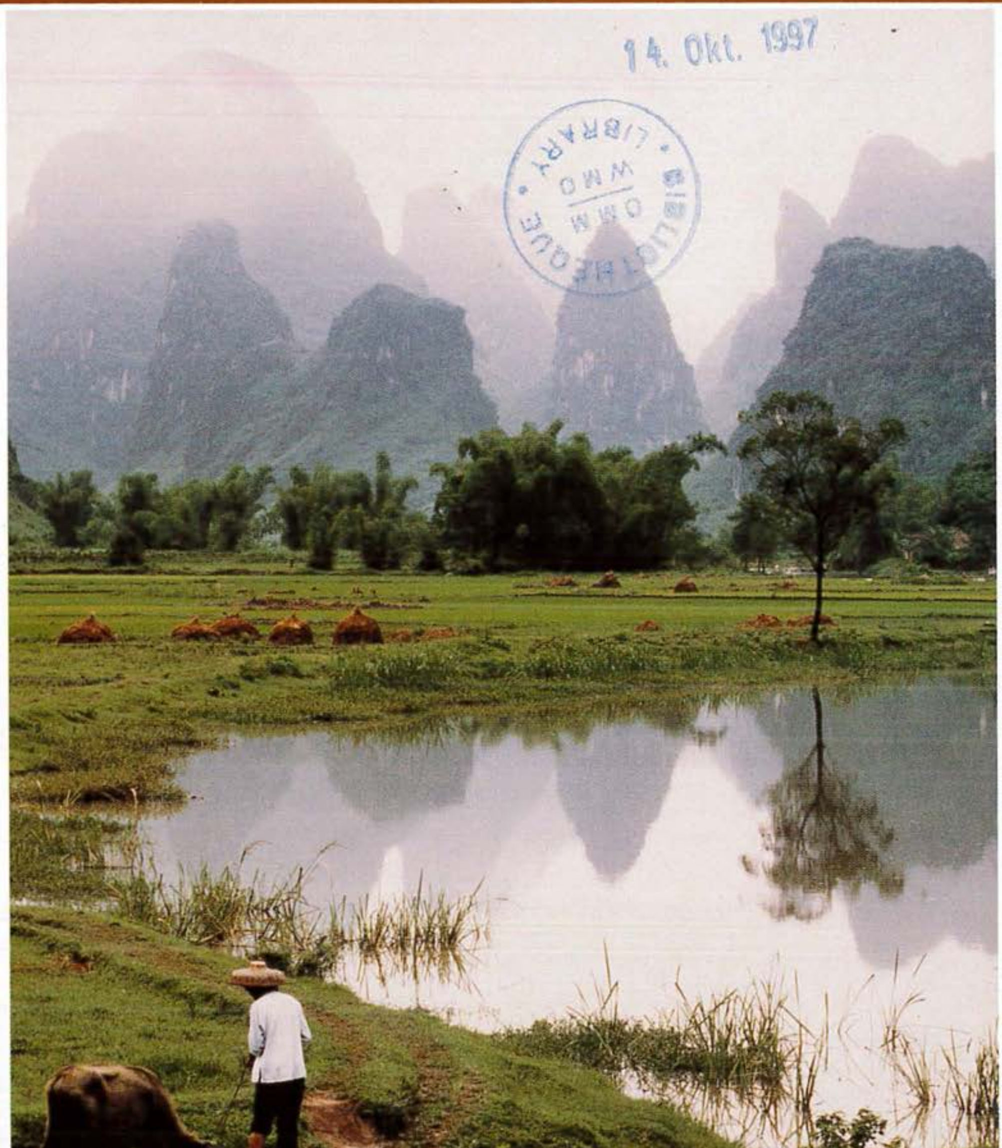
WORLD METEOROLOGICAL ORGANIZATION

BULLETIN



Volume 46 No. 4

October 1997

THE WORLD METEOROLOGICAL ORGANIZATION (WMO)

is a specialized agency of the United Nations

The purposes of WMO are:

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

The World Meteorological Congress

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

The Executive Council

is composed of 36 directors of national Meteorological or Hydrometeorological Services serving in an individual capacity; it meets at least once a year to supervise the programmes approved by Congress.

The six regional associations

are each composed of Members whose task it is to coordinate meteorological and related activities within their respective Regions.

The eight technical commissions

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

THE SECRETARIAT OF THE ORGANIZATION IS LOCATED AT 41 AVENUE GIUSEPPE-MOTTA, GENEVA, SWITZERLAND.

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In this issue

Fittingly enough for an issue whose theme is "Weather prediction", our interview is with the eminent scientist, Prof. Arnt Eliassen of Norway, whose research activities in meteorology spanned more than 50 years. He is the father of another well-known meteorologist, Anton Eliassen, who also makes a brief contribution to this interview.

There follows a detailed description of the ALADIN project for mesoscale modelling for weather forecasting and atmospheric research, written by some of the 110 members of the international scientific team. ALADIN has its roots in the firm belief that international cooperation between NMSs, whatever their technological capacities, is both essential and mutually beneficial (pages 317–324).

Numerical prediction of thunderstorms is the subject of the next article by Kelvin Droegemeier of the Center for Analysis and Prediction of Storms, University of Oklahoma, USA. The author presents results from operational tests which indicate that, in many cases, the atmosphere possesses considerable predictability, even on the scale of individual storms (pages 324–336).

The operational observing network using both conventional and satellite measurements is an expensive one. At a time when radiosondes are being drastically reduced for financial reasons, Graeme Kelly of the European Centre for Medium Range Weather Forecasts explains why there is an urgent need to investigate the importance of different observing systems in numerical weather prediction performance (pages 336–342).

Over the past few years, there have been considerable advances in our capability to make short-term (seasonal to interannual) climate predictions and to use them for socio-economic benefit. Antonio Moura of the International Research Institute for climate prediction (Columbia University, USA) and Ed Sarachik of the University of Washington, USA, paint an optimistic view of the future, when both rich and poor countries share their knowledge, help one another to learn how to make accurate short-term climate predictions, pool their resources and apply the information derived for the benefit of all (pages 342–347).

Michael Douglas of the National Severe Storm Laboratory, Oklahoma, USA, and Walter Fernández of the Laboratory for Atmospheric and Planetary Research, Costa Rica, are the principal investigators of the project entitled "Strengthening the meteorological sounding network over the tropical eastern Pacific Ocean and the intertropical Americas" and are also authors of the article with the same title (pages 348–351). The authors point out that the data obtained are available and free to the scientific community (see page 350).

The feature "Human and economic impacts of weather events in 1996" (pages 351–369) synthesizes and summarizes the reports received from 70 Members. The author, Stan Cornford, would welcome suggestions about ways to improve the assessment and evaluation of impacts of weather for future articles (see page 368).

Concise accounts of the forty-ninth session of the WMO Executive Council and the twelfth session of Regional Association IV (North and Central America) begin on pages 369 and 375, respectively.

A wealth of news about WMO programmes and activities is to be found between pages 379 and 405. Events to commemorate World Meteorological Day and World Day for Water around the globe in 1997, based on contributions from Members, are briefly described in the section "News and Notes".

In view of the abundance of material in this issue, several articles and reviews planned for inclusion have had to be postponed. We extend our apologies to the authors and reviewers concerned.

Cover: The River Li, fed by countless streams and waterfalls, winds serenely through a green carpet of ricefields among the myriads of conical mountains in Guilin, China.

Photo: Alessandra Meniconzi

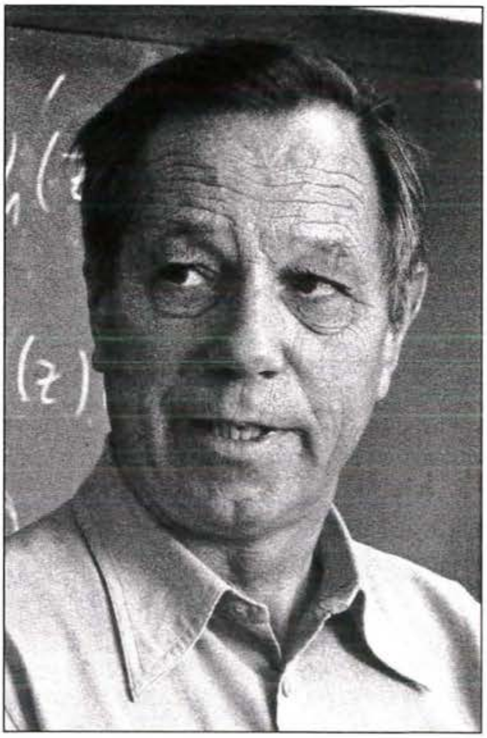
THE *BULLETIN* INTERVIEWS
Professor Arnt Eliassen

To be the recipient of the Balzan Prize is a great honour and a wonderful experience of recognition for an old scientist. The Prize has for the first time been given for research in meteorology; this is a sign that meteorology has now reached a stage of maturity, being firmly based on the laws of physics. The progress is the result of cooperation of scientists in many countries around the world. They should all share this honour with me.

The above statement is an extract from the acceptance speech of Arnt Eliassen in 1996. It reflects the extreme modesty of a man of outstanding talent, a well-known scientist with more than 50 original scientific papers to his credit. His theoretical research has also yielded valuable practical applications. During the 1940s and 1950s, when the science of meteorology was advancing rapidly, Eliassen emerged as one of its leading proponents. The progress of his career was so closely linked to that of dynamic meteorology, and numerical weather prediction (NWP) in particular, that the two can hardly be separated.

Dr Taba recalls the landmarks in Arnt Eliassen's distinguished career:

When the observational network became global (in the 1940s), meteorologists realized more than ever that the atmosphere was in constant flux, consisting of systems of motion on vastly different scales, ranging from tiny eddies to air currents with global circulation. At the beginning of the century, the Norwegian physicist, Vilhelm Bjerknes, advocated that weather prediction could, or should, be based on the numerical integration of differential equations of hydrodynamics and thermodynamics. In 1922, the British physicist, Lewis Richardson, had made the first attempt at predicting numerically the following day's weather; the result was total failure. Fortunately, Bjerknes and his collaborators, Halvor Solberg and Einar Høiland, were still active at the University of Oslo in the field of atmospheric wave motions and vortices. In 1938, Arnt Eliassen attended one of their lectures, became fascinated by their work and decided to continue in meteorology. With the advent of electronic computers after World War II, the situation in meteorology changed radically and atmospheric scientists, who were among the first to use computers, saw the enormous possibilities available to them. At the Institute of Advanced Study in Princeton, USA, and at the initiative of the famous mathematician John von Neumann, a group of scientists, including Jule Charney, developed the principles for a new electronic computer to study NWP. In 1947, Charney visited Oslo, met Eliassen and invited him to join the group in Princeton; he accepted and stayed one year. It should perhaps be mentioned here that the first 24-hour prediction based on Rossby's flat atmosphere was produced by von Neumann, Charney and Ragnar Fjørtoft[1] and published in 1950. That was indeed a breakthrough.



Arnt Eliassen during a seminar at the National Center for Atmospheric Research (NCAR), Boulder, Colorado, USA, in 1974

Photo: NCAR, courtesy Anton Eliassen

During World War II, Eliassen studied the problems faced by Richardson and found that the over-sensitivity of the primitive equations he had used could be minimized by making use of the geostrophic wind approximation: this was

1 Interviewed in *WMO Bulletin* **37** (1)

an important step forward. Similar conclusions were reached by Charney in the USA and by Reginald Sutcliffe[2] *in England. Eliassen also proposed the use of air pressure as a vertical co-ordinate in the atmospheric equations of motion, which led to a considerable simplification of the procedure in numerical integration. With the rapid advances in computing techniques, meteorologists in various countries realized that the time was ripe for leaving aside, at least temporarily, the use of Rossby's flat one-dimensional atmosphere in favour of more sophisticated models. In 1955, Charney and Bert Bolin*[3] *both found, independently, that the primitive equations could be utilized if the initial state were carefully balanced so as to eliminate large amplitude oscillations.*

A major obstacle was the determination of the initial state of the atmosphere from the existing observation system randomly distributed—either too close or too far apart—over the Earth's surface. Here again, Eliassen made an ingenuous proposal based on reducing the mean-square error. Later on, the method was developed by Lev Gandin and used extensively in routine weather forecasting.

One of the fields in which Eliassen made a substantial contribution was mountain waves. His first contacts with meteorology being with Solberg and Høiland at Oslo University, it was only natural that Eliassen should also develop similar interests. He started to study the internal gravity waves which often form when air flows across a mountain ridge. The waves occur on the lee side; they are steady and the air flows through them with clouds formed in the crests. Eliassen and Enok Palm took account of the fact that the waves transfer energy from the mountain upward in the atmosphere and obtained a unique solution with waves occurring on the lee side. "Eliassen-Palm fluxes" are well known and have often been used by meteorologists.

An important problem which occupied the thoughts of many meteorologists in those days was how the strong airflows from west to east (in winter) in the upper troposphere and stratosphere at around 40° latitude were maintained despite frictional damping. Eliassen showed, by mathematical analysis, that the meridional circulations could be at least partly responsible for maintaining the middle-latitude westerlies.

The theory of the polar front and extra-tropical cyclone was introduced by Bjerknes and his research team in Norway at the end of World War I. Tor Bergeron suggested that fronts would form by the meeting of warm and cold air currents and J. S. Sawyer[4] *in Great Britain found that the maintenance of geostrophic equilibrium required the warm air to rise and the cold air to sink as a result of Bergeron's frontogenic flow. With a re-interpretation of the equation for vertical circulations, Eliassen showed that the theory of frontal circulation was closely related to the theory for meridional circulation in a circular vortex.*

During the 1970s, Eliassen conducted extensive research in the field of isentropic formulations of atmospheric models. Although interesting from many points of view, the isentropic coordinate system has not been used widely in numerical weather forecasting or climate simulations, owing to practical difficulties.

Eliassen has been visiting scientist and professor in several institutions outside Norway: the Massachusetts Institute of Technology (MIT), the Universities of Princeton, California Los Angeles and Chicago in the USA; Reading in the United Kingdom; Venice; Warsaw; Helsinki; Stockholm; and Copenhagen. He is a member of the Norwegian Geophysical Society (1947); the gian Academy of Science and Letters (1953); the Societas Scientiarum Fennica *(1966); the* Deutsche Akademie der Naturforscher Leopoldina *(1970); Honorary Member, Swedish Geophysical Society (1981); Honorary Member, Royal Meteorological Society (1982); Foreign Associate, US National Academy of Sciences (1991); Honorary Member, American Meteorological Society (1992) and Honorary Member, European Geophysical Society (1992).*

Eliassen has received the Meisinger Award (1950); the Carl-Gustaf Rossby Medal (1965); the Rossby Award (Swedish Geophysical Society) (1965); the Fridtjof Nansen Award (Norwegian Academy of Science, 1977), Knight of the Royal Norwegian Order of St Olav (1984) and the Balzan Prize (1996).

In 1965, Arnt Eliassen was designated a member of the then CAS Working Group on Numerical Weather Prediction, whose terms of reference included, inter alia, *keeping developments in the field under review and recommending to the Commission any action by WMO to facilitate research in this area. He made a valuable contribution to the work of the Group.*

After his retirement in 1982 at the age of 67, Eliassen was active for several years in a research project with the Norwegian Research Council for Science and the Humanities. He has been professor emeritus since 1985 and continues to be active in his scientific field.

Dr Taba concludes:

One of Arnt Eliassen's most noteworthy qualities is his excellent pedagogical manner of presenting complicated scientific topics clearly and systematically. Other outstanding characteristics are his pleasant smile and tremendous

2 Interviewed in *WMO Bulletin* **30** (3)

3 Interviewed in *WMO Bulletin* **37** (4)

4 Interviewed in *WMO Bulletin* **46** (2)

sense of humour. Once, in Stockholm, after a lively reception, we went to Jule Charney's hotel room, located in a long corridor, to continue the evening. The other hotel guests had already left their shoes outside their doors to be cleaned. We proceeded up and down the corridor, mixing up the pairs. I would not have liked to have been there to see the reaction of the owners of the footwear!

I met Arnt Eliassen for the first time when he visited Stockholm in early 1950s at the invitation of Rossby. I was happy to see him once again and his wife, Ellen Kristine, to conduct this interview in June 1997 at their summer cottage on the southern coast of Norway.

H.T. — **Let us start this interview with some words about the date and place of your birth, your parents and your schooling.**

A.E. — My father, Georg Eliassen, was an architect. He was born in Oslo (or Christiania as the city was called then). He received his architectural education in Stockholm, where he met and married my mother, Helfrid Stromberg, who was a textile artist and painted in water colours. In 1913, the family settled in Oslo, where I was born on 9 September 1915.

I went to free public schools which were run by the city. Since I knew the letters and could read a little when I started school at seven, I was put into second grade. This was not such a good idea; as a result I was immature both mentally and physically compared with my classmates, throughout my school years.

In high school (*gymnasium*) a bias in my mental equilibrium became clear. I was poor in language and history, but quite good in science and mathematics. My difficulty with the humanities is, I believe, due to a poor memory for names and disconnected words, with which I have struggled all my life.

H.T. — **Which university did you go to and what courses did you choose? How did you become involved in meteorology?**

A.E. — In 1933, I finished high school and enrolled as a student at the Mathematics-Science Faculty of the University of Oslo. I was privileged since I could live with my parents who also supported me financially during the first four years of study.

At that time, undergraduate study was organized in comprehensive courses in 10 different subjects, of which one had to take four according to choice, in order to attain the bachelor's degree. I chose mathematics, mechanics, physics and geography.

In the autumn of 1938 I attended Prof. S. Rosseland's lectures in astrophysics. I also got myself an office in the Astrophysics Building on the University campus in Blindern in Oslo. It so happened that Vilhelm Bjerknes and his assistant Einar Høiland—neither of whom I had met before—also had their offices in the same building. They were preparing a text on classical theoretical physics (which was never published) and went through the manuscript in seminars in the astrophysics auditorium. I went to listen and was fascinated by their way of explaining difficult subjects. Ragnar Fjørtoft was also in the audience.

Starting in January 1939, Sverre Petterssen, who was Director of the Weather Service for Western Norway, gave a three-month meteorology course at the University of Oslo. He used the manuscript of his textbook *Weather Analysis and Forecasting* as the basis of the course. The students attending the Bjerknes-Høiland's seminars were encouraged to sign up for Petterssen's course, and I followed suit. The thought of becoming a weather forecaster was quite new to me and I was delighted.

H.T. — **Who were your professors? Did you receive any training in weather forecasting?**

A.E. — In mathematical analysis, I was fortunate to have Prof. Carl Störmer, who calculated the trajectories of electric particles from the Sun in the Earth's magnetic field, ending up in the aurora zones on the Earth. He also measured the altitude of the aurora by simultaneous photographing from two sites.

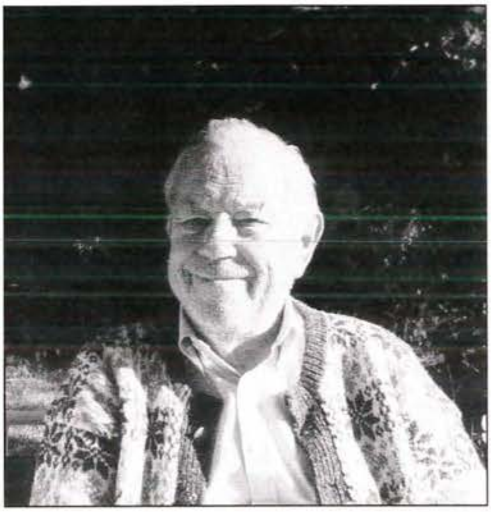
My geography teacher, Werner Werenskiold, devoted much of his curriculum to meteorology, oceanography and solid Earth physics—the result, I think, of Bjerknes's influence.

I was in doubt about the choice of my graduate subject, and started to study theoretical physics with Prof. E. Hylleraas. He hired me for a term in 1938 as research assistant. I was not very useful and did mostly typing for him.

Halvor Solberg taught the graduate course in meteorology. He was a prominent member of the Bergen school and followed mostly the "Bergen School Bible": *Physikalische Hydrodynamik* (*Physical Hydrodynamics*).

At the end of Sverre Petterssen's course (January to April 1939), we were offered positions as meteorologist trainees in one of the country's three forecasting centres. I applied for Tromsø and worked there for three months. It was not a regular course; I participated in the daily work without, of course, having responsibility for forecasts.

In Tromsø, one is really exposed to the elements and it was an extremely interesting and exciting experience.



Arnt Eliassen in June 1997
Photo: H. Taba

H.T. — **From 1940 to 1942 you were research assistant at the Institute of Theoretical Meteorology in Oslo. Is this the same as the Norwegian Meteorological Institute?**

A.E. — In Norway, university departments are usually called institutes. The Institute of Theoretical Meteorology at the University of Oslo was a small department indeed, consisting only of Prof. Solberg (he did not even have a secretary)! Upon return from Tromsø in 1939, I joined the small group of graduate students in Solberg's Institute. He gave strong emphasis to theoretical topics, as one would expect from a former student of Bjerknes. As a result, Norwegian meteorologists at that time had a better theoretical background than their colleagues in most other countries.

The Astrophysics Building, which housed Bjerknes and Høiland also housed Solberg, C. Størmer (aurora), L. Harang (ionosphere) and J. Fjeldstad (oceanography); it was quite a geophysics centre. I shared a room with the Icelandic student G. Arnason, later professor at Albany, New York.

I obtained my Master's degree with Prof. Solberg in the spring of 1941 and he employed me as a research assistant at his Institute, which, therefore, now consisted of two persons (still no secretary!). Solberg was much involved in university affairs and had little time for research. I spent most of the time reading Bjerknes, Margules and Richardson, and in discussions with Einar Høiland, who had become my close friend, and from whom I learned more than from anybody else.

H.T. — **You then worked as a meteorologist at the Norwegian Meteorological Institute from 1942 to 1952. What did you do exactly during this 10-year period?**

A.E. — War had come to Norway with the German occupation in April 1940, and weather forecasting was forbidden. Ludwig Weickmann was in charge of the German Weather Service in Norway. He knew both Vilhelm and Jack Bjerknes and Solberg from their time in Leipzig and it may have been due to his influence that the Norwegian Meteorological Institute was left in peace.

H.T. — **In 1942, you published your first paper entitled "On the motion of the air over a mountain ridge" and another in 1944 on the correction and reduction of barometer readings. Tell us about these papers.**

A.E. — The first paper was a short version of my Master's thesis. The topic was quite natural; in Oslo, lenticular wave clouds are quite common in westerly airflows. Solberg gave me a paper by Joachim Küttner[5] to study entitled "*Moazagotl-Wolke* in the lee of the *Riesengebirge*", which proved most helpful. In my thesis, I applied the theory I knew, but could not determine the stationary flow because I lacked an upper boundary condition. G. Lyra's paper in 1943 did not solve the question either. Many years later, Enok Palm and I found that the missing conditions could be provided by Sommerfeldt's radiation condition.

[5] Interviewed in *WMO Bulletin* **38** (4)

About the second paper: when I came to the Norwegian Meteorological Institute in 1942, I was asked to recalculate correction and reduction tables for the barometer stations in Norway. The paper to which you refer gives an account of the formulae which were used. Its only point of interest is the method of pressure reduction to sea-level for stations situated in valleys which may contain a deep layer of very cold air.

H.T. — **From 1952 to 1953, you were Scientist at the Institute for Weather and Climate Research. Can you tell us about this institute?**

A.E. — A serious drought in Norway in 1947 resulted in empty reservoirs and posed difficulties for the electricity supply. In order to investigate the possibility of such weather anomalies being predicted, the Norwegian Academy of Science and Letters set up in 1950 the small Institute of Weather and Climate Research, with Einar Høiland as Director. The Institute existed for only 10 years and certainly did not solve the long-range prediction problems it was meant to tackle. On the other hand, it supported a number of young geophysicists during a time when positions for them were very scarce, and kept them alive until the end of the 1960s, when the universities expanded and positions became abundant.

Enok Palm and E. Riis were employed from the beginning; later came Kaare Pedersen and A. Foldvik, R. Fjørtoft, J. Nordø and myself. Many others worked at the Institute for shorter periods. Some studies were made on the original subject of precipitation in Norway but, as time went on, research focused on hydrodynamical problems, gravity waves and NWP. But the Institute also carried out seeding experiments with silver iodide in orographic clouds in Telemark to see if orographic precipitation could be increased artificially.

Perhaps the most important function of the Institute was its role as an advanced school of physics and applied mathematics. This was entirely due to Høiland's untiring initiative. In his series of seminars, he ordered us to read classic and modern papers, whether we were employed at his Institute or not. We studied theories of turbulence, kinetic theory of gases, light scattering, irreversible thermodynamics, generalized Fourier analysis etc.: we learned a lot from Høiland.

H.T. — **The paper "The quasi-static equation of motion with pressure as independent variable" published in 1949 was your Ph.D. thesis. This paper is a classic, which has been studied and used by all meteorologists. How did you come to work on this subject?**

A.E. — Weather forecasting began again when World War II ended. Sverre Petterssen came home from England and became head of weather forecasting in Norway. He introduced the British analysis recipe—which, by the way, was nothing but the method proposed by Bjerknes and J. Sandstrøm in 1910, and which the Germans and Soviets had used all along: analysis of isobaric contours and thickness lines.

After having drawn a few hundreds of these maps in the routine service, I asked myself: "Why can't we write the equations so that they apply directly to isobaric maps?". That turned out to be quite easy; but I admit that the simple form of the mass continuity equation came as a surprise to me.

I gave a paper on the pressure coordinates at a meeting of the Norwegian Geophysical Society in September 1947. Høiland told me that I ought to add my unfinished quasi-geostrophic theory from the War years, and whatever else I had, in order to make the paper sufficiently bulky for a D.Phil. thesis, which, at that time, had to be just one printed paper. So I worked on it between forecasting duties and submitted the manuscript in March 1948. A week before, Reggie Sutcliffe's paper on pressure coordinates came to my attention, and I added a note about it. Later information revealed that a version of the continuity equation in pressure coordinates was first given in a report by O. Godard of Belgium in 1942.

H.T. — **You went to the University of Chicago in 1948 as a visiting scientist in the Department of Meteorology. Whom did you see there and what did you do?**

A.E. — Upon an invitation from Rossby, I spent two summer months at the Meteorology Department in Chicago before starting in Princeton. My first experience of the USA came as a shock and encountering the Chicago School was no less of a shock. George Cressman gave a map seminar every day and, in my view, he had everything upside down: first he looked at the long waves on the upper-air maps and their development in the light of the Rossby formula and constant vorticity trajectories; and then he took a brief look at the surface map to see if there were any surface fronts which could fit into the picture. It was an informative stay for me.

In Chicago, I met many students who later became prominent meteorologists: George Platzman, Chester and Harriet Newton, George Cressman[6], H. L. Kuo, Dave Fultz, Yeh, D. Bradbury and others. I enjoyed in particular the evening discussions between Rossby, Erik Palmén[7], Erwin Biehl, Victor Starr and others at their favourite café.

H.T. — **From 1948 to 1949 you stayed at the Institute of Advanced Study, Princeton, New Jersey. Is that when you met Jule Charney?**

A.E. — I first met Jule Charney when he came to Oslo in the summer of 1947. He gave guest lectures on his celebrated paper on baroclinic instability and participated in seminars and discussions with Høiland, Fjørtoft and myself. It was a pity that I did not have more time to discuss with him; I had weather forecasting duty day and night, and I was writing up and struggling with the English language to write my D.Phil. thesis.

Before leaving Norway, Charney invited me to join him in Princeton where he was going the following year to lead a small meteorology group set up by the renown mathematician John von Neumann at the Institute for Advanced Study. Von Neumann had new ideas about the logical design of electronic computers and a computer was being built in Princeton under his supervision. As a suitable problem for testing the new computer, von Neumann had chosen NWP; Jule Charney's meteorology group was supposed to formulate the problem mathematically for the computer.

H.T. — **Together with Jule Charney, you published a paper in 1949 on a numerical method for predicting the perturbations of the middle latitude.**

A.E. — We had decided to begin the NWP experiments by using the barotropic model, and we had the equations ready, but the work was blocked by the computer which was never finished. All we could do with these equations was to compute height tendencies by hand relaxation. We also used a desk calculator to evaluate 500 hPa height changes along 45°N from a linearized, one-dimensional version of the barotropic model, and published a joint paper about it. The significant part of this paper was an unintended by-product: we found that the large mountain ranges in America and Asia would cause quasi-stationary perturbations of the westerlies, which are realized in the monthly mean maps in approximate form. Many years later we published our second joint paper, on hurricanes.

In the summer of 1949, Ragnar Fjørtoft replaced me as member of the NWP team in Princeton. Since the Princeton computer was

Eliassen, father and son

Anton, Arnt Eliassen's older son, is Professor and Deputy Director of the Norwegian Meteorological Institute. It is indeed rare for father and son to be such eminent figures in the meteorological world. In reply to questions about his scientific relationship with his father, Anton Eliassen wrote the following to Dr Taba:

> **My father never tried to influence me in choosing to study meteorology. However, throughout my childhood, a number of famous meteorologists visited our homes in Oslo, Princeton and Los Angeles. I remember Jule Charney, Ed Lorenz, Norman Phillips, Joe Smagorinsky, Jack Bjerknes and Jørgen Holmboe very well and there were a number of others. A child certainly did not understand the scientific questions discussed. In retrospect, however, it seems clear that most of these scientists were unusual persons in one way or another and made a lasting impression on a young boy. The choice seemed natural with this background.**
>
> **I have chosen to work in other areas of meteorology than Arnt. This is partly because these other areas were the ones under development when I was a young scientist. Then, in addition, I am sure you will appreciate the difficulty of trying to follow Arnt in the areas where he has made his outstanding contributions. Since we cover different fields, we don't discuss scientific questions as thoroughly as one would with ones close scientific colleagues.**

6 Interviewed in *WMO Bulletin* **45** (4)

7 Interviewed in *WMO Bulletin* **30** (2)

still not operative, they decided to use the ENIAC computer instead. In 1950, Charney, Fjørtoft and von Neumann published the first 24-hour numerical forecasts based on the barotropic model, which was a breakthrough for NWP.

The year in Princeton with Jule was a wonderful experience to me. Jule had broad interests; he was well read, not only in science but also in literature, and he was interested in theatre and music. His friendship and encouragement meant much to me. He and his wife, Elinor, came to Oslo several times on extended visits, and we kept in touch as long as he lived.

H.T. — **Tell us about your visits to the University of California, Los Angeles.**

A.E. — I left Princeton in September 1949 and went to UCLA, where I had been invited by Jack Bjerknes to work for three months on his general circulation project, together with Yale Mintz. I was fortunate to be acquainted also with Jørgen Holmboe and Zdenek Sekera.

My next stay at UCLA was from March 1955 until January 1956, when I gave a lecture series on NWP. Ed Lorenz[8] was there at the same time; I think he lectured on the general circulation. We became close friends, and Ed and his wife, Jane, have visited Oslo several times. Ed was fond of hiking, and we have had many wonderful hikes together in the woods and the mountains.

H.T. — **You stayed quite a long time (1951–1953) at the International Meteorological Institute, University of Stockholm. What did you do there?**

A.E. — Upon an invitation from Rossby, I came to his new International Institute of Meteorology in Stockholm in the autumn of 1951. At that time, atmospheric scientists from both war camps had had little contact, and I think one of Rossby's ideas was to bring such "enemy scientists" together. It was an interesting group of meteorologists: Karl Hinkelmann, Ernst Kleinschmidt, Fräulein Steuer, Hollmann and Wippermann from Germany; Van Mieghem from Belgium; Eric Eady from the United Kingdom; Phil Clapp, Chester and Harriet Newton and Bill Hubert from the USA; L. Vuorela from Finland, and Bert Bolin and Olof Lønnqvist from Sweden. Rossby's Institute was a success from the start.

I was fortunate to have the opportunity to spend considerable time with Eric Eady. Each of us had a version of a two-level model which were published in *Tellus*. Also, together with Bill Hubert, I made a study of blocking.

Upon my return to Norway, I became a lecturer at the University of Oslo and gave graduate courses in meteorology. After Prof. W. Werenskiold retired, I gave some lectures in physical geography for undergraduates until a new professor of geography was appointed in 1958. The subjects were gravimetry, seismology, meteorology and oceanography.

H.T. — **Tell us about your visits to MIT.**

A.E. — In 1962, I spent the autumn term at MIT with Jule Charney, Norman Phillips[9] and Ed Lorenz. Jule and I spent a week in a deserted farm house in New Hampshire with the intention to work on the hurricane problem. The result was our second joint paper. I was also at MIT several times on shorter visits.

Dr Taba with Prof. Eliassen during the interview
Photo: H. Taba

H.T. — **As from 1958 until your retirement in 1982, you were Professor of Geophysics at the University of Oslo. Were you teaching subjects other than meteorology?**

A.E. — I was mainly teaching meteorology, and gradually took over Prof. Solberg's lectures. In 1963, Solberg's Institute for Theoretical Meteorology and Prof. Fjeldstad's equally small

8 Interviewed in *WMO Bulletin* **45** (2)

9 Interviewed in *WMO Bulletin* **44** (3)

Oceanographic Institute were fused into the Institute of Geophysics with four sections: meteorology, oceanography, hydrology and solid Earth physics. It took some time to find staff for the latter two sections. To get things started, I gave an introductory graduate course in solid Earth physics for the first two years.

The Institute of Geophysics has grown steadily and now has a permanent staff of some 15 scientists and a similar number of project employees. Over the years, many meteorologists from the USA have come to Oslo on extended visits, such as Jule Charney, Norman Phillips, Philip Thompson, Ed Lorenz, Dave Fultz, Ronald Smith and Melvyn Shapiro. A considerable number of post-doctoral research fellows have spent a year at our Institute, beginning with William Blumen and RIchard Lindzen in 1964. I wish to express our gratitude for this important contribution to our milieu in Oslo.

H.T. — **After 1982, you started working for the Norwegian Research Council for Science and the Humanities. In what sort of humanitarian activities were you engaged?**

A.E. — Normal retirement age for university professors is 70 years. However, one may apply to the Research Council for Science and the Humanities for a senior stipend which makes it possible to retire from teaching and administration duties at 67 and still retain full professor's salary until the age of 70. I found this useful, since it enabled me to complete some unfinished work. I am afraid, however, that my activities were not particularly humanitarian!

H.T. — **You and Ragnar Fjørtoft have been close friends and collaborators ever since the time you were students. Did you coninue your joint scientific activities after your retirement?**

A.E. — After retirement, Ragnar and I found ourselves in the same office at the Institute of Geophysics. After tough discussions we managed to assemble our only joint paper, which however was turned down by the *Journal of Fluid Mechanics*. We considered the paper dead and buried until it mysteriously reappeared as a page-proof for a publication of the New York Academy of Sciences. We thought the paper had some merit and did not stop its publication. But we still do not know who submitted the manuscript!

Arnt and Ellen Kristine Eliassen
Photo: H. Taba

H.T. — **You have published more than 50 first-class papers, full of original ideas, in more than 50 years of scientific activity. Is there any topic which you wish you had taken up but had no time or opportunity?**

A.E. — Yes, there are some such topics. But with the vigorous research activity in the world today, I am sure that they will be taken up and satisfactorily treated by others. Thus science will not suffer!

H.T. — **Have you even been interested in questions related to the protection of the environment?**

A.E. — I have been interested in such questions, but I am afraid I have not contributed much. I have mostly taken up problems to which I thought I would be able to contribute without regard to their possible importance to the environment. Those were mostly fluid dynamical problems which, however, are not completely uninteresting to environmental questions. After all, it is the currents in air and sea which transport pollutants.

H.T. — **You have received numerous awards and recognitions. Are there any you would like to mention in particular?**

A.E. — To receive the Balzan Prize was a fantastic experience and a great surprise to me.

The Royal Order of St. Olav is an award given by the King of Norway for merits to the benefit of the country. I received it for research and teaching in the field of meteorology.

H.T. — **Tell us something about your family.**

A.E. — Ellen and I were married in 1944. We have two boys, Anton and Jørgen. When they reached school age, Ellen resumed her studies and took her bachelor's degree in 1957 in geography, history and English. She worked as a high school teacher until her retirement in 1991. She has been my good companion on most of my travels.

H.T.— **It has been delightful to meet you both again and share reminiscences in such a beautiful setting.**

THE ALADIN PROJECT: MESOSCALE MODELLING SEEN AS A BASIC TOOL FOR WEATHER FORECASTING AND ATMOSPHERIC RESEARCH

by members of the ALADIN international team

Introduction

The acronym ALADIN (*aire limitée adaptation dynamique développement international*) describes several facets of an international project (for limited area mesoscale modelling) involving as many as 110 persons from the 14 national Meteorological Services (NMSs) of Austria, Belgium, Bulgaria, Croatia, the Czech Republic, France, Hungary, the Republic of Moldova, Morocco, Poland, Portugal, Romania, Slovakia and Slovenia. We shall first describe the four "vital" characteristics of this project, before making a more in-depth analysis of its historical, organizational, scientific and technical aspects.

The concept

While it is generally accepted that today's numerical weather prediction (NWP) requires international collaboration and that a model of cooperation between NMSs of differing technological levels must be mutually beneficial, despite the obvious imbalance, the combination of the two ideas had apparently never been proposed before. Yet, such is the backbone of the ALADIN concept: NMSs with less experience in operational NWP bring their scientific know-how and a fresh view of NWP problems while *Météo-France* ensures the organization of the project and its links with advanced technologies; this distinction will become less and less pronounced as the project progresses. All partners accepting the rules of the project are, by definition, equally free to benefit from the fruits of the common work for both research and operational applications.

The system

ALADIN was entirely built on the notion of compatibility with its "mother" system, IFS/ARPEGE. The latter, a joint development between the European Centre for Medium Range Weather Forecasts (ECMWF) and *Météo-France*, was only meant to consider global NWP applications; hence the idea, for ALADIN, to complement the IFS/ARPEGE project with a limited area model (LAM) version, while keeping the differences between the two softwares as small as possible. It was, therefore, absolutely necessary to copy the organization of the code from one system to the other. The key words for this organization are *integration* (all applications are developed and maintained inside a single software piece); *flexibility* (as many options as possible available on simple manipulations of unformatted input files); *modularity* (one function = one single piece of code); and *generality* (as few restricting assumptions as feasible, both for the science and for its algorithmic transcription). Furthermore, the duality between ARPEGE (global with the possibility of variable resolution) and ALADIN (LAM), sharing the same grid-point dynamics and physics, is a formidable advantage for tackling the NWP challenges of the coming years at high resolution. For example, inside the two projects, advanced (variational) data-assimilation aspects have mostly been tackled in the global framework, while high-resolution aspects (non-hydrostatism) were explored in the LAM framework, always keeping open the possibility of transfer from one side to the other. The strict application of the integration-flexibility-modularity-generality (IFMG) rule inside the ALADIN part of the work is now a rather well-established practice. Of course, the compatibility with IFS/ARPEGE complicates matters. There are, for instance, four types of ALADIN routine: those common with IFS/ARPEGE (e.g. physics or grid-point dynamics); those duplicating the scientific functions of one IFS/ARPEGE routine in the LAM framework (e.g. spectral computations); those duplicating the controlling functions of one identically named IFS/ARPEGE routine (e.g. organization of one time step); and those specific to ALADIN (e.g. coupling with larger-scale information). This complexity is especially penalizing for the crucial maintenance process, which is copied from the IFS/ARPEGE one, i.e. it is organized around "cycles" (fully validated releases every six to nine months). Currently, the IFS/ARPEGE cycle 17 exists, as well as the ALADIN cycle 7, the latter being phased with cycle 16 of ARPEGE. The difference of 9 between the numbers simply reflects the fact that the ALADIN project was launched roughly four years after IFS/ARPEGE. The help of ECMWF staff in solving these complex problems is gratefully acknowledged here.

The use of configurations

Five are currently fully validated (the number is likely to increase in the near future, given the momentum of the project): (*a*) the creation of the "geographical" conditions for any given geometry of the LAM, anywhere on the globe; (*b*) the creation of initial and/or lateral boundary conditions starting from an ARPEGE or an ALADIN file; (*c*) the optimal interpolation analysis module nicknamed CANARI; (*d*) the model integration itself (with its digital filter initialization (DFI) option); and (e) the fully compatible post-processing Full-Pos (itself not an independent configuration but a variant of one (*d*) time-step).

The advantage of this structure is that all these applications can be driven from a single "object" version of the code, for any localization, geometry, number and spacing of vertical levels, etc., with the implicit certainty that all these characteristics will be compatible with all consecutively employed configurations, as well as the definitions of basic constants (gravity, radius of the Earth, gas constant, etc.) and of thermodynamic functions (saturation pressure and derived expressions). Contrary to the above-mentioned maintenance problem, which required much individual investment for a few key persons, this advantageous simplified use of the code (simple unix-scripts) was a bonus for a project that needed to involve many part-time ALADIN scientists (average presence in Toulouse = 25 per cent of that of the "standard" team member).

The multiple applications

At the time of writing, ALADIN is in a pre-operational or operational state for five applications (see map of participating countries and domains of integration in Figure 1):

- At *Maroc-Météo*, full LAM application including data assimilation, 16.6 km mesh, 169 x 169 points, 27 levels;
- At *Météo-France*, fine-mesh dynamical adaptation forecasting, 12.7 km mesh, 189 x 189 points, 27 levels;
- For RC-LACE (NMSs of Austria, Croatia, the Czech Republic, Hungary, Slovakia and Slovenia, the application running in Toulouse on purchased computing resources and monitored by RC-LACE scientists), the same, 14.7 km mesh, 205 x 181 points, 27 levels;
- In Slovenia, the same, 11.7 km mesh, 61 x 61 points, 27 levels, coupled to the RC-LACE application;
- In Romania, lagged-mode fine-mesh dynamical adaptation forecasting, 12.3 km mesh, 89 x 89 points, 27 levels.

A sixth application is in preparation in Belgium: 7.0 km mesh, 97 x 97 points, 27 levels, coupled to ALADIN-France.

History of the project

Only the main events will be mentioned here, relative to the political, financial and technical aspects.

November 1990: *Météo-France* offers the NMSs of Bulgaria, the Czech Republic, Hungary, Poland, Romania and Slovakia jointly to develop and maintain a LAM version of the ARPEGE system with a view to a mutually beneficial collaboration in NWP and mesoscale modelling.

January 1991: The so-called MICECO support (from the French Ministry of Foreign Affairs

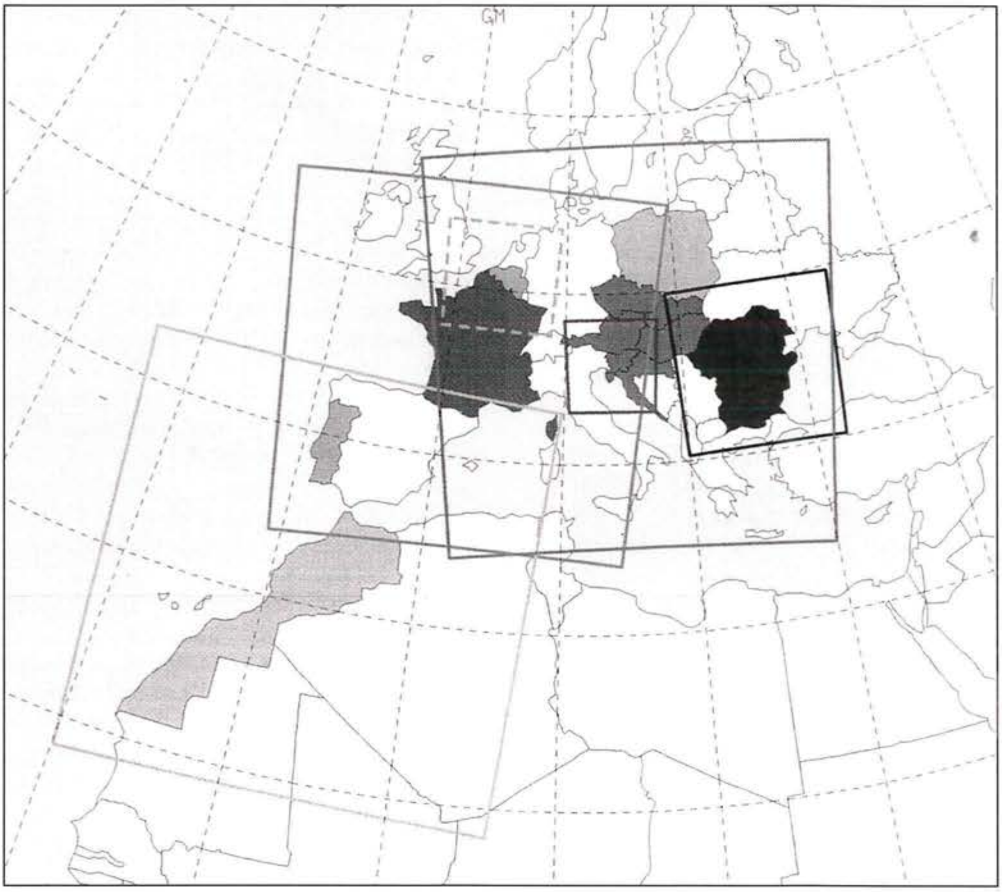


Figure 1 — Map of the ALADIN partners (with RC-LACE and SELAM grouped under one shade of grey each) and the operational pre-operational (broken lines) domains

for the visits to Toulouse of the specialists of the partner NMSs) that will be the continuous and main source of financing for the project is acquired.

March 1991: In Paris, three scientists from the NMSs of the Czech Republic, Hungary and Romania evaluate the feasibility of the proposed common project.

September 1991: Start of the active phase of the project in Toulouse: Slovakia declines the offer to participate but, meanwhile, Austria, through what will be the RC-LACE endeavour, joins in. Thus, 17 people from seven countries start to work on the project LAM-ARPEGE (that will be renamed ALADIN one month later).

August 1992: The French Ministry for Research accepts to finance four Ph.D. grants in the framework of the ALADIN project. These would allow the scope of the project to be enlarged by studying basic questions related to its usefulness and further evolution.

October 1992: Cycle 0 of the ALADIN library is ready.

January 1993: The Commission of the European Communities selects the pre-operational work on ALADIN as one of the subjects financed under the so-called PECO action, in a competitive context (1 to 35).

November 1993: The NMSs of Morocco, Slovakia and Slovenia join the project. The nine partners carry on the efforts towards a first quasi-operational implementation in Toulouse for the benefit of the central and eastern European NMSs.

May 1994: The work of the seven members of the PECO-financed pre-operational team (with the additional contributions of the Ph.D. students and an established team of *Météo-France* scientists) leads to a successful conclusion. ALADIN becomes quasi-operational on *Météo-France*'s C98 computer on 31 May. Although the application is run only once a day (in sequential mode with respect to ARPEGE), up to 36 hours only and without a specific data-assimilation cycle, proof of the wisdom of the concept is nevertheless at hand.

April 1995: The NMSs of Croatia and Spain (the latter will later leave) join the project.

December 1995: A workstation version is built (still in dead-branch mode with respect to the development cycles) by the SELAM group (NMSs of Bulgaria and Romania, later to be joined by the Republic of Moldova). This work also prepares the way for the distributed-memory version of ALADIN foreseen for cycles 6 and 7 of the library.

January 1996: RC-LACE and *Météo-France* sign an agreement to use the J916/12 computer in Toulouse as host for an ALADIN-LACE pre-operational application from 1 July 1996 to 31 December 1997 in order to provide a transition for the build-up of the central European joint application of ALADIN between the six contributing NMSs.

February 1996: The success of the first Ph.D. phase (two theses already defended and two about to be defended) leads the French Ministry for Research to renew the grant. Five new Ph.Ds. are thus now in the pipeline.

March–August 1996: In a form of cascade, the five above-mentioned applications start their cycle of pre-operational to operational status.

November 1996: in Paris, the Directors of the ALADIN partner NMSs sign a Memorandum of Understanding (MoU) that formalizes and regulates the further progress of the project, in the presence of the Secretary-General of WMO, Prof. G. O. P. Obasi.

March 1997: The Czech NMS launches a computer ITT with the aim of transferring the central European application from Toulouse.

Organization of the project

The organization described below is the one in use until now. It will surely not be that of the future, since several questions (transition to multiple operational status, transition from "platform dependent" to "standard open" code, multiplication of the declarations of interest of potential new partners, ...) require a more formalized and less centralized solution.

From September 1991 until recently, work on ALADIN centred around visits to Toulouse of scientists of all partners, their ALADIN-related work at home being mostly conditioned by the tasks they had been performing in Toulouse (this situation, of course, is rapidly changing as the operational versions are transferred outside Toulouse). The number of hours of work shared in Toulouse with colleagues of all origins allowed a homegeneous and united team to be formed. The main difficulty of the set-up was the financing of the travel and visits, with an average of nearly 15 people working on the project (7.9 visitors and 3.9 *Météo-France* staff in Toulouse, 3.0 persons in the other places (see Figure 2 for the distribution among the different partners). Generally speaking, travel was provided by the partners and the grants for the stays were funded by *Météo-France* or by French ministries or raised in competitive applications by either all partners or by *Météo-France* and one partner for bilateral support or directly financed by the partners. The fact that some 17 different sources are involved gives an idea of the complexity of this financing scheme.

The necessary formalization of the project before its decentralization was completed by the signing last autumn of an MoU by all 14 partners. It lays down the principles observed by ALADIN since the beginning, the choice of software, conditions of its use by the partners and of membership of, admission to, and withdrawal from the ALADIN "club".

Scientific content of the project

The relevance of all that has already been said to a scientific-technical topic may appear rather thin. One has to realize, however, that modelling aspects of meteorology will rely more and more on tools developed in an operational environment, which will require more and more "industrial" methods for their production and maintenance. In that respect, all the above information anticipates the working conditions that atmospheric science will witness in the 10 coming years. Nevertheless, all that "environment" is still there to foster scientific and technical progress and that will be the subject of this text from now on.

We shall first review the common points between ARPEGE and ALADIN:

- Both models use the spectral technique for the horizontal representation of fields. This means that special provisions have to be taken for the use of a bi-Fourier LAM representation. The solution chosen here is that of Machenhauer and Haugen (1987) that requires the so-called bi-periodicization of

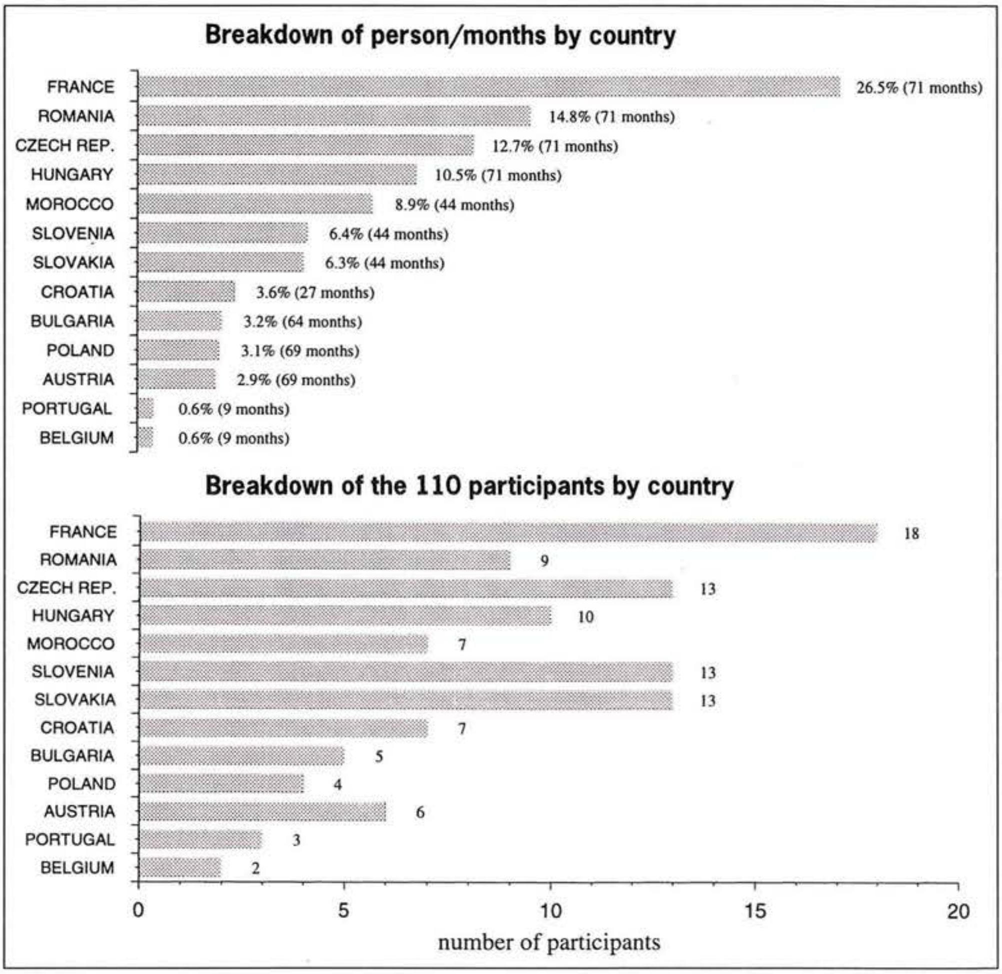


Figure 2 — Participation in the ALADIN project for each partner: proportion of the total effort (together with the duration of the specific participation) and number of involved people (on 30 June 1997)

fields through a fictitious "extension zone". As an example, Figure 3 features the "extended" orography of the ALADIN-LACE application; one notices the smoothness and isotropic character of the transition from one side to the other through the additional zone. It is sometimes claimed that spectral methods are unsuitable for LAM applications and/or that they cannot represent sharp features for lack of "locality". Figure 4, representing 18-hour forecasts of 10 m winds, is a good counter example: no apparent boundary problems exist but many realistic features over land as well as over sea at the two grid-length scale do (plotting);

- The vertical discretization is hybrid (going progressively from "p" to σ);
- The time stepping now uses the semi-implicit semi-Lagrangian scheme with two-time-levels solution;
- The physics is for the time being identical with ARPEGE (which also benefited from ALADIN work); (see Geleyn *et al.*, 1994);
- The DFI technique is used, the latest, most efficient version (Lynch, Giard and Ivanovici, 1997) having been suggested in the framework of ALADIN;
- The CANARI and Full-Pos applications are mirrors of the ARPEGE ones, with specific steps linked to the LAM geometry.

The points specific to ALADIN concern:

- The bi-periodicization is accomplished only on the files interpolated from the coupling model (i.e. as seldom as possible) and can thus be performed with a quite sophisticated iterative combination of splines and filters;

- The form of the coupling function (i.e. the relative weight taken at each time step by the larger-scale solution near the boundaries of the LAM) that has been optimized as much as possible in the spectral context;
- The implementation of the semi-Lagrangian scheme in the case of trajectories originating in the "extension zone" which required an original treatment of the link between semi-implicit time stepping and coupling (Radnoti, 1995) as well as a specific adaptation of Rochas's idea about Coriolis terms in the two-time-level algorithm;
- The existence of a non-hydrostatic option, based on Laprise's "hydrostatic pressure" type of vertical coordinate, which also requires a redefinition of the "Simmons-Burridge" vertical discretization operators (Bubnova *et al.*, 1995).

Finally around the project itself:

- A special study (Caian and Geleyn, 1997) was performed to evaluate the respective merits of the stretched solution in ARPEGE and of the coupled solution represented by ALADIN; the conclusion was that the combination of moderate stretching for the global part and of local adaptation via the LAM solution is the best combination, given the current computing constraints;
- ALADIN was used as a tool for adjoint sensitivity studies on frontogenetic problems (Horanyi and Joly, 1996);
- A simplified physics package and its adjoint version for future mesoscale 4D variational

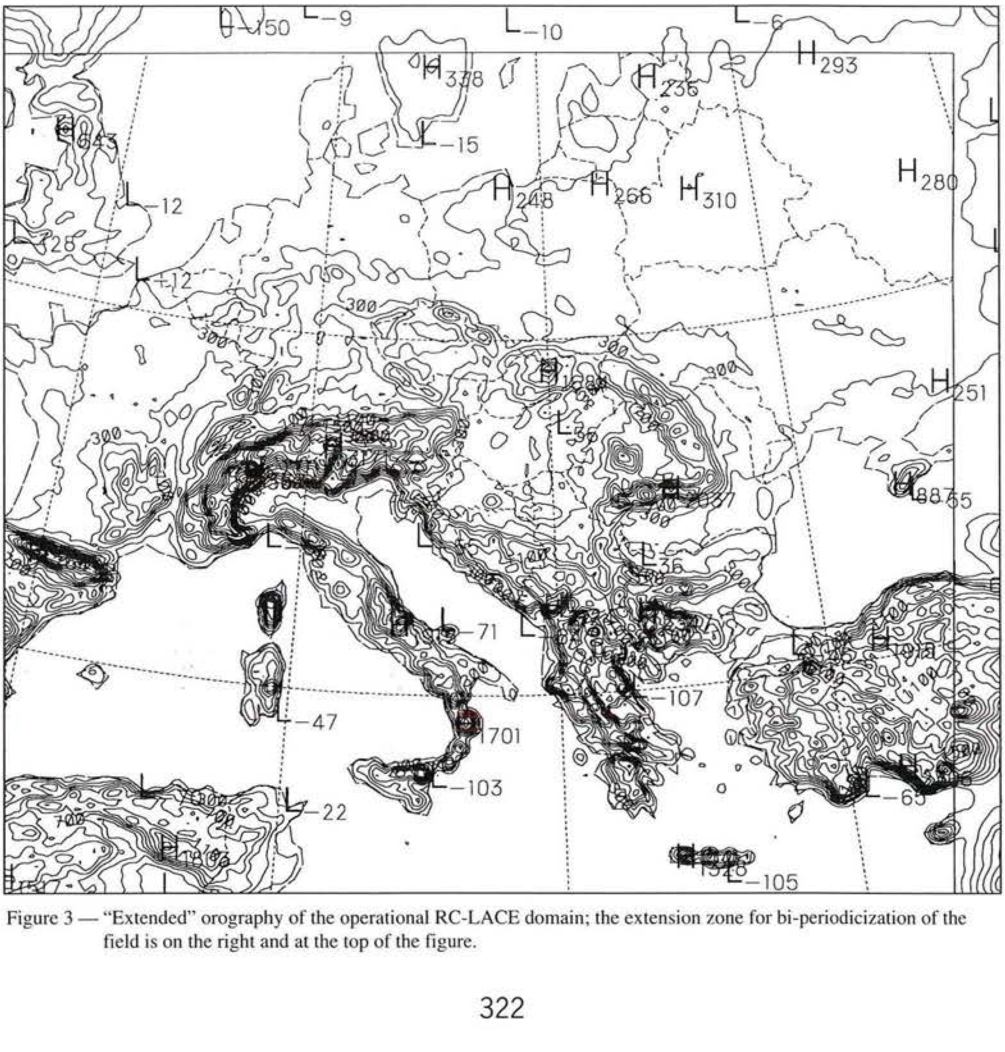


Figure 3 — "Extended" orography of the operational RC-LACE domain; the extension zone for bi-periodicization of the field is on the right and at the top of the figure.

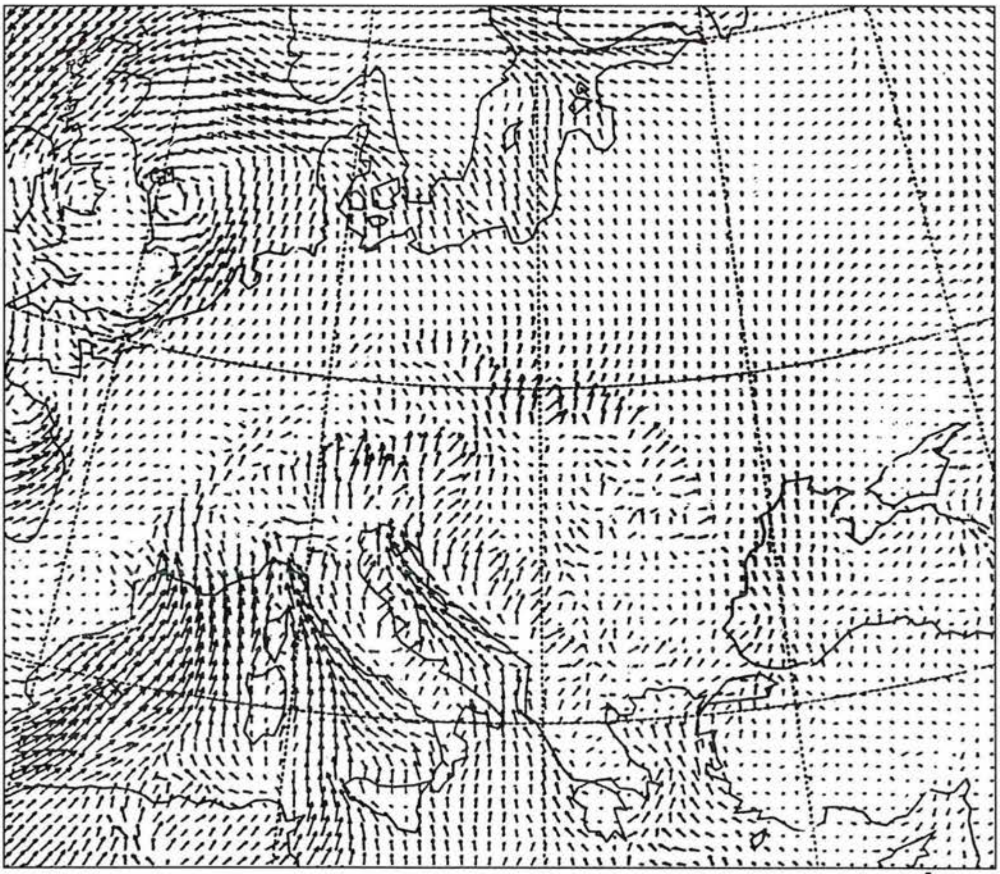


Figure 4 —Eighteen-hour forecast of the 10 m wind on 6 January 1996 at 00Z: notice the three mesoscale vortices around Brittany and Great Britain, the Adriatic channelling effect and several mountain barrier sharp effects.

data assimilation are currently being developed (Janiskova, Thépaut and Geleyn, 1996);

- Other important (past and present) topics of scientific activity are: the behaviour of the model's physics at the limit of validity of the hydrostatic assumption (and beyond); the conditions for a successful dynamical adaptation process; and the intrinsic properties of the semi-Lagrangian time-stepping scheme.

Some technical data about the project

This part will be short but important. The presented data are those concerning the speed of computation and the telecommunication needs for coupling. With the two-time-level version of the semi-implicit semi-Lagrangian scheme, the ratio of the collocation grid mesh size to the time step is about 26 m s^{-1}, a favourable number when compared with other operational NWP models. The number of individual instructions per grid point, level and time step can be estimated (coupling, DFI and post-processing included) for a standard run to about 7 700. For the coupling files, the figure to mention is 1.8 bytes per grid point, level and coupling file, under similar standard conditions and assuming a ratio of two between the mesh sizes of the coupling model and of the coupled model. These three numbers allow an estimation of the computing power and of the telecommunication bandwidth needed for any given application.

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THE NUMERICAL PREDICTION OF THUNDERSTORMS: CHALLENGES, POTENTIAL BENEFITS AND RESULTS FROM REAL-TIME OPERATIONAL TESTS

By Kelvin K. DROEGEMEIER*

Introduction

Since the time of the first numerical weather prediction (NWP) experiments conducted in the late 1940s by John von Neumann and associates at Princeton's Institute for Advanced Study, USA, meteorologists have pushed operational models to higher resolutions and greater levels of scientific and technical sophistication. Limited-area operational models now run at grid spacings of the order of 30 km, and sub-10 km resolutions are only a few years away. As a result of continued increases in computer power, the availability of new observing systems, such as a comprehensive Doppler radar network in the USA, and techniques for retrieving unobserved quantities from single-Doppler data, the challenge of predicting explicitly, in an operational setting, the initiation and evolution of individual deep convective thunderstorms and their wintertime counterparts appears within reach.

Though a goal with considerable societal and economic significance, operational storm-scale NWP is not without notable scientific and technological challenges. I describe herein some of these challenges and present results from several years of real-time operational tests performed at the University of Oklahoma in collaboration with the National Weather Service and other groups. These results suggest that the atmosphere does indeed appear to possess, in many cases, considerable predictability down to the scale of individual storms.

Scientific and technical challenges

The fundamental predictability of small-scale flows

Because it is not possible to observe all atmospheric variables for all scales of motion continuously in time, some error will always exist in the initial state of a numerical forecast model. Even if the model is perfect and computer resources are unlimited, this observational uncertainty or error can grow in amplitude and propagate among spatial scales, eventually rendering the forecast indistinguishable from a randomly chosen atmospheric state. The time required for such growth to occur is deemed the predictability limit, and for large-scale motion is approximately two weeks (Shukla, 1985).

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In contrast to large- and mesoscale flows, the dynamics of which are quasi-two-dimensional with energy residing principally at lower wave numbers due to upscale energy cascade, storm-scale motions are characterized by highly three-dimensional structures with significant down-scale cascade across an inertial sub-range. (For the purposes of discussion, I define the storm-scale somewhat loosely as including the most energetic updraft and downdraft elements (of the order of 0.1–10 km in horizontal dimension) associated with individual storms and their larger aggregates (e.g. squall lines, mesoscale systems)). As a result, storms dissipate energy more rapidly and are shorter-lived than their larger-scale counterparts.

In his discussion of storm-scale predictability, Lilly (1990) reviews Lorenz's classic analysis and notes that, for large-scale models, improvements in resolution lead theoretically to improved predictions. On the meso- and storm-scales, this improvement is limited, with the predictability limit of 20 km wavelengths estimated at about two hours. This time limit may be somewhat conservative, however, as Lorenz's analysis neglects some important aspects of storm-scale phenomena.

For example, thunderstorms tend to be highly intermittent in both time and space, in contrast to Lorenz's assumption of continuous horizontal isotropy. Further, some thunderstorms exhibit unusually high degrees of organization, with strong rotation about a vertical axis (so-called supercells). This characteristic appears to inhibit the downscale transfer of energy and stabilize the flow against turbulent dissipation, presumably enhancing predictability (Lilly, 1986(*a*), (*b*); Droegemeier, Lazarus and Davies-Jones, 1993). Finally, the Lorenz model assumes periodic lateral walls, thereby allowing errors (e.g. in the initial conditions) to be recycled through the flow. In contrast, initial errors in limited-area domains can simply pass through the evolving storms and out through the lateral boundaries, never to return. (It has been demonstrated that the lateral boundary conditions of limited area models do, however, exert a strong influence on the evolution and thus predictability of the interior flow. The extent to which errors in the initial interior state, in the presence of perfect boundary condition information, affect the solution depend upon the type and scale of the error (e.g. Errico and Baumhefner, 1987; Vukicevic and Paegle, 1989; Warner, Key and Lario, 1989; Vukicevic and Errico, 1990; Vukicevic, 1991; van Tuyl and Errico, 1990; Berri and Paegle, 1990).)

While idealized simulation experiments conducted with cloud-resolving models have suggested that storm evolution can, in some cases, be extremely sensitive to initial conditions (e.g. McPherson and Droegemeier, 1991; Brooks, 1992; Droegemeier and Levit, 1993), more recent experiments using full-physics models with terrain and horizontally non-uniform initial conditions suggest practical predictability limits of several hours for moderately to strongly forced events (e.g. Droegemeier *et al.*, 1996 (a), (b); Xue *et al.*, 1996(*a*), (*b*); Carpenter *et al.*, 1997). The issue of predictability, both theoretical and practical, for storm-scale weather thus remains a topic of debate (Brooks, Doswell and Maddox, 1992), though operational tests such as those described in the following section ("A prototype storm-scale NWP system") are painting a generally optimistic picture. Important questions concerning the impact on forecast quality of observations (e.g. from radars, surface networks, satellites) as well as other aspects of the physical system (e.g. soil type and land cover) are currently being investigated, and are of vital importance if storm-scale models are to be applied successfully in both domestic forecasting as well as other venues (e.g. to support remote military operations where observations are extremely limited).

Parameter retrieval and data assimilation

The explicit prediction of storm-scale weather requires observations at the dominant scales of interest, and only Doppler radars or lidars are suited to this task. However, because Doppler radar cannot observe directly all variables needed to initialize a numerical forecast model, techniques have been developed to retrieve such information. In this context, data assimilation and parameter retrieval on the storm-scale differ significantly from that for larger (e.g. global) scales.

For example, on the large scale, all variables necessary to initialize a forecast model (e.g. temperature, horizontal wind, humidity, and pressure), except for vertical velocity, can be obtained directly from upper-air balloon soundings. Further, the associated mass and wind fields satisfy known physical approximations (e.g. geostrophy, hydrostatic balance) and, with proper filtering of unimportant modes such as sound and gravity waves, these observations are suitable for use as initial conditions in a forecast model.

On the storm-scale, however, Doppler radar measures only the intensity of precipitation (reflectivity), radial wind speed, and variance of the velocity spectrum in volumes containing a sufficiently high concentration of scatterers. From a time history of these quantities and information on the larger-scale flow, all other physical variables (e.g. polar and azimuthal wind components, temperature, pressure, water substance fields) within the storm must be retrieved. Because no simple balances or approximations are known to exist at this scale, the full model equations, or suitably chosen subsets, must be used in the retrieval process.

Two broad classes of methods have been developed for retrieving unobserved quantities from single-Doppler radar data. The first, shown schematically in Figure 1(a) and known as forward assimilation, involves repeated insertions of single-Doppler wind, reflectivity, and perhaps retrieved quantities into a forecast model. With each insertion, the model is forced to accept the externally supplied information (e.g. via nudging) while using its own equations to determine all other fields subject to statistical and dynamical constraints (these constraints may be satisfied exactly or in a least squares sense). After some number of insertions, the assimilation process ceases and a forward prediction is begun. This technique has been applied to storm-scale research datasets (e.g. Weygandt, Shapiro and

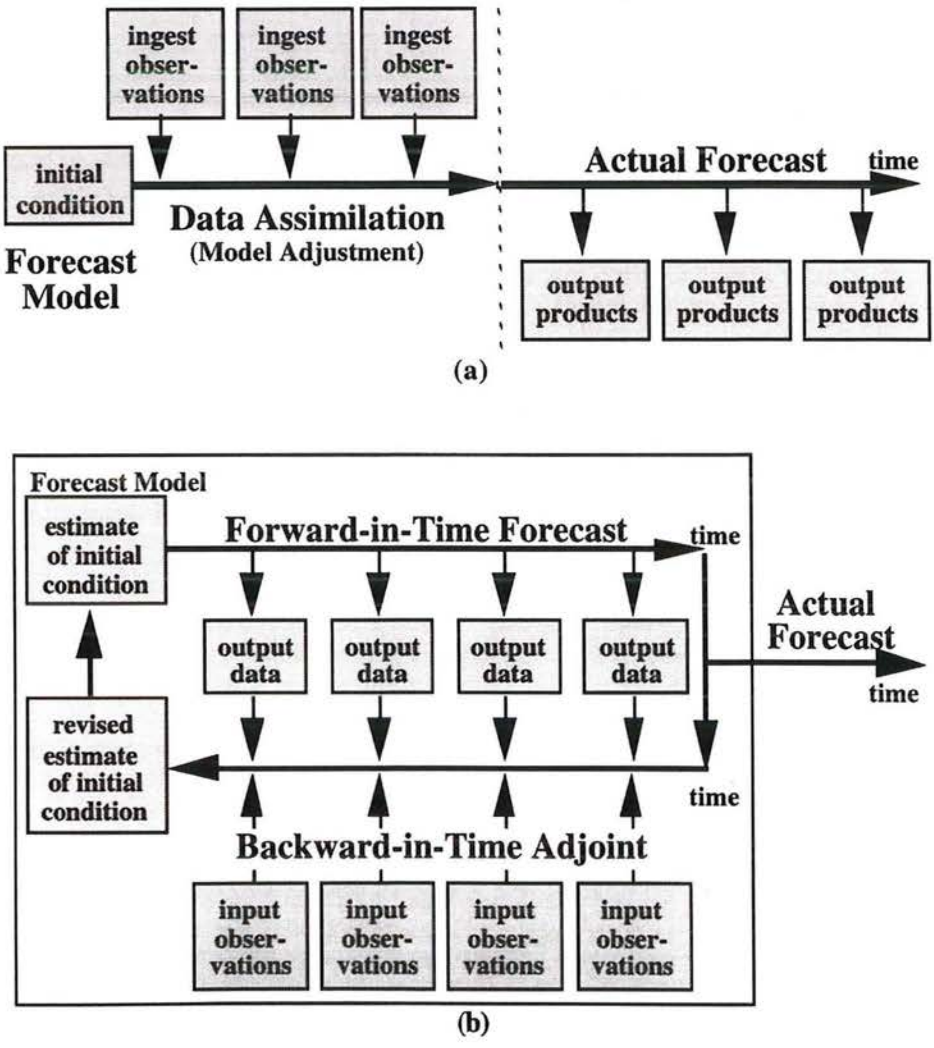

Figure 1 — Schematic of (*a*) forward and (*b*) variational (adjoint) data assimilation

Droegemeier, 1995; Shapiro *et al.*, 1996) and, more recently, to real-time operational predictions (Droegemeier *et al.*, 1996(*b*); Xue *et al.*, 1996(*b*)).

The second method, known as variational data assimilation (or the adjoint method; LeDimet and Talagrand, 1986) and shown in Figure 1(*b*) is a more elegant, though computationally intensive, approach based on control theory that seeks to optimize, in an objective manner, all available observations. In this method, the model is provided with a first guess of the initial state (e.g. from a previous forecast). A short prediction (e.g. 15 to 30 min for storm-scale applications) is then initiated, with output from the model saved frequently. At the end of this so-called assimilation window, the adjoint of the forward model is run backward in time in an attempt to minimize the discrepancy between the output from the forward model and any observations made during this short forward prediction. The adjoint integration provides information on how to adjust the initial state of the model such that the observations and forecast are in better agreement. This process is repeated in an iterative fashion until a converged or optimal initial state is reached, and at that point the actual forecast is initiated.

Sun, Flicker and Lilly (1991) and Kapitza (1991) were the first to apply the adjoint technique to the single-Doppler retrieval problem using simulated data, and since then it has been used to retrieve wind and thermodynamic fields (e.g. Sun and Crook, 1994) and microphysical quantities (e.g. Verlinde and Cotton, 1993; Sun and Crook, 1995; Sun, Crook and Miller, 1995; Sun and Crook, 1997) from real data. Simpler and computationally more efficient forms of the full adjoint method have also been developed and similarly applied for non-microphysical retrievals (e.g. Xu *et al.*, 1995; Xu and Qiu, 1995).

Ensemble forecasting

One of the greatest challenges in operational NWP, brought about by the predictability issues described above, is the quantification, through objective means, of forecast reliability. While a single forecast obviously has measurable value, information concerning the extent to which other solutions, started from nearly the same initial state, are plausible would provide the forecaster with a measure of the likelihood that a particular forecast outcome will occur.

A variety of so-called "ensemble" forecasting techniques have been developed to satisfy this need and are being applied routinely to large-scale models by most operational prediction centres around the world (e.g. Toth and Kalnay, 1993; Molteni *et al.*, 1996). In this strategy, a single "control" forecast is augmented by a number of other forecasts made using lower spatial resolution and initial conditions perturbed in some manner relative to those of the control. Various analysis techniques are then applied to evaluate the "spread" of the ensemble solutions about the control forecast.

Ensemble forecasting will no doubt play a key role in operational storm-scale NWP (Brooks, Doswell and Maddox, 1992), particularly because events at that scale are initiated and governed, at least in part, by processes and structures that are not well observed, understood, or represented in current numerical models (e.g. boundary-layer convergence lines and rolls; variations in land-cover type and soil-moisture content). Two important considerations must be addressed, however. The first involves the creation of initial conditions for the various ensemble members. While this task is relatively straightforward for large-scale flows, it represents a considerable challenge on the storm-scale because the associated natural variability is not known. Second, it is likely that, given the types of events being represented, the spatial resolution used for the ensemble members on the storm-scale will be rather similar to that of the control forecast (e.g. if 1 km resolution is needed to capture the structure of multicell convection in the control forecast, the ensemble resolution probably cannot exceed 2 km). This is in sharp contrast to current large-scale implementations.

Quantifying forecast skill

Fundamental to NWP is the quantification of forecast skill. On the larger-scale, this process is well established and involves the use of mostly conventional statistical techniques (e.g. rms errors, anomaly correlations, S1 scores) suited for fields that exhibit relatively smooth spatial variations (see Wilks, 1995, Chapter 7). In contrast, the temporally and spatially intermittent nature of storm-scale weather makes the definition of a "good" forecast exceedingly difficult.

Consider, for example, the situation in which a model produces a supercell thunderstorm of precisely the correct type, morphology and timing, but with a position error of 20 km. Traditional error scores would judge this forecast to be a failure, while it clearly has some value (based in part on the manner in which the information is to be used). Considerable effort is now being directed toward developing techniques for assessing forecast skill on the storm-scale (e.g. Carr *et al.*, 1996), with emphasis placed on strategies similar to those now being used for hurricanes.

Computing, data and networking

Operational storm-scale NWP will place tremendous demands on high-performance computing and networking, principally because such forecasts are highly perishable and thus must be generated quickly in order to be of practical value. Given the high spatial resolution, relatively large domains, and detailed physics required to represent storm-scale motions faithfully, together with the required pre-processing of very fine-scale radar data and the creation of ensemble forecasts, the computational challenge quickly becomes apparent. Indeed, it is likely that computers having sustained performances of 300 gigaflops to 1 teraflop, memories of 100 gigabyte capacity or greater, highly parallel I/O, and very high bandwidth links to remote data and storage facilities will be required in order for storm-scale NWP to become practicable in the operational environment.

A prototype storm-scale NWP system

Overview

In an effort to focus considerable national resources on the storm-scale prediction problem, the National Science Foundation (NSF) established the Center for Analysis and Prediction of Storms (CAPS) at the University of Oklahoma in 1989. As an NSF Science and Technology Center, CAPS seeks to demonstrate the practicability of storm-scale numerical weather prediction with an emphasis on deep convective storms, and to develop, test, and help implement, in a variety of operational settings, a complete prototype storm-scale numerical prediction system (Droegemeier, 1990).

CAPS's ultimate goal is to produce a six- to nine-hour forecast in 30 to 60 minutes within a domain of the order of 1 000 x 1 000 km^2. In order to represent the multiple scales present, adaptive grid refinement (two-way nesting, e.g. Skamarock and Klemp, 1993) is being applied (Figure 2). The key elements of the prediction process and associated dataset sizes and bandwidths are shown schematically in Figure 3. After being ingested and quality controlled, observational data pass through a number of retrieval steps. Once initialized, the prediction model solves approximately 1 trillion equations to produce a nine-hour forecast. The associated datasets can range in size from 100 Gbytes to 5 Tbytes, depending on their ultimate use.

The prediction system

The foundation of CAPS is a new three-dimensional, non-hydrostatic numerical prediction system known as the Advanced Regional Prediction System (ARPS). As shown schematically in Figure 4, it includes a data ingest, quality control, and objective analysis package known as ADAS (ARPS Data Analysis System), a single-Doppler radar parameter retrieval and assimilation system known as ARPSDAS (ARPS Data Assimilation System, of which ADAS is a component), the ARPS prediction model itself, and post-processing packages known as ARPSPLT and ARPSVIEW. This system has been under development for the past several years (e.g. Xue *et al.*, 1995; Xue and Droegemeier, 1997), and was written using industry-standard coding practices. The ARPS is highly modular, extensively documented, specifically designed to be portable among a wide variety of scalable-parallel computers, and written to be maintainable as an operational or commercial tool with minimal involvement by those who developed it. The source code and all documentation are free and may be used and redistributed without restriction.

Operational test results

Since 1993, CAPS has focused considerable resources on real-time operational tests of its forecast system in collaboration with the National Weather Service, the NOAA Storm Prediction Center, Tinker Air Force Base, the National Aviation Weather Center, American Airlines, the Korean Meteorological Administration, and a private meteorological consulting firm (Janish *et al.*, 1995; Droegemeier *et al.*, 1996(*a*), (*b*); Xue *et al.*, 1996(*a*), (*b*)). CAPS conducted its fourth real-time operational test from 15 May to 6 June 1996. Relative to earlier tests, this experiment involved: the use of real-time wide-band or full-volume (Level II) data from the KTLX (Twin Lakes, Oklahoma) WSR-88D radar; the use of NEXRAD Information Dissemination Service (NIDS) (Level III) digital wind and reflectivity data; application of the new ARPS Data Analysis System (ADAS); the use of real-time Oklahoma Mesonet data; and application of the ARPS single-

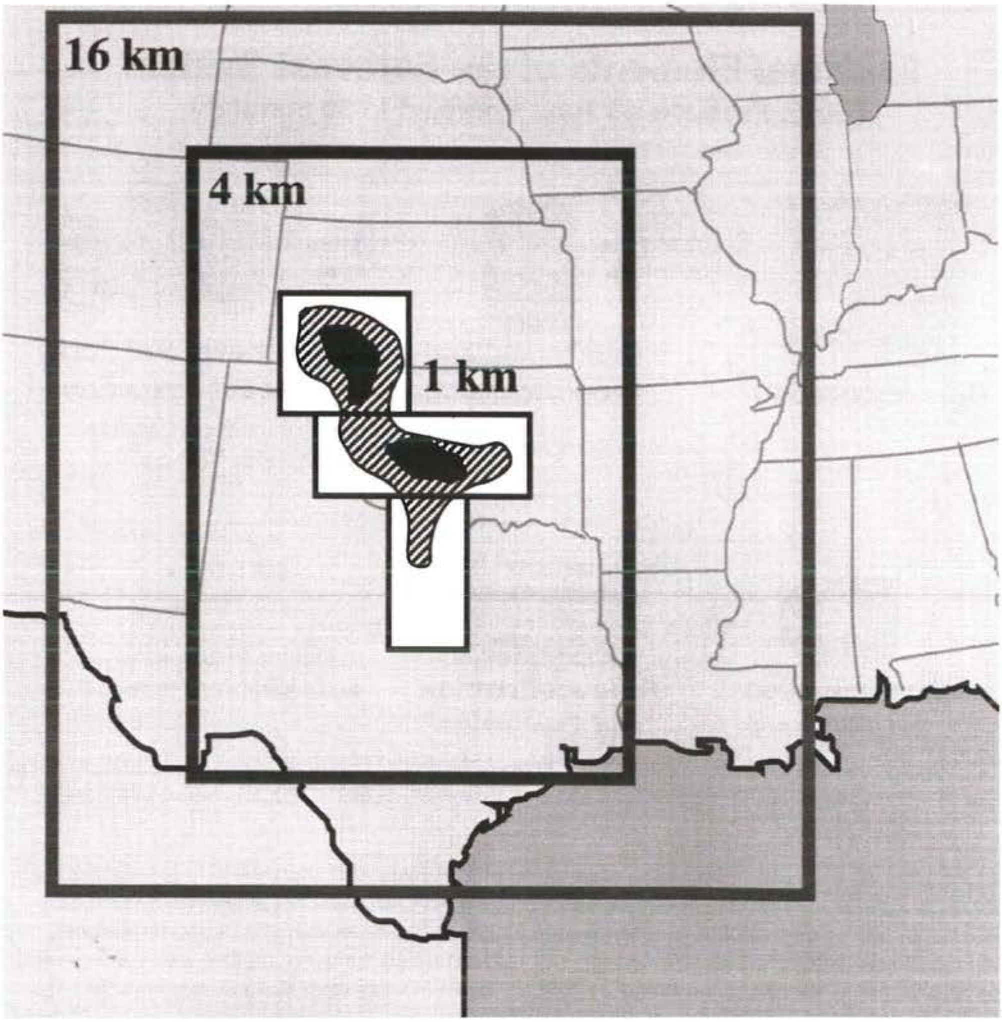

Figure 2 — Computational domains for storm-scale NWP as envisioned by CAPS

Doppler velocity retrieval and forward-variational data assimilation system, from which the 3-D wind field can be retrieved from the radial flow component provided by a single Doppler radar.

Because space does not permit an extensive discussion of the 1996 operational tests, we present only a few results from the six-week period. Each day, two seven-hour forecasts (17Z to 00Z) were produced using the two computational domains shown in Figure 5 (Droegemeier *et al.* 1996(*b*); Xue *et al.* 1996(*b*)). The fixed-in-location outer grid, at 9 km resolution, was augmented by a 3 km resolution re-locatable inner grid. The vertical grid resolution for both domains varied over 43 levels from 20 m near the ground to around 1 km at the top of the model (20 km), and the inner grid was nested one-way within the outer grid.

All predictions were made using identical numerics and physics parameterizations for both the inner and outer grids, including fourth-order horizontal and second-order vertical advection, a 1.5-order TKE representation for sub-grid-scale processes, explicit Kessler warm-rain microphysics, and the Tao and Simpson (1993) radiation physics coupled with a surface energy budget and two-layer soil model that considers soil and vegetation type.

Figure 6 shows the sequencing for the spring 1996 forecasts, each of which was produced as a "cold start", i.e. no continuous assimilation cycle was used whereby a previous ARPS forecast could serve as the first guess for the next cycle. This was done as a first step toward a continuous or semi-continuous cycle, the testing of which is under way (see section "Plans

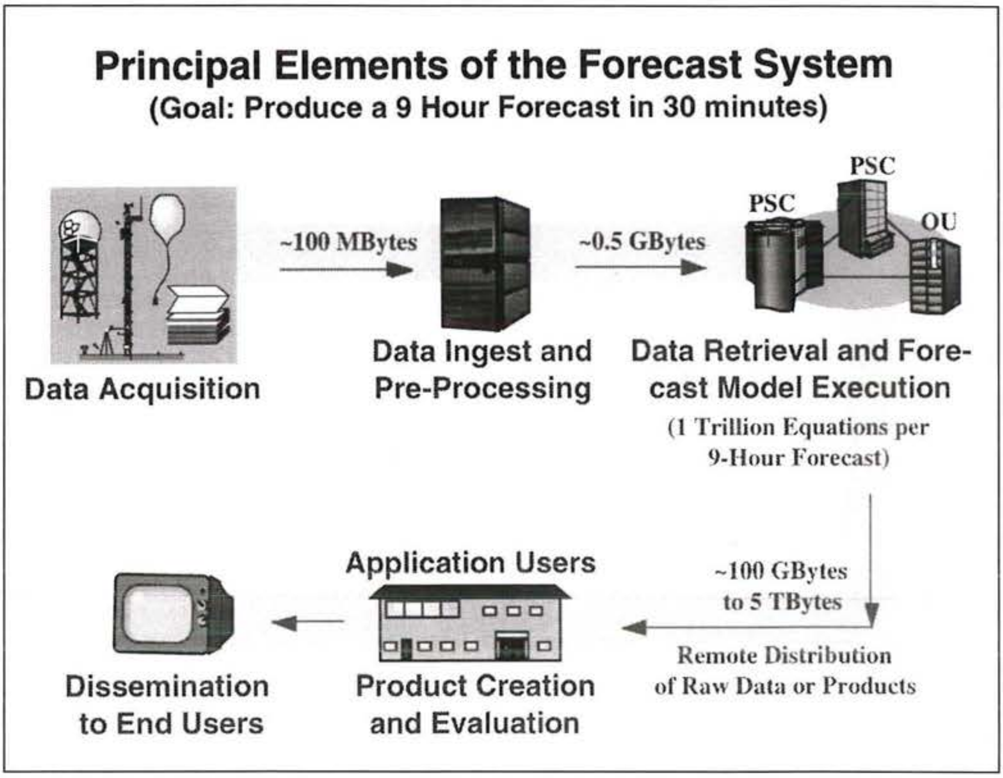

Figure 3 — The principal elements and bandwidth-dataset sizes involved in creating a nine-hour storm-scale forecast in 30 minutes at CAPS

for the near future"). The background fields for the outer grid (at 17Z) were provided by the 12Z run of the National Center for Environmental Prediction (NCEP) 60 km resolution rapid update cycle (RUC) model (Benjamin *et al.*, 1994). These fields were interpolated to the ARPS grid for use by ADAS, and then all other available data, particularly those from the Oklahoma Mesonet, were added. Because real-time wide band (Level II) WSR-88D data were available only from the KTLX

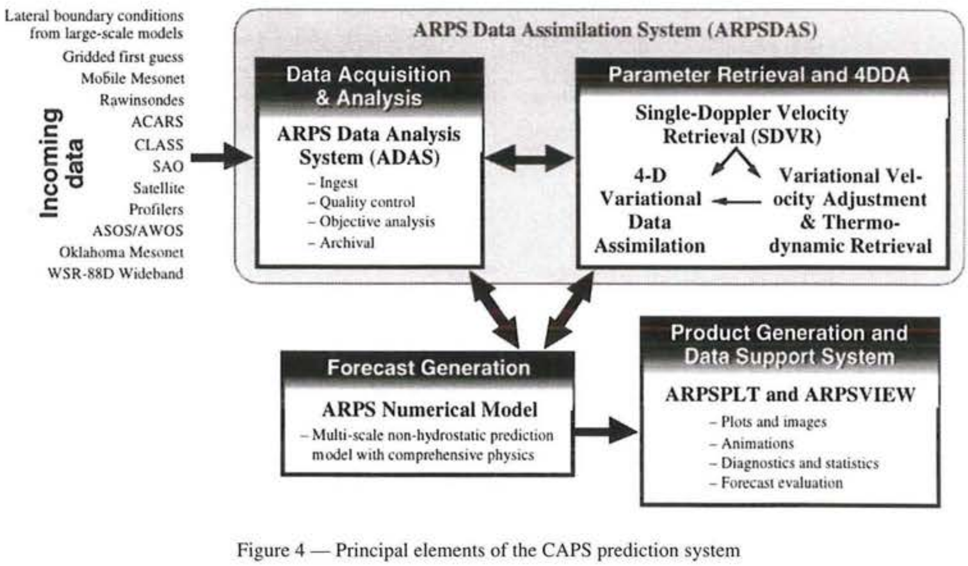

Figure 4 — Principal elements of the CAPS prediction system

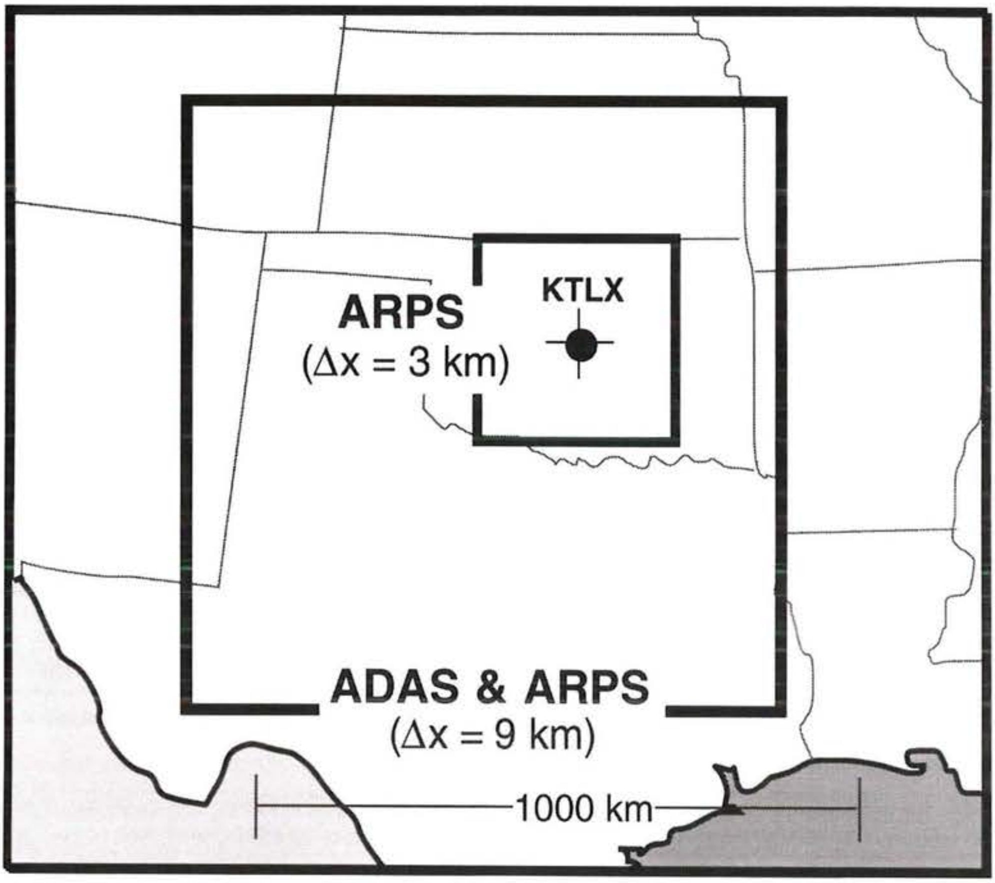

Figure 5 — Configuration of the ARPS prediction grids used in the spring 1996 operational tests. The 9-km resolution ADAS and outer ARPS grid covered essentially the same area. Also shown is the relocatable, 3-km inner grid, centred in this example over the Oklahoma City NEXRAD radar (KTLX).

radar, alternative methods were sought to improve the windfield over a larger portion of the ADAS and ARPS domains. A solution implemented toward the end of the operational period consisted of ingesting the lowest four tilts of digital Level III WSR-88D radial wind data from several radars into the ADAS. The reflectivity fields were also used to enhance the humidity analysis in rainy areas.

The lateral boundaries of the outer ARPS grid were forced by the RUC forecast using three-hourly data linearly interpolated in space and time. The initial and one-way nested lateral boundary conditions for the inner fine grid were provided by the ARPS coarse grid forecast. When active weather was anticipated or occurring within the scan volume of the KTLX radar, wide band data from it were added to the fine grid by ADAS.

In an effort to mimic, as closely as possible, a true operational forecast environment, the Pittsburgh Supercomputing Center dedicated to CAPS, for about six hours each day, six processors on its Cray C90 and 256 processors on its Cray T3D supercomputers. The coarse grid prediction, run on the C90, required approximately 45 minutes of wall clock time for a seven-hour forecast with a memory requirement of 29 million words (232 megabytes) (Figure 6). The fine grid, run on the T3D using Parallel Virtual Machine (PVM), took about 1 hour and 45 minutes and consumed 41 million words (328 megabytes) of memory. CAPS used the World Wide Web as a primary means for making its prediction results available to end-users. An electronic evaluation form allowed them to submit detailed comments on model performance for later analysis.

To illustrate the potential of storm-scale NWP, we show in the left half of Figure 7(*a*) the composite radar reflectivity field from the five-hour, 9-km grid ARPS model forecast on 24 May

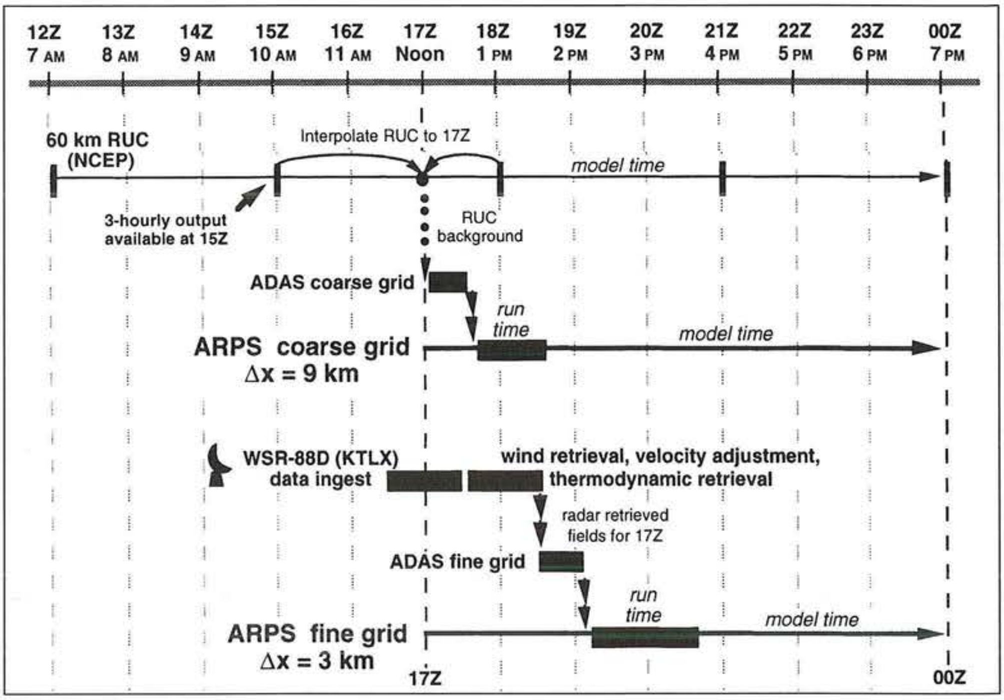

Figure 6 — The daily prediction timeline for the 1996 spring operational test (SOP). Thin arrows represent model time and thick blocks represent wall clock or model execution time.

1996; the corresponding radar image at nearly the same time is shown on the right. On this day, storms formed along a dry line in the northeastern corner of the Texas panhandle at approximately 19 UTC. With time, the storms became severe, resulting in numerous reports of golf ball-size hail and two brief tornadoes. The model storms first appeared at around 20 UTC near the Oklahoma-Kansas border, then evolved quickly into a line of storms along the front. At the end of the five-hour prediction (22 UTC), the 3-km resolution fine-grid storm structure (Figure 7(*b*)) appears closer to the observation than the coarse-grid prediction (Figure 7(*a*)). The model storm initiation was about one hour late and the line location was about one county too far to the west on the coarse grid, but closer on the fine grid. Overall, the prediction was very good (note that no WSR-88D data were used in this forecast and that, outside the Oklahoma Mesonet region, few additional observations were available).

On 8 June 1995, a strong cold front and dryline were present in the northern Texas panhandle; even without radar data, the model was able to capture the overall structure and morphology of these intense storms (Droegemeier *et al.*, 1996(a); Xue *et al.*, 1996(a)). In cases where the dynamical forcing is less strong, the model's skill is reduced. As discussed below, a complete assessment must await the availability of real-time wideband data over the entire forecast domain as well as spatial resolutions more suited for the events under consideration (e.g. down to 1 km using multiple two-way nests).

During winter and spring 1997, two other real-time operational test periods were conducted as part of a research and development collaboration between CAPS and American Airlines that seeks to determine the value of storm-scale NWP in commercial aviation. These tests utilized real-time NIDS data from some 20 WSR-88D radars, and represented the first fully automated implementation of the entire forecast system. Results from the winter operational period were reported by Carpenter *et al.* (1997), and the reader is encouraged to visit the CAPS Web page at http://www.caps.ou.edu to examine results from the spring experiments.

Plans for the near future

CAPS plans to continue its real-time operational testing and begin daily runs by the end of 1997. An intensive test involving multiple models is being organized by CAPS for the spring 1998

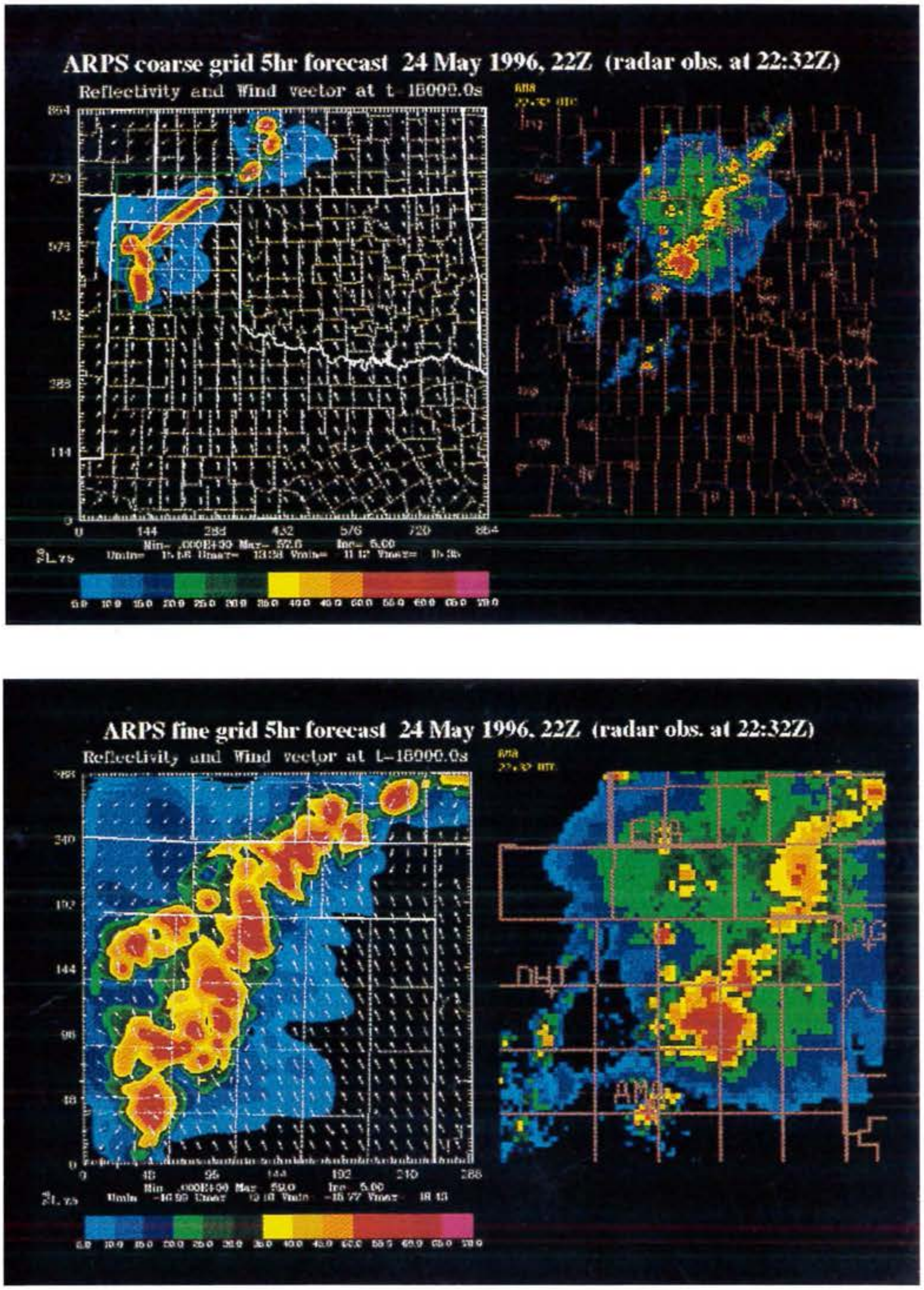

Figure 7 — Coarse-grid (*above*) and fine-grid (*below*) ARPS prediction at 22Z on 24 May 1996; the model equivalent reflectivity is shown on the left and the corresponding radar images on the right.

severe weather season over the USA Southern Great Plains, for which CAPS hopes to be using real-time wideband data from several WSR-88D radars, two-way nested gridding down to 1 km resolution, a satellite-based 3-D cloud analysis, and elements of its adjoint data assimilation and parameter retrieval system. The testing of intermittent data assimilation, continuous forecast cycles and forecast ensembles is under way and is expected to be evaluated operationally sometime in 1999. Only when these capabilities are in place can a full determination of the practicability of storm-scale NWP be made.

The future of operational storm-scale NWP

With the advent of a national network of scanning Doppler radars, the availability of the world's most powerful parallel-processing supercomputers and a much improved understanding of the small-scale atmosphere through intensive research across all sectors of the meteorological community, the ability to predict explicitly the initiation and evolution of individual convective storms and their winter counterparts appears to be within reach. In the light of these advances, operational prediction centres face extraordinary challenges in determining how to best implement storm-scale NWP.

A number of options exist. Given that weather on small scales is often driven by highly local effects, one must ask whether storm-scale NWP should be conducted centrally or in a distributed manner. The cost effectiveness of a centralized operation is obvious, but a regionally distributed scenario, in which local forecast offices either run their own "customized" versions of a unified model (perhaps in collaboration with nearby universities or research institutes), or guide the execution of centrally operated models over their particular geographic region, is an attractive alternative. Another issue concerns the mode of model operation. One can envision a strategy of continuous forecast cycles, as is now the case at most centres; however, the intermittent and often highly localized nature of storm-scale weather suggests that relocatable models, run "on demand" so as to target areas of particularly active weather, might prove effective.

Several other hurdles also exist, but are not insurmountable. The fundamental predictability of small-scale motions remains to be determined, but may be determined only through practical experiments rather than theoretical analyses. Accessing and processing huge volumes of radar data in real-time is another formidable challenge, particularly in the light of the expense of running the forecast system when adjoint data assimilation and ensemble forecasting are taken into consideration. Finally, the accurate representation of land surface processes, particularly as related to sensitivities induced by spatial and temporal variations in vegetation cover and soil moisture, will likely be critical to the success of operational storm-scale NWP.

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INFLUENCE OF OBSERVATIONS ON THE OPERATIONAL ECMWF[1] SYSTEM

By Graeme KELLY

Introduction

The global meteorological observing system is extremely expensive and in the present economic climate, conventional observations such as radiosondes are beginning to be severely reduced. At the same time, improved satellite systems are becoming available. The operational observing network, which uses both conventional and satellite measurements, influences how accurately the initial atmospheric state can be prescribed and, to a large extent, the resulting forecast accuracy. There is, therefore, an urgent need to investigate the importance of different observing systems in numerical weather prediction (NWP) performance.

In this work, we quantify, through observing system experiments (OSEs), the contribution made by the main ground- and satellite-based operational systems to medium-range forecasting. In an OSE, the impact of a specified observing system is assessed by comparing extended data assimilation and regular forecasts based on the total operational system with those generated, excluding the particular observing system under investigation. The value of a new or experimental observing system can be assessed in a similar manner.

In a previous study (Kelly *et al.*, 1993) performed a series of OSEs using the then operational ECMWF system based on optimal interpolation (Lorenc, 1981). They used a baseline observing system consisting only of *in situ* data, comprising radiosondes, AIREPs, SYNOPs, ships and buoys. OSEs were used to assess the impact of adding satellite-derived temperature and humidity information (SATEMs) only, cloud motion winds (SATOBs) only, and SATEMs plus SATOBs to the baseline system. They found that adding SATEMs or SATOBs alone improved the

[1] European Centre for Medium Range Weather Forecasts

forecast but that adding both SATEMs and SATOBs gave less improvement than adding just one of those observing systems. These unsatisfactory results triggered an appraisal of the use of data in the O/I system and helped motivate the decision to develop a 3D-Var system which could analyse the Tiros operational vertical sounder (TOVS) radiances directly, together with all other data. The purpose of this paper is to repeat and extend the earlier experiments, but this time using the 3D-Var assimilation system which became operational in early 1996. These new results, described in subsequent sections, demonstrate that the main observing systems are contributing in important ways to medium-range forecasts in the northern hemisphere, in the tropics, and in the southern hemisphere.

Experiment design

Two series of OSEs were run for periods in December 1996 and February 1997. These experiments used the operational system of 15 May 1997, which includes a revision to the background cost function of the variational analysis (Andersson *et al.*, 1994, 1996; Bouttier, Derber and Fisher, 1997). In earlier experiments (Kelly *et al.*, 1993) problems were revealed with the use of SATEMs in the northern hemisphere (Kelly and Pailleux, 1988). As a consequence, these satellite data were removed from the northern hemisphere and the tropics until the introduction of 1DVAR (Eyre *et al.*, 1993). The interpretation of OSEs is not always straightforward. The value of an observing system is most easily demonstrated when an energetic event seen only by one observing system occurs in the area being observed. A case study demonstrating this is included.

The new OSE experiments systematically removed the following observing systems from the full operational system:

(*a*) Satellite clear-radiance data from TOVS satellites (NOTOVS);

(*b*) Geostationary atmospheric motion winds (AMWs) from cloud and water vapour (NOAMW);

(*c*) Radiosonde wind, temperature and humidity data (NORAOB);

(*d*) Aircraft winds and temperatures (NOAIREP);

(*e*) The combined removal of both (*a*) and (*b*) (NOSAT).

All these experiments have been compared to the full operational system (CONTROL).

The results are grouped into two sections, first the satellite measurements and second the conventional upper-air measurements. All verification statistics use the operational ECMWF analysis. Similar results were obtained for the two periods, 5–20 December 1996 and 1–14 February 1997; the two experiments have therefore been combined to give a 29-day set of forecast scores.

Results

Satellite OSEs

A series of four experiments has been included: CONTROL, NOTOVS, NOAMW and NOSAT. The ERS scatterometer has been included in all experiments. Its impact will be discussed in a future article.

Forecast wind impact at 200 hPa

Aviation forecasts which use upper level winds are a major output product of NWP and the impact of satellite data on the upper-level winds is illustrated. Figure 1 shows the overall impact of satellite data and it varies in the short range from one-third of a day in the northern hemisphere, to 1.5 days in both the tropics and the southern hemisphere. AMWs have most value in the

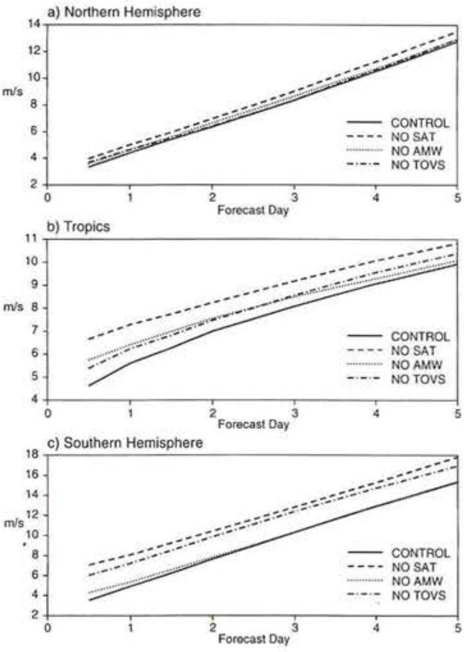

Figure 1 — Satellite OSE 200 hPa vector wind root mean square forecast for (*a*) northern hemisphere; (*b*) tropics; and (*c*) southern hemisphere

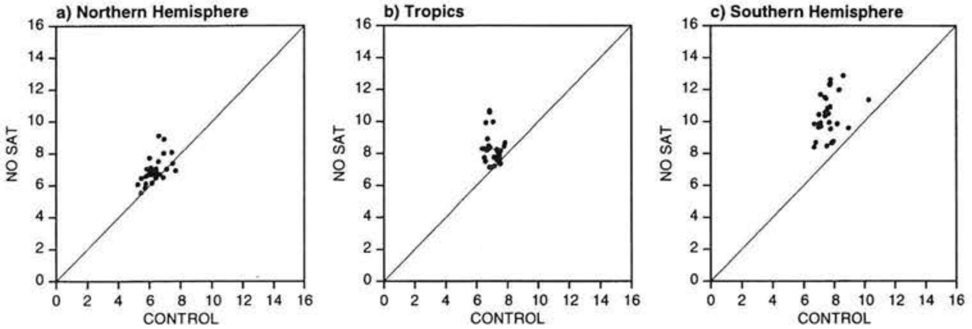

Figure 2 — Satellite OSA (CONTROL v NOSAT) 200 hPa vector wind root mean square 48-hour forecast scatter plots for (*a*) northern hemisphere; (*b*) tropics; and (*c*) southern hemisphere

tropics but give a significant improvement in the northern hemisphere. TOVS have a significant impact in the tropics and a large impact in the southern hemisphere.

The scatter of these forecast wind rms error for the NOSAT v CONTROL at day two is shown in Figure 2. Almost all forecasts are positive for CONTROL. In all cases, CONTROL gives a smaller rms error and the largest deterioration in the NOSAT forecast varies from 2 m s^{-1} in the northern hemisphere to 5 m s^{-1} in the tropics.

Forecast height impact at 500 hPa

Figure 3 shows the performance of the Operational ECMWF forecast model. The scores calculated are for 500 hPa geopotential height anomaly correlation. The NOSAT experiment shows a negative impact in all areas. This is an important finding, as it is often suggested that it is not possible to demonstrate the impact of satellite data, especially in the northern hemisphere. This result comprises both the effect of AMWs and also of TOVS clear radiance data. In the case of AMWs, there is a positive impact in the northern hemisphere which must be largely influenced by the tropics, where the bulk of the data is found. TOVS data, however, have only a small impact in the northern hemisphere, its main impact being in the southern hemisphere, where it improves the medium-range forecast by up to one and a half days. In the presence of TOVS data, then, the AMWs provide little additional benefit in the southern hemisphere. If TOVS data are not present, then the AMWs have a positive impact.

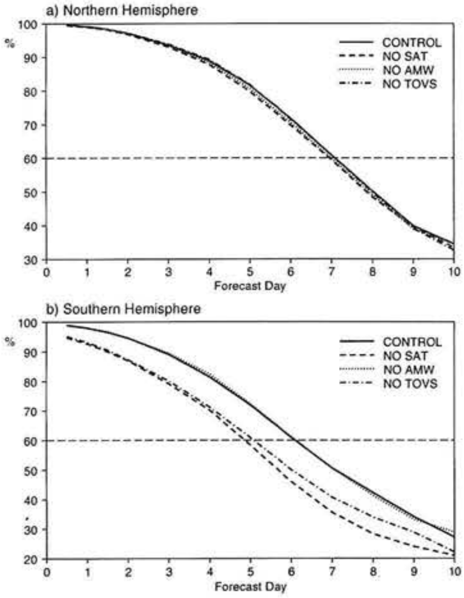

Figure 3 — Satellite OSE 500 hPa anomaly correlation forecast for (*a*) northern hemisphere; and (*b*) southern hemisphere

Conventional upper-air OSEs

The experiments included in this group are:

- CONTROL, which uses all data;
- NORAOB, which excludes both radiosonde winds, temperatures and humidity data; and
- NOAIREP, which excludes both aircraft wind and temperature observations.

For purposes of comparison, the NOAMW experiment will also be considered in this group in order to assess the relative importance of the AIREP and AMW wind observing systems.

Forecast wind impact at 200 hPa

The impact on the 200 hPa winds is shown in Figure 4. As for the satellite system experiments, all verification is based on the ECMWF operational analysis.

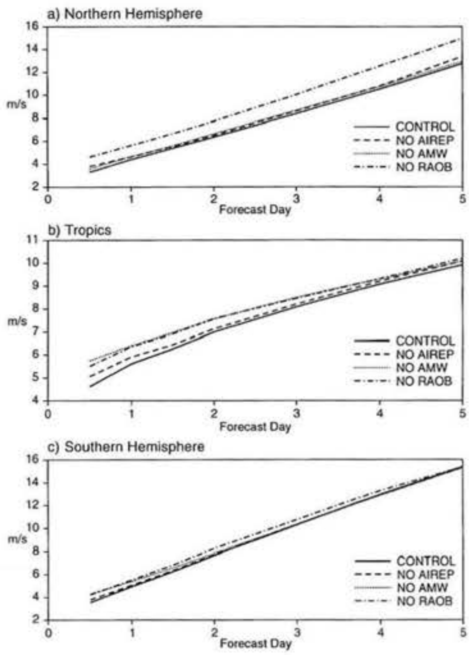

Figure 4 — Conventional upper-air OSE 200 hPa vector wind root mean square forecast for (*a*) northern hemisphere; (*b*) tropics; and (*c*) southern hemisphere

In the northern hemisphere, the scores are dominated by the radiosondes; with their exclusion (NORAOB) the forecast accuracy is reduced by one day. The AMWs and AIREPs have a lesser effect and both have about equal weight, each degrading the forecast by one-third of a day, if omitted.

In the tropics, radiosondes and AMWs have a comparable impact of about two-thirds of a day. Removing the AIREPs has a smaller but still negative impact. Currently, there are few radiosondes in the tropics and this number is being reduced. Such a reduction will adversely affect forecast skill.

As seen previously, TOVS data dominate the forecast impact in the southern hemisphere. Removing when degrades the forecast skill by around one and a half days. Excluding the radiosonde data in this region reduced the forecast skill by about one-third of a day and AMWs and AIREPs have only a small impact.

Scatter plots are shown for NORAOB v CONTROL 48-hour forecasts (Figure 5) and almost all points in the three regions show a negative impact due to the exclusion of radiosondes. The largest radiosonde impact is in the northern hemisphere and has a magnitude of about 3 m s^{-1}.

Forecast height impact

Figure 6 shows the 500 hPa anomaly correlation scores. In the northern hemisphere the forecast accuracy is dominated by the radiosondes without which the five-day forecast skill is reduced by about one day. The radiosondes have less impact in the southern hemisphere. The influence of AMWs and AIREPs is somewhat smaller but still positive.

Synoptic case

After the discussion of objective scores it is of interest to look at the synoptic impact. A case has been selected during the February experiment in which strong cyclogenesis occurred in the North Atlantic. The base date of this situation is 12 UTC on 10 February 1997. As discussed, the OSE experiments which have the most impact are NORAOB and NOSAT and forecasts from these have been compared with the control and the verifying operational analysis.

The 48-hour forecasts and the verifying analysis are shown in Figure 7. Large errors are clearly seen in both the NORAOB and NOSAT south of Newfoundland. Both of these forecasts fail to deepen the low-pressure system which is

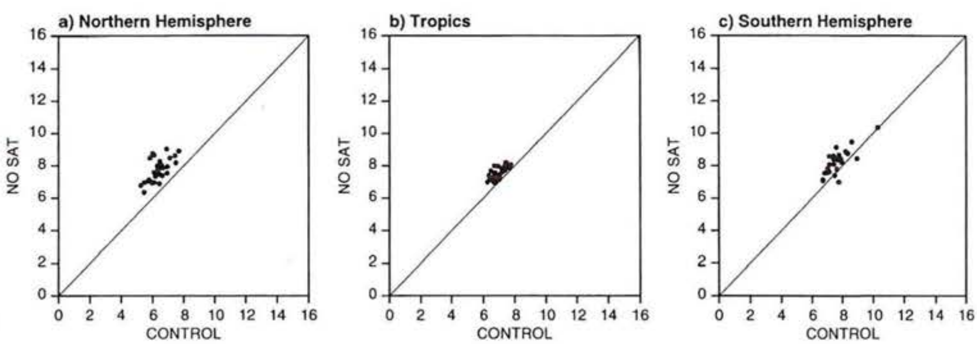

Figure 5 — Conventional upper-air OSE (CONTROl v NORAOB) 200 hPa vector wind root mean square forecast scatter plots for (*a*) northern hemisphere; (*b*) tropics; and (*c*) southern hemisphere

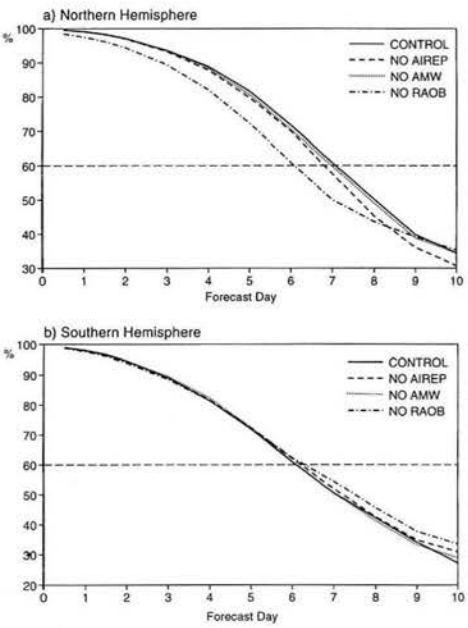

Figure 6 — Conventional upper-air OSE 500 hPa anomaly correlation forecast for (*a*) northern hemisphere; and (*b*) southern hemisphere

captured well in the control. In order to capture this development, both the radiosonde and satellite observations are required. Another region in which the NORAOB experiment is further degraded in comparison with the remaining experiments is in the complex low-pressure system extending from the mid-Atlantic, over Scotland to the east of the Baltic. In this experiment, the system is much weaker in intensity than the CONTROL OR NOSAT. The low-pressure system in this complex near Scotland is also poorly forecast.

Moving to the 96-hour forecasts, shown in Figure 8, the low pressure system south of Newfoundland at day two has moved north-west and deepened. The control forecast provides the best representation of this low pressure system. It deepens the low considerably more than the other experiments, even though its central pressure is too high and its position has a 2° error. The complex low pressure seen in the 48-hour forecast has now developed into four main low-pressure systems. Large errors in the NORAOB forecast are evident, providing a poor forecast for Europe. The NOSAT forecast is a little better but there is a large error in the system south of Ireland. In comparison, the control forecast develops this low pressure system very well.

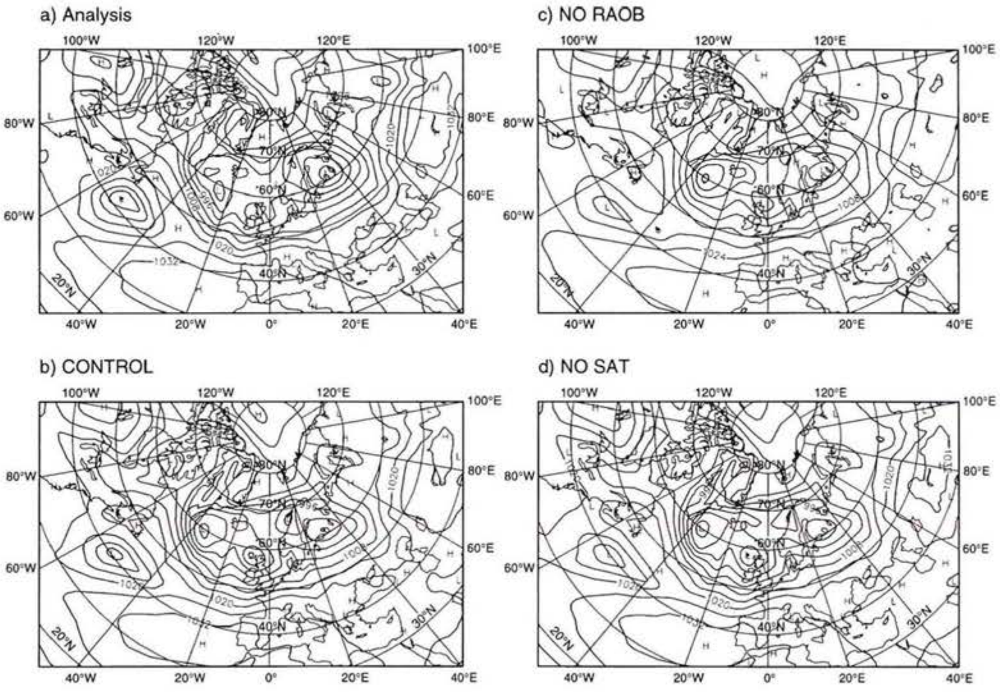

Figure 7 — Mean sea-level fields valid at 12 UTC on 12 February 1997 for (*a*) surface pressure operational analysis; (*b*) 48-hour forecast for control experiment; (*c*) for NORAOB experiment; and (*d*) for NOSAT experiment

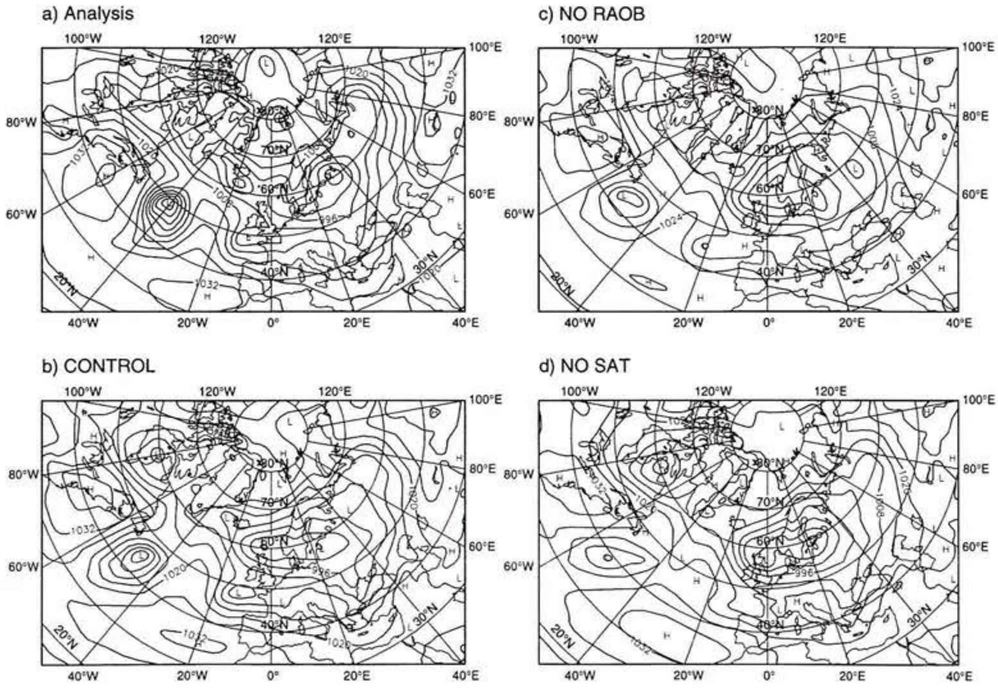

Figure 8 — Mean sea-level fields valid at 12 UTC on 14 February 1997 for (*a*) surface pressure operational analysis; (*b*) 96-hour forecast for control experiment; (*c*) for NORAOB experiment; and (*d*) for NOSAT experiment

Conclusions and recommendations

In general, the results obtained in this set of experiments are encouraging. The current operational 3D-Var system has been shown to benefit from the assimilation of both satellite data and conventional observations and, broadly speaking, its performance in each of the northern hemisphere, the tropics and the southern hemisphere is satisfactory. It is clear that, in some regions, there is a degree of redundancy in the current observing system but this is necessary to provide coverage in the event of occasional failures in parts of the observing system. The inclusion of each data type almost always improves the forecast system, however, which was not invariably the case in the past.

The satellite OSEs show that AMWs have a positive impact, particularly in the northern hemisphere and the tropics. High space and time resolution AMWs are now being produced and their impact should be tested. Alternatively, the TOVS clear radiances provide benefits in the southern hemisphere and the tropics but have only a small impact in the northern hemisphere. In this region, the radiosonde network is particularly important in improving forecast accuracy. However, if the current trend to reduce this network continues it will soon result in a reduction in forecast accuracy. The large impact of TOVS in the southern hemisphere suggests that increasing the use of TOVS in the northern hemisphere could become a priority with the continuing decline of the radiosonde network. Finally, TOVS data provided a large, positive impact on the tropical winds, a result which has not been reported from previous experiments.

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SEASONAL-TO-INTERANNUAL CLIMATE PREDICTION AND APPLICATIONS: NEW INSTITUTIONS, NEW POSSIBILITIES

By A.D. MOURA[1] and E.S. SARACHIK[2]

Scientific capabilities for short-term climate prediction continue to increase

Since the previous article on climate prediction in the *WMO Bulletin* (Moura, 1994) there have been significant advances in our capability to make short-term (seasonal to interannual) climate predictions and to learn how to use them for the benefit of economies and societies. Since that time, the Tropical Ocean–Global Atmosphere (TOGA) Programme, a major research initiative of the World Climate Research Programme (WCRP), has ended and, while its results are still arriving, and will continue to do so for several more years, the legacy of TOGA is becoming apparent: the will, ability, and means to make useful short-term climate predictions connected with the *El Niño/* Southern Oscillation (ENSO) phenomenon (see National Research Council, 1996).

The concept of making of climate predictions is not different from that of making of weather predictions: it requires appropriate data, appropriate models, appropriate methods of initialization, and continuing research to improve all aspects of the process. The major difference in climate prediction compared to weather prediction is that the data for initialization are primarily ocean data and the prediction models are coupled atmosphere ocean models. The important quantity predicted is sea surface temperature (SST) and the consequent atmospheric statistics determined by the SST.

Since the first successful climate prediction by a coupled atmosphere-ocean model in the mid-1980s (Cane, Zebiak, and Dolan, 1986) which predicted the warm phase of the 1986-1987 ENSO a year in advance, it was assumed that progress in coupled modelling would be rapid and that climate prediction would advance expeditiously. The reality has been more sobering: modelling of ENSO by coupled general circulation models (GCMs) has run into a series of problems involving the simulation of the annual cycle and progress in prediction by coupled GCMs has been comparably slow in coming. It appears that the physics of the annual cycle involves a different mix of processes than the physics of ENSO. In particular, the heat fluxes into the ocean on annual time-scales seem to be in phase with the annually varying SSTs while the anomalous heat fluxes into the ocean on interannual time-scales seem to be completely out of phase with the anomalous SST characteristic of the interannual ENSO variations. It is likely that the problem with the seasonal simulations involve the correct simulation of Stratus cloud cover and thickness. It also appears that predictability of SST anomalies varies decadally and that this may be due to decadal fluctuations in ENSO itself.

Despite these problems, much progress has been made (recent reviews are given in Battisti and Sarachik, 1995; and Latif *et al.*, 1997). The simple coupled models have demonstrated

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reasonable skill in predicting SST in the tropical Pacific as much as a year in advance with indications that skill beyond a year is possible (Chen *et al.*, 1995, 1997). Because precipitation in the equatorial Pacific region is so tightly coupled with SST, skill in predicting SST translates into local precipitation predictions which are immediately useful to those nations and regions directly affected by ENSO, in particular, Australia, Chile, Ecuador, the island nations of the central and western Pacific and Peru. The translation of this skill to other regions of the world influenced by ENSO through teleconnections is less robust but is progressing as atmospheric models begin to converge to uniform and understood representations of mid-latitude effects in terms of tropical SST anomalies.

Advances in data assimilation have also unambiguously shown that subsurface data improve the initialization of predictions by coupled GCMs (e.g. Rosati, Miyakoda and Gudgel, 1997; Ji and Leetmaa, 1997). Regular and systematic predictions are now being made in a research mode at several institutes around the world. A list of prediction web sites as well as an up-to-date list of ENSO prediction papers can be found at: http://www.atmos.washington.edu/tpop/pop.htm

In addition to predictive models, another crucial element to prediction is the TOGA Tropical Atmosphere Ocean (TAO) Array in the tropical Pacific that reached full deployment at the end of 1994 and has been maintained since then. The importance of this array of moorings is that it measures precisely those quantities needed to initialize coupled predictions of SST in the tropical Pacific: in particular, surface winds, and surface and subsurface temperature. Not only does the array measure these crucial quantities, it makes them available in real-time to the Global Telecommunication System and to anyone who wishes to use the data.* The existence of the TAO Array and its associated real-time *in situ* and remote measurements not only assures that the world will be able to watch warm and cold phases of ENSO as they develop and not be surprised by them, it also guarantees the continuing interest in modellers in making the best possible predictions.

Expansion of the TAO array in the Atlantic is being pursued through the Pilot Research Moored Array in the Tropical Atlantic (PIRATA) project, and others, which are expected to provide additional data for global ocean model initialization for research and prediction.

The concept of end-to-end prediction: from prediction to applications

Soon after the first dynamical forecast was made, the realization arose that this information was valuable and could be used to help the countries and regions directly affected by ENSO. Some of these were reported previously (Moura, 1994) and more and more uses of forecast information are being found in both public and private sectors of the regions affected by ENSO. As applications of predictions began to be made, the intrinsic human dimension of the problem gradually became apparent. As this happened, the intimate interconnections between the physical and social science aspects of the problem came to the fore. These interconnections have been characterized as "end-to-end prediction" (see Sarachik and Shea, 1997), a concept that is simple in theory, but difficult to implement.

Because the elements of end-to-end prediction are so tightly coupled, the starting point is arbitrary but there are, basically, three major groupings to the effort: making the predictions, identifying the potential application in terms of the consequences of climate variability; and making the application.

We have already discussed the physical aspects of short-term climate prediction so we can move on to identifying the potential application. If it is to have an application, short-term climate prediction, climate variability has to have some consequence on some sector of the society or economy. It is important to note that the consequences of short-term climate variability may be either beneficial or harmful and that the role of short-term climate predictions can therefore be either to exploit the predicted beneficial consequences or ameliorate the harmful ones. Climate variations can be harmful to some sectors and beneficial to others—again, the problem will be to identify which sectors are affected by short-term climate variability and how climate information supplied in advance may be used to advantage.

The intrinsic human dimensions aspect is especially clear at this point. In order to understand well the consequences of climate variability and the potential range of responses to predictive information, it is important to understand both the normal workings of the system and the workings of the system as perturbed by predic-

* http://www.pmel.noaa.gov/toga-tao/realtime.html

tive climate information. No system of social or economic importance seems to exist that does not have an intrinsic human dimension aspect connected to it. For example, the operator of a dam whose prime purpose is to generate hydroelectric power may have to be especially careful that this purpose does not conflict with the need to avoid flooding down- or upstream. While, technically, job performance may depend on the total amount of power generated, the adverse consequences and publicity of seeing houses and farms destroyed by floods may modify the operation of the dam so that it is less than optimal for its stated purpose. A dam whose main purpose is to apportion water distribution to cities and farms may come under extraordinary pressure from farmers to increase their allocation during times of low rainfall, since their livelihood depends on it, yet the pressures for drinking water for cities which have more electoral power may exert a powerful countervailing influence. When dams with different purposes exist on the same river and control the same water stream, some way has to be found, in law or in custom, to apportion the water equitably. When predictive information is presented to the operators of these dams, they not only have to consider the pressures on them in their reactions, but also to take into account how the other dam operators will react to the same information. Water-management systems in general are complex systems made even more complex by the tangle of laws, agreements and political pressures within which they operate.

The third grouping of end-to-end prediction is making the application. In order for a sector to use the information for its specific purpose as, say, in our previous example, water management, the information has to be presented in a way the water manager can make use of it and may be aware of the uncertainty of the forecast so that trade-offs involved in altering the operation of the dam are understood and weighted. The best way of guaranteeing that the information is properly used is to insure the involvement of the manager with the predictive system, probabilistic in nature, at the outset. The scientists who make the prediction must be aware of the needs of the users and must shape the forecasts into a form, including the specification of uncertainties, that the user can profitably use. End-to-end forecasting thus comes full circle back onto itself: the process of prediction itself depends on how the prediction is to be used and the use may vary from sector to sector. Routine and regular feedback mechanisms need to be established for improvements of both the forecast system and the efficiency of application of forecast information.

One of the surprising results of trying to apply short-term climate predictions is the existence of barriers to their use: one might have thought that predictive information was useful *a priori* and that this would be recognized and accepted by all. Recent interviews with water managers in the Pacific north-west of the USA (Pulwarty and Redmond, 1997), however, has indicated resistance to the use of short-term climate predictions on the basis that the predictions are not accurate enough or that the usefulness of the forecasts has not been demonstrated. While some of this resistance can be classified as fear of the unknown (most of the water managers in the above-mentioned interviews who said the forecasts were not accurate enough did not, in fact, know the accuracy of the forecasts), the resistance is real and can best be dissipated by a demonstration of the effective use of forecasts for their sector. The demonstration of the efficacy of end-to-end forecasting becomes an important prerequisite to its adoption. There is also a need to involve the decision-makers early on as the end-to-end prediction system is developed for the specific sector/ region.

The WCRP and end-to-end prediction

The real benefit of a short-range climate forecast can only be realized if, on the basis of the forecast, a decision is made and suitable action taken within the affected region and/or sector. The quality and reliability of the forecast, the proper presentation and understanding of the forecast in probabilistic terms, and the trust invested by the decision-maker and earned by the forecaster, are all crucial elements for the optimal beneficial use of the information. The need to develop pilot demonstration projects becomes apparent: projects that bring together scientists, providers of climate forecasts and users in a continuous dialogue in order to understand the skills and limitations of the forecasts, the nature of the impacts of climate anomalies and the reactions of societies and economic systems. These projects would demonstrate all the elements of an "end-to-end prediction" system, connecting the science of climate prediction to societal needs.

The concept of an international centre for climate prediction was first mooted in 1989 during discussions related to the international TOGA Programme of the WCRP. This WCRP legacy remains an important element of planning for the implementation of the International Research Institute for seasonal-to-interannual climate prediction (IRI), recently established under a cooperative agreement between the National Oceanic and Atmospheric Administration (NOAA) Office of Global Programs, the Lamont-Doherty Earth Observatory of Columbia University and the Scripps Institution of Oceanography of the University of California at San Diego. As a research institute, the IRI will maintain close ties with WCRP programmes, in particular the Global Ocean-Atmosphere-Land System (GOALS) component of the CLIVAR Programme. In addition, it will serve as an important integrating function in connecting the results of GOALS with the WCRP/GEWEX Programme as they relate to anticipating changes in precipitation patterns and amounts over continental regions. Interaction with WCRP programmes is expected to be a two-way collaboration with the IRI capitalizing on new scientific insights produced by programmes like CLIVAR/GOALS and GEWEX while, at the same time, providing scientists participating in those international research programmes with advanced forecast information, computational capabilities, access to key data streams, and insights into the practical applications of the results of their research. Thus, the IRI will help bring the scientific achievements of the WCRP Programme to a more rapid and complete fruition and lead to fulfilment of societal needs.

In addition to the WCRP programmes, the IRI will work closely with related activities of the WMO Commission for Climatology and the International Geosphere–Biosphere Programme (IGBP), particularly the IGBP/START programme on regional education, training and targeted research. The IRI also anticipates close collaboration with the climate components of the emerging International Human Dimensions of Global Change Programme, particularly those projects which address the vulnerability and adaptive capacity of human systems to climate variability, and the value of forecasting information for decision-making.

From its inception, planning for the IRI assumed the existence of a focused observational programme (TOGA TAO, GOOS, GCOS, WMO/WWW, satellites) designed to deliver critical information on the current state of ocean, atmosphere and land-surface conditions. TAO and its proposed expansion in the context of the CLIVAR/GOALS programme is also critical to the success of the IRI. Conversely, the practical applications of forecast information produced by the IRI represent a significant societal rationale for support of those observations. Of particular importance is the integration of ground-based, *in situ* observing systems (e.g. TOGA/TAO) with satellite observations (e.g. altimetry and scatterometry). In addition, the IRI is expected to participate in discussions related to support for the critical observations of the WWW.

National Meteorological and Hydrological Services (NMHSs) in affected regions represent significant assets in several fields relevant to short-term climate forecast applications. The establishment and maintenance of a dynamic partnership between the IRI and the NMHSs are particularly important to the development of application programmes throughout the world. In addition to providing NMHSs (and other users) with new forecast guidance products, the IRI will support demonstration projects designed to explore new applications opportunities and stimulate the development of enhanced regional capabilities.

As a focal point for this collaboration with the NMHSs, the IRI will work closely with the emerging WMO Climate Information and Prediction Service (CLIPS) programme. Both CLIPS and IRI share a common objective—enhancing the ability of a user to translate short-term climate forecast information into real social and economic benefit.

As is the case with critical observing systems, the existing climate research and modelling centres provide valuable assets in the areas of model development, experimental forecasting and focused research designed to explore and extend the current limits of predictability on seasonal-to-interannual time-scales. Establishing a close and mutually beneficial collaboration with this network of seasonal-to-interannual climate research centres is essential for IRI to work together with research institutes in the USA and internationally. An IRI network of modelling and application research centres and programmes is emerging and will set the modes of cooperation between the IRI and its partners in the network.

New institutions

The demonstration of the real benefits of a well established "end-to-end prediction" system requires new institutional structures and collaboration among existing programmes and organizations engaged in climate research, forecasting and applications.

As a new institutional capability that builds an efficient bridge between the science of climate forecasting and the societal needs of real applications, the establishment of the IRI for seasonal-to-interannual climate prediction recognizes and builds on the capabilities of the existing network of national and international scientific institutions engaged in research on climate variability and prediction, the NMHSs and a variety of national, regional and international institutions, organizations and programmes focused on the application of short-term climate forecasting capabilities to address societal problems such as public health and safety, global food security and sustainable economic development.

The IRI has been established within the USA but is undertaking discussions with its founding members in order for it to assume multinational governance in the near future. The IRI is the nucleus of a network of prediction and applications research centres and programmes and has the mission to assess and develop continually seasonal-to-interannual climate forecasts and to foster the application of such climate forecasts to the explicit benefit of societies.

The IRI will address all aspects of end-to-end prediction, including model and forecast-system development, experimental prediction, climate monitoring and dissemination, applications research, and training, in coordination and collaboration with the international climate research and applications community. Its applications work will be coordinated with NMHSs and other agencies in the delivery of forecast products and the establishment of climate applications activities on a worldwide basis.

As well as building its institutional capabilities, a simultaneous parallel effort is made to provide a suite of IRI prediction products and facilitate their application to practical decision-making through targeted research and demonstration projects in selected regions. These efforts include:

- The production and continuous development of global-scale predictions of key processes and climate variables, including, but not limited to, ENSO in the tropical Pacific, sea-surface temperature in other oceans, ocean–land–atmosphere interactions in monsoon regions, etc.;
- Provision of regional forecasts that incorporate relevant local- and regional-scale physical processes by downscaling from the global- to the local-scale prediction and reflecting the information needed for applications. Beginning in regions where predictability is high, the initial focus of activities supporting this objective will include: the coupling of global-scale general circulation models with higher-resolution, regional- and mesoscale models and the use of statistical methods to relate changes in SST with local and regional patterns of precipitation, temperature;
- A targeted programme of human dimensions research for applications which provides insight into the regional consequences of climate variability, the vulnerability of communities and development sectors, the identification of opportunities to exploit climate forecasts for economic development, the value of new forecast information to support decision-making, and the identification and understanding of barriers to the use of forecast information;
- The implementation of a selected set of applications demonstration projects designed to demonstrate the practical value of short-term climate predictions to decision-makers. Activities supporting this objective will focus initially on: supplementary support for selected ongoing programmes developed during the IRI pilot project phase; and the identification of promising new opportunities for applications activities in regions where predictability is high or where complementary programmes are supporting regional scientific infrastructure (e.g. regional global change research institutes: IAI, APN and ENRICH).

The future

There is much yet to be done. The GOALS component of the CLIVAR Programme began with the demise of TOGA and will carry on not only ENSO prediction research, improving data, models and methods of ENSO predictions, but will also seek to identify and exploit seasonal-to-interannual predictability globally, wherever it exists and by whatever mechanism. The IRI (and other national prediction centres) will incorporate these scientific advances into its forecasting system to make short-term climate forecasts of higher skill and increased specificity. The IRI, working in partnership with the IRI network of applications research centres and programmes, will apply these forecasts and demonstrate the validity of the concept of end-to-end forecasting and will undoubtedly learn a great deal of both physical and social science in the process. The knowledge gained here, we believe, will greatly benefit the more complex problem of global change research including anthropogenic influences on the climate system.

We look forward to a world that has learned to use short-range climate forecasts. We see a time when poorer countries can plan against future droughts by stocking grain-resistant seed and conserving water well in advance of the drought with the wealthier countries stabilizing international agriculture markets by intelligently hedging their futures contracts. We see water being more intelligently managed for both public and private gain in the interest of sustainable development. We see the nations of the world stewarding their resources and looking to the future more confidently in the face of rising populations. We see the wealthier nations unselfishly sharing their data and working together to use the predictions of the future with those nations who cannot yet make the predictions. We see a process where both rich and poor nations learn how their internal economic and social systems really work and how people can work together to the advantage of all.

All intelligent planning depends on some knowledge of the future. Short-range end-to-end climate prediction is an important step toward that future.

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STRENGTHENING THE METEOROLOGICAL SOUNDING NETWORK OVER THE TROPICAL EASTERN PACIFIC OCEAN AND THE INTERTROPICAL AMERICAS

By Michael W. Douglas[1] and Walter Fernandez[2]

Introduction
Pan American Climate Studies (PACS) is a USA federal programme in the 1995–2004 time-frame directed toward the goal of improving the skill of operational seasonal-to-interannual climate prediction (with emphasis on precipitation) over the Americas (PACS, 1994). PACS is supported by contributions from NOAA Environmental Research Laboratories and Cooperative Institutes, and a NOAA grant programme administered by the NOAA Office of Global Programs.

The authors are the principal investigators of a PACS project entitled "Strengthening the meteorological sounding network over the tropical eastern Pacific Ocean and the intertropical Americas" to support PACS, which is described in this article. This project was motivated by the fact that the present atmospheric sounding network over Central and northern South America does not reliably depict the structure of the Intertropical Convergence Zone (ITCZ) over the region. No soundings are routinely made over the eastern tropical Pacific, except for recently renewed soundings on one of the Galapagos Islands. Thus, the variability of the ITCZ, on time-scales from daily to seasonal and interannual, can be described over much of the PACS domain only from a satellite perspective. In addition, most of the current radiosonde stations in Central and northern South America, located close to population centres at higher elevations and surrounded by mountains, sample the lower tropospheric flow over the eastern Pacific littoral very poorly.

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During the boreal summer, the ITCZ appears to lie over, or very close to, parts of Central America (Sadler *et al.*, 1987). Variations in the position and intensity of cloudiness and rainfall have been used to explain some of the variability of the warm season rainfall over Central America and southern Mexico, though supporting observations, especially meteorological soundings, have generally been lacking to support such assertions. In a similar manner, the ITCZ has been associated with the formation of tropical storms; periods of frequent tropical cyclogenesis being associated with an "active" ITCZ.

The tropical eastern Pacific Ocean is a region of major uncertainty in the meteorological fields above the surface, due, in large part, to the lack of inhabited islands from which to establish atmospheric sounding stations. The deduction of the atmospheric circulation over the region comes from the blending of surface observations from ships, cloud-tracked winds derived from satellite observations (mostly in the lower and upper troposphere) and infrequent reports from commercial aircraft. These observations, together with satellite soundings that provide only limited information on the tropical thickness field, are assimilated by global forecast models to produce what is considered to be the most reliable depictions of the tropospheric flow over the region. Unfortunately, it is well known that such depictions depend strongly upon the characteristics of the assimilating model in data voids (Lambert, 1988; Trenberth and Guillemot, 1995) and, all too frequently, observations that deviate substantially from the model first guess are eliminated from the analysis cycle. Thus, widely separated, infrequent observations may not be assimilated correctly even when they are available.

Objectives of the project

Our work involves two principal tasks. The first is to establish a prototype special meteorological sounding network in a section of the PACS domain that focuses on the ITCZ in the far eastern tropical Pacific and surrounding land areas. The second task is to use the observations to answer questions about the accuracy of the current observing network and operational analyses and aspects of the intraseasonal variability over the region. More specifically, the data will be used to address the following questions:

- How large are the errors in the routine National Meteorological Centre (NMC) and European Centre for Medium Range Weather Forecasts (ECMWF) analyses over this usually data-sparse region? How closely does the observed mean structure of the ITCZ resemble that routinely analysed by operational centres?
- Does the current radiosonde network in Central America provide an accurate depiction of the lower tropospheric flow in this region?
- What large-scale meteorological conditions are associated with dry and wet spells over Central America during the May–November rainy season?

Other questions that can be addressed with the special observations of the project include:

- What relationships exist between monthly mean meteorological conditions (winds, vorticity, divergence) measured by the enhanced sounding network and satellite-based estimates of precipitation and cloudiness over the same region?
- What is the annual cycle of the depth of the boundary layer and the northward moisture flux in the eastern tropical Pacific? How do these observed fluxes compare with currently analysed fluxes?
- Are cross-equatorial wind surges associated with the initiation of tropical storms in the north-eastern Pacific?
- What fluctuations in the ITCZ circulation strength are associated with extended periods of tropical cyclogenesis in the eastern Pacific?

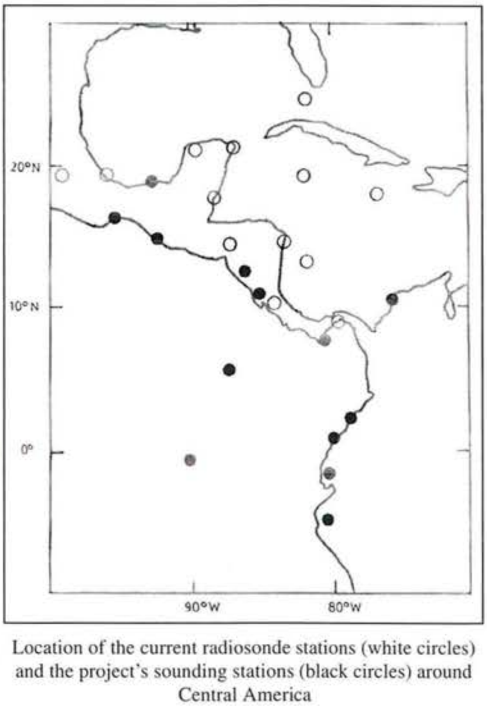
In addition, the observations should also be useful for forecasting purposes and studies of particular meteorological systems, such as the Central American *temporales* (e.g., Fernández, 1996a, 1996b; Galo *et al.*, 1996a, 1996b) and cold surges associated with wind jets over the gulfs of Tehuantepec, Papagayo and Panama (Schultz *et al.* , 1997a, 1997b).

Finally, if the network proves to be feasible to operate indefinitely, a host of questions related to interannual variability of the atmospheric flow over the eastern tropical Pacific and its relation to rainfall over South, Central and North America can be addressed.

The atmospheric sounding network

The sounding network of the project is shown in the figure below and the stations are listed in the table overleaf. Pilot balloon observations are carried out at all stations twice daily (in the morning and in the afternoon), except for Cocos Island, where a radiosonde observation is made once daily in the morning and a pilot balloon observation is made in the afternoon.

Currently, there is moderately good radiosonde coverage over the region of the western Caribbean Sea and Central America. Radiosonde stations at San Andres Island, Kingston, Grand Cayman, and Belize permit a reasonable depiction of conditions on the Caribbean side of tral America. This contrasts with the nearly complete lack of stations in the Pacific Ocean, a



Location of the current radiosonde stations (white circles) and the project's sounding stations (black circles) around Central America

List of the project's sounding stations

Station	*Country*	*Latitude*	*Longitude*
Frontera	Mexico	18°31'N	92°39'W
Salina Cruz	Mexico	16°10'N	95°11'W
Puerto Madero	Mexico	14°42'N	92°24W
Managua	Nicaragua	12°09'N	86°10'W
Liberia	Costa Rica	10°36'N	85°32'W
Cocos Island	Costa Rica	5°30'N	87°00'W
Los Santos	Panama	7°56'N	80°25'W
Cartagena	Colombia	10°26'N	75°34'W
Tumaco	Colombia	1°48'N	78°47'W
Esmeraldas	Ecuador	0°58'N	79°38'W
Galapagos	Ecuador	0°54'S	89°37'W
Guayaquil	Ecuador	2°09'S	79°58'W
Piura	Peru	5°10'S	80°30'W

fact that makes the Central American radiosonde stations critical to estimating conditions over the eastern Pacific, at least near Central America. Unfortunately, as pointed out above, most of the current radiosonde stations in Central and northern South America are surrounded by mountains and sample the lower tropospheric flow over the eastern Pacific littoral very poorly. The most adversely affected stations are Bogotá in Colombia, San José in Costa Rica and Tegucigalpa in Honduras. Only Panama City is relatively unaffected by nearby topography. Thus, only one radiosonde station on the Pacific coast between Acapulco (Mexico) and Lima (Peru) is unaffected by local topographic effects. All are affected by the strong diurnal sea- and land-breeze circulations near the surface.

To attempt to obtain a better estimate of the windfield over Central America and the near-shore eastern Pacific the pilot balloon stations have been situated in locations that minimize local topographic effects on the windfield. These sites are relatively flat and near sea-level, relatively distant from high mountains, and those in Central America should better describe the low-level southwesterly flow that enters this region during the northern summer. Enhanced south-westerly flow, associated with a northward movement of the ITCZ, is often associated with heavy rain spells on the Pacific side of Central America.

There are several reasons for using pilot balloons to measure the lower to mid-tropospheric windfield instead of employing alternative observing systems (Douglas, 1991); cost is the primary consideration. In addition, the entire system is rugged, independent of electrical power, can be transported easily and requires relatively little operator training. The main disadvantage of using pilot balloons is the loss of data due to clouds, but we have attempted to reduce this in this project by locating the stations in areas where low cloudiness is a minimum.

The single most important step in the project's development was the deployment of a radiosonde system at Cocos Island. The first sounding was made on 28 April 1997 at 20h35 GMT.

Many institutions from different countries are participating in the project. The participants include the National Severe Storm Laboratory/ NOAA (USA), the *Armada de Mexico* (Mexico), the *Instituto Nacional de Estudios Territoriales* (Nicaragua), the *Instituto Meteorológico Nacional, Universidad de Costa Rica*, and *Area de Conservación Marina Isla del Coco* (Costa Rica), the *Instituto de Recursos Hidráulicos y Electrificación* (Panama), the *Centro de Investigaciones Oceanográficas e Hidrográficas* and *Centro de Contaminación del Pacífico* (Colombia), *Escuela Superior Politécnica del Littoral* and *Instituto Nacional de Meteorología e Hidrología* (Ecuador) and the *Universidad de Piura* (Peru). It is expected that forecasters and scientists from these countries will use the data for both operational forecasts and research purposes.

Duration of the project and dissemination of the data

The observing network will operate for six months, until the end of October 1997, except for the observations at Cocos Island, which will continue until May 1998.

The data, which are received by various means, are subjected to quality-control procedures. The data dissemination is not delayed by this step; the monitoring proceeds in parallel with dissemination. Contrary to what often occurs in research projects, the data are available freely to the scientific community as soon as possible at the following Internet address (more easily accessed with Netscape): http://www.nssl.noaa.gov/pena/public_html/p ©sspan.html

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HUMAN AND ECONOMIC IMPACTS OF WEATHER EVENTS IN 1996

By S. G. CORNFORD[1]

Introduction

The weather brings great benefits to humankind and imposes great losses. At the 1995 WMO Symposium on Education and Training, in Toulouse, Spangler [1] noted that losses from natural disasters in the ***USA**** approached US$ 1 000 million per week and that 85–90 per cent involved the weather. Such a loss of US$ 45 000 million a year is equivalent to 0.67 per cent of the Gross National Product (GNP) of the ***USA*** or an annual tax of US$ 172 on every American man, woman and child. Looking at it another way, the whole economic activity of 1.75 million Americans does nothing but pay for weather-related disasters.

Benefits are, of course, more difficult to evaluate than losses, particularly because data are less readily available. Nevertheless, FAO (personal communication) estimates that the benefits to the ***USA*** of rainwater to agriculture and energy production, and solar radiation as the main input to photosynthesis and sources of renewable energy, significantly exceed the 0.67 per cent of GNP attributed to weather losses. Ultimately, of course, air, water, solar energy and the processes in the hydrological cycle which constitute weather, are essential to sustaining life on Earth, and so are beyond price.

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The review of reports for 1995 [2] emphasized agriculture as the main weather-sensitive activity in many Members' economies and commented on the lack of data for most other sectors. Members were invited to help future reviews to be more authoritative by suggesting ways in which they might standardize their reporting. This would include a methodology for evaluating economic impacts of the weather, so as to establish a benchmark for assessing the value of national Meteorological Services (NMSs). The present article includes the suggestions received. The first time the name of a reporting country or territory appears, it carries an asterisk.

Loss of life from weather events

Table I summarizes the 70 reports received from Members (and some press reports) of the numbers of deaths (including persons reported missing) as a result of weather in 1996, and the weather events mainly responsible. The worldwide total (8 340) was remarkably similar to that in 1995 (8 300). The number of countries and territories reporting weather-related deaths was also similar, 44 (42), but the major loss of life was more concentrated, with over 6 000 in contiguous ***China*****, ***India***** and ***Bangladesh***** alone. Nine (15) Members had more than 100 weather-related deaths and 30 Members (28) had 10 or more. As last year, the loss of life was overwhelmingly in floods resulting from rain. The seven Members marked # near the top of the table are each within two places or less of their rank within the group of the same seven Members in the corresponding table for 1995. ***Armenia*****, ***Bahamas*****, ***Ghana*****, ***Saint Lucia***** and ***Sweden***** reported that there had been no deaths as the result of abnormal weather during 1996. ***Argentina*****, ***Azerbaijan*****, ***Chile*****, ***Croatia*****, ***Ecuador*****, ***Finland*****, ***Guyana*****, ***Hungary*****, ***Iceland*****, ***Israel*****, ***Kazakstan*****, ***Kenya*****, ***Lithuania*****, ***Moldova*****, ***Netherlands*****, ***Norway*****, ***Portugal*****, ***Saudi Arabia*****, ***Sri Lanka*****, ***Switzerland*****, ***Turkey*****, ***Turkmenistan***** and ***Uzbekistan***** did not report any.

In early November, a severe cyclonic storm from the Bay of Bengal, with a core of hurricane-force winds, crossed the coast of Andhra Pradesh, ***India***, and left some 1 000 people dead and more than 1 000 missing. Estimated wind strengths were 150 to 200 km h^{-1}: a microwave tower near Kakinda collapsed and harvests were lost. Insurance sources (e.g. [3]) quote the same number of fatalities and list this as the worst catastrophe of any kind in 1996 (500 000 were left homeless and damage was estimated at US$ 1 500 million). A total of 546 people died in other cyclones in ***India***. Earlier, 482 died in floods: a record flow of 47 500 $m^3 s^{-1}$ was measured on the river Yamuna on 25 August after prolonged and extensive rain; south-east of Delhi, five raingauges, spread 250 km along the river, recorded falls averaging 12.4 $l\ m^{-2}\ d^{-1}$ (mm d^{-1}) on this scale for nine consecutive days.

The figure for ***China*** in Table I is rounded. Press reports (e.g. [4]) gave 1 522 lost as a result of persistent and extensive rain during the *meiyu* season. In some places, falls totalled 700–1 000 $l\ m^{-2}$, 60–150 per cent more than normal. Water levels in some major rivers were higher than ever before. In early August, heavy rain from tropical cyclones fell on more than 10 provinces in eastern ***China***, leading to more than 500 deaths [4]. Insurance reports say 1 200 died between 1 and 14 August, when the Yangtze and other rivers overflowed following continuous rain (with an estimated total damage amounting to US$ 6 500 million) [3]. On 9 September, typhoon 9615 with maximum winds of hurricane force and heavy and widespread rain passed over Guangdong and Guangxi provinces: more than 16 million people suffered; 294 died; and more than 90 were missing; nearly 2 000 000 houses collapsed and over 2 000 boats sank. Earlier in the year, snow lay 1.5 m deep in places after five heavy falls: 84 people died, three were missing, about 40 000 were injured or suffered from snow-blindness; nearly 1 500 000 head of livestock died. Altogether, 450 000 people and 9 million livestock were affected.

All the reported 570 deaths in ***Bangladesh*** occurred on 13 May, when a severe tornado devastated 59 villages in a swath 50–60 km by 0.5–2 km about 100 km north of Dhaka. In one afternoon, 9 855 people were seriously injured, 1 531 head of cattle killed, 16 225 homes and 31 educational institutions destroyed, a further 6 765 homes, 5 039 tonnes of crops and 3 000 tube wells were damaged.

The 224 deaths and 108 people missing in ***Malaysia*** all occurred on 26 December, when, untypically, tropical storm *Greg* (9627) lashed the western part of Sabah, Borneo. The estimated economic loss was US$ 92 million: damage came partly from unusually strong winds of up to 90 km h^{-1} and partly from high tides associated with the winds and the lowered central pressure of the storm. The sparse network of rainfall stations did not indicate high intensity rainfall.

TABLE I

Number *n* of reported fatalities[1] from weather events in 1996

Country	*n*	*Principal weather events*
India#	3 320	Cyclone; tornado; rainfloods; snow, rain, avalanches
China#	2 500	Rainfloods; typhoon; snow
Bangladesh#	570	Tornado
Malaysia*	332	Tropical storm *Greg*
USA#	292	Snowstorms; hurricanes; floods; tornadoes
Brazil*#	234	Rainfed landslides; rainfloods; wind; cold; hail; lightning
Thailand*#	158	Rainfloods from tropical storm *Willie* (9620)
South Africa*#	155	Rainfloods; cold; wind; lightning
Republic of Korea*	133	Rain; strong winds
Spain*	84	Rainflood and mudslide
Ethiopia*	69	Rainfloods; lightning
Japan*	67	Typhoons; snow; avalanches; debris flows; lightning; gusts
Costa Rica*	59	Rainfloods and associated landslides
Egypt*	41	Rainfloods; sandstorm; heat wave; thunderstorm; fog
Latvia*	29	Frost
United Kingdom*	26	Cold; fog; blizzards
Russian Federation*	24	Strong winds; snowfall; rain; lightning
Colombia*	23	Rains; landslides
Italy*	22	Storms; rainfloods; sea fog
Madagascar	21	Cyclone
Kyrgyz Republic*	18	Avalanches
Germany*	15	Freezing rain
Venezuela*	14	Tropical cyclones
Nigeria	14	Rain
Macao*	13	Cold
El Salvador*	13	Flooding; strong winds
Oman*	12	Thunderstorm flash flood
Austria*	12	Avalanches with snow; rain
Belgium*	10	Cold
Australia*	10	Floods; gusts; lightning; hail
Benin*	7	Storm rains
Morocco*	6	Rainfloods
Greece*	5	Thunderstorms; rain
Yugoslavia*	5	Storms and flash floods
Algeria*	5	Rainfloods
Mauritius*	3	Cyclone
Trinidad and Tobago*	3	Rainfloods
Uruguay*	3	Lightning; flash flood
Georgia*	3	Avalanche
Hong Kong*	3	Typhoons
Dominican Republic*	3	Hurricane *Hortense*
France*	2	Rain leading to flood in cave
St. Vincent, W. I.[2]	1	Flash flood
Cyprus*	1	Tornado
Total	**8 340**	

1 People reported dead and missing, based on reports from WMO Members and a selection of press reports. For ***Brazil***, it includes 30 missing after being buried under their homes following heavy rain in the state of Rio de Janeiro in February, but excludes more than 10 others buried alive in landslides.

2 Meteorological Service coordinated with British Caribbean Territories.

In the ***USA***, causes of death were more varied. Three hurricanes led to 72 deaths: *Bertha* (12), *Fran* (34)[2] and *Hortense* (26). Snowstorms, however, were the principal cause: 154 died in three storms, 6–16 January; falls ranged from 0.5 to 1.3 m when the snowpack in the mountains was already deep. Along the mid-Atlantic coast, the second storm, on 7 and 8 January, was one of the most severe this century. An area from Boston, Massachusetts, to Washington, DC, had snowloads with recurrence intervals exceeding 50 and, in several places, including New Jersey, 100 years. Subsequent mild weather produced severe flooding, 19–24 January, which took 33 lives: major rivers reached 1.2–3.6 m above flood stage. Despite the occurrence of some 1 200 tornadoes in 1996, the total of 24 fatalities was five fewer than in 1995 and well below the norm of 82.

In ***Brazil***, too, a variety of weather events caused deaths, particularly in mud- and landslides. Each month brought one disaster or more. In January, strong winds, rains and lightning caused 14 deaths and over 1 600 people were made homeless. In February, heavy rains in Rio de Janeiro state left 66 dead and 30 missing, after being buried under their homes. In March, heavy rains left 26 dead in Bahia, and, together with lightning, 39 in Paraná, as well as preventing 660 children from reaching school, and destroying roofs and power lines. However, rain in Pernambuco in April filled the region's reservoirs and ended a drought, though frost destroyed crops in Curitiba, Paraná. In May, heavy rains left 21 people dead in the city of Recife and 14 other events each led to deaths numbered in single figures. In June, tonnes of earth slid down a hillside in the outskirts of Salvador, burying alive a family of six, while snow and high winds in Rio Grande do Sul caused one death and left over 700 homeless. In July, a fire in dry weather destroyed 8 ha of the Botanical Garden of Brasilia; in Paraná, Matinhos was hit by an unusually violent "tidal reflux", which swept away retaining walls, roads, houses and electricity poles and rain destroyed 250 000 tonnes of beans. In August, in São Paulo state, winds of up to 150 km h^{-1} blew in the Santos area, whereas air pollution led to a state of emergency. Strong winds came again in September: in Minas Gerais, winds up to 65 km h^{-1} toppled trees and left 45 000 people without power; in Tapjaria, Paraná, 700 roofs were damaged; in Itaguí, Rio de Janeiro state, hail and gusts to 100 km h^{-1} injured 50 people and destroyed 40 houses; in the city of Rio de Janeiro, 48 hours of rain stopped traffic, partly destroyed three buildings and left a wake of death and destruction; in São Paulo state, five days of heavy rain caused the River Preto to rise over 10 m, overflow its banks, cause widespread destruction and cut off the main road, creating a traffic jam of 130 km and serious accidents; in the Jates area, some farmers lost 80–100 per cent of their crops from hail, just as they were ready to be picked. Further prolonged rains in October caused landslides in Rio Grande do Sul; in São Paulo state, the River Tieté overflowed, destroying eight houses and affecting the power supply to 40 000 homes; many houses near the Aricanduva elevated motorway were flooded when water levels rose by 1.5 m. In November, in Bahia, a hailstorm with strong winds killed four people and injured 15 in the town of Utinga and destroyed 80 per cent of homes in Capelinho; in Espirito Santo, rain left seven people dead, eight injured and 30 families homeless; 200 people had to be evacuated; in Minas Gerais and Rio de Janeiro states, continuous rain and landslides led to the destruction of homes and four deaths. In December, heavy rains and strong winds affected Brasilia: floods and landslides damaged roads and caused several traffic accidents. At the end of the year, however, ***Brazil*** expected near-record wheat outputs [5].

Loss of life from weather in relation to population of the Member

Table I summarizes the absolute numbers of those reported killed or missing. Every human life is, of course, of equal and infinite value, yet, in assessing the impact of disasters, it is useful to take into account Members' very different populations. Last year's review [2] defined an index *N*, which measures the proportional impact on those at risk; it expresses the numbers of fatalities as one person in every *N* of the Member's population. Table II gives the values for 1996; the rankings are very different from those in Table I. Where *N* was also calculated for 1995 ([2]), it is shown for comparison. The highest rates (smallest values of *N*) for the two years are similar. The unusual cold in ***Macao*** (13 deaths in a population of 426 000), rain leading to floods and landslides in ***Costa Rica*** (59 in 3 161 000),

2 An insurance source gives 39 dead and missing in association with *Fran* [3].

TABLE II

Number of fatalities in weather events, 1996, expressed as 1 in *N* of the Member's population[1]

	N (*1996*)	*N* (*1995*)
Macao	33 000	-
Costa Rica	54 000	400 000
Malaysia	59 000	-
Latvia	86 000	-
St. Vincent, W. I.[1, 2]	110 000	-
Oman	175 000	-
Bangladesh	210 000	150 000
Krygyz Republic	250 000	-
South Africa	260 000	100 000
India	275 000	600 000
Republic of Korea	330 000	-
Mauritius	370 000	-
Thailand	370 000	100 000
El Salvador	430 000	400 000
Trinidad and Tobago	430 000	-
Spain	470 000	2 000 000
China	480 000	900 000
Cyprus	580 000	-
Madagascar	620 000	-
Austria	670 000	-
Brazil	680 000	1 200 000
Benin	760 000	-
Ethiopia	800 000	600 000
USA	890 000	300 000
Belgium	1 000 000	1 600 000
Uruguay	1 100 000	-
Egypt	1 400 000	300 000
Venezuela	1 500 000	-
Colombia	1 600 000	-
Australia	1 800 000	1 300 000
Georgia	1 800 000	-
Japan	1 900 000	-
Hong Kong	2 000 000	400 000
Greece	2 100 000	-
Yugoslavia	2 100 000	-
United Kingdom	2 200 000	5 000 000
Dominican Republic	2 500 000	-
Italy	2 600 000	-
Morocco	4 400 000	100 000
Germany	5 400 000	900 000
Algeria	5 500 000	500 000
Russia	6 200 000	3 000 000
Nigeria	7 700 000	-
France	29 000 000	2 300 000

1 Values of populations were taken from [6, 7] where possible; if not from [8], where most are for 1992.

2 Meteorological Service coordinated with British Caribbean Territories

tropical storm *Greg* in ***Malaysia*** (332 in 19 700 000), frost in ***Latvia*** (29 in 2 500 000) and a flash flood in ***St. Vincent, W.I.*** (1 in 109 000) reduced their populations by proportions which were similar and greater than elsewhere in the world; only ***Costa Rica*** was in the corresponding list for 1995 [2].

Whilst the incidence of hazardous weather differs from Member to Member climatologically, there is also a random element, so that, despite differences in criteria for reporting, the figures reflect the way in which Members with small areas and small populations often have no deaths and then occasionally have catastrophic losses. By contrast, Members with large populations and a large land surface area at risk are more likely to suffer deaths in most years. Table III separates effects of population and of area.

Economic impacts of weather events

The absolute value of damage by weather depends on the severity of the event and on what is at risk: absolute losses tend to be large in better-off communities. Table IV shows the ranking of losses reported by Members from unusual weather in 1996. Losses in the ***USA*** greatly exceed the rest put together. All reported figures are included in Table IV but, although Members made the estimates with integrity, they had no basis of assessment in common, did not evaluate the damage caused by all reported events and have not been asked to include the large numbers of small losses day by day from quite usual weather events. In total, these may well exceed the losses which get the attention of the insurance companies and the media[3]. As a consequence, all the figures in Table IV are believed to be underestimates of total annual losses. (Compare, for example, the US$ 10 300 million total losses for the ***USA*** in Table IV with the US$ 45 000 million per year reported by Spangler [1].)

3 FAO (personal communication) point out, for example, that, in the Mississippi floods of 1993, most agricultural losses occurred not in the flooded areas but in the higher-lying, waterlogged, parts of the river basin. Similarly, individual deaths from lightning are not always reported when events are considered on a national scale, although the total number over a year may sometimes be quite high. Indeed, Vavrek *et al.* [9] quote 8 316 deaths from lightning in the USA in the period 1940–1991, a larger figure than deaths from floods (5 828), tornadoes (5 731) or hurricanes (2 031). Holle, however, has said (personal communication) that more recent figures indicate that the number of deaths caused in the USA each year by lightning are now 75–100 and nearly 200 by flooding.

TABLE III

The increasing likelihood of weather-related deaths with Members' population and surface area

	Number of countries appearing in 1995 and 1996 lists of deaths	*Number of countries making no reports of deaths in 1996*	*Number of services reporting on impact of weather in 1996*
Population (millions)			
Less than 1	0	4	6
1 to 10	3	12	25
10 to 100	12	11	32
Greater than 100	6	0	7
Surface area (km^2)			
Less than 100 000	4	12	27
100 000 to 1 000 000	7	13	29
Greater than 1 000 000	10	3	14

There are also difficulties in comparing costs in different economies. Members usually estimate costs in their national currency, sometimes giving their own conversion to international US dollars. For Table IV, figures reported in national currencies have been converted using the United Nations' operational rates of exchange, effective 1 December 1996.

Tropical storms and hurricanes caused most damage in the ***USA*** (US$ 4 100 million), which heads Table IV. Four named storms struck the mainland in 1996, a fifth crossed Puerto Rico, and three other Atlantic storms and one Pacific storm gave rain over continental USA. Hurricane *Bertha* hit the North Carolina coast on 12 July, with winds exceeding 160 km h^{-1}, and dropped 50–150 l m^{-2} of rain in a swath to the north-east. As well as 12 deaths, *Bertha* caused US$ 270 million worth of damage. *Fran* was the most destructive of the year: *Fran* struck North Carolina on 5 September, with gusts near 190 km h^{-1}, gave up to 500 l m^{-2} of rain to North Carolina and Virginia and caused major flooding from the Carolinas to Pennsylvania; the estimated death toll was 34–39 and damage US$ 3 200 million, of which half was covered by insurance, making *Fran* the twelfth most costly weather insurance loss since 1970 [3]. On 10 September, hurricane *Hortense* crossed Puerto Rico, with 130 km h^{-1} winds, rainfall up to 580 l m^{-2}, 26 deaths and US$ 500 million worth of damage. The next most costly evaluated sources of damage in the USA were the blizzards in the east in January, which were followed by wet, mild, weather and severe flooding. Total damage and costs (including snow removal) were estimated at US$ 3 000 million. Places from the Great Lakes to the mid-Atlantic and New England states recorded the snowiest season of the century. A storm moved north along the east coast on 7 and 8 January and dropped 40–75 cm of snow between Boston and Washington, DC. Falls of 50–70 cm were common in the major cities, paralysing transportation. Most airports closed, as did businesses, schools and government offices. Federal Government offices closed from Monday to Wednesday, 8–10 January, re-opened on Thursday and closed again on Friday as another snowstorm arrived. Later, mild, wet weather led to massive snowmelt and severe flooding, 19–24 January. This forced over 125 000 people from their homes and washed out numerous roads and bridges. Estimated costs just to repair a scenic canal in Maryland came to US$ 20 million. The third most costly evaluated source of damage was the flooding from heavy rain and melting snow during the second half of November and December in the north-west, west and western north-central regions; cumulative falls for November and December were the highest in 102 years of records. Continuous heavy precipitation during the last week of the year resulted in major flooding in Idaho, Washington, Oregon, California and Nevada. Some places in the Sierra Nevada had falls of more than 1 000 l m^{-2} for the month. Officials in California estimated flood damage of at least US$ 1 800 million and losses in Nevada may have reached a further US$ 500 million. The north-west had suffered heavy rains earlier, mainly 6–9 February, which melted snow and turned rivers into raging torrents across Washington and Oregon; water and mudslides blocked hundreds of roads, destroyed or severely damaged more than 1 000 houses and forced an estimated 30 000 people from their homes; overall damage was estimated at over US$ 600 million. There were some 1 200

The Riga–Jurmala highway, Latvia, on 19 August 1996, when fog caused 29 vehicles to crash.
Photo: Diena

tornadoes over the USA during the year: on 21 April, two struck north of Fort Smith, Arkansas; they damaged or destroyed 1 800 homes; total damage there and in nearby van Beuren was assessed at US$ 300 million. The total cost of all tornadoes in 1996 has not been reported. Nor has the cost of one of the most extreme cold waves of the century that affected north-central states in late January and early February and set a new low record for Minnesota of –51°C. Temperatures below –20°C in Kansas further damaged a winter wheat crop which had already been battered by sharp temperature fluctuations, high winds and drought. On 5 February, all-time low-temperature records for February were broken or equalled at about a dozen stations, including –9°C at New Orleans in the Gulf of Mexico. During February as a whole, more than 50 such new records were set. Even so, between 18 and 24 February, some 130 new daily records for high February temperatures were set in the area of the southern plains (including 38°C at San Antonio, Texas), worsening the drought there. Drought, along with the wind, heat and cold, harmed the Great Plains' winter wheat crop: national winter wheat production was 52 million m^3, the third lowest since 1979. Several Texas reservoirs were at one-third or less of their normal capacity. From the northern plains to the north-east, however, spring was one of the coldest on record. Freezes on 7–10 and 21–23 March damaged wheat, ground crops and tree blooms, including peaches, from Texas to South Carolina.

Upper-air windflow in the summer was not very different from the winter, with ridging over the western third of the ***USA*** and troughing over the east. Consequently, the west had hot, dry weather (the south-west had its second hottest summer since 1895), whereas temperatures elsewhere were normal or below normal. This worsened the drought in the west and south-west, which, together with strong winds and lightning, made it the worst fire year in 20 years of records: by 1 September, wildfires had consumed 23 000 km^2. In the western corn belt, by contrast, summer temperatures averaged 1–2°C below normal; the lack of sustained heat and dryness resulted in good harvests of maize and soya bean, although spring storms made crops

TABLE IV

Loss to national economies of some evaluated weather events in 1996[1,2]

	Millions of US$	*Principal weather events*
USA	10 300	Tropical storms; snowmelt floods; rainfloods; tornadoes
China	3 240	Typhoon; cold
Japan	730	Typhoon; thunderstorm
Republic of Korea[3]	559	Rain; wind; snow; cold
Thailand	282	Rainfloods
Australia	241	Severe thunderstorms with hail; rainfloods
Costa Rica	235	Rains; floods; landslides
Croatia	200	Rains; hail; wild fires
South Africa	166	Rainfloods; hail
Spain	147	Rain
Malaysia	92	Typhoon
Portugal	87	Rain; wind; tornado
Moldova	58	Drought; rainfloods; glazed frost
Norway	45	Cold; wind storms
Armenia	30	Hail and heavy rain
Georgia	23	Avalanches; strong winds
France	20	Rain; swell
Austria	9	Hail
Dominican Rep.	6.3	Hurricane *Hortense*
Saint Lucia	5.3	Rainfloods
Hungary	3	Hail; rain; tornado
Venezuela	(3)[4]	Rainfloods from tropical storm *Cesar*
Chile	2.4	Rainfloods and snow
Bahamas	1	Hurricane *Lili*
Yugoslavia	1	Heavy rain; freezing rain; hot spells; flash floods; hail; drought
Sweden	0.5	Tornadoes; lack of rain; cold; snow
Hong Kong	0.45	Rain
Ethiopia	0.019	Rain; floods; lightning
Total	**16 287**	

1 Usually there was other damage which was not evaluated in monetary terms; sometimes only one event was evaluated; 33 Members[2] reported significant damage but did not evaluate it. Weather events are shown in order of the reported cost of damage. As in 1995, the most costly source of reported damage was flooding. It followed widespread rainfall alone or rain together with melting snow or violent winds, and led to landslides, mudslides, damage to national infrastructure such as roads and bridges, and damage to crops. There were reports of no significant damage to the economy, or anomalous weather, from ***Ghana***, ***Kazakstan***, ***Lithuania***, ***Macao*** and ***Turkmenistan***, whilst the reports from ***Finland***, ***Iceland*** and ***Netherlands*** did not mention any damage.

2 The following 33 Members reported significant damage to their economy but evaluated none of it in monetary terms: ***Algeria***, ***Argentina***, ***Azerbaijan***, ***Bangladesh***, ***Belgium***, ***Benin***, ***Brazil***, ***Colombia***, ***Cyprus***, ***Ecuador***, ***Egypt***, ***El Salvador***, ***Germany***, ***Greece***, ***Guyana***, ***India***, ***Israel***, ***Italy***, ***Kenya***, ***Kyrgyz Republic***, ***Latvia***, ***Mauritius***, ***Morocco***, ***Oman***, ***Russian Federation***, ***Saudi Arabia***, ***Sri Lanka***, ***Switzerland***, ***Trinidad and Tobago***, ***Turkey***, ***United Kingdom***, ***Uruguay*** and ***Uzbekistan***.

3 Serious floods in the ***Democratic People's Republic of Korea*** resulted in large crop losses [5].

4 ***Venezuela*** reported losses of "several" million dollars, treated here as three million. Figures are indicative only.

late. Production of maize, up 26 per cent from 1995, was the third largest on record, and production of soya beans, up 9 per cent on 1995, was the second highest ever.

In ***China***, too, the greatest single evaluated loss was from tropical storms (typhoons). As noted above, on 9 September, typhoon 9615 crossed the coast at Wuchuan in Guangdong province bringing hurricane-force winds and disastrous floods. Direct economic losses were estimated at US$ 2 633 million. Next most costly was a severe freeze in south ***China*** in the second half of February; the cold and snow killed about 150 000 tonnes of pond fish and damaged 670 km^2 of sweet potato crops and 1 470 km^2 of tropical and subtropical fruit; direct economic losses were US$ 565 million. In Guangxi province alone, 10 400 km^2 of winter crops suffered from this disaster, about 80 per cent of spring plants were affected and 4 500 head of cattle died; loss exceeded US$ 42 million. In one county of Hainan province, where seeds and young plants rotted, more than 50 tonnes of seed rice were damaged and 33 km^2 of fruit and vegetables suffered from frost damage. Persistent and extensive rains during the *meiyu* season caused serious losses and great damage; nevertheless, towards the end of the year, it was clear that a good early rice crop had been harvested [5].

Typhoons were also the greatest single cause of evaluated loss in ***Japan***. In mid-July, *Eve* (9606) made landfall over Kagoshima prefecture and gave 200–250 l m^{-2} of rain in southern Kyushu district. The maximum wind speed recorded was 115 km h^{-1}. *Eve* claimed one person's life, injured 27, damaged 3 361 houses and flooded 933; total agricultural damage amounted to about US$ 634 million. Earlier in July, lightning killed two people in the Tohoku district; thunderstorms with hail damaged six houses and flooded 254; agricultural damage alone amounted to US$ 97 million). After typhoons *Kirk* (9612) and *Violet* (9617), 15 people were killed or missing, 150 were injured, nearly 4 000 houses were damaged and 14 000 flooded, nearly 400 landslides occurred and over 80 ships were lost or damaged: the cost was not evaluated in monetary terms. Typhoons *Dan* (9605), *Herb* (9609) and *Zane* (9621) also affected ***Japan*** seriously; as *Violet*, they did not, however, make landfall.

The ***Republic of Korea*** compiled a particularly well-structured report, including a table which might be a model for wider use. Table V is based upon it and shows that not only were 133 people killed and missing through weather events and more than 5 000 made homeless, but also that rain was by far the greatest cause of economic loss (US$ 557 million of the total loss of US$ 559 million). Of this, US$ 534 million was caused by floods after the storm of 26–28 July which killed over 1.5 million head of livestock, destroyed 59 bridges, damaged 415 roads, 313 river embankments, 764 irrigation facilities, 11 ports and harbours and 27 railways and caused 138 landslides or collapses of slopes. Of the total cost of the damage by this storm, over US$ 400 million (75 per cent) was from the loss of public works facilities. A relatively smaller loss from rain, 29–30 June, was predominantly from loss of agricultural production, whilst wind and rain together during 17–19 June caused about equal monetary losses in these two sectors.

In ***Thailand***, too, the great evaluated loss was from flooding following rains: US$ 282 million. Much of the rain fell between 20 September and 4 November. Upper Thailand had severe floods, 20–23 September, caused by a combination of tropical storm *Willie* (9620) and a monsoon trough. The maximum daily fall, 259.6 l m^{-2}, was recorded on the offshore island of Ko Samui in the Gulf of Thailand on 29 October, when a tropical depression moved from the Gulf across southern Thailand and caused heavy rain and flooding in many provinces, including flash floods in Upper Thailand, 2–4 November. In all, during this six-week period, 74 provinces were flooded. In addition to the 158 deaths, 8 345 331 people were affected: 80 500 people were evacuated to higher ground, 76 807 houses were destroyed and 14 351 km^2 of farmland was damaged.

In ***Australia***, the most costly damage (US$ 160 million), occurred on 29 September when severe thunderstorms moved through northeastern New South Wales (NSW). The town of Armidale, in the Great Dividing Range, had hailstones 7 cm in diameter, gusts to 156 km h^{-1} and damage to buildings and cars alone of US$ 80 million. On 11 December, hail up to 11 cm diameter fell at Singleton, NSW, damaging factories, cars and 40 homes; a man died during the storm, when his car hit a tree. These were just two of 11 severe storms noted during the year. One at Woodside, also on 29 September (see photo on page 366), spawned a tornado which moved cars 200 m and pushed a full oat silo off its foundations. Heavy rains produced flash floods, which damaged buildings as they swept through the town of Murrurundi, NSW, and, combined with a high tide around Coffs Harbour, NSW, drowned one person and extensively damaged 200 businesses, 300 homes and some banana plantations. Lightning killed a schoolgirl at Bendigo, Victoria, injured seven other students and ignited fires. Strong winds uprooted trees which fell on cars and killed three people; at Dubbo, NSW, on 8 February, gusts to 117 km h^{-1} pushed about 100 houses off their foundations and produced debris which seriously injured a boy. Strong winds on a larger scale affected southern Australia on four occasions; in particular, on 15 and 16 March, an intense depression led to widespread damage in the Adelaide area, estimated at about US$ 0.8 million. On 29 and 30 September, an intense depression crossed

TABLE V

Tabular form of report for 1996 by the Republic of Korea

Type of weather event		*Strong wind*	*Strong wind*	*Cold wave*	*Heavy snow*
Date(s) of occurrence		*13–15.1.96*	*1–2.2.96*	*2–3.2.96*	*17–19.2.96*
Regions affected		*Chunnam Cheju*	*Chunbuk Cheju*	*Inchon*	*Kwangwon Kyunbuk*
Human damage					
Dead and missing	(persons)	2	20	-	-
Injured	(persons)	-	-	-	-
Homeless	(persons)	-	-	-	-
	(families)	-	-	-	-
Affected	(persons)	-	-	-	-
	(families)	-	-	-	-
Material damage in physical terms					
Houses, buildings destroyed	(units)	-	-	-	6
Houses, buildings damaged	(units)	-	-	-	-
Houses, buildings affected	(units)	-	-	-	3
Farmland damaged	(ha)	-	-	-	1
Agricultural crops destroyed	(tonnes)	-	-	-	-
Livestock killed	(head)	-	-	-	7
Fruit crops destroyed	(ha)	-	-	-	-
Other agricultural losses		-	-	27	1 901
Roads damaged	(sites)	-	-	-	-
Bridges destroyed	(units)	-	-	-	-
River embankments damaged	(sites)	-	-	-	-
Irrigation facilities damaged	(ha)	-	-	-	-
Reservoirs, dams destroyed	(units)	-	-	-	-
Harbours, ports damaged	(sites)	8	-	-	-
Other public works facilities damaged or destroyed	(sites)	-	-	-	7
Railways	(km)	-	-	-	-
Electricity supplies	(affected families)	-	-	-	-
Water supplies	(affected families)	-	-	-	-
Telecommunications	(circuits)	-	-	-	-
Other public utilities	(sites)	-	-	-	-
Ships lost or damaged	(vessels)	-	2	-	-
Landslides or collapses of slopes	(sites)	-	-	-	-
Material damage in monetary terms (1 000 US$)					
Damage to houses and loss of private property		-	-	373	175
Loss of agricultural production		-	-	-	1 071
Loss by industry		-	-	-	-
Loss of public works facilities		125	314	-	116
Loss of public utilities		-	-	-	-
Total monetary loss		**125**	**314**	**373**	**1 362**

the western coast of Tasmania and generated severe winds which unroofed houses, uprooted trees and caused power blackouts, a tidal surge in the northern part of the island and flash floods in St. Mary's on the east coast. Altogether, 16 tropical cyclones affected the Australian region; seven of them crossed the coast. Despite this unusually high acitvity, no lives were lost. Tropical

TABLE V (continued)

Strong wind *7–10.3.96* *Chunnam*	*Strong wind* *14.3.96* *Cheju*	*Rain, strong wind* *17–19.6.96* *All*	*Rain* *24–25.6.96* *All*	*Rain* *29–30.6.96* *All*	*Rain* *4–7.7.96* *Chunla Chungnam*	*Rain* *26–28.7.96* *Kyungki Kwangwon*	***Total*** ***1996*** ***All***
10	5	3	4	-	-	89	*133*
-	-	1	-	2	-	4	*7*
-	-	64	17	-	2	5 398	*5 481*
-	-	17	8	-	1	1 372	*1 398*
-	-	-	-	-	-	11 535	*11 535*
-	-	-	-	-	-	2 886	*2 886*
-	-	11	3	2	1	1 002	*1 025*
-	-	16	-	-	-	11 800	*11 876*
-	-	11	16	17	2	579	*628*
-	-	17 056	292	-	235	18 073	*35 657*
-	-	9 866	12 775	411	162	18 482	*41 696*
-	-	4 000	22 500	7 601	-	1 560 524	*1 594 632*
-	-	-	-	-	-	-	-
-	-	684	113	40 339	6	-	*43 070*
-	-	49	15	-	-	415	*479*
-	-	1	4	-	-	59	*64*
-	-	171	21	-	-	313	*505*
-	-	83	9	-	2	764	*858*
-	-	-	-	-	-	-	-
-	-	3	-	-	-	-	*11*
-	-	-	11 875	3	2	1 593	*13 480*
-	-	-	-	-	-	27	*27*
-	-	-	-	-	-	-	-
-	-	4	-	-	-	112	*116*
-	-	-	-	-	-	-	-
-	-	362	-	-	-	144	*506*
1	1	10	-	15	-	67	*96*
-	-	4	6	-	-	138	*148*
-	-	24	66	56	10	85 218	*85 922*
-	-	7 979	717	4 056	4	40 930	*54 757*
3	36	274	-	85	-	61	*469*
-	-	7 522	1 664	97	138	400 301	*410 277*
-	-	14	-	-	-	7 903	*7 917*
13	**36**	**15 813**	**2 447**	**4 294**	**152**	**534 413**	***559 342***

cyclone *Olivia* produced the strongest gust ever recorded in the region: 267 km h^{-1} at Varanus Island in the Monte Bello Group. There was significant damage to oil and natural gas production facilities and to the inland township of Pannawonica, but no serious injuries.

Impacts of weather on people and the economy, are of course, positive as well as negative, but there were no reports this year of evaluations in monetary terms of positive impacts, although qualitative assessments may be made from reports of good harvests (e.g. [5]).

Relative economic impact of weather events

Some economies can withstand weather losses better than others. Agricultural economies, for example, are especially vulnerable. Industrialized countries may appear less so, but they often have more costly infrastructure at risk. GNP is broadly related to the capital invested in national infrastructure. Consequently, in assessing relative impacts on communities, losses may usefully be seen as a proportion of GNP. Table VI is based on Table IV but reported national losses have been normalized by dividing by the national GNP per head [7a, 8] to show values of index *E*. This index expresses the economic loss as the contribution to the GNP of one person in every *E* of the Member's population (see [2], p. 354, for a more detailed explanation). Where available, the corresponding figure for 1995 [2] is given in brackets. Values of *E*, ranked in this way, show that the principal economic losses to Members as a proportion of their economy also come from rain and consequent floods. In this list, only ***Norway*** and ***Sweden*** did not suffer from too much rain.

At the beginning of the year, several tropical weather events led to abnormally intense rains in ***Costa Rica*** on land sloping down towards the Caribbean. In some areas, falls were 470 per cent of normal. There was extensive economic and social damage, as well as loss of human life. Hurricane *Cesar* caused the greatest damage, however, especially in the south, on land

TABLE VI

Economic impact of assessed weather events in 1996, expressed as the personal contribution to the Gross National Product (GNP) of one person in every *E* of the Member's population

	E (*1996*)	*E* (*1995*)	*Principal weather events*
Costa Rica	30	284	Rains; floods; landslides
Saint Lucia	35	-	Rainfloods
Croatia	61	-	Rains; hail; wild fires
Moldova	67	-	Drought; rainfloods; glazed frost
Armenia	84	-	Hail and heavy rain
China	200	24 direct 718 indirect	Typhoon; cold
Thailand	500	264	Rainfloods
USA	650	837	Tropical storms; snow melt floods; rainfloods; tornadoes
Republic of Korea	660	-	Rain; wind; snow; cold
South Africa	740	-	Rainfloods; hail
Malaysia	750	-	Typhoon
Portugal	1 100	5 390	Rain; wind; tornado
Dominican Republic	1 600	-	Hurricane *Hortense*
Norway	2 600	519	Cold; wind storms
Bahamas	3 000	-	Hurricane *Lili*
Spain	3 700	358	Rain
Japan	5 900	-	Typhoon; thunderstorm
Hungary	13 000	35 000	Hail; rain; tornado
Australia	13 400	15 400	Severe thunderstorms with hail; rainfloods
Chile	20 500	547	Rainfloods and snow
Austria	22 000	-	Hail
France	68 000	-	Rain; swell
Yugoslavia	69 000	-	Heavy rain; freezing rain; hot spells; flash floods; hail; drought
Ethiopia	290 000	24 000	Rain; floods; lightning
Hong Kong	290 000	-	Rain
Sweden	410 000	-	Tornadoes; lack of rain; cold; snow

Severe thunderstorms at Xanthi, Greece, on 30 November 1996, caused floods with the loss of three lives, havoc in rural areas and extensive damage to buildings, railways and roads; power and water supplies were cut off.

Photo: Eurokinissi

sloping down towards the Pacific. Rainfall was particularly intense, reaching 920 l m^{-2} in 24 hours, and causing many landslides, massive soil erosion and flooding. There was major damage to low-lying areas, farmlands, inhabited areas, roads and other infrastructure. Later, hurricane *Marco* caused further floods. Overall, floods and landslides caused by torrential rains led to the deaths of 59 people and damage to homes, bridges, aqueducts, farms and roads to a value exceeding US$ 235 million.

The Caribbean island of ***Saint Lucia*** has an area of 617 km^2, a population (1992) of 135 000 and a GNP per head of US$ 1 370 (1987) [8]. On the most devastating rainfall day of the 1996 wet season, 26 October, a strong tropical wave was interacting with an upper tropospheric trough. Most rain fell between 1200 and 1800 UTC. The report contains measured falls at nine of the 29 rainfall stations; floods filled gauges at some stations. Twenty-four-hour falls were highest in the south-east, exceeding 250 l m^{-2}, and lowest in the east, exceeding 100 l m^{-2} . Moderate-to-severe flooding occurred in most low-lying areas, especially in towns and villages situated on river banks. Altogether, 435 business, public and residential buildings were damaged moderately or severely. The estimated damage to banana plantations amounted to US$ 0.3 million of the US$ 0.4 million total for agriculture. Losses in other sectors were (in US$ million): utilities, health and education, 0.5; road and river rehabilitation, 4.4. No estimates are available for housing. The total evaluated damage of US$ 5.3 million is equivalent to the personal contribution to the GNP of 3 869 islanders, or one in 35 of the population. The island has not yet recovered fully from the damage caused by the heavy rain, which induced widespread flooding and mudslides. There were no human casualties. The island authorities are adamant that the island would have suffered much greater structural damage and economic loss had they not taken precautions after the severe flooding from tropical storm *Debbie* in 1994. The rain in 1996 highlighted the need for a better hydrological network on the island and for radar coverage of the island and adjacent waters.

The next three countries in Table VI are all in central Europe and western Asia. In ***Croatia***, the total damage of US$ 200 million was estimated by the State Statistic Institute and Republic Commission for Estimation of Disaster Damage. In June and July, a few strong storms with hail and torrential rain caused localized floods and economic losses in agriculture and power utilities. A very warm June and windy July favoured more than 4 500 wildfires on the eastern Adriatic coast and islands; direct damage amounted to more than US$ 30 million. Early September saw heavy rain and torrential floods in the Drava and Sava river basin caused about US$ 40 million worth of damage to agriculture, roads and drainage systems. The end of December brought blowing snow along the eastern Adriatic coast, and over the islands (gusts of up to 210 km h^{-1} in a strong bora near Split) and great disruption of land and sea traffic. South Dalmatia also suffered great damage to fruit trees and vegetables. ***Moldova*** has suffered drought for seven of the past 10 years: in May–August 1996, losses in the agriculture and food sectors amounted to US$ 40 million. Persistent rainstorms with falls of 120 l m^{-2}, 22–24 September, flooded small rivers and drainage channels, causing water levels to rise by 4–5 m, flooding agricultural land and many villages. Total losses in 1996 from adverse weather amounted to about US$ 57.6 million. In ***Armenia***, although there was no loss of human life, and total losses from adverse weather were not evaluated, the biggest losses came from heavy hail and torrential rain. About 600 km^2 of the country's agricultural land was affected at a cost of around US$ 30 million. On 14 May, in one region of the Ararat valley, 42 l m^{-2} of rain and hail fell in 30 minutes (117 per cent of the normal monthly fall). In the Armavirok region, hail damaged 60–100 per cent of crops. In Vanadzor on 16 June, hail fell having a diameter of 20 mm, and in Ashetsk, the next day, 23 mm. In various mountain regions, communications and electrical transmission lines and roofs of buildings, were damaged in gusts up to 144 km h^{-1}.

Effects of using "purchasing power parity estimates" of GNP

So far, the economic assessment has followed last year's review [2]; it has used conversion to a single currency (US dollars) to allow comparison of financial losses, and the concept of GNP per head to estimate the relative impacts on countries with different economies and different sizes of population. *World Development Report 1996* [7] lists a refinement to the concept of GNP: the "purchasing power parity estimate of GNP per head". "PPP GNP per head" is specified in the technical notes of [7] but, essentially, takes account of the US dollar (at official rates of exchange) buying more goods and services in one country than in another. By and large, developing country Members have PPP GNPs per head which are larger than their conventional GNPs per head, and industrialized countries have PPP estimates which are rather smaller than their conventional GNPs per head; as a baseline, the PPP GNP per head in the ***USA*** is defined to be the same as the US GNP per head. The overall effect is that PPP estimates of GNP per head differ rather less than the more familiar GNPs per head. Conventional GNPs per head range from US$ 80 to US$ 37 930; PPP estimates vary between US$ 330 and US$ 25 880, reducing the ratio of greatest to least from nearly 500 to below 80.

Ratios of the PPP estimate to the conventional GNP per head vary from 9.5 (***Mozambique***) to 0.6 (***Japan***). For estimating the relative cost to different Members of repairing the same damage, when local labour and materials are used, the PPP estimate of GNP per head is appropriate; when the damage is repaired using materials and services bought on the international market, the conventional GNP per head is more relevant.

For countries for which PPP estimates of GNP per head are available for 1996, Table VII shows values of F (analogous to E but calculated using the PPP estimates), to allow comparison with corresponding values of E in Table VI. Although Table VII shows some changes in rank, it leads to no overall different conclusions. However, F is probably the more appropriate general tool, since the most common and expensive damage, flood damage to agriculture, roads and bridges, is largely repaired using local labour and materials.

Loss of "economic life"

We may also express economic losses in terms of "economic lives", in which each "life" equals 40 times the contribution to the GNP by one person in one year (see [2a]). Table VIII contains the values n_e' using the conventional values of GNP per head and n_f' using the PPP estimates. Note, however, that estimates of PPP were not available for ***Costa Rica***, ***Saint Lucia***, ***Croatia*** or ***Moldova*** (the top four in Table VI) nor for ***Yugoslavia***. For most Members, the two estimates of the loss of economic life, n_e' and n_f', far exceed the number of human deaths n (Table II): warnings by NMSs allow governments and people to take precautions which are often effective in saving human life but cannot, for example, often save crops; infrastructure can be protected only by taking weather with long recurrence periods into account during planning, design and building. In 1996, only in ***Malaysia***,

TABLE VII

Economic impact of assessed weather events in 1996, expressed as the contribution to the economy of one person in every F of the Member's population, as in Table VI, but using the PPP estimate of GNP per head

	F	E
Armenia	270	84
USA	650	650
Republic of Korea	820	660
China	920	200
South Africa	1 300	740
Thailand	1 400	500
Portugal	1 400	1 100
Malaysia	1 800	750
Norway	2 000	2 600
Japan	3 600	5 900
Spain	3 700	3 700
Dominican Republic	4 500	1 600
Australia	13 300	13 400
Austria	17 000	22 000
Hungary	22 000	13 000
Chile	52 000	20 500
France	57 000	68 000
Sweden	300 000	410 000
Ethiopia	1 200 000	290 000

Estimates of PPP were not available for ***Costa Rica*, *Saint Lucia*, *Croatia or Moldova***, the top four in Table VI, nor for ***Yugoslavia***.

Values of E for 1996 from Table VI are shown for comparison.

Venezuela and ***Ethiopia*** did the number of human lives lost exceed one or both of the estimates of the loss of economic life.

The number killed in ***Malaysia*** was exceptional, since tropical storms rarely affect Malaysian territory. In ***Venezuela***, too, tropical storms are not common but, on 25 July 1996, when *Cesar* crossed the north of the country, rain led to landslides and heavy flooding; dams and rivers overflowed; roads and bridges were washed away with "losses in the millions of dollars"; thousands of people were left homeless and 14 were killed; material losses came to "several million dollars".

This was the second year out of two that the loss of human life in ***Ethiopia*** exceeded economic loss. ***Ethiopia*** (GNP per head US$ 100; PPP estimate of GNP per head US$ 430) is the only Member with a GNP per head < US$ 250 (and PPP estimate < US$ 1 200) to report the impacts of its weather in both 1995 and 1996. In January, unseasonal rain destroyed 2 700 tonnes of grain crops on 44 km^2, because farmers without mechanized means could not harvest in time or thresh what had already been cut. In March, floods following heavy rain in two areas killed 300 cattle, demolished more than 150 houses, rendered over 100 families homeless and damaged 60 tonnes of grain. Further rain-floods in each month from April to August killed a total of 59 people and lightning killed ten. In August, the rains caused the country's main rivers to flood and overflow. High lake-levels threatened towns and displaced settlers but were controlled by building dykes, based on weather forecasts and climatological records. A major disaster

TABLE VIII

Economic losses expressed as the number of "economic lives" lost, calculated using the traditional GNP per head (n_e') and PPP estimates of GNP per head (n_f')

	F	E
	$n_f' = f/40$	$n_e' = e/40$
China	32 000	150 000
USA	9 900	9 900
Republic of Korea	1 400	1 700
Thailand	1 000	2 900
Japan	860	530
South Africa	800	1 400
Armenia	350	1 100
Australia	330	330
Malaysia	270	660
Spain	270	270
Portugal	180	230
Norway	54	42
Dominican Republic	42	120
France	25	21
Hungary	12	20
Austria	11	9
Venezuela	10	25
Chile	7	17
Azerbaijan	4	6
Ethiopia	1	5
Sweden	1	1
Totals	**47 257**	**169 286**

Where human lives were lost, the number is given in Table I. They total 3 831.

n_f' and n_e' are calculated using "PPP estimates of GNP per head" (where available—see note to Table VII) and conventional "GNP per head", to give the numbers of "economic lives" lost, depending on whether damage is put right using internal resources available, or with goods and services bought at international prices.

Shaded areas show where the loss of human life exceeded the "loss of economic life".

loomed when waters of the river Awash, east of Addis Ababa, broke through dykes, threatened the Koka and Melkassa hydroelectric plants, submerged sugar-cane plantations and homes and damaged fields, sources of drinking water, and disrupting the normal activities of life over a vast area.

International insurance (and reinsurance)

Major weather events are amongst the most economically damaging of all peace-time catastrophes, as well as costing the most human lives. Fifteen of the 40 worst catastrophes in terms of human life between 1970 and 1996 were weather events (515 000 people dead or missing, among whom the 300 000 fatalities in the 1970 tropical cyclone in ***Bangladesh*** predominate[3a]). Moreover, weather events (including two forest fires) made up 32 of the 40 most costly insurance losses [3b]. Insurance losses totalled US$ 89 250 million at 1996 prices, or approximately 0.35 per cent of the sum of the GNPs of almost all nations for one year [7a]. Of

A tornado near Bearbung, NSW, Australia, at 14h30 on 29 September 1996 caused damage to farm buildings, fences and trees.
Photo: Chris Cooke

this loss, over 27 years, more than US$ 60 000 million fell in the ***USA*** and the Caribbean. Compared with a total loss of US$ 45 000 million dollars each year in the ***USA*** alone [1], however, this suggests that most of the loss is uninsured, or comes from many smaller events, or both.

Insurance is a means of pooling risk. The costs of insuring against weather-related losses affect the economies of the countries of the insured, of the insurer and, since many insurers themselves insure against major risks to them, of the reinsurer. For the most part, reinsurers pool the risk of major catastrophes and insurance companies pool the risks associated with the less extreme variations in the range of ordinary, but naturally fluctuating, weather. Since major disasters (costing thousands or tens of thousand of millions of US dollars) are relatively rare in both space and time, and there is a limited area (the surface of the Earth) over which they can be pooled, reinsurers have a particular interest in pooling the risk of major disasters over as long a time as possible. Thus Berz [12], for example, calls for funds to be set aside as disaster reserves and calls on tax authorities not to regard premiums paid for the coverage of natural catastrophes as earned at the end of the tax year but rather only after very long periods. In the ***United Kingdom,*** the Meteorological Office is working with other research institutes to find the probability of extreme weather events for the insurance industry [4].

"As a business on the front lines of society's most risky activities the [insurance] industry has a long tradition of spurring important policy changes to help reduce society's risks." [11]. Consequently, the entry of insurance companies into assessing the impact of weather worldwide [3, 10] is of great long-term significance. To minimize effects on them of extreme weather events, insurance companies have the ability, for example, to direct capital into prevention and alleviation measures and the financial influence to help shape national policies. There may well be synergy between NMSs and insurers based in their countries. As happens now in the marine industry, insurers might require the would-be insured to have effective means of receiving, and acting upon, meteorological forecasts and warnings as a condition of the insurance of their operational work. Insurers might invest in meteorological infrastructure, so as to reduce their own exposure. For example, the extent and so the cost to insurers, of damage caused by a catastrophe depends not only on the severity of the natural forces involved, but also on human factors such as methods of construction or the efficiency of disaster-protection measures in the region concerned: based on their long-term gathering of data and expertise in interpreting it, and the likely bounds of the effects of future climate change, Meteorological Services have much to offer at the planning and design stages.

In a UNEP Statement of Environmental Commitment, the insurance industry has pledged to address key environment issues, such as pollution reduction, the efficient use of resources, and climate change and to endeavour to identify realistic, sustainable solutions. By 30 October 1996, 61 companies in 23 different Members of WMO were committed to the Statement.

Insurance companies have good data on claims, but are less confident of the authority of data on the total (insured plus uninsured) losses. Their sources [3] include daily newspapers, insurance and reinsurance periodicals, specialist publications (in printed and electronic format), as well as reports from insurance and reinsurance companies; they have developed a feeling for the quality of their data (Berz, personal communication). Newspapers, television and radio, however, report very soon after events which, by their nature, create chaos and uncertainty. Officials making estimates for the media make their assessments even earlier. Insurers are well aware of this. It seems that only governments are likely to build up data on impacts which are reliable enough for their use, including that by an NMS, and it may be that NMSs will have to work with other government departments to specify the basis for the collection and collation of data.

For their purposes, international reinsurance companies have defined a few terms. They divide natural catastrophes, for example, into flood, storm, earthquake (including seaquake and tsunami), drought (including bushfire and heat wave), cold (including frost) and other (including hail and avalanche). They scan sources for all events and compile monthly summaries on less strict criteria (available on the Internet at, for example, http://www.swissre.com and http://www.munichre.com). For their major summaries for reinsurance purposes, however, Swiss Reinsurance, for example, include only events at least as costly as those set out in Table IX. Permanent representatives of Members, in compiling their returns, on the other hand, use their own judgement on what was relevant or

TABLE IX

Lower limits of losses considered in some international reinsurance statistics [3, 10]

	1995 US$ million	*1996 US$ million*
Insurance losses:		
shipping	12.0	12.5
aviation	24.0	24.9
other losses[1]	30.1	31.1
and/or		
Total losses	60.1	62.3
and/or		
Personal injury:		
fatalities[2]	20	20
injured	50	50
homeless	2 000	2 000

1 Includes insured weather losses.
2 Includes dead and missing.

interesting. Most of the reported events were less costly than 20 fatalities (includes both deaths and persons missing after the weather event) or 12 million dollars.

Total weather-related loss (insured plus uninsured) is made up of many small losses and relatively few major ones; consequently, global losses, which include all smaller losses (insured or uninsured), must exceed the totals given in Table X, which are for events more costly than

TABLE X

Major losses from natural catastrophes in 1996, reported by international reinsurers [3, 15]

	Dead and missing	*Insured loss US$ million*	*Economic loss US$ million*
[3]			
Floods	6 853	233.1	
Storms	5 385	5 252.4	
Cold, frost	779	2 360.0	
(Earthquake	544	0.0)	
Drought, bush fires	97	0.0	
Other	292	60.6	
Total[1]	**13 406**	**7 906.1**	
[13]			
Flooding	6 920	1 118.4	34 638.9
Windstorm	3 582	7 176.4	19 446.4
Others	1 359	1 025.2	6 684.7
Total	**11 861**	**9 320.0**	**60 770.0**

1 Excludes dead and missing following earthquakes.

the criteria given in Table IX. It seems wise for Members to continue to monitor all losses, the few large and the many small (or measured samples of the many small), at least for a while, to establish national and world baselines.

Compared with other years, insurers report [3, 15] that there were no extremely costly natural disasters in 1996. Only the floods in ***China*** and hurricane *Fran* in the ***USA*** were classified as "great" catastrophes (fatalities numbering thousands, or casualties numbering hundreds of thousands or economic losses exceeding US$ 1 000 million [13]). Nevertheless, almost 7 000 people died in floods and 5 000 in storms, giving a total much greater than that amassed from Members' reports in Table I. Natural catastrophes accounted for insured losses of US$ 7 900 million, as against insured losses from man-made disasters of US$ 4 900 million. The floods in ***China*** between June and August which claimed 2 700 lives (more than the total for the year for ***China*** reported in Table I) and caused a total (i.e. insured plus uninsured) loss of US$ 18 000 million [3] to US$ 24 000 million [13] (five to seven times the figure for ***China*** in Table IV).

Table XI lists some assessments by Münich Reinsurance [13] of significant events which are not included in the returns from Members of WMO. They total 783 deaths (adding 9 per cent to the figure in Table I) and damage amounting to US$ 4 802 million (adding 29 per cent to the total in Table IV). If included in Table I, these deaths would put the ***Republic of Yemen*** in fourth position in the ranking, ***Viet Nam*** eighth, ***Sudan*** tenth and ***Pakistan*** eleventh. The economic losses would put ***India*** in third place in Table IV, ***Canada*** in fourth and the ***United Kingdom*** in fifth.

Conclusions

Members' comments on the various approaches suggested to improve the assessment and evaluation of the impacts of weather would be welcome, particularly on:

- The need to work out an optimum way of standardized reporting. The author considers that this is necessary before any authoritative worldwide assessment can be made of the contribution which NMSs as a whole make to their national economies. Data for such reports by NMSs will need to be gathered from relevant departments of government so that PRs report on the impact of the weather on a wide range of aspects of national life;
- The assessment and evaluation of the impact of the multiplicity of small everyday weather events;
- Ways of allowing for the impact of weather on events in which it is not the only factor;

TABLE XI

Some assessments in the records of international reinsurers not in returns by WMO Members

Date	*Loss event*	*Area*	*Deaths*	*Economic loss (US$ million)*
4–9 January	Flooding	Indonesia* (Sumatra, Java)	24	110
24 January	Snowstorm; flooding	United Kingdom		600
20–24 March	Flooding; hail	United Arab Emirates*; Saudi Arabia; Kuwait*		290
April	Drought	India (Rajasthan)		570
14–16 June	Flooding	Republic of Yemen*	338	
19–23 June	Flooding; storms	Italy; Austria	38	32
13–27 July	Flooding; landslides	Bangladesh; India		150
18–26 June	Flooding; landslides; hailstorms	Canada*	10	1 100
22–28 August	Flooding	Pakistan*	111	
11 Sept.–23 Oct.	Flooding	Sudan*	100	
5 Oct.–5 Nov.	Flooding	Viet Nam*	162	360
16–24 October	Flooding; storms	India		90
6 November	Tropical cyclone; flooding	India		1 500
Total			**783**	**4 802**

- Sectors of the economy where NMSs may usefully cooperate with other interested parties, such as insurance and reinsurance companies;
- The choice of concise and useful indices for the presentation of results and for comparing them between countries and from year to year.

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WMO EXECUTIVE COUNCIL

FORTY-NINTH SESSION, GENEVA, 10–20 JUNE 1997

CONSIDERATIONS, RECOMMENDATIONS AND DECISIONS

The forty-ninth session of the Executive Council took place at the Geneva International Conference Centre from 10 to 20 June 1997 under the chairmanship of the President of the Organization, Dr John Zillman. The following is a necessarily selective summary. Full details of the session will be found in the abridged final report (WMO-No. 867).

Designation of acting members of the Executive Council

The Council designated Messrs P. Ewins (United Kingdom), A. Jaime (Mexico) and F. J. B. Hounton (Benin) in replacement of Messrs J. Hunt, G. E. Ortega Gil and A. B. Diop. These changes are reflected on the inside front cover of this issue. These new members will replace their predecessors on the various panels and other bodies reporting to the Council.

World Weather Watch (WWW)

The Council examined the report and recommendations of the eleventh session of the Commission for Basic Systems (Cairo, Egypt, October/November 1996). With the exception of the definitions of forecasting ranges, the Council approved all eight of the commission's recommendations, which included a list of requirements for the international exchange of data and products to be included in the WMO Technical Regulations, as well as amendments to the operational manuals on the GOS, GDPS and GTS and the designation of four new RSMCs. Of major concern was the critical situation in the implementation of the upper-air component of the GOS with the cessation of the OMEGA radio-navigation system in September 1997 and CBS was requested to continue vigorously its efforts towards the determination of the best and most cost-effective mix of observing systems, including better use of observations from satellites, and the safeguarding of radio-frequencies used for meteorological systems. CBS was also requested to pursue, as a matter of high priority, "the year 2000 problem" with a view to ensuring the sustained and reliable operation of WWW systems.

As regards **Satellite activities**, the Council was extremely pleased to learn that China had launched its geostationary satellite FY-2 in June 1997 and that the commissioning phase was proceeding smoothly. It was also pleased to note the initiative and activities of the Committee on Earth Observation Satellites towards an integrated global observing strategy and urged CBS to continue its efforts to establish WMO requirements for space-based observing systems.

Under the **Tropical Cyclone Programme**, the Council endorsed a number of recommendations of the TCP RSMCs technical coordination meeting (Miami, November 1996) and agreed that WMO should continue to play an active role, with the IOC, IHP/UNESCO and other international organizations, in developing a storm-surge project, particularly for the Bay of Bengal and the northern part of the Indian Ocean.

World Climate Programme (WCP)

The Executive Council noted the establishment of the Interagency Committee on the Climate Agenda (IACCA), which would be in the most appropriate position to deal with the coordination of the WCP. The World Climate Impact and Response Strategies Programme constituted a significant part of international climate-related activities under Thrust 3 of the Climate Agenda and UNEP's intention to provide support to the work of the IACCA was welcomed.

The Council noted the report of the president of the Commission for Climatology and in general endorsed his views on the future high-priority activities of the Commission to be further elaborated during its twelfth session (4–14 August 1997). The Commission needed to develop guidance material on the role of climate services in the climate change issue, on the statistical analysis of time-series of climate data and on the quality control and preservation of climate data, and to enhance its activities related to climatological aspects of desertification and its impact.

Members were urged to maintain observation programmes at designated sites for a GCOS Surface Network (GSN) and routinely distribute data over the GTS using the **CLIMAT** message code. The requirements for, and implementation of, the climate observing systems needed to be carefully coordinated. The future development of climate database management systems through the WMO CLICOM project should take into full account the need for Members to maintain their national climate data management systems.

The Council commended the action taken to facilitate and promote the development of the Climate Information and Prediction Services (CLIPS) project, including the establishment of the CLIPS Project Office in the WMO Secretariat. It endorsed the conducting of an information campaign as well as training on CLIPS within the framework of various training events to be organized in all WMO Regions.

The Council requested the Secretary-General to promote the role of NMHSs in follow-up action at the national, regional and international levels on projects related to urban development. Sustainable development in cities was threatened by increasing pressure from population and water needs, while extreme events such as urban flooding were becoming more serious threats.

The Council confirmed WMO's continuing support to the United Nations Convention to Combat Desertification. WMO needed to be even more involved in various aspects of its implementation, in particular through projects dealing with research and interactions between desertification and climate.

Atmospheric Research and Environment Programme (AREP)

Tribute was paid to Dr D. J. Gauntlett, the outgoing president of the Commission for Atmospheric Sciences (his tenure comes to an end at CAS-XII in 1998), in recognition of his contributions to WMO and, in particular, to AREP.

In matters concerning urban environment, the Council approved an amendment to its Resolution 7 (EC-XLVI) in the form of a new term of reference to the responsibilities of the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution, Atmospheric Chemistry and Urban Environment, which reads: "To

Geneva, June 1997 — Participants in the forty-ninth session of the WMO Executive Council
Photo: WMO/Bianco

keep informed of scientific developments in the field of urban atmospheric environment and to provide advice to Members' Meteorological and Hydrometeorological Services".

Considerable satisfaction was expressed with the progress being achieved with CAS programmes in general and high-priority areas, such as the further development and implementation of the **Global Atmosphere Watch** (GAW), in particular. In this regard, the importance of external funding sources and support being provided by individual Members was noted. A great deal of emphasis was placed on the further development of GAW and on the need to strengthen links with the broader scientific community and Members' further collaboration was urged. CAS would consider a Strategic Plan which the Council approved as a working document for the long-term development of GAW.

The Council also gave its broad support for initiatives currently taking place within CAS to establish a World Weather Research Programme (WWRP) to develop improved and cost-effective techniques for forecasting high-impact weather and to promote their application among Members. The WWRP would be implemented through a re-ordering of internal CAS priorities and would be considered more fully at CAS-XII in 1998.

In considering the **Weather Prediction and Tropical Meteorology Research Programmes**, the Council encouraged ongoing activities to improve the accuracy and reliability of prediction of high-impact weather, and to promote the transfer of forecast methodologies and experience to all Members, particularly developing countries, within the new focus given to current weather prediction research by the World Weather Research Programme (WWRP) initiative. The Council noted the increased activities in monsoon research and encouraged Members in monsoon-affected regions to cooperate in future research activities and field experiments.

Note was taken of the continued interest in weather modification activities in support of the **Programme on Physics and Chemistry of Clouds and Weather Modification Research** and satisfaction was expressed with activities where expertise acquired within WMO was being called for in activities being undertaken outside the Organization.

Applications of Meteorology Programme

The Executive Council was concerned at the low level of resources available to the **Public Weather Services (PWS) Programme**; it pledged its continued support for the programme with a view to the development and improvement of services at the national level, especially in developing countries, and urged that the new CBS Working Group on PWS be activated as soon as possible.

Under the **Agricultural Meteorology Programme,** the Council considered the progress achieved, especially in publishing Technical Notes and CAgM reports, and in organizing training events, and current efforts in the Commission to compile case-studies on validation of information requirements for agricultural crops. It requested the Commission to undertake a study of the extent to which the publications are used by Members to provide a quantitative assessment of the effectiveness of the contents. The Council noted the emphasis placed by the Commission on agrometeorological factors related to extreme events and recommended the inclusion of the topic of saltwater intrusion into coastal agricultural lands under this subject. It requested that, given the importance of ENSO, the consequences of this phenomenon, at least for Regions II and V, should be taken into consideration.

The Council reiterated the importance of training in agrometeorology and was pleased to note recent initiatives taken by China, Israel, Nigeria and the Russian Federation in organizing training workshops. The recent organization by WMO of a roving seminar on extreme events in India was appreciated. The Council requested that emphasis continued to be placed on organizing similar training seminars and workshops in the future.

With respect to coordinating activities between FAO and WMO in the area of agrometeorology, the Council considered that FAO could involve national Meteorological and Hydrological Services more actively in their programmes on food security. The Council urged the Secretary-General to pursue this matter with the Director-General of FAO.

In considering the **Aeronautical Meteorology Programme**, the Council endorsed the proposal that a Panel on Aircraft Meteorological Data Reporting be established to coordinate and promote global AMDAR development.

Under the **Marine Meteorology and Associated Oceanographic Activities Programme**, the Council considered and approved all the recommendations of the twelfth session of CMM (Havana, Cuba, March 1997). It also agreed to the continuation of an in-depth study of the possibilities and implications of closer cooperation between CMM and the IOC, including a possible co-sponsorship of the Commission. The results of this study are to be presented, as a joint WMO/IOC report, to the Executive Councils of both Organizations in 1998.

Hydrology and Water Resources Programme

Discussions on this Programme concentrated on the report of the president of the Commission for Hydrology, which presented the outcome of the tenth session of CHy (Koblenz, Germany, 2–12 December 1996) and, mainly, its recommendations for future work, and on recent developments regarding in particular WHYCOS and follow-up to the Commission on Sustainable Development as regards freshwater issues. The Council welcomed the participation of the Regional Hydrological Advisers, who were attending the full session of the Council for the first time; it further noted with appreciation that a number of members of the Council were also accompanied by their hydrological advisers.

The Council approved the recommendations of CHy-X. This included support for the activities recommended for the next intersessional period and for the new component programmes proposed for inclusion in the 5LTP; recommendations for the strengthening of hydrological networks; endorsement of the revised terms of reference for CHy; and support for the participation of women in the work of WMO. It also recognized the unique role that WMO was called upon to play within the UN system as regards water resources assessment in response to the growing concern over the water crisis facing the world. The importance was also stressed of an integrated approach to hydrology and meteorology in the WMO system. A call was made for a new campaign to publicize the importance of hydrology within WMO and for the strengthening of the Hydrology and Water Resources Programme.

Under the agenda item on the international exchange of data and products, the Council considered the draft resolution on the exchange of hydrological data prepared by CHy-X and recommended that UNESCO, ICSU and IAHS be invited to work with the Commission on its submission to the Thirteenth World Meteorological Congress in 1999.

Under the agenda item related to the International Decade for Natural Disaster Reduction, the Council was of the opinion that WMO should convene a meeting based on the mechanism established under the System for Technology Exchange for Natural Disaster (STEND), with the aim of preparing an interdisciplinary, policy and operation orientated plan for post-Decade disaster reduction activities.

Education and Training Programme

The importance of the human resources development in assisting NMHSs to assess their future needs for trained personnel and in mobilizing the necessary financial and other resources to meet those needs was reaffirmed by the Council. In that respect the Council was pleased to note the new design of the recently released seventh edition of the mandatory publication WMO-No. 240: *Compendium of Training Facilities for Meteorology and Operational Hydrology* and the fact that a substantial part of its content was available on the Internet.

The WMO Regional Meteorological Training Centres were encouraged to continue their contribution to the Programme and the Secretariat was requested to continue to assist them, especially in connection with the training of instructors in modern methods and techniques.

The Council recognized the Institute of Agrometeorology and Environment Analysis for Agriculture in Florence as an additional component of the WMO RMTC in Italy for the training of Class I meteorological personnel in the area of agricultural meteorology.

Noting with concern the considerable reduction of fellowships funded under the UNDP, the Council urged Members to make maximum use of the training opportunities in their respective Regions, in particular at the RMTCs, in order to optimize the use of the limited financial resources available for fellowships and to minimize the cost of training.

It also encouraged donors and the Secretariat to make every effort to assist in satisfying the pressing needs for long-term fellowships at Class I and II levels, particularly in Regions I, III and IV.

Technical Cooperation Programme

The Council noted with satisfaction the action taken by the Secretary-General to implement the relevant decisions of Twelfth World Meteorological Congress and of the Executive Council, especially with regard to the harmonization of the functions of the Regional Offices with those of the Technical Cooperation Department. In this respect, the Council expressed its appreciation for the establishment of two subregional offices, which began operations in February 1997 and would provide enhanced support to Members.

Implementation of the Programme had continued in a satisfactory manner and that several new UNDP and trust-fund projects had been approved. The Voluntary Cooperation Programme (VCP) had also continued satisfactorily and the Council approved additional allocations for the implementation of VCP(F) projects during 1997. Furthermore, the Council approved the 1998–1999 budget for Secretariat support to the Technical Cooperation Programme. The Council requested Members to continue providing support for new projects and programmes.

International exchange of data and products

The Executive Council reviewed the status of implementation of Resolution 40 (Cg-XII)—WMO policy and practice for the exchange of meteorological and related data and products. Feedback had been largely positive and there was generally a strong commitment to make it work. Focus over the coming years should continue to be on monitoring the implementation and the resolution of practical difficulties. It was considered inappropriate to propose a renegotiation of Resolution 40 (Cg-XII) at Thirteenth Congress but the incorporation of a reference to "free and unrestricted international exchange" in the WMO Convention should be studied.

With respect to the proposed WIPO treaty on the protection of databases, the Council agreed that it would be desirable to seek the explicit recognition and/or incorporation of the essence of Resolution 40 (Cg-XII) in any database protection legal instrument.

The Council stressed the importance of ensuring the consistency of the data policy for WMO-sponsored research experiments with Resolution 40 (Cg-XII). It provided certain guidelines in this connection, as well as in relation to data access policy for WMO World Data Centres.

Role and operation of NMHSs

The Council confirmed the importance of underscoring the role of NMHSs, especially in connection with the protection of life and property, safeguarding the environment and contributing to sustainable development. A legal instrument defining the mission and mandate of an NMHS was crucial to ensuring that the NMHS's contribution to society was recognized and its responsibilities were well defined.

The Council requested the Secretary-General to build upon and enhance the coordination and integration of activities related to the role and operation of NMHSs; to provide relevant information and advice relating to the complementary nature of ongoing and planned activities; and to report to the next session of the EC Working Group on Long-term Planning.

Relations with other disciplines and programmes

The Council supported the recommendation of the Meeting of Eminent Persons on the Geosciences and the UN System regarding the establishment of a process involving major stakeholders (including interested governments, relevant intergovernmental agencies and non-governmental organizations) to determine how best to ensure increased joint programme activities, consolidation of work in the geosciences and related services.

Programme and budget for 1998-1999

The Council approved regular budget appropriations amounting to SFR 125.1 million for 1998–1999 in conformity with the maximum expenditure for the twelfth financial period. Provisions were made for the following sessions: RA I-XII, RA V-XII, RA VI-XII, CBS (ext.), CAS-XII and CIMO-XII in 1998; and CAgM-XII and CAeM-XI in 1999. The Council approved the budget amounting to SFR 5 554 200 for the joint WMO/ICSU/IOC Climate Research Fund for the coming biennium and authorized the WMO contribution of a maximum of SFR 4 003 200 from the regular budget. The Council also approved the budget of SFR 6 million for Secretariat support to the Technical Cooperation Programme and authorized a regular budget contribution of SFR 1.5 million for 1998–1999.

Structure of WMO

The Council considered the second report of its Task Team to Review the WMO Structure, together with some proposals for a radical restructuring of the main subsidiary bodies of the Organization. It was agreed that proposals should be linked to the development of the Fifth WMO Long-term Plan and to the changing roles and circumstances of NMHSs. The Secretary-General was requested to carry out an analysis of the Task Team's proposals taking into account, *inter alia,* the impacts on NMHSs, particularly of developing countries, on the Convention of the Organization, including the legal implications, on the regular budget, and on the calendar of meetings of the Organization. The analysis will be considered by a session of the Working Group on Long-term Planning to be convened towards the end of 1997.

The 1997 Norbert GERBIER-MUMM International Award: (*from left to right*): Dr J.W. Zillman, President of WMO; a representative of MUMM Foundation; Mme Geneviève Guiard-Gerbier; Messrs J. F. B. Mitchell, S. F. B.Tett, R.C. Johns (three of the winners of the Award); and Prof. G. O. P. Obasi, Secretary-General

International cooperation

The Council was pleased to learn of the WMO/IUGG Alliance for Capacity Transfer (ACT), whose purpose was to stimulate and expand voluntary collaboration and exchange of information and data, within and across the boundaries between NMHSs, the university community and scientific community at large. ACT would consist of a loose and flexible framework making use of currently available Internet Web sites relating to meteorology, hydrology and oceanography. The Council agreed that the establishment of working arrangements concerning scientific and technical cooperation activities between WMO and the Islamic Educational, Scientific and Cultural Organization would be of mutual benefit to both Organizations.

Regional matters

The Executive Council studied the views of XI-RA I on the need to change the title "Association" to reflect better the status of an intergovernmental body. It requested the Secretary-General to consult WMO Members on the proposed change as well as the choice of an appropriate alternative title.

The Council expressed its appreciation to the Governments of Nigeria and Costa Rica for hosting Subregional Offices for Western Africa and for Northern and Central America and the Caribbean, in Lagos and San José, respectively. It also acknowledged with appreciation the facilities offered by the South Pacific Regional Environment Programme for the Subregional Office for the South-West Pacific that is planned to be established in Western Samoa.

World Meteorological Day

The Council confirmed that the themes for World Meteorological Day in 1999 and 2000 would be, respectively, "Weather, climate and health" and "The World Meteorological Organization—50 Years of Service". Regarding the draft plan for the celebration of the WMO's fiftieth anniversary, the Council decided that the objective was to focus not only on the achievements of the Organization over the past 50 years but also on WMO's future role in the forefront of the world's global agenda. It established a trust fund for this purpose and invited Members and other sponsors to contribute.

Awards and prizes

The Council awarded the 42nd IMO Prize to Dr Mariano A. Estoque (Philippines).

The twelfth Professor Dr Vilho Vaisala Award was conferred upon Mr B. W. Forgan (Australia) for his paper entitled "A new method for calibrating reference and field pyranometers".

The 1997 Research Award for Young Scientists was conferred upon Mr H. R. da Rocha (Brazil) for his paper "A vegetation–atmosphere interaction study for Amazonian deforestation using field data and a single column model".

The Selection Committee for the Norbert GERBIER-MUMM International Award could not recommend a paper for the Award in 1998. Nominations should be invited once again with the deadline of 30 September 1997. The Selection Committee would make a recommendation to the President of WMO in the first week of November 1997 to take a decision on behalf of the Executive Council.

Scientific lectures

The following lectures were delivered: "Climate variability and food production", by Dr M. V. K. Sivakumar (WMO Secretariat); "New developments in satellite observation capability and its contribution to weather forecasting", by Dr A. Hollingsworth (ECMWF); and "The use of electronic media in public weather services", by Mr C. Fuller (National Meteorological Service of Belize). The lectures would be issued as a forthcoming WMO publication.

Dr G. A. McBean (Canada) would be invited to deliver the ninth IMO Lecture at Thirteenth World Meteorological Congress on the subject "Weather forecasting in the twenty-first century".

Date and place of future sessions of the Council

It was decided that the fiftieth session of the Council would be held in Geneva from 16 to 26 June 1998. It was tentatively agreed that the fifty-first session would be held in Geneva from 27 to 29 May 1999. ❐

REGIONAL ASSOCIATION IV (NORTH AND CENTRAL AMERICA)

TWELFTH SESSION, NASSAU, BAHAMAS, 12–20 MAY 1997

Opening of the session

The twelfth session of Regional Association IV (North and Central America) was held in Nassau, Bahamas, from 12 to 20 May 1997. It was attended by 35 participants, including representatives of 16 Members in Region IV, three observers from Members outside the Region and five observers from other regional and international organizations. The opening ceremony was attended by the Rt. Hon. Hubert Ingraham, MP, Prime Minister of the Commonwealth of the Bahamas; the Hon. Pierre V. L. Dupuch, Minister of Consumer Welfare and Aviation of the Bahamas; Prof. G. O. P. Obasi, Secretary-General of WMO; and Mr Hugo Hidalgo (Costa Rica), vice-president of the Association and chairman of the session.

Prof. Obasi expressed his appreciation to the Government and people of the Bahamas for hosting the session. Such meetings provided the opportunity to take stock of new developments in meteorology, operational hydrology and related sciences and he highlighted the most significant events since the Association's last session. One of the most pressing concerns in the Region was the mitigation of natural disasters, some of which had affected many countries severely in 1995 and 1996. In order to implement WMO programmes and activities successfully in the Region, it was essential that the World Weather Watch system operated at the optimum level. Moreover, a Subregional Office for North America, Central America and the Caribbean had been established in Costa Rica earlier in 1997 to enhance the Organization's support to Member countries.

The Rt. Hon. Hubert Ingraham remarked that, at less than one month from the hurricane season in the Caribbean, the meeting was particularly timely. He stressed the vital importance of early warning and continuous planning for disaster prevention, preparedness and relief. Global climate change and potential sea-level rise had tremendous implications for small island developing States, whose economic prosperity depended on their coastal areas.

The Hon. Pierre V. L. Dupuch said that the Bahamas had participated in various WMO activities since 1961 and had hosted several meetings, including the fifth and nineteenth sessions of the Hurricane Committee in March 1982 and May 1997, respectively. He was keen to know the outcome of this meeting so as to be able to introduce all innovations and improvements which would prepare Bahamians to cope better with the devastating impacts of hurricanes.

Main items of discussion

Concerning the implementation of the World Weather Watch in the Region, 97 per cent of available SYNOP reports were transmitted over the GTS within one hour, and 92 per cent of TEMP reports within two hours. A list of silent stations had been identified in the WMO annual monitoring exercise. Members were urged to check the status of operation of those stations and inform the Regional Association through the Secretariat. One reason for discrepancies in monitoring results was that the information contained in Volume A was not always updated correctly; Members were requested to check regularly the information pertaining to their own country and send updates to the associated RTH and the WMO Secretariat. The Regional Basic Synoptic Network should also be updated through agreed procedures, with a view to ensuring that observational reports were properly distributed over the GTS.

The RA IV Working Group on Planning and Implementation of the WWW was carrying out a study of a comprehensive radar network with a view to ensuring appropriate coverage and efficient radar data exchange. The study should also investigate the possibility of preparing and exchanging composite mosaic radar images, taking advantage of the experience gained with WMO representation formats. The Working Group was requested to pursue the study as a matter of urgency, with the aim of adopting a regional radar network plan in the near future.

The numerous requirements of NMHSs in the field of instrumentation needed to be addressed, in particular long-term stability, maintenance and repair and calibration. Members were encouraged to develop capabilities for maintaining, servicing and manufacturing instruments, using endogenous resources. In this connection, the appointment of a CIMO Rapporteur on Capacity Building was welcomed and Members were encouraged to use the facilities and experience available at their Meteorological Instrument Centres for calibration and training purposes.

Several Members raised the issue of the gap existing between the private sector and some Meteorological Services in the southern part of the Region for accessing Internet. A consultant study had been carried out to assess current capabilities, determine initial and recurring costs for full connectivity and formulate proposals. The USA offered to work with a few interested countries on a pilot project to help them establish an Internet Web Page.

An RA IV E-mail Discussion Group on Data Management was established, consisting of the president of RA IV, the RA IV Rapporteur on Data Management, and other experts.

The International Satellite Communications System, designed to handle both WAFS and WWW traffic, had been implemented.

RSMC Miami, having specialization in tropical cyclone tracking and forecasting, had continued to provide services of high-level operational and scientific capability. The increase of the hurricane model resolution had further increased that capability.

In connection with developments and events related to climate and climate change under the various components of the World Climate Programme, Members were urged to ensure that positions of national delegations at appropriate intergovernmental meetings would include support to the Climate Agenda and related WMO activities.

A number of activities of the Inter-American Institute (IAI) and the International Research Institute (IRI) were of special interest and importance for the Region but NMHSs and the Caribbean Meteorological Organization were, in many cases, not yet involved. The outcome of research projects, espe-

Nassau, Bahamas, May 1997 — Participants in the twelfth session of Regional Association IV (North and Central America)

cially seasonal and interannual climate predictions, should be made available to national decision-makers and other users through the NMHSs, which were responsible for the provision of national climate services.

Activities under the Climate Information and Prediction Services (CLIPS) project had contributed to an increased awareness of the value of application of climate information and prediction services in economic and social decision-making and Members were encouraged to develop CLIPS implementation plans for their NMHSs and RSMCs.

As regards the Atmospheric Research and Environment Programme and the Global Atmosphere Watch, Members had responded favourably to the efforts made through the introduction of the Quality Assurance/Science Activity Centre for the Americas established at the State University of New York and the World Calibration Facilities which had been established in Canada and the USA.

Under the Public Weather Services Programme, in response to concerns expressed by the Executive Council and CBS regarding the proliferation of weather forecasts from different sources in the media and international television broadcasts, by satellite, in particular, discussions had been held with producers and disseminators of those forecasts with a view to agreeing on the "best practice".

A large number of technical notes and reports had been published under the Agricultural Meteorology Programme and several members from the Region were translating some of them into Spanish.

The Association requested the Secretary-General to provide appropriate guidelines to Members concerning WMO activities in desertification, including the implementation of the International Convention to Combat Desertification. It was important to establish a close connection between agrometeorological and agricultural communities at the national level and all possibilities should be explored to convey meteorological, hydrological and agrometeorological information to farmers, especially seasonal predictions needed for evaluating potential water resources.

In discussing the Hydrology and Water Resources Programme and the CARIB-HYCOS project proposal, a distinction should be made between the design criteria to be applied to large mainland countries and small island States. HOMS continued to make a significant impact at the regional and national levels, particularly in promoting technical cooperation between developing countries; there were currently 19 HOMS National Reference Centres in the Region. Support to HOMS activities was also provided by the Central American Isthmus focal point in the *Comité Regional de Recursos Hidráulicos*. As of mid-1995, the *HOMS Reference Manual* had been available on the WMO World Wide Web server.

When considering the Education and Training Programme, the Association reviewed the report of the ad hoc Working Group on Education and Training Needs in RA IV, which had been established as a result of the lack of professional meteorologists (Class I) in national Meteorological Services of the Region. Over the following six years, most of the experienced staff would retire and severe shortages among Class I and Class II personnel would be encountered by the NMHSs; long-term fellowships were urgently needed.

The WMO RMTCs in the Region were functioning satisfactorily and contributing significantly to the training of operational personnel. In urging them to make the maximum use of the training programmes offered by RMTCs, Members were requested to assist in organizing specialized (including management) courses, using instructors on short-term assignments, and in the provision of relevant training materials and teaching aids. It was considered important that the RMTCs improve their capabilities, both in terms of facilities and expertise, including through the use of distance learning technology, for the provision of meteorological, hydrological and related training in all aspects of natural disaster management.

Nations were adjusting to fundamental economic and political changes, as well as accelerating technological opportunities. Among the forces directly affecting WMO's technical assistance programmes were policy changes of international development funding agencies. Tightened national budgets were leading to more requests for funds through the WMO Voluntary Cooperation Programme. While such changes were having adverse effects on technical assistance funding, the needs of developing countries had been growing.

The Association agreed that the permanent representatives of Members with WMO should have a more substantial role to play in the mobilization of resources and encouraged them to ensure closer liaison with national, bilateral and multilateral funding agencies in order to access resources for the development of meteorological and hydrological services and institutions.

A host country agreement had recently been signed between WMO and the Government of Costa Rica to establish a Subregional Office in San Jose, which began operating on 3 February 1997. The Office served all Members in Region IV, which were called upon to collaborate closely with it.

A number of initiatives had been made, aimed at assisting RA IV Member countries through the development of new technical cooperation projects with the help of WMO. Projects which were in the formulation and/or negotiation stages included: the Radar Network System for English-speaking Caribbean countries; the Ibero-American Climate Project; CARIB -HYCOS; Natural Disaster Prevention in the Central American countries; and water resources project proposals for Haiti and Nicaragua. The Association requested the Secretary-General to pursue his efforts in mobilizing the necessary resources for these, and other relevant projects.

The president was requested to keep Members informed with regard to the preparation of the Fifth WMO Long-term Plan (5LTP). Concerning the "Preliminary programme structure for the formulation of the 5LTP", as approved by the Executive Council, it was suggested that financial considerations for the Plan's various components be included to provide more definition.

The Information and Public Affairs Programme was crucial to the successful implementation of NMHSs' and WMO's scientific and technical programmes and enhancing public awareness of their valuable contributions in the Region. The strategy should be to highlight, in a balanced manner, the work of the Organization and of the NMHSs. It was important to establish national focal points for information dissemination.

As well as many other items concerning WMO programmes, the Association also discussed several other issues of importance, including the exchange of meteorological and related data and products, UNCED follow-up and the WMO Regional Office for North and Central America.

Two scientific lectures were presented during the session and an informal meeting was arranged for the consideration of internal matters of the Association.

Messrs Arthur Dania (Netherlands Antilles and Aruba) and Carlos Fuller (Belize) were elected president and vice-president of the Association, respectively. Working Groups were re-established, together with eight rapporteurs, on Planning and Implementation of the WWW in Region IV, Hydrology, Agricultural Meteorology and the Hurricane Committee. Two independent rapporteurs, having their own terms of reference were appointed. The twelfth session of Regional Association adopted 14 resolutions. ❐

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WMO programme news

WORLD WEATHER WATCH

Global Data-processing System

Expert meeting on Implementation of Workstation Version of NWP Regional Models for Emerging GDPS Centres

This meeting was held at Kenya Meteorological Department facilities in Nairobi, Kenya, from 14 to 18 April 1997. The 17 participants came from RSMCs Nairobi and Dakar (Senegal), DMCs Nairobi and Harare (Zimbabwe), the University of Nairobi, the Environmental Modelling Centre/ National Centre for Environmental Prediction (NCEP) Washington (USA) and the National Centre for Meteorological Research/RSMC Toulouse (France).

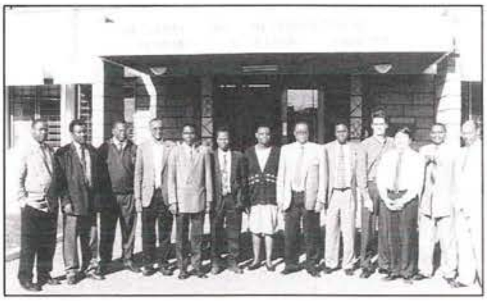
Despite the spectacular advances in forecasting skills achieved by high-resolution regional models and fine-scale mesoscale models run by major GDPS centres, regional centres in Africa are still using manual forecasting methodologies supported by imported products. This meeting was an attempt to address this gap.

Detailed presentations of the NCEP regional spectral model (RSM) and the ALADIN RSM were made by experts from NCEP Washington and RSMC Toulouse, respectively. Subsequent discussions focused mainly on the formulation of the RSMs' spectral computation, model dynamics and perturbation method, model numerical techniques and physics, the transition from hydrostatic to non-hydrostatic version and future modelling plans.

Presentations and extensive discussions on the applications of the two RSMs were made. These focused on applications in daily weather forecasts, case-study experiments, regional climate simulations; regional enhancement on reanalysis; provision of weather conditions for other models; and future applications.

Presentation and discussion on running an RSM workstation focused mainly on the implementation issues related to file system structure, data requirements, input/output file records, display system and the configuration of an experiment.

Concerning hardware requirements and given current market prices, a 2GB memory



Nairobi, Kenya, April 1997 — Participants in the Expert Meeting on Implementation of Workstation Version of NWP Regional Models for Emerging GDPS Centres

was recommended, which would allow recent experiments to be conserved and the workstation to be utilized during the time not dedicated to the daily forecast. For a given increase in the number of grid points in the model, it is more costly to increase the resolutions than to enlarge the domain. This is because when increasing the resolution, the time step needs to be proportionally decreased. Some characteristics of a medium-performance workstation capability which can run a RSM were also given.

The NCEP RSM was successfully implemented on a Silicone Graphics Indy workstation (CPU speed 132 MHZ and 160 MB RAM). The model horizontal resolution was 50 km with a vertical resolution of 28 sigma levels for a domain covering eastern parts of central and eastern Africa for a forecast range of 48 hours. The boundary conditions were obtained in real-time from the NCEP global model via the Internet. RSMC Nairobi is making arrangements to run the model for evaluation and then to run it quasi-operationally.

Third session of the Working Group on Planning and Implementation of the WWW in Region VI

This meeting was held in the WMO Secretariat in Geneva from 26 to 30 May 1997 and was chaired by Mr Manfred Kurz (Germany).

Discussions included the Integrated Observing Network; the Regional Basic Synoptic Network; the proposed Regional Meteorological Telecommunication Data Network; the Global

Telecommunication System; the Global Data-processing System and public weather services.

The meeting was informed about the development of the EUMETNET Composite Observing System (EUCOS), which will include, the Composite Observing System for the North Atlantic (COSNA). COSNA structures will be maintained until EUCOS is in place.

Upper-air and surface stations where operations had to be restored or enhanced were identified. Any proposed changes to the RBSN should be promptly announced to all concerned. The session recommended that Lead Data Quality Monitoring Centres should be invited to monitor availability of reports at regionally agreed standard hours from all stations, as well as non-adherence to telecommunications procedures and to disseminate the results.

The Regional Meteorological Data Communication Network (RMDCN) would be an integrated system, complemented by regional satellite-based distribution systems, which would provide data communication services between centres. RTHs might have to manage a transitional period during which some GTS centres in the Region would be connected via the RMDCN and others by existing circuits. The need for a coordinated project to assist countries in implementing their connection to the RMDCN was recognized and allocated the highest priority within the framework of technical cooperation activities related to the WWW in Region VI.

The proposed RMDCN would support traffic using X.25 or IP protocol only. Any remaining use of analogue facsimile between NMCs and RTHs should be phased out by the end of 1998 or arrangements made for support outside the framework of the RMDCN.

A technical proposal to upgrade the GTS in the south-eastern part of Region VI was endorsed.

Closer cooperation in Europe in numerical weather prediction had resulted from the establishment of the Short-range Numerical Weather Prediction Network.

The volume of boundary condition data from global models transmitted over the GTS had been reduced by the use of dedicated medium-speed links. Workstation versions of small-domain LAM were becoming popular and RSMCs might be requested to make relevant model code and boundary condition data available. Members were developing their own workstation systems based on several different agreed standards. NMCs in Region VI were urged to pursue the development

Geneva, May 1997 — Participants in the third session of the Working Group on Planning and Implementation of the WWW in Region VI

of common software modules for the next generation of meteorological workstations.

The Working Group recommended that the decision to use metres per second be maintained for all WMO codes, with the exception of aeronautical codes. Members were urged to implement that decision and to code CLIMAT reports correctly.

Members were encouraged to put in place a programme of work within their NMS to address potential year 2000 problems. The WWW Operational Newsletter and WMO Web site could be used to exchange information about progress or of common interest.

Regarding public weather services, the session considered cooperative arrangements for issuing warnings and agreed on concrete ways and means for increasing the competence of NMSs in this domain through, for example, the exchange of additional observational and remotely sensed data, data on dangerous weather phenomena and enlarged model output.

INSTRUMENTS AND METHODS OF OBSERVATION

Third Regional Pyrheliometer Comparison of RA III

In view of the need for high-quality radiation data for operational and research applications, the Regional Radiation Centre of Chile hosted the third Regional Pyrheliometer Comparison of RA III (RPC-3/RA III) in Santiago de Chile from 24 February to 7 March 1997. It was attended by 18 radiation experts of nine Member countries and nine regional and national standard pyrheliometers were calibrated. In addition, an expert from the World Radiation Centre, Davos, Switzerland, participated with an instrument of the World Standard Group. The results of the RPC-

Santiago de Chile — Two of the participants in the third Regional Pyrheliometer Comparison of RA III (24 February–7 March 1997)
Photo: WMO/K. Schulze

3/RA III will be published by WMO. The training aspect and the exchange of experience between the experts were highly appreciated. An ad hoc session of the RA III Working Group on Solar Radiation was also held to review results in preparation for the forthcoming twelfth session of RA III.

TROPICAL CYCLONE PROGRAMME

RA IV Hurricane Committee

The nineteenth annual session of the RA IV Hurricane Committee was held in Nassau, Bahamas, from 7 to 10 May 1997, in conjunction with the twelfth quadrennial session of Regional Association IV (North and Central America). The meeting was chaired by Mr Jerry Jarrell (USA) and was opened by the Hon. Mr Pierre V. L. Dupuch MP, Minister of Consumer Welfare and Aviation. The session was attended by 26 participants from 18 WMO Members and four regional organizations.

A report on the 1996 hurricane season in the Atlantic basin and in the eastern north Pacific was presented by the Chairman of the Committee on behalf of RSMC Miami-Hurricane Center. In the Atlantic basin, 13 named tropical cyclones, nine of hurricane intensity, developed during 1996. In the eastern Pacific, only five hurricanes formed from just nine tropical storms. An active season of 13 tropical cyclones was responsible for the deaths of at least 140 people throughout the Caribbean, Central America and the USA and more than US$ 3.5 billion in damage in the USA alone in 1996. A fairly light eastern Pacific Hurricane Season brought five tropical cyclones to Mexico, directly causing the (known) deaths of around 10 people; indirectly, a further two were killed with the same number missing, and considerable damage incurred. (See also article "Human and economic impacts of weather events in 1996", starting on page 351 (*Ed.*).)

The Committee noted with satisfaction the informative report of Mr Carlos Fuller (Belize) on

Conference announcement and call for papers

Technical Conference on Meteorological and Environmental Instruments and Methods of Observation

TECO-98

Casablanca, Morocco, 13–15 May 1998 (immediately after the twelfth session of the WMO Commission for Instruments and Methods of Observation)

It will be accompanied by an exhibition METEOREX-98.

Conference themes

- **New developments, operational experience and results of intercomparisons in meteorological and environmental measuring technology related to surface measurements, surface-based remote sensing techniques and upper-air *in situ* measurements;**
- **Quality management, sensors calibration technology and methodology, validation of surface-based remote sensing systems;**
- **Management and cost aspects related to instruments and observing methods; technology transfer; capacity building including training needs and opportunities.**

Deadline

Abstracts (300-400 words) should include the name, address and fax number of the author(s) and be sent by 31 October 1997 to: WWW Department, WMO, P.O. Box 2300, CH-1211 GENEVA 2, Switzerland. Fax: (+41 22) 7330 242

Further information may be obtained from: Mr K. Schulze
Tel: (+41 22) 7308 409. Fax: (+41 22) 7330 242
E-mail: schulze@www.wmo.ch

the advantages and disadvantages of the Internet for the Meteorological and Hydrological Services of RA IV and endorsed the recommendations it contained. In particular, RSMC Miami-Hurricane Center agreed to include a reference to national Meteorological Services in their bulletins when a tropical cyclone watch or warning was issued by those countries.

The Committee noted that the OMEGA system, on which the rawinsonde network in the Region had been operating, would be discontinued in September 1997. In view of its crucial importance for the hurricane warning system, the Committee endorsed the urgent need for technical assistance in order to ensure the operation of the upper-air stations in the Region.

A presentation was made by the delegate of France regarding a computer-aided learning (CAL) CD-ROM, in French, aimed at education and training in schools on tropical cyclones and the related issues of disaster prevention, preparedness and mitigation. The session congratulated *Météo-France* and urged the development of additional CAL training modules, especially tropical cyclone case-studies, in all the official languages of the Region. *Météo-France* offered to provide technical support to develop CAL training modules

It was decided that the twentieth session of the RA IV Hurricane Committee would be held in Havana, Cuba, from 11 to 16 May 1998.

RA IV Workshop on Hurricane Forecasting and Warning

An RA IV Workshop on Hurricane Forecasting and Warning was held at RSMC Miami-Hurricane Center from 10 to 21 March 1997 with English/Spanish interpretation for Class I and II meteorologists having some forecasting experience. The workshop was opened by Mr Jerry Jarrell, Deputy Director, National Hurricane Center (NHC). The WMO Secretariat representative, speaking on behalf of Prof. Obasi, WMO Secretary-General, welcomed participants and thanked the USA for its continued support to this workshop series. All the lecturers were from NOAA and most were from NHC. The workshop was coordinated by Dr Richard Pasch, hurricane specialist at the RSMC.

Twenty-four participants from 21 Hurricane Committee member countries attended the Workshop. Two others, one from a non-member and another from a university, also attended. This high attendance reflects the continuing interest of Members in the series.

The workshop included lectures, group discussions, demonstration of operational equipment and facilities, practical exercises and discussions. The trainees improved their knowledge of hurricane forecasting and warning, acquiring an understanding of the RSMC products they use and, additionally, exchanging relevant information and experiences with the RSMC and amongst themselves.

The participants recognized the significant contribution of the Workshop to the highly successful cooperative and coordinated system for hurricane warning and disaster mitigation throughout the Region and hence of its contribution towards the goals of the International Decade for Natural Disaster Reduction.

WORLD CLIMATE APPLICATIONS AND SERVICES PROGRAMME

Climate and human health

Impacts of present climate and climate change are intimately related. Further research and studies focusing on climate and health are necessary to help identify the potential for mitigating the negative impacts of future climate change. The Second Assessment of IPCC (1995) concludes that: "Climate change is likely to have wide-ranging and mostly adverse impacts on human health, with significant loss of life.". The proposed Inter-Agency Network on Climate and Human Health, within the framework of the Climate Agenda, will serve as a gateway for information on climate-environment-health relationships. It will help developing countries obtain the assistance and information necessary to develop capacities to deal with these issues.

WMO has joined forces with WHO and UNEP to address issues relating to climate, weather and human health. The three Organizations have already published jointly a booklet *Climate and Human Health* (WMO-No. 843) and a major monograph on climate change and human health. Plans for future joint activities were discussed during a meeting of experts at the Biometeorological Laboratories of the *Deutscher Wetterdienst* in Freiburg, Germany, in January 1997. Recommendations from this meeting include initialization of show-case projects (SCPs) with focus on warning systems for heat waves and possibly other extreme weather events. The goal for these projects is to develop extreme weather watch/warning systems for three selected cities, which permit local health officials to implement mitigation action more efficiently. Procedures for developing SCPs with these goals and recommended criteria for selection of suitable cities to be targeted in such projects, were put forward by the meeting.

The meeting furthermore concluded that the issues most likely in focus in the context of climate and human health in the next few years—and maybe the next decade—include the concern about potential impact of climate change on health and human well-being. This would include the risks associated with severe and extreme weather conditions, the spread of diseases as tourism becomes increasingly globalized, and the risks of losses in agricultural production.

Progress in TRUCE

The following are the revised objectives for the Tropical Urban Climate Experiment based on proposals from a meeting of the Task Force on TRUCE held in Geneva in October 1996 and subsequent consultations with agencies involved (see WCASP-40, WMO/TD-No. 789):

- To provide a basis for urban environmental planning and operation which will achieve more sustainable human settlements. This aims at attaining an environmental quality which provides for improved health, well-being and productivity of the population and also meets the global energy issue;
- To provide for capacity building through improved scientific understanding of the physical mechanisms and processes controlling the modification of the atmospheres of tropical urban areas, including their interaction with regional- and global-scale climatic variability and change.

In planning future activities, the focus should be on documenting and making available information and datasets showing the differences in climatological parameters between the city and the surrounding rural area. Furthermore, there is a need to provide guidance on how to include climatological aspects in capacity building in the area of urban design, building and operations.

Climate Information and Prediction Services (CLIPS)

CLIPS is stepping forward

CLIPS is capitalizing on the major advances which have been made in the monitoring and analysis of climate information, prediction of climatic conditions on seasonal to interannual time-scales and the ability to exchange climate information rapidly and efficiently. It has become feasible to develop an enhanced range of operational climate services.

National Meteorological and Hydrological Services (NMHSs) have gained extensive experience in preparing various climate products for use in socio-economic activities and decision-making. The WMO CLIPS project focuses on sharing this experience among NMHSs. One goal is to build the capacity of NMHSs to deliver climate services and meet the expectations and needs of all customers. This will strengthen the role of NMHSs and ensure the provision of better climate services to governments and other national users.

The plan to implement CLIPS includes a suite of complementary components which respond to the need to enhance the application of climate services. At the same time, a geographical balance of activities is needed to ensure that the project responds adequately to the priorities of the socio-economic needs in all parts of the world. The four major components of the CLIPS project are:

- *Training*: Training seminars/workshops, broader and more advanced training courses and roving seminars;
- *Demonstration/pilot projects*: Demonstration projects are generally organized by Members having already gained experience in the provision of modern climate services; pilot projects normally require substantial external assistance using, for example, the Voluntary Cooperation Programme;
- *Liaison with research programmes*: Climate outlook fora, exploring regional/ subregional climate information and predictions and expert meetings organized on specific topics requiring coordination of the CLIPS project with research programmes such as CLIVAR;
- *Networking*: Feasibility studies of the use of telecommunication channels such as the GTS and Internet to disseminate climate products.

The attributes and implementation plans for these components are described in more detail in a booklet entitled *Stepping forward: Implementation of the WMO CLIPS project* (WMO-No. 864).

Economic and social benefits of CLIPS

The economic and social benefits of climate information and prediction services have been clearly demonstrated in several studies. Available information on the economic and social benefits have been reviewed by a consultant, Mr M. Nicholls (United Kingdom). The conclusions and summary include the following:

- For historical data there are many examples of economic benefit to national or regional treasuries and at the level of individual end users such as farmers or companies. Some robust examples of savings exist of over US$ 1 million per annum in operational costs at national/sectorial level and US$ 1.5 million of capital costs at company level. Additionally, cases are quoted where damage avoided or avoidable by the gathering and/or application of climate data is valued at US$ 40–300 million (present-day rates). Examples of minor savings or gains by individual users are numerous;
- For forecasts of average climatic conditions over the following month, economic values have been agreed by commercial users and even with the existing forecast imperfections, actual savings or gains of US$ 1 million are quoted by major companies;
- In Peru, the value of seasonal forecasts has reached 18 per cent of the gross value of the agricultural sector and up to 85 per cent of agricultural production has been saved in north-east Brazil. Values of *El Niño*/Southern Oscillation (ENSO)-based seasonal forecasts to agriculture in the south-eastern USA of US$ 96 million per annum have been predicted; US$ 180 million to agriculture, forestry and fisheries across the entire USA; and US$ 34 million to the New Zealand economy;
- The value of climate change projections and related impacts cannot be quantified as yet, but massive potential benefits exist. Climatological information and applications can also be a major tool in reducing the spread of diseases and thus in improving health, health care and general well-being;
- Benefits derive from the availability and input of information and services to a user and from their use in decision-making processes. A benefit is defined as a marginal change in the outcome for a user, welcomed by the user(s) and ascribed to the application of the climatological input. In the literature, benefits are often expressed as improvements in quality (e.g. of plans, designs, operations) or in quantitative but non-financial terms (improvements in yields, efficiency, safety, demands) or in economic terms;
- Whilst examples which describe financial benefit to decision-makers exist for many areas of application, they are dominated by cases relating to agriculture (for all types of information), construction (for historical data), manufacturing, and energy supply (for monthly and seasonal forecasts). The examples relating to use of historical data come from all continents and represent most climatic regimes, while those relating to seasonal forecasts mostly represent the tropics, sub-tropics and continental North America, reflecting the strong connection between ENSO and predictability.

The report "Economic and social benefits of climatological information and prediction services", WCASP–38 (WMO/TD-No.780) includes discussions on types of beneficiary, measures of benefit and impediments to the use of climate information and services.

CLIPS for fisheries

Management of fisheries in relation to climate and the environment is part of a larger and more general problem, namely protection of the environment and sustainable development for the benefit of all societies, present and future. This is one of the main conclusions reached by the author, Jean-Luc Le Blanc in the report "Climate information and prediction services for fisheries" (WCASP-39, WMO/TD-No. 788). The report reviews the influence of the physical and chemical environment on fish populations and the impacts of climate and its variability. A major part of the report reflects the fisherman's problems relating to catchability and sustainable management of fisheries.

The author presents an extensive list of existing and potential climate services for fisheries and relevant international and national programmes. He concludes that fisheries represent one of the most climate-sensitive socio-economic sectors and identifies a broad spectrum of specific users. An overall conclusion is that CLIPS products could help the fisheries community in its search for a balance between resources and the effort of exploitation that permits a maximum, sustainable profit. This is in agreement with the findings of some of the experts who have conducted special sectoral support missions for CLIPS over the last few years. In particular, it is suggested that CLIPS products could be developed in collaboration with the fisheries community, which would enable fisheries managers to foresee resource fluctuations based on predicting climate variations.

WORLD CLIMATE DATA AND MONITORING PROGRAMME

Climate Change Detection Project

Workshop on Indicators and Indices for Climate Extremes

This landmark international meeting was held at Asheville, North Carolina, USA, 3–6 June 1997, attracting scientists from 23 countries as well as 15 representatives from the insurance industry, mostly in the USA. The purpose of the meeting was to initiate the development of indices and indicators of extreme climate and weather events that could be used by the scientific community and insurance industry to monitor the frequency of occurrence and severity of such events in various parts of the world.

The principal convener of the workshop, Mr Tom Karl (National Climatic Data Center), spelled out the specific objectives of the meeting. These were primarily to stimulate research which could be considered for the third assessment of the Intergovernmental panel on Climate Change to be published in the year 2000. Issues of interest included whether the climate is becoming more extreme; identifying critical datasets and determining inhomogeneities; finding indices or indicators that capture the multi-dimensional aspects of climate change and variability; detection and attribution of climate change; and meeting the needs of the insurance industry (which relate primarily to a better understanding of the effects of climate variability and change on the occurrence of extreme events).

Representatives of the insurance industry made several presentations. In recent years, viable insurance claims as a result of natural disasters have increased markedly due to a number of factors: population growth and shifts to flood- and hurricane-prone areas (e.g. Florida); increased property values; expanding insurance coverage by customers; poor or inadequate land-use policies; lack of enforcement of building codes; and climate variability and change. It was the devastation caused by hurricane *Andrew* in 1991 that startled insurance companies into an awareness of their vulnerability to extreme weather and climate events. As a result, they are now considering the frequency of occurrence of extreme meteorological events in models to determine insurance premium rates.

The other presentations were more scientific in nature, giving some insight into the trends and frequency of floods, winds, tropical and extratropical storms, thunderstorms, hot and cold spells, etc. Each speaker was asked to address the question of data availability and homogeneity and numerous problems in these areas were exposed.

Towards the end of the workshop, participants split into three groups to discuss the development of indices related to temperature, precipitation, storms and related data requirements. At the final plenary, each group presented a number of recommendations with regard to the research work needed to define and develop indices and to assemble and prepare the necessary datasets.

CLICOM

Expert Meeting to Review and Assess the ORACLE-based Prototype for Future Climate Database Management Systems

The main purpose of this meeting (held at *Météo-France*, Toulouse, 12–16 May 1997) was to begin the process to review and assess possible climate database management systems (CDMSs) that could be considered for use by countries needing a system more advanced than CLICOM. It had been recommended to base one such prototype on the ORACLE database management software in order to ascertain its advantages over the DataEase software currently used in CLICOM. A presentation was made by Mr Ari Supperi, a WMO data-processing expert working in San José, Costa Rica.

The other participants (from Australia, Canada, France, Germany, Hungary, Malaysia, the Russian Federation, the United Kingdom, the USA and Zambia) also had the opportunity to present other CDMSs. The results of a survey of relational database management systems used in WMO Member countries, prepared by the two rapporteurs to the Commission for Climatology (CCl), were also presented.

Météo-France, Toulouse, May 1997— Participants in the Expert Meeting to Review and Assess the ORACLE-based Prototype for Future Climate Database Management Systems

The experts agreed that the CDMSs with which they were familiar all had the same functional aim but different development approaches. In several cases, mistakes had been made or problems encountered which significantly delayed development. More integrated efforts between NMHSs were desirable as it was not possible for developing countries to try to develop their own CDMS as many developed countries had done. The experts agreed with the CDMS strategy upon which the ORACLE-based prototype was based and recommended that a task group be established to develop and advise on its implementation. It was expected that the Commission for Climatology would pursue this initiative further.

A preliminary version of CLICOM 3.1 was made available for testing to several of the experts. They agreed with the recommendation of a previous expert meeting in Washington, DC, in August 1994 that there should be no further development of the CLICOM core software beyond version 3.1.

ATMOSPHERIC RESEARCH AND ENVIRONMENT PROGRAMME

Commission for Atmospheric Sciences

Working Group on Tropical Meteorology Research

The CAS Working Group on Tropical Meteorology Research, chaired by Dr Greg Holland (Australia), met in Jakarta, Indonesia, from 3 to 7 March 1997. In addition, several experts were invited to participate in the meeting to discuss various components under the WMO Tropical Meteorology Research Programme (TMRP).

The meeting had the tasks of reviewing the development in each component of the TMRP since the last session of the Group (Monterey, California, USA, September 1992) and discussing future strategies.

The Working Group affirmed its continuous collaboration with the other WMO programmes, in particular, the Tropical Cyclone Programme, and the promotion of the transfer of research results to operational use. The Group welcomed the COMPARE project's selection of a combined dataset from the Tropical Cyclone Motion (TCM-90), SPECTRUM and TYPHOON-90 field experiments for its case-study. It is expected that the intercomparison for mesoscale numerical models will significantly contribute to the improvement of the capability of numerical weather prediction to forecast the behaviour of tropical cyclones.

The Group warmly welcomed the World Weather Research Programme (WWRP) initiative and recommended a strong interaction between WWRP and TMRP. A major initial collaboration could be joint work on the Landfalling Tropical Cyclones and Aerosonde projects.

The Working Group endorsed a report entitled "Tropical cyclones and global climate change", which was presented by Prof. A. Henderson-Sellers, the chairperson of the Steering Committee on Scientific Assessment of Climate Change Effects on Tropical Cyclone.

The Group also endorsed the organization of the forthcoming East-Asian monsoon-related field experiments such as the South China Sea Monsoon Experiment and the GEWEX Asian Monsoon Experiment; the international nature of these experiments would benefit all nations throughout the region.

The Group decided to establish, during the next four years, a substantial project on African drought that would involve the rationalization of several current TMRP projects into one: Tropical Droughts and Related Rain-producing Systems, including the ITCZ.

The Group also expressed the desirability of establishing a demonstration project on the application of limited-area models to tropical countries in collaboration with the WWRP.

EMEP/WMO Workshop on Data Analysis, Validation and Reporting

Under the co-sponsorship of WMO and the European Monitoring and Evaluation Programme (EMEP), a workshop was held in Usti nad Labern, Czech Republic, from 27 to 30 April 1997. The two-fold purpose of the workshop was to iden-

Usti Nad Labern, Czech Republic, April 1997 — Dr Terje Krognes of NILU (centre) demonstrating the new data-archiving system to workshop participants

tify the needs for data analysis in the European regional monitoring network and to offer training on the new data-acquisition system being implemented by the Norwegian Institute for Air Research (NILU).

One of the greatest challenges for the GAW/EMEP programme is to assist countries in techniques of data analysis: there is no standard manual for analysis of atmospheric chemistry measurements. Issues discussed included identifying proper statistical methods, applying meteorological filters such as back air trajectories, using advance Kriging methods and choosing the correct multivariate analysis. The information assembled will be used to analyse measurements made at GAW/EMEP regional stations. It was recommended that an ad hoc working group be formed to compile all pertinent information useful for air chemistry data analysis.

Part of the workshop was devoted to training by NLU scientists on the latest methods of data formatting and archiving.

Weather prediction research

International Symposium on Cyclones and Hazardous Weather in the Mediterranean

The International Symposium on Cyclones and Hazardous Weather in the Mediterranean was organized jointly by the National Meteorological Institute of Spain and WMO. It was held in Palma de Mallorca, Spain, from 14 to 17 April 1997. The Secretary-General of WMO and the Spanish Minister of Environment addressed the opening ceremony.

About 150 participants from 25 countries attended and 111 scientific papers were presented in the following six oral and poster sessions: research and observational technology and methodology; observational, synoptic and dynamical case-studies; characterization of phenomena (including cyclone, heavy rainfall, convective systems, combined severe weather, and external influences and interactions); climatic modelling and tendencies; forecasting techniques and experiences; and numerical modelling (including numerical model behaviour and tuning).

The scientific programme was prepared by the International Programme Committee and was co-chaired by Dr Philippe Bougeault (France) and Dr Augustin Jansá (Spain). The Symposium provided an excellent forum for research scientists and weather forecasters to exchange ideas and current research results. Moreover, it contributed to the enhancement of early warning systems for the mitigation of the effects of adverse weather on the socio-economic development of countries in the Mediterranean basin.

Tropical meteorology research

First WMO International Workshop on Monsoon Studies

The First WMO International Workshop of Monsoon Studies was held in Denpasar, Bali, Indonesia, from 24 to 28 February 1997. It was the first in a quadrennial series of international workshops to be conducted jointly under the CAS projects Research Initiatives on East-Asian Monsoon and Long-term Asian/African Monsoon Studies. An International Programme Committee, with Prof. Ding Yihui (China) as its chairman, prepared the Workshop; the Local Organizing Committee was chaired by Dr Gunawan Ibrahim, Meteorological and Geophysical Agency (MGA), Indonesia.

Some 105 participants from all over the world attended and about 70 scientific papers were presented. Mr Sri Diharto, Director General, MGA, opened the Workshop on behalf of the Minister of Communications, and welcomed participants. Mr S. Karjoto, Permanent Representative of Indonesia with WMO and president of RA V, addressed the opening ceremony.

The main objectives were to review recent advances in research on the characteristics and prediction of monsoon-affected subregions and to provide a forum for discussion between researchers and forecasters on the current status of monsoon knowledge and on priorities and opportunities.

The US NOAA Global Program Office cosponsored the Human Dimensions session, which included a panel discussion on social and

Denpasar, Bali, Indonesia, 24 to 28 February 1997 — Participants in the First WMO International Workshop on Monsoon Studies

economic impact of monsoons and improved forecasts thereof.

GLOBAL ATMOSPHERE WATCH

GAW station opening

The official opening of the Iskrba, Slovenia, GAW regional station took place on 8 September 1996. The station is located in a rural area in a pristine, non-polluted part of Slovenia.

Some 25 dignitaries, including representatives of the local authorities and the Secretary-General of WMO, participated in a short ceremony. The Director of the Slovenian Hydrometeorological Institute, Dr Dusan Hrcek, introduced the guests. Speeches were made by Dr Pavle Gantar, Minister of Environment and Physical Planning, and Prof. Obasi.

A presentation was made explaining the mission of the station and the measurements being made and a tour of the facilities was arranged.

Iskrba, Slovenia, 8 September 1996 — Official opening of the GAW regional station

Since the opening, the station has contributed data concerning gases/aerosols (sulphur and nitrogen compounds), precipitation chemistry, surface ozone and meteorological parameters to the various WMO World Data Centres. Iskrba also serves as a station within the Economic Commission for Europe's Cooperative Programme for the Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP).

WMO Meeting of Experts on the GAW Regional Network in RA VI

Experts from more than 25 countries in Region VI met at the Hungarian Meteorological Service headquarters in Budapest, Hungary, to discuss the state of the GAW Regional network in Europe (5–9 May 1997).The GAW network has been in place for a number of years but the changing political situation in the area has brought a completely new framework in which it must now function. Although global and regional needs have been stressed in the past, the present situation requires that the network must also have a definite national role in understanding the changing composition of the atmosphere. This means that air-quality requirements must be addressed, as well as climate-change issues.

The participants—especially those from the newly independent countries—recommended that a survey be conducted of the GAW Regional network in RA VI to evaluate its regional coverage and distribution of operating technologies. Because of the wide range of expertise and implementation of the GAW programme, they further recommended that particular emphasis be placed on a self-help approach. Twinning activities, for example, would facilitate the sharing of training, calibrations, data acquisition and analysis procedures and instrument repairs.

Participants in the Meeting of Experts on the GAW Regional network in RA VI visit K-Pusta, the Hungarian GAW station

It was further recommended that national monitoring networks be evaluated to identify centres of excellence that could be incorporated into the GAW programme and that these centres could be utilized for harmonizing the GAW network to improve regional coverage and provide an internally consistent set of measurements. A formalized set of regional GAW requirements should be established concerning siting and regional coverage for the pollutants measured, recommended instrumentation and operational procedures and a harmonized approach to data collection and analysis and assessment of air quality. It was also suggested that requirements and recommendations be prepared concerning how the regional networks could fit and contribute to global atmospheric monitoring so that specific contributions could be made.

During the meeting, the participants were given the opportunity to visit K-Pusta, the Hungarian GAW station. It is one of the longest-running stations in the European network.

Meeting of the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry

The fifth session of the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry was held in Geneva from 7 to 10 April 1997. The

WMO Headquarters, Geneva, April 1997 — Reception for the EC Panelof Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry

Panel members and a number of invited experts met to review the Global Atmosphere Watch programme and consider other related activities.

A Strategic Plan for GAW, and urban and regional pollution were among the many subjects discussed. A draft was produced, which was subsequently approved as a working document for the long-term development of GAW by the forty-ninth session of the Executive Council (June 1997). A recommendation was made to prepare a fact sheet on urban pollution, monitoring and modelling approaches.

The Panel strongly endorsed the continued activities of GAW in air quality/pollution problems to assist national Meteorological and Hydrometeorological Services (NHMSs), especially in developing countries and made numerous recommendations, pertaining particularly to South-East Asia, including: that the Panel and the Secretariat should provide advice on monitoring regional smoke and haze pollution; that regional stations in the area should measure these parameters, that a pilot project be developed involving regional stations which would investigate the sampling of particulate material, and possibly selected gaseous constituents using passive samplers. It was also proposed that modelling workshops be organized as a means of technical transfer in areas where assistance of this nature is required.

The Panel declared that it would be pleased to provide technical guidance and advice on monitoring and modelling techniques to any NHMS which so requested.

PUBLIC WEATHER SERVICES

Expert Planning Meeting on Public Weather Services

The Expert Planning Meeting on Public Weather Services (PWS) was organized in Nassau, Bahamas, from 12 to 16 May 1997, following the decision of CBS-XI (November 1996) to establish a Working Group on Public Weather Services.

The objectives of the meeting were to develop and expand the preliminary *Guide to Public Weather Services Practices* (WMO-No. 834), prepare strategic goals for the programme, propose a work plan for the Working Group on PWS and develop a questionnaire on PWS practices for distribution to Members.

As regards the preliminary *Guide*, the meeting agreed that it should be left unchanged in

Nassau, Bahamas, May 1997 — Expert Planning Meeting on Public Weather Services

so far as it served as a general reference tool, as a source of ideas and for promotional purposes for use by directors of NMHSs with external audiences and other governmental agencies. The readership of an expanded *Guide* would primarily be NMHS staff and should, therefore, focus on providing detailed information on techniques, methodologies and related material of direct utility to them. The scope of the PWS Programme, as defined in the *Guide*, should include a core component common to all NMHSs, focused on the safety of life and property aspect, together with another component which would encompass unique national or domestic priorities and practices. The meeting then developed a detailed proposal for an expanded *Guide*, including a proposed format and outline of chapters and their contents.

The meeting reviewed the guidance provided by CBS-XI regarding PWS issues which required action and agreed that they provided a solid basis for the refinement of strategic goals for the Working Group on PWS and the development of a work plan. Possible courses of action to achieve the strategic goals were then reviewed. Although early activation of the Working Group was considered a priority, participants considered that undertaking immediate action on items in the work plan would represent a significant step towards meeting CBS and EC requirements. One such action was the questionnaire on PWS. The replies received would facilitate the implementation of well-targeted capacity-building initiatives.

AGRICULTURAL METEOROLOGY

United Nations Convention to Combat Desertification

Intergovernmental Negotiating Committee

WMO was represented at the tenth session of the Intergovernmental Negotiating Committee for the Convention to Combat Desertification held in New York from 6 to 17 January 1997. The United Nations Convention to Combat Desertification (UNCCD) entered into force on 26 December 1996 after the 50th ratification (by Chad). As of 1 March 1997, 65 countries had submitted their instruments of ratification. At the tenth session, delegates addressed outstanding issues related to arrangements regarding the global mechanism for finance, scientific and technical cooperation, rules of procedure, financial rules and communication of information. The INC accepted the offer of the Secretary-General of the United Nations to provide administrative and support arrangements for the UNCCD Secretariat.

Recent meetings

Regional Meeting for the Northern Mediterranean

A Regional Meeting for the Northern Mediterranean was organized within the framework of Annex IV to the UNCCD with the collaboration of the Interim Secretariat of the Convention, in Murcia, Spain, from 22 to 23 May 1997.

The aims of this meeting were to advance the elaboration of the Northern Mediterranean Regional Action Programme; exchange experiences with experts responsible for other Regional and Subregional Action Programmes; learn about joint action being carried out by affected countries; identify possible areas of collaboration with other regions; present the efforts made at the national level in scientific research and technological development in the subject of desertification; and demonstrate, through visits to pilot areas, the possibilities of technology transfer.

The opening ceremony was attended by the Spanish Minister of Environment and seven international agencies, including WMO. A field trip was organized to the Sierra Espuña, an area that has been recovered from desert land.

Use of Meteorological Data for the Effective Planning and Management of Water for Irrigated Crop Production

The Joint WMO/FAO/UNEP Roving Seminar on the Use of Meteorological Data for the Effective Planning and Management of Water for Irrigated Crop Production was held in Kathmandu, Nepal, from 3 to 14 February 1997.

Support Group on Agrometeorology

WMO was represented at the eleventh meeting of the Support Group on Agrometeorology held in the office of the project for Monitoring Agriculture by Remote Sensing (MARS) of the Joint Research Centre of the European Commission, at its headquarters in Ispra, Italy, from 19 to 21 February 1997. Yield estimates made by MARS and the official results over the period between 1993 and 1996 were discussed and participants were asked to examine possible improvements to the modelling. Progress has been made to extend monitoring activities to eastern European countries, Turkey and three of the Maghreb countries, in addition to the 15 Member States of the European Union. Participants started a critical analysis of various inputs into the crop growth monitoring system, error assessment, sensitivity and the relative importance and validation of the parameters used in the present system when it is extended. A summary was given of research and development activities relating to the use of agrometeorological models and low resolution meteorological satellite data for crop yield forecast.

Workshop on Climate Variability, Agricultural Productivity and Food Security in the Asia Monsoon Region

This Workshop was held in Bogor, Indonesia, from 19 to 22 February 1997. It brought together 43 participants representing the agricultural modelling and climate communities from 16 countries to develop recommendations for an integrated joint programme of research and capacity building. A report will be published to outline recommendations for a proposed end-to-end study and provide the basis for a more detailed study. The basic dataset containing weather, soil and agricultural inputs for the crop models will be consolidated and made available to the research community.

Regional Workshop/Expert Meeting on Agrometeorological Techniques in Operative Agriculture in Latin America

A Regional Workshop/Expert Meeting on Agrometeorological Techniques in Operative Agriculture in Latin America took place in Paipa, Colombia, from 17 to 21 March 1997. It was attended by 39 participants from 10 countries.

The Workshop covered fields such as models for the assessment of potential evapotranspiration and water balance, agrometeorological models for cattle protection and geographical information systems as a tool for analysis and characterization in agroclimatology and agrometeorology. A wide variety of subjects was

Paipa, Colombia, March 1997 — Participants in the Regional Workshop/Expert Meeting on Agrometeorological Techniques in Operative Agriculture in Latin America

treated, putting emphasis on agroclimatic types, cartography and zoning; microclimatology and specific cultures; plant, animal and environment protection; warnings and information for users; case-studies of climatic anomalies and variability and the effect of atmospheric pollutants on crop yields.

National experiences were shared and a visit was made to the Experimental Farm of Tungavita (University of Agronomy of Tunja).

Working Group on Agrometeorology Related to Extreme Events

The meeting of the CAgM Working Group on Agrometeorology related to Extreme Events was held in the WMO Secretariat, Geneva, from 8 to 11 April 1997 and chaired by Dr H. P. Das (India).

Members of the Group made presentations on agrometeorological aspects related to extreme hot and dry weather and heat stress; high winds, local severe storms, landslides/avalanches and their effects on plants; excess rainfall and flooding, heavy snowfall and forest fires; tropical storms and storm surges; environmental aspects of volcanic eruptions and water pollution; and economic and social aspects of extreme events on agriculture.

Much information is available on extreme events which needs to be synthesized for operational applications. Many extreme events are statistically rare and the database regarding quantitative assessment is poor.

It is necessary to maintain and improve observational networks if extreme events and their impact on agriculture are to be assessed accurately. As routine instruments cannot withstand extreme events, it was recommended that collaboration with CIMO be promoted to develop more robust ones. Agrometeorological services in developing countries should be strengthened by an increased number of automatic weather stations to overcome the problems of data quality and observer biases. Remotely sensed data could be used to fill gaps and radar coverage should be extended to more areas affected by extreme events.

Standard methods of impact assessment should be developed and disseminated for use by Meteorological Services. Practical applications should be generated from successful case-studies on ways to combat extreme events, taking questions of environment and sustainable development into account. It was recommended that international collaboration and cooperation should be enhanced. The proposed structure of a technical report on agrometeorology for extreme events was discussed and responsibilities were assigned to different members of the Working Group.

Expert Group Meeting on Wind Erosion in Africa: Problems and Control Strategies

Despite the growing realization of wind-erosion problems in West and Central Africa (WCA) and West Asia North Africa (WANA), there is little quantitative information of their seriousness or location of problem areas. As a consequence, there are no long-term strategic plans to counter wind erosion and reduce ensuing damage. Hence, the International Centre for Agricultural Research in the Dry Areas (ICARDA), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), UNEP and WMO organized this Expert Group Meeting to review the occurrence and form of wind erosion in the dry areas of WCA and WANA; to discuss available control measures, both indigenous and improved, and assess the extent and potential of application in different regions; and to identify appropriate methodologies for pinpointing hot spots (on different scales), quantifying erosion and risk of erosion, and developing simple control measures. Twenty-two experts from eight countries and two UN agencies participated in the meeting held in Cairo, Egypt, from 22 to 25 April 1997.

The meeting prioritized the major problems of wind erosion in WCA and WANA and identified a number of control strategies. It recommended the development of a multi-stakeholder action research proposal to complement current eco-regional initiatives of the Consultative Group on International Agricultural Research, address the priority issues identified in international conventions and linked to existing networks and National Action Programmes of the UNCCD. The Group agreed to prepare a four-page information brochure on the problems of wind erosion and control strategies in English, French and Arabic to be diffused widely in the WCA and WANA regions.

Cairo, Egypt, April 1997 — Participants in the Expert Group Meeting on Wind Erosion in Africa: Problems and Control Strategies

Roving Seminar on Extreme Events

WMO and the India Meteorological Department organized a Roving Seminar on Agrometeorology related to Extreme Events from 28 April to 10 May at Pune, India. It was attended by 25 participants from various universities and institutes in India, demonstrating the extent of interest in national programmes on monitoring extreme events and the strategies to cope with them.

International Workshop on Drought and Desertification

Bet Dagan, Israel, May 1997 — Participants in the International Workshop on Drought and Desertification

WMO sponsored an International Workshop on Drought and Desertification in Bet Dagan, Israel, from 26 to 30 May 1997. It was attended by 65 participants from 35 different countries.

In addition to training, the objective of the workshop was to discuss the early assessment of drought conditions and develop a rational and sustainable policy of preparedness. Presentations made by the participants were grouped in the following sessions: drought and desertification definitions; drought and desertification causes and management response; drought monitoring and mitigation; and assessing drought and its impact and the development of a rational policy.

Committee on World Food Security

The Committee on World Food Security (CWFS) held its twenty-third session from 14 to 18 April 1997 at FAO headquarters in Rome. A total of 105 members (out of 139) of the Committee for the biennium 1996–1997 were represented, as well as 12 international organizations and 28 non-governmental organizations.

Within the context of the World Food Summit (WFS), the CWFS will serve as the forum in the UN system for review and follow-up of policies concerning world food security, including food production, sustainable use of the natural resource base, nutrition, physical and economic access to food, related aspects of poverty alleviation and the implications of food trade for world food security.

The basic elements of FAO's Special Programme for Food Security (SPFS) include improving small-scale irrigation and water management, intensification of sustainable plant-production systems and diversification of production, as well as analysis and resolution of constraints impeding production and productivity. The Committee encouraged further coordination of the activities of SPFS with other relevant UN agencies and requested that future reports provide information on these matters.

The Committee was informed of the outcome of a technical consultation on the Food Insecurity and Vulnerability Information and Mapping System (FIVIMS) in March 1997. FIVIMS is being established as a tool for the monitoring of chronic and transitory food insecurity as part of the follow-up to the WFS. It was agreed that FIVIMS should include indicators which are simple and reliable, readily available and of a social and anthropometric nature at all levels, including the household level. Full involvement of national governments in the development of FIVIMS guidelines and an early appointment and activation of country focal points were called for. The Committee will hold its twenty-fourth session at FAO headquarters in Rome during the spring of 1998.

Expert Consultation Meeting on Early Warning and Crop Yield Forecasting

The project Early Warning and Crop Yield Forecasting (EWCYF), funded by the Ministry of Foreign Affairs of Italy and executed by WMO, has been implemented at the AGRHYMET Centre in Niamey, Niger, since November 1995. An Expert Consultation Meeting took place from 28 to 30 April 1997 and a mid-term evaluation of the project from 1 to 2 May 1997.

The meeting brought together 17 external experts (from Niger, Mali, Senegal and six organizations) and eight project personnel. A number of recommendations were made regarding the organization of the databases and analytical methodology for the assessment of risk in the integrated early warning system.

Recent publications

CAgM Reports

- Meteorological Information Required for Managing Forests in Arid and Semi-arid Regions, by J. L. Clayton and M. Elosmani (No. 64);
- Agroclimatic Factors and Coca Production, by E. Owusu-Manu (No. 67);
- The Definition of Agrometeorological Information Required for Pasture and Livestock Production in Temperate Regions, by A. J. Brereton and C. J. Korte (No. 71).

AERONAUTICAL METEOROLOGY

PROMET

The CAeM Working Group on the Provision of Meteorological Information Required Before and During Flight (PROMET) met at WMO Headquarters in Geneva from 23 to 27 June 1997. The session, under the chairmanship of Mr J. R. Dear (Australia), was attended by experts from 27 countries and representatives from four international organizations. It was opened by Dr A. S. Zaitsev, Assistant Secretary-General of WMO.

PROMET was informed about the current state of implementation of the World Area Forecast System (WAFS) and progress achieved towards its final phase, which included the completed transfer of responsibilities of European RAFCs to WAFC London, the planned transfer of the remaining RAFCs and the use of the BUFR code for SIGWX dissemination. Proposals to meet the requirements for medium-level SIGWX to support Extended Twin Engine Operations were discussed, as was the need to disseminate volcanic ash advisories in chart form.

The meeting considered the development or update of regulatory and guidance material related to the provision of services to aviation. In view of the planned implementation of

Geneva, June 1997 — Participants in the CAeM Working Group on the Provision of Meteorological Information Required Before and During Flight (PROMET)

Amendment 71 to ICAO Annex 3/WMO Technical Regulations [C.3.1] in November 1998, PROMET discussed and agreed on changes resulting in WMO Technical Regulations [C.3.3]—Format and Preparation of Flight Documentation and its appendix—Model charts and forms. Also considered were the development of a Compendium on Tropical Meteorology and an update of the current WMO *Guide to Practices for Meteorological Offices Serving Aviation* (WMO-No. 732).

Dr N. D. Gordon (New Zealand), vice-president of CAeM, briefed PROMET on the development of the part of the WMO Fifth Long-term Plan (5LTP) dealing with the Aeronautical Meteorology Programme. He identified five key areas, namely the gathering of basic data in support of the WWW and WAFS, the production of aerodrome forecasts, SIGMETs and warnings of hazardous weather in the vicinity of aerodromes, SIGWX forecasts for en-route phase below FL 180 and customer-oriented provision of information to aviation. Among a number of suggestions made by the group to be included in the 5LTP was the need to highlight the fundamental importance of all aspects of training. The future role of national Meteorological Services and the increasing role of the private sector in providing meteorological services to aviation was debated at length.

PROMET discussed and agreed on a proposal defining meteorological visibility for aeronautical purposes. The group further discussed proposed criteria for precipitation intensity and specifications of dust/sand whirls (dust devils) and funnel clouds or waterspout. The meeting examined the question of automated surface observing systems and their increasing use for aeronautical purposes, together with the results of a questionnaire on the subject sent to WMO Members by the CAeM Rapporteur on Aeronautical Meteorological Observations, Mr Mike Edwards (South Africa).

METEOROLOGY AND OCEAN AFFAIRS

Operational monitoring of upper-ocean thermal structure

An operational expendable bathythermograph (XBT) ship-of-opportunity programme (SOOP) was established under IGOSS in 1996 (see *WMO Bulletin* **45** (4), October 1996). The programme came into being in practical terms with the first meeting of the SOOP Implementation Panel (SOOPIP), which took place in Cape Town, South Africa, in April 1997, hosted by the South African Sea Fisheries Research Institute and the South African Weather Bureau. The Panel is chaired by Mr R. Bailey (Australia) and includes members from agencies and institutions in more than 10 countries which are directly involved in operating SOOP XBT lines. Representatives from oceanographic data-management centres also participate in its work.

The SOOPIP meeting was preceded by a session of the SOOP Task Team on Instruments and Quality Control. This ad hoc task team includes representatives of manufacturers of oceanographic instrumentation, in particular XBTs. It is concerned with coordinating and implementing intercomparison and intercalibration tests on existing operational instrumentation, as well as assessing new instrument types for their potential in operational deployment, in particular from ships-of-opportunity. The team has already finalized and published the results of a major assessment of the fall-rate equation for certain types of XBTs. It is now extending the study to other XBTs, as well as preparing an extensive assessment of XCTDs, oriented towards their future operational use. The team recognized that GOOS will eventually require a full instrument intercomparison and intercalibration programme (similar to that in place under the World Weather Watch and coordinated by CIMO), and noted that its own work already formed the core of such a programme, which could be expanded and developed further, provided the necessary resources were available.

The Implementation Panel reviewed in detail the resources likely to be available for the operational SOOP, as well as the status of individual ship lines, on the basis of the resources survey undertaken by the IGOSS Operations Coordinator and of information provided at the meeting by ship operators. Adjustments to line status were made at the meeting as a result of this review, including the switching of XBT resources among lines to maintain those of highest priority, the identification of new operators for some lines, and the deletion from the plan of others which had never been sampled. While overall resources appeared likely to remain, for the next few years, at around 60 per cent of those required for the full design network, the Panel nevertheless recognized that there remained substantial deficiencies in specific ocean areas. Priorities for addressing those deficiencies needed to be developed by the Ocean Observations Panel for Climate, in collaboration with SOOPIP, and in the context of an overall, detailed SOOP Implementation Plan which is currently being completed. The Panel also reviewed and revised the various data-flow monitoring activities being undertaken on a routine basis by the operations coordinator. It regarded this work, and all the activities of the coordinator, as being essential to the operational SOOP and, in that context, was concerned that a replacement for the outgoing coordinator, Mr B. Hillard, should be found as soon as possible.

Overall, this first SOOPIP session was a very successful start to the operational SOOP, The Panel was encouraged by the developments under way at the national level towards operational funding and management of SOOP lines.

Oceanology International 97—Pacific Rim

Oceanology International is a major marine science and technology exhibition and conference, which normally takes place every two years in Brighton, United Kingdom, attracting several thousand participants, exhibitors and visitors. To respond to the large and expanding interest in this field in the Pacific rim countries, the organizers held the 1997 event at the World Trade Centre, Singapore, from 12 to 14 May. This was the first dedicated marine science and ocean technology exhibition and conference to be held in the Pacific region. More than 1 500 professionals from 36 countries participated, 244 companies and organizations exhibited and more than 200 papers were presented.

WMO was a co-sponsor of both the conference and the exhibition, together with IOC and several other international organizations. The WMO Secretariat mounted an exhibit, jointly with the Australian Bureau of Meteorology and with considerable support from the Singapore Meteorological Service, and a member of the Secretariat presented a paper on operational ocean monitoring. The WMO stand included posters, brochures and publications and attracted a steady stream of visitors throughout the three days. For many visitors, this was their introduction to the Organization, and all were impressed by its wide range of marine activities, as well as by the extensive marine services provided by national Meteorological Services. A number of valuable contacts were also made, relevant to the future development of the WMO marine programme.

The WMO/Australian Bureau of Meteorology stand at Oceanology International 97 in Singapore, with WMO Senior Information and Public Affairs Officer, Ms Eirah Gorre-Dale
(Photo: P. Dexter)

The organizers plan to return Oceanology International to Singapore in the first half of 1999, and have again asked WMO to co-sponsor.

Marine services enhancement in the western Indian Ocean

The Commission for Marine Meteorology has recognized that, in specific ocean areas, cooperative regional projects can be a cost-effective way of enhancing the capabilities of participating meteorological and oceanographic agencies and institutions for the provision of both marine data and services in support of the requirements of various users and applications, national, regional and global. Following a recommendation from CMM, and the successful finalization of the project documents for the SEACAMP project (see *WMO Bulletin* **45** (4), October 1996), a first joint WMO/IOC planning meeting for a possible marine services enhancement project in the western Indian Ocean took place in Mauritius, 20–22 May 1997, hosted by Mauritius

Meteorological Services. The primary objectives were to explore interest in, and possibilities for, such a project, involving both meteorological and oceanographic agencies in the region, to define a project outline and specific objectives, and to agree on procedures for its further development. The meeting was opened by the Hon. D. Bhima, Minister of State, Prime Minister's Office, Mauritius, who indicated his Government's strong support for the meeting and its objectives and for an eventual cooperative regional project along the lines being drawn up.

Twenty-one participants attended, representing both disciplines equally, from eight countries and two organizations in the western Indian Ocean area. Following a detailed review and assessment of existing marine data, services and user requirements in the western Indian Ocean, the meeting addressed the need for, and possible form of, a project to enhance marine services in support of sustainable utilization of the marine environment, integrated coastal area management, marine safety and climate change studies in the region. The concept of a multi-disciplinary, cooperative regional project, broadly along the lines of SEACAMP, received general and enthusiastic support. The overall purpose of the project was seen as the enhancement of operational marine services in the region, based on applied research and greater accessibility to, and exchange of, marine data. The project was tentatively entitled the Western Indian Ocean Marine Applications Project (WIOMAP), and was clearly seen as eventually being a regional contribution to GOOS in the western Indian Ocean.

As well as establishing the purpose, specific objectives of, and activities under, the project, the meeting agreed on a broad project outline and a timetable for development and implementation. In addressing the project outline in particular, the meeting:

Participants in the first WIOMAP planning meeting relaxing in the beautiful Mauritian tropical environment (May 1997)

(Photo: P. Dexter)

- Recognized that more comprehensive background information was needed on existing data, expertise, services and user requirements in the region. It revised a detailed questionnaire to be distributed to all potentially interested institutions and agencies;
- Recognized that enhanced expertise in the region, in particular in marine meteorology and physical oceanography, was essential to the success of the project. Reviewing the joint WMO/IOC proposal for a long-term diploma course in this field at RMTC Nairobi, it was agreed that the proposal in its present form was now unlikely to be implemented. A small task team was therefore established to reassess requirements and restructure the course objectives and concept, incorporating the use of new distance learning techniques such as computer-assisted learning (CAL) to improve effectiveness and cost-efficiency;
- Agreed, in principle, on the idea of a single, operational, marine modelling and product preparation centre in the region as a part of the project, to be eventually self-sustaining, but without addressing detailed questions such as specific objectives, structure, functions and location.

Both during and after the meeting, informal contacts with officials of the UNDP office in Mauritius indicated potential support for the project concept and objectives. Mr R. Vaghjee, Permanent Representative of Mauritius with WMO, has written to the UNDP resident representative, seeking comments and advice on the project outline and on the possibilities of attracting initial UNDP support to develop a detailed project proposal. It is hoped that sufficient support can be found to enable completion of the new status report and full project documents, as a joint WMO/IOC activity, by mid-1998.

Wave forecasting workshop

The Second International Workshop on Ocean Wave Analysis and Forecasting took place from 28 April to 9 May 1997 in Miami, Florida, hosted by the US National Hurricane Center and jointly organized by WMO and the Cooperative Programme for Meteorology, Education and Training (COMET). A high number of requests to participate were received, of which, unfortunately, only 22 could be selected, because of space and budgetary limitations. Participation was well

Participants in the COMET/WMO Second International Workshop on Ocean Waves Analysis and Forecasting (Miami, Florida, April/May 1997)

distributed geographically; all WMO Regional Associations were represented.

The organizers made good use of the experience gained in the first workshop which took place in Boulder (December 1995) and modified the overall programme to integrate the CAL modules on marine meteorology, as well as CAL techniques, into the programme, together with a new subject: "Coastal zone management' (at the suggestion of COMET). The main subjects covered were: winds over the oceans; marine boundary layer concepts; wind/wave relationships; wind waves; swell waves; wave/swell decay; numerical wave models and prediction; first-, second-, third- and fourth-generation models; the wave model in action; big event climatology; operational aspects of windfield preparation; wave/swell and modified forecast aids; and two laboratory cases (Gulf of Mexico and North Pacific Ocean).

The team of international lecturers was led by Dr Steven Lyons, better known on US TV as "Mr Wave". Other lecturers included Dr Maria Paula Etala (Argentina), Mr Jean-Michel Lefèvre (France), Dr Vladimir Ryabinin (Russian Federation) and Mr Fernando Guzmán (WMO Secretariat). A novel experience was a video-conference lecture by Dr Hendrick Tollman direct from the US National Weather Center in Washington, DC.

Participants returned to their countries with newly acquired tools which will allow them to apply modern techniques to wave forecasting and hence improve their national marine meteorological services.

HYDROLOGY AND WATER RESOURCES

IAHS celebrates its 75th anniversary

The International Association of Hydrological Sciences (IAHS) has long been WMO's strongest link with non-governmental organizations in the field of water. As a member of the International Union of Geodesy and Geophysics (IUGG), the Association organizes a series of symposia and workshops on the occasion of each IUGG Assembly, the last of which was held in Boulder, USA, in July 1995. Between these assemblies, i.e. every four years, IAHS regularly organizes its own scientific assemblies, the fifth of which was held in Rabat, Morocco, from 23 April to 3 May 1997.

Over 430 participants from 53 countries met in Rabat and took part in the various plenary sessions, six symposia, five workshops, poster sessions and numerous informal meetings which were organized during the 11 days of the Assembly. This level of participation was more than anticipated and encouraging for the future of the Association, which was marking the 75th anniversary of its founding.

The proceedings of the six symposia held during the Assembly are available as IAHS publications. Future issues of the Association's *Hydrological Sciences Journal* will contain papers presented at some of the workshops.

Water and climate

A key role in WCP-Water is played by planning meetings, the seventh of which was hosted by the Federal Institute of Hydrology in Koblenz, Germany, from 13 to 16 May 1997.

The Koblenz meeting was convened as a joint HWRP-WCP activity, with the active collaboration of UNESCO. Its task was to review progress in the 39 projects listed under WCP-Water and to commence a fundamental review of its aims and future.

It was established that 18 projects had been completed and the remaining 21 were continuing under various auspices. Proposals were received for some six new projects, but action on these was deferred until the future of WCP-Water had been agreed between the parent organizations, in particular WMO and UNESCO. The Second International Conference on Climate and Water (Espoo, Finland, 17–20 August 1998) (see *Bulletin* **46** (3), p. 278) will provide a valuable opportunity to finalize this review process, with the expectation that it will be completed and agreement reached in early 1999.

WMO-UNESCO links

Under one element of the working agreement between WMO and UNESCO in relation to their water programmes, each organization invites the other to send representatives to meetings of their relevant constituent and subsidiary bodies. Accordingly, WMO was represented at the twenty-fifth session of the Bureau of UNESCO's International Hydrological Programme, which was held in Paris from 2 to 4 June 1997.

A second element of the agreement calls for meetings of the Joint WMO/UNESCO Liaison Committee on Hydrological Activities, the eighteenth session of which was held in Geneva on 6 and 7 June 1997. The matters of common interest discussed at those meetings included global databases and the exchange of hydrological data, revision of the *International Glossary of Hydrology*, and assisting countries in defining their training needs.

A third element of the agreement calls for Joint International Conferences on Hydrology to be held ever few years. Plans are now being laid for the fifth of these conferences to be held in Geneva in February 1999, although the date and place have yet to be confirmed.

Any deficiencies in your flood forecasting system?

A Workshop on the Management Overview of Flood Forecasting Systems (MOFFS) was hosted by the Ministry of Construction and Transportation and the Korea Water Resources Corporation in Seoul, Republic of Korea, from 19 to 21 March 1997. Together with the publication of WMO Technical Reports in Hydrology and Water Resources Nos 51 and 55, this workshop brought to an end the development phase of MOFFS. Report No. 51 describes MOFFS Version 3 and Report No. 55 summarizes past experience with the application of MOFFS and the potential for its wider use.

The workshop was led on behalf of WMO by Mr A. Lambert of Watertight Solutions Ltd., United Kingdom. Twenty participants discussed recent progress and applications of MOFFS. The purpose was to make a critical review of existing flood forecasting systems (FFS) through the MOFFS scoring criteria, exchange experiences on flood forecasting using case-studies from the countries represented and gain experience in the application and use of MOFFS for system management purposes.

MOFFS was developed to assess objectively the performances of FFSs by highlighting their deficiencies and thus identifying what action needs to be taken to correct any problems.

Participants also discussed the individual characteristics of their specific FFS and the applicability of MOFFS. One was that for the Han River and the participants visited the Han River Forecasting Centre. They concluded that the following messages should be emphasized:

- Flood forecasting is a matter not only of modelling rainfall/runoff. To be effective, flood forecasting must be followed by proper action during the flood, such as flood fighting and evacuation;
- Comparatively simple FFSs can produce reliable forecasts in many circumstances. Sometimes, forecasters are obliged to use limited or even erroneous data, or try to prepare forecasts when many important data are missing; this emphasizes the importance of a thorough understanding of the hydrological characteristics of the river basin concerned;
- Where computing power has reduced data-processing time, the time saved should be used effectively;
- As regards the content and dissemination of warnings, it is recommended that the forecaster identify next-users and end-users, know their expectations and how they react to warnings. A user-friendly format is recommended for warnings, which should be disseminated through the appropriate media.

It was recommended that MOFFS Version 3 should be accepted as the standard version for international comparisons on representative basins and that individual countries should take the initiative in seeking to develop MOFFS-type scoring systems for addressing other problem areas. WMO has been asked to support such activities and facilitate the discussion and awareness of such systems on a wider (regional or international) basis.

RA III Working Group on Hydrology

The seventh session of the Working Group on Hydrology of Regional Association III (South America) was held in Caracas, Venezuela, from 21 to 26 April 1997. It was attended by 17 participants from nine countries and was chaired by the Regional Hydrological Adviser, Mr C. Caponi (Venezuela).

The level of participation, together with the increasing participation of experts from the Region in CHy sessions, confirms the high priority that RA III is giving to hydrology and water resources.

The meeting considered the draft technical reports prepared by its rapporteurs on hydrological networks, WMO standards and recommended practices, hydrology of natural disasters, hydrological forecasting, hydrological components of the World Climate Programme, hydrological aspects of *El Niño*, sediment transport, hydrology in Region III, HOMS, promotion of hydrological activities and dissemination of related data and information.

The Group discussed in detail new ways to ensure that its work has the largest impact in the improvement of the activities of the water sector of its Members. It was considered a good time to start a new phase in which different projects at the regional level could be prepared and promoted. The Group proposed the establishment of three subgroups, composed of co-rapporteurs, to cover the following subjects:

- Follow-up of the conference on Water Resources Assessment and Management Strategies in Latin America and the Caribbean (San José, Costa Rica, May 1996);
- HOMS and professional training;
- Promotion, dissemination, commercialization.

The Group foresaw the future implementation of projects on water-resources assessment; *El Niño/* Southern Oscillation; groundwater; water quality; education, professional training and technology transfer; and water resources information centres.

The meeting also considered a proposal for a HOMS regional project as an example of one way the Group might be of greatest benefit to countries. If the Working Group succeeds in these activities, countries will receive substantial contributions for their use at national level.

The lectures presented and a visit to the Caracas water supply system all focused on the importance of hydrological data for the design and operation of water projects.

Gridding of hydrological data

There has been an increasing interest in gridded maps, in which an aggregate value of a hydrological variable is assigned to every rectangular cell of a regular grid network. This results from the advent of raster-based geographical information systems (GIS), mathematical models using finite differences or elements and automatic interpolation techniques. Gridded maps are now frequently used in a wide spectrum of problems.

WCP-Water Project B.3 "Development of grid-related estimates of hydrological variables" aims to study the methodology of gridding and its application to hydrological variables. Past activities within this project include a number of meetings, such as the Workshop on Global Runoff Data Sets and Grid Estimation, held in Koblenz in 1988, and three planning meetings, held in Laxenburg, 1990, Warsaw, 1992 and Berne, 1995, respectively. One specific component of this project was an international case-study undertaken for gridding runoff data in Central Europe, in response to the common need for such maps.

Maps of river runoff have three main groups of users. Firstly, geographers, ecologists, foresters, land-managers, spatial planners, lawyers and politicians need to have summarized data presenting the spatial distribution of the natural environment, including water. Secondly, river-runoff maps, when combined with precipitation maps, can be used to determine water budgets on different spatial and temporal scales across physical-geographical or administrative units, such as drainage basins, countries and continents. They thus contribute to the understanding of water fluxes and are useful for planning and managing water resources. Thirdly, mapped runoff provides validation data for atmospheric simulation models and macroscale hydrological models. As a variety of methods exists for the construction of runoff maps, the choice of the method should be guided by the purpose for which the map is being developed.

For the majority of applications, maps of runoff should be preferably based on the synthesis of all the available information, where a water balance approach (i.e. a joint utilization of runoff and climate observations) is used. The problem can then be seen as that of producing consistent water balance maps, i.e. maps of runoff, precipitation and actual evapotranspiration should balance to zero over each of the fundamental units (grid cells) used.

For validation purposes, a map should be determined from runoff data only. Meteorological and climatological data that are used to formulate the external forcing and/or boundary conditions for the model to be validated, should not, of course, be used to determine runoff.

A report on grid estimation of runoff data has recently been prepared by Prof. Gottschalk and Dr Krasovskaia. Besides reviewing the work carried out within the WCP-Water Project B.3, the report gives valuable background material on gridding hydrological signals, including research results of the authors and an extensive literature review. It provides, *inter alia*, a short review of the methodology of producing runoff maps and discusses a number of case-studies and examples of gridded runoff maps produced for Europe. The application of gridded maps for different purposes brings forward the topic of their accuracy and correct use. The report is being issued as a technical document in the WCP Applications and Services Series.

Commission on Sustainable Development and freshwater

In its review of the sectoral cluster on health, human settlements and freshwater, in 1994, the second session of the Commission on Sustainable Development (CSD) recommended that countries give priority to the integrated management, mobilization and use of water resources in a holistic manner. Moreover, it requested the UN Secretary-General to strengthen coordination within the United Nations system with a view to concentrating and consolidating the great amount of international action in the field of water, including implementation of Chapter 18 of Agenda 21.

As reported in *Bulletin* **46** (1), p. 74, WMO participated, together with other organizations concerned, in the preparation of the "Comprehensive assessment of the freshwater resources of the world". The fifth session of the CSD, which was held in New York in April 1997, considered this assessment, together with progress in implementing Chapter 18 of Agenda 21, five years after the UN Conference on Environment and Development. It recommended that the nineteenth special session of the General Assembly (UNGASS), held in New York in June 1997, call for the highest priority to be given to the serious freshwater problems facing many regions, especially in the developing world. It also proposed that UNGASS call for a dialogue under the aegis of the CSD, aimed at building a consensus on the necessary actions and, in particular, on the means of implementation and tangible results. This dialogue is to start after the sixth session of CSD with the aim of initiating a strategic approach for the implementation of all aspects of the sustainable use of freshwater for social and economic purposes and their role in natural ecosystems. This would include, *inter alia*, safe drinking water and sanitation, water for irrigation, recycling and wastewater management. The CSD also recommended to UNGASS that this inter-governmental process would only be fully fruitful if there was a proven commitment by the international community for the provision of new and additional financial resources for the goals of this initiative.

In particular, CSD called for a strengthening of the capability of Governments and international institutions to collect and manage information, including scientific, social and environmental data, in order to facilitate the integrated assessment and management of water resources, and for the regional and international cooperation for information dissemination and exchange. If accepted by UNGASS, this would be important support for WMO's activities in the field of water resources assessment.

WHYCOS update

The programme for the development of the World Hydrological Cycle Observing System (WHYCOS) and the implementation of its regional components (HYCOS) is successfully progressing. The WHYCOS concept is gaining considerable momentum globally and is currently supported by external support agencies including the World Bank and the European Union. It was given significant recognition during the session of the World Water Forum held in Marrakesh, Morocco, in March 1997. A framework mechanism for coordinating WHYCOS activities, both within the WMO Secretariat and externally with WHYCOS partners, is being developed. The most recent developments concerning the various regional components are as follows:

MED-HYCOS

Thirteen countries of the Mediterranean basin are participating in this project. The Pilot Regional Centre is located in Montpellier, France. The first 20 data-collection platforms (DCPs) have been purchased and are being sent to the participating countries. Two stations (Neretva at Metkovic in Croatia and Medjerdah at Ghardimaou in Tunisia) have already been installed and are operational. The data collected are available via Internet on the MED-HYCOS Web site: <http://antares.mpl.orstom.fr/medhycos/index2.html>.

Two training courses have been organized for the installation, operation and maintenance of the DCPs, one in Toulouse and Montpellier, France, in September 1996 and the other in Metkovic in May 1997.

With funds recently made available by the World Bank, an additional 10 DCPs will soon be purchased. Two expert missions have been fielded to Morocco and Tunisia to assess the feasibility of a direct connection of NHS to GTS (via NMS) for real time data recovery. The MED-HYCOS Regional Task Force N° 2 (Data Bases) and N° 4 (Information Infrastructure) met in July 1997 to develop the plan for future activities.

At the meeting in Croatia in May 1997, the participating countries expressed their support for the extension of the project to cover the Black Sea countries (Bulgaria, Georgia, Moldova, Russian Federation and Ukraine). Negotiations are under way with the World Bank to mobilize resources to support the extension of the project activities.

SADC-HYCOS

This project, which covers the 11 continental countries of the Southern African Development Community, started in 1997, with European Union funding. The Pilot Regional Centre is hosted by the Directorate of Hydrology, Department of Water Affairs and Forestry in Pretoria, South Africa. The process of awarding contracts for technical assistance and the supply of equipment, including 50 DCPs, was initiated in April 1997.

AOC-HYCOS (western and central Africa)

A project document for an estimated budget of US$ 6.0 million has been prepared by WMO with funding from the French Ministry of Cooperation. This project is expected to contribute to the development of a water resources information system for the 23 countries of the west and central African subregion. Funds are currently being sought.

CONGO-HYCOS

This project is being developed to support the six countries of the Congo River basin. A project document is being prepared, with funding from the European Union, for the implementation of a Regional Hydrological, Meteorological and Climatological Information System (RHMCIS), within the framework of the Regional Environmental Information Management Programme funded by the World Bank. CONGO-HYCOS will be implemented concurrently with the strengthening of the regional component of the WWW Observing Network and Reference Climatological Stations.

CARIB-HYCOS

The development of the project for the countries of the Caribbean basin was supported by most of the countries participating in the Conference on Water Resources in Latin America and the Caribbean (San José, Costa Rica, May 1996). More recently, XII-RA IV (May 1997) reiterated the importance of CARIB-HYCOS and fully supported its implementation. Two expert missions will be fielded during 1997 to visit the countries in the region to assess the situation of national Meteorological and Hydrological Services and develop the project document. A Technical Steering Committee has also been established to assist with the preparation and implementation of this project.

Other WHYCOS regional components

The Inter-Governmental Authority on Development (IGAD) has requested WMO to develop a project for the eight countries of eastern Africa and funds are being sought. A project profile for the Nile basin has also been prepared in cooperation with TECCONILE, and the Canadian International Development Agency has expressed its willingness to support the project formulation. There is also interest in the development of a HYCOS component for the Baltic Sea region. A proposal for such a project presented by Prof. J. Zielinski, Permanent Representative of Poland with WMO, has already received the support of several countries of the subregion.

EDUCATION AND TRAINING

Training course in the Russian Federation in aeronautical meteorology for Class I meteorologists from Mongolia

By Yuri Belyaev, Course Coordinator, WMO RMTC in the Russian Federation

A training course in aeronautical meteorology for Class I meteorologists was given at the WMO RMTC in the Russian Federation from 29 May to 12 June 1997 to a group of 24 participants from Mongolia. The course was held within the framework of an intergovernmental agreement on scientific and technical cooperation between the Hydrometeorological Services of the Russian Federation and Mongolia and was a contribution to the WMO Voluntary Cooperation Programme.

The two-week course covered the most important aspects of meteorological services to aviation in the current stage of their development and organization within the new economic conditions. These included the latest scientific developments in forecasting weather phenomena which are dangerous or extremely dangerous for aviation; new methods for forecasting and analysing atmospheric fronts; automated methods for analysing and forecasting meteorological elements in the area of an aerodrome; and use of satellite information in forecasting meteorological conditions for flight safety.

Of particular interest to the participants was information about WAFS and automated systems for aeronautical meteorological stations of various categories. Legal and methodological questions were considered concerning the commercial use of meteorological information and services and the cost to users; the roles of ICAO and WMO; and the main regulations for services to aviation at international level.

A meeting was held at the Hydrometeorological Centre with the Director, Prof. A. A. Vasiliev, where the participants learned about the work of the Centre's operational subdivisions. Visits to the Main Computer Centre and the Vnukovo Main Aeronautical Meteorology Centre permitted them to become acquainted with geographical information system technology and with methods of information technology.

A short talk was given on the main directions for the development of the Russian Federal Service for Hydrometeorology and Environmental Monitoring by Mr V. N. Dyadyuchenko, Deputy Director. He underlined the need to strengthen further the ties between the two countries in the field of hydrometeorology, especially as regards training.

During their free time, the guests from Mongolia had the opportunity to discover the historical sites and monuments of the capital city of the Russian Federation.

Recent education and training events

Second EUMETSAT/WMO Core Trainers Course on Satellite Meteorology

During the period 6–23 May 1997, the European Organisation for the Exploitation of Meteorological Satellites and WMO organized the second Core Trainers Course on Satellite Meteorology in Africa (the first course was reported in *WMO Bulletin* **46** (2)).

The course was held in Nairobi, Kenya, at the Institute for Meteorological Training and Research, which is a component of the Regional Meteorological Training Centre (RMTC) in Kenya. Fifteen participants attended the course, which was conducted in English. The objectives were fully attained and participants were appreciative of both the level and content of the course.

Postgraduate Training Course in Agrometeorology

The first Postgraduate Training Course in Agrometeorology for the west African subregion was organized by RMTC Lagos, the Nigerian Meteorological Department and the Federal Ministry of Aviation, in collaboration with the Centre of International Cooperation of the Israeli Ministry of Foreign Affairs and WMO. It was held in Lagos from 5 to 23 May 1997.

The course was attended by 24 participants, comprising 13 Nigerians and 11 candidates from Benin, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Mali, Sierra Leone and Togo. Participants received extensive training in the operation and maintenance of radiation instruments and special instruments (neutron probe) in agrometeorology. Practical sessions were held at the RMTC demonstration farm and the standard meteorological enclosure. Two field trips were organized to enable participants to gain practical experience outside the classroom. They visited the International Institute for Tropical Agriculture at Ibadan (about 150 km from Lagos) and the Ogun/Osun River Basin Authority at Abeokuta (about 100 km from Lagos). Each of the field trips lasted one day. The trip to Ibadan enabled the students to see the results of crop-weather modelling techniques and improved crop species at the Institute. The trip to Abeokuta exposed them to water resources management as applied to agriculture.

The aims and objectives of the course were achieved and participants recommended that the course should last for four to six weeks and be held on a regular basis.

Fellowships

During the first half of 1997, 137 fellowships were awarded, four of them for long-term studies. By the end of July 1997, 475 requests for fellowships were still pending, because of the lack of funding. More than half these unsatisfied requests were for long-term fellowships. The Secretariat continues its efforts to increase traditional financial resources for fellowships by seeking additional extrabudgetary resources as well as new potential sources of funding.

Training Library

In addition to its ongoing services to WMO Members in the area of audio-visual aids and computer-aided learning modules, the WMO Training Library has recently distributed, on request, all surplus copies of textbooks and other written training materials to WMO RMTCs, which are located in Algeria, Brazil, Egypt, Iraq, Islamic Republic of Iran, Nigeria, Philippines, the Russian Federation, Uzbekistan and Venezuela.

WMO training publication

The Royal Netherlands Meteorological Institute (KNMI) has kindly offered to WMO an English version of its training module "Basics of marketing and commercial skills", authored by Mr A. F. W. M. van Vessem, for the benefit of the meteorological community at large. It has been issued in the WMO Technical Document series of the Education and Training Programme as WMO-TD/No. 805 (ETR-14) and is available to Members on request.

We are confident that this training module will help Members familiarize their staff in basic marketing and in the commercial approach to the provision of meteorological products and services to customers. Members wishing to have this module presented in their training institutions by KNMI instructors can contact Mr van Vessem or Mr C. Floor.

Technical cooperation

Haiti

The project HAI/97/006: "Hydrometeorological information for economic and social development in Haiti" was approved, further to negotiations between WMO, the UNDP Regional Bureau for Latin America, the UNDP Office in Haiti and the Permanent Representative of Haiti with WMO. The project will be funded by UNDP to an amount of US$ 1 100 000 for a period of 30 months, starting in the second half of 1997.

WMO will be the executing agency for the project, while the *Service National des Ressources en Eau* (SNRE) will act as implementing agency. Objectives include the upgrading and strengthening of the hydrometeorological networks, development of a hydrological and climatological database available to all users in the country and institutional development of the SNRE. The project will be carried out with the assistance of a part-time expert in hydrology, who will be supported by consultants in specific technical fields.

Ibero-American Climate Project

As reported in *WMO Bulletin* **45** (3), 294–295, an agreement for the implementation of the feasibility study for the Ibero-American Climate Project was signed in Washington, DC, on 7 March 1996 by WMO and the Inter-American Development Bank (IDB).

All the pre-conditions requested by the IDB for the start of the feasibility study of the project have been fulfilled by WMO and include:

- Signature of agreements between WMO and the 13 participating countries (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Mexico, Paraguay, Peru, Uruguay and Venezuela);
- Completion and signature of agreements between WMO and the the National Meteorological Institute of Spain; WMO and Delcan (Canada); and WMO and TASC, Inc. (USA);
- Appointment of Mrs Blanca Pérez-Marin (Spain) as Project Director;
- Establishment of executing units for the study in all participating countries, including a focal point;
- Selection of national experts to assist in the preparation of documents for selected components of the project; and
- Preparation of terms of reference and distribution of tasks among the participating countries.

A Coordinating Committee meeting was held in the WMO Regional Office for the Americas in Asunción, Paraguay, from 28 to 29 April 1997. It was agreed that 1 May 1997 would be the starting date for the 18-month feasibility study and a detailed work plan was established.

A preliminary mission was carried out by the Project Director and WMO staff to participating countries in July 1997. The purpose was to establish contact with the Meteorological

Asunción, Paraguay, April 1997 — Participants in the Coordinating Committee meeting for the Ibero-American Climate Project

Services, make arrangements for the technical missions, and inform the Ministries of Finance about the feasibility study.

Islamic Republic of Iran

In a ceremony at the WMO Secretariat on 1 May 1997, a trust fund agreement between the Islamic Republic of Iran Meteorological Organization (IRIMO) and WMO was signed by Dr A. M. Noorian, Permanent Representative of the Islamic Republic of Iran with WMO, and the Secretary-General of WMO. The ceremony was attended by HE Mr Bozorgmehr Ziaran, Ambassador, Deputy Permanent Representative of the Islamic Republic of Iran to the UN Office and other International Organizations in Geneva, Mr H. Moeini Meybodi, Second Secretary, and senior staff of WMO. The purpose of the agreement is to implement a technical cooperation project through consultancy missions and human resources development for the installation of a network of seven weather radars. Such a network will increase the capabilities of IRIMO to comply with its national and regional obligations to provide all sectors of the national economy with the meteorological information and products they require for sustainable development. The project will be implemented in two phases. Total input for the first will be an estimated US $3 million and US $4 million for the second.

Mexico

WMO continues to provide technical assistance services to the National Water Commission (CNA) of Mexico and activities are progressing satisfactorily. A mission for the preparation of the terms of reference and technical specifications for the modernization of the hydrological network system of the Rio Bravo Basin (USA/Mexico border) was completed in June 1997. Other missions include training courses and preparation of technical specifications for several telemetric networks in Mexico that will transmit hydrological data by satellite.

Technical assistance services are being provided to CNA by WMO staff and external consultants in the fields of hydrology and meteorology. Activities foreseen in 1997 for the National Meteorological Service included assistance in the modernization of the upper-air and automatic weather stations networks.

Oman

The implementation of the trust-fund project "Meteorology, training and equipment" in Oman is making satisfactory progress (see *WMO Bulletin* **45** (1), p. 88). The Meteorological Service has been provided with a complete turnkey SADIS workstation with application software and TIROS data-processing software. Seven automatic weather stations and two upper-air stations have been installed at Seeb International Airport and Salalah to replace the OMEGA stations. In addition, spares and consumables have been provided. Provisions were made within the project for specialized consultancy missions and upgrading the knowledge of staff through familiarization visits and training abroad.

Saudi Arabia

During the visit of the Secretary-General to the Kingdom of Saudi Arabia from 2 to 7 May 1997, a trust-fund agreement for the implementation of a study on cloud physics with a possibility for rain enhancement was signed during a ceremony organized at the premises of the Ministry of Defence and Civil Aviation in Jeddah on 5 May 1997. HH Prince Fahad Bin Abdulla Al-Saud, Assistant to the Minister of Defence and Civil Aviation and Inspector General of Civil Aviation, signed the agreement on behalf of Saudi Arabia, and Prof. G. O. P. Obasi, on behalf of WMO. The ceremony was attended by Dr Abdulbar Algain, President of the Meteorology and Environmental Protection Administration; Dr Samir Boukary, Acting Director of the National Meteorological and Environmental Centre; Dr Gamil Sofi, Senior National Programme Officer representing the UNDP Resident Representative in Saudi Arabia; and Mr Eisa H. Al-Majed, Director, WMO Regional Office for Asia and the South-West Pacific.

With a total input of US$ 1.3 million, the agreement provides for an expansion of the activity already completed under a similar agreement signed in 1986 through the provision of expert services, sub-contracts and training of personnel with a view to developing local expertise so that a national precipitation enhancement experiment may be managed and carried out by local staff. The study will start with a consultancy mission to review and report on the previous work carried out in the field of cloud physics particularly in the southern part of the country.

United Arab Emirates

The project in the United Arab Emirates "Establishment of the National Meteorological Service" (see *WMO Bulletin* **44** (4), p. 402), was successfully completed in December 1996. During the tripartite review meeting held in November 1996, it was agreed that the national project coordinator, in close collaboration with the national counterpart of the Ministry for Communication, would arrange for the necessary administrative formalities for establishing the Service as a Department of Meteorology under the Ministry of Communication. It was further decided to extend the project for a transitional period of two years as from January 1997 in order to ensure the continuation of the meteorological services being provided to different users for the sustainable development of the country.

Implementation of the extended project has been started with the provision of consultancy and support staff, equipment, spares and consumables and through the training of nationals. The Central Forecasting Office and other meteorological facilities have been transferred from Al-Dafra Airbase to the Headquarters of the Ministry of Communication. Meteorological information and products continue to be provided to different users.

Western Samoa

A mission was carried out by a WMO consultant, Mr Ho Tong Yuen (Malaysia) in March 1997 to assess the present status of the national Meteorological Service and to assist in formulating a development plan. The resulting five-year plan provides an outline of coordinated activities prioritized to address deficiencies requiring urgent attention and takes into consideration the national Statement of Economic Strategy. It also covers a number of projects among which the acquisition of meteorological equipment, the improvement of station networks and related facilities, such as telecommunications, data processing and manpower development activities.

Support for the most urgent needs, especially data-processing facilities, is being provided under the WMO Voluntary Cooperation Programme.

In the Regions

Iranian National Commission for Agriculture

The 95th General Assembly of 17 specialized committees of the National Commission for Agriculture and Climate (NCAC) was held at the Headquarters of the Islamic Republic of Iran Meteorological Organization from 12 to 14 May 1997 in Tehran.

The committees reviewed and discussed 940 research projects on agriculture and the impact of climate. The projects selected will be supported financially by the Government after final approval by the NCAC. Many policy-makers, directors, university professors and agricultural scientists participating in the Assembly emphasized the value of climatological and agrometeorological information applicable to agricultural research. ❐

Tehran, Islamic Republic of Iran, May 1997 — Participants in the 95th General Assembly of specialized committees of the National Commission for Agriculture and Climate

Aerometeorological workshop in Guyana

A workshop on VSAT/STAR IV operations was held at the Timehri Meteorological Office in Guyana from 2 to 3 July 1996. Topics included data-transmission techniques, the role of the Global Telecommunication System, in-house management of VSAT, vorticity and divergence, use of STAR IV for climate information, weather forecasting technology and operation and display of STAR IV WAFS products. ❐

News and notes

World Meteorological Day 1997

The theme for World Meteorological Day (WMD) in 1997 was "Weather and water in cities", which was also the title of a special brochure (WMO-No. 853) and poster. The message of the Secretary-General appeared in the January 1997 issue of the *WMO Bulletin*.

Many national Meteorological and Hydrological Services (NMHSs) held joint celebrations of WMD and the World Day for Water (WDW) (22 March). The theme for this year's WDW was water resources assessment and the slogan was "The world's water: is there enough?" (see next article).

NMHSs commemorated these events with "open days", exhibitions, special seminars and conferences, concerts and programmes to mark the occasion. Media coverage was, in general, very wide. Documentary and media features on radio, television and in the printed press focused on the WMD theme and helped generate greater public awareness of the importance of meteorology and operational hydrology and the NMHSs to sustainable urban development.

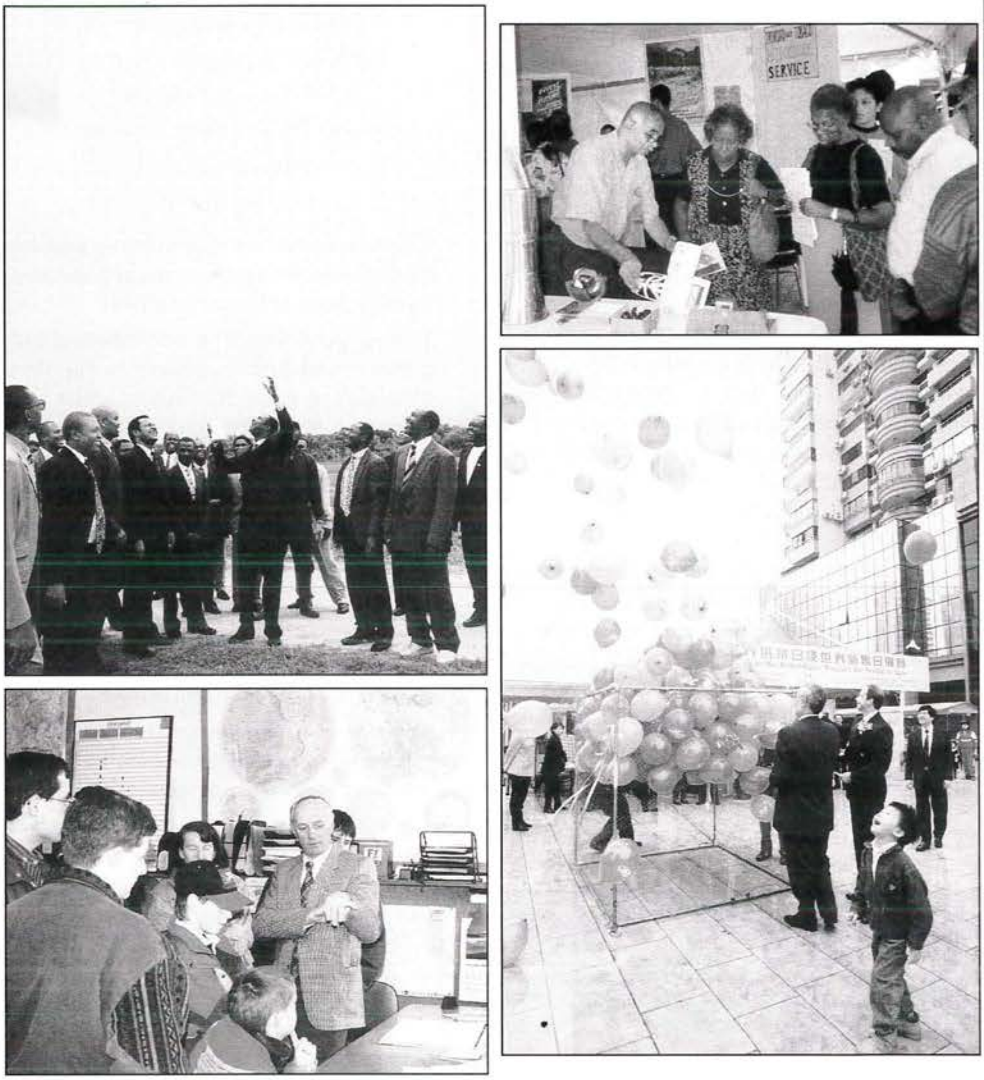
Some Services (e.g. Colombia, Hungary, South Africa, Togo and Trinidad and Tobago) emphasized the importance of education, paying visits to schools, organizing TV briefings and workshops with young people and holding painting and crossword competitions. Some countries, such as Australia, Benin, Cameroon, Ethiopia, South Africa, Tunisia and Turkey, produced their own posters and banners.

The occasion also provided an excellent opportunity for launching new services, products and projects: in Ireland, projects to monitor rainfall over Dublin and to develop a flood-forecast model; a new numerical mesoscale model in Slovenia (ALADIN/SLO); a meteorology awareness project in Trinidad and Tobago; a new daily TV weather show in the United Kingdom and, in Nigeria, new project equipment was commissioned. Some countries (Argentina, Australia and Venezuela) used the occasion to recognize services to meteorology with special awards.

Exhibitions, conferences, open days and guided tours were held, *inter alia*, in Algeria, Benin, Brunei Darussalam, Bulgaria, Czech Republic, Comoros, Ethiopia, Italy, Jordan, Kenya, Libyan Arab Jamahiriya, Macao, Morocco, Nigeria, Peru, the Philippines, Republic of Korea, the Russian Federation, Slovakia, South Africa, Sweden, Trinidad and Tobago, Tunisia and Turkey.

The large number of photographs, press clippings, postage stamps, and other memorabilia received from Members demonstrated the success and appeal at all levels of these annual celebrations, enhancing the visibility and prestige of WMO and the NMHSs.

The guest of honour at WMD celebrations in the WMO Secretariat was Dr Pietro Garau, Special Representative of the Secretary-General of UNCHS/Habitat, Dr Wally N'Dow, who read out a special message on his behalf to participants that included Secretariat staff, representatives of diplomatic missions and UN organizations based in Geneva. The Secretary-General of WMO, Prof. G. O. P. Obasi, gave an address on the theme of weather and water in cities and a videofilm,



World Meteorological Day celebrations around the world in 1997 (clockwise from top left): Cameroon; Trinidad and Tobago; Macao; and the Czech Republic

which was co-produced by WMO and the Television Trust for the Environment, was screened.

The following Members submitted accounts of their WMD and/or WDW celebrations in 1997: Algeria, Argentina, Armenia, Australia, Bangladesh, Benin, Brunei Darussalam, Bulgaria, Cameroon, Colombia, Comoros, the Czech Republic, Ecuador, Ethiopia, Georgia, Guatemala, Hungary, Indonesia, Ireland, Italy, Jordan, Kenya, Kyrgyz Republic, Libyan Arab Jamahiriya, Macao, Morocco, New Zealand, Nigeria, Peru, the Philippines, Republic of Korea, the Russian Federation, Slovakia, Slovenia, South Africa, Sri Lanka, Sweden, Togo, Trinidad and Tobago, Tunisia, Turkey, Ukraine, the United Kingdom, the USA, Uzbekistan and Venezuela. ❐

World Day for Water events

Water is a basic requirement for all life and is facing more and more demands from, and competition among, users. In 1997, the theme for World Day for Water (WDW) was "Water resources assessment", and the slogan was "The world's water: is there enough?". In view of their involvement in water resources assessment, WMO and UNESCO were designated as the lead agencies for this year's celebration.

This year's event was also celebrated by a non-governmental organization, the World Water Council, during the first World Water Forum held in Marrakesh, Morocco, from 21 to 25 March 1997 under the patronage of HM King Hassan II. It was attended by some 500 participants from water-related agencies, as well as donors and NGOs.

The Secretary-General of WMO, Prof. G. O. P. Obasi, addressed the Forum on The challenges of the twenty-first century, focusing on the theme "Climate change and freshwater management". He said that freshwater shortage was expected to be the most dominant problem in the forthcoming century and one that, along with water quality, might well jeopardize all other efforts to secure sustainable development, and even lead to social and political instability.

Prof. Obasi participated in a special ceremony to commemorate the WDW on 22 March with Dr F. Mayor, Director-General of UNESCO and Dr M. Abu Zeid, President of the World Water Council. He also held a joint press conference with Dr Mayor and Mr J. Diouf, Director-General of FAO.

To mark the occasion, WMO produced an information kit which included a message from the Secretary-General, a poster and feature stories by 10 specialized agencies and United Nations programmes active in the field of water resources. WMO and UNESCO also published a brochure entitled *The World's Water: Is There Enough?* (WMO-No. 857), which draws on the Comprehensive Assessment of Freshwater Resources of the World. That report was prepared by the UN with contributions from WMO and UNESCO and submitted by the UN Commission on Sustainable Development to the June 1997 Special Session of the UN General Assembly on the review and appraisal of the implementation of Agenda 21.

A parallel exhibition was held during the Forum, to which all agencies were invited to display materials and demonstrate relevant activities. The exhibit of WMO was highly appreciated by participants; it featured a display on

Marrakesh, Morocco, March 1997 — Prof. G. O. P. Obasi addresses the first World Water Forum.

Conference announcement

European Geophysical Society

23rd General Assembly

Basic Turbulence Studies

Nice, France, 20–24 April 1998

Topics

- **Characterization of turbulence and the mixing and stirring properties of boundary-layer regimes in the atmosphere**
- **Scale-dependent parameterization of turbulence and mixing processes for flow dynamics at respective larger scales in a hierarchy of models (large-eddy simulations of boundary-layer flows with subgrid turbulence parameterization, regional models with subgrid boundary-layer flow parameterization and global climate and weather prediction models)**
- **Mixing-height parameterization over flat homogeneous-heterogeneous terrain and over complex terrain, including theoretical and field experiment methods**
- **The role of organized vortices and other coherent motions in the planetary boundary layer and their parameterization**

For more information, contact Dr Arakel Petrosyan, Space Research Institute, Profsoyuznaya 84/32, 117810 Moscow, Russian Federation. Tel.: 7-095-3333256. Fax: 7-095-3107023. E-mail: <apetrosy@iki.rssi.ru> or Dr Thomas Gerz, Institut für Physik der Atmosphäre, DLR Oberpfaffenhofen, Postfach 11 16, 82230 Wessling, Germany. Tel.: 49-8153-28-1333. Fax: 49-8153-28-1841. E-mail: <thomas.gerz@dlr.de>

the World Day for Water theme, with particular emphasis on the MED-HYCOS project, currently being implemented with the support of the World Bank. ❒

Conference announcement/call for papers

ICAM 98

25th International Conference on Alpine Meteorology 1998

Turin, Italy, 14–19 September 1998

Session topics

- **Mountain meteorology forecasts and analysis**
- **Meteorology observations and mountain nowcasting**
- **Alpine climatology**
- **Nivology and glaciology; scientific theory and applications**
- **Biometeorology, hydrobiology and pollution in alpine environments**
- **Hydrometeorological risk in alpine environments**
- **Meteorology and alpine economy**

The languages of the Conference are English, French, German and Italian. The deadline for sending abstracts (title and summary of oral or posted presentation in English or Italian) is 31 December 1997.

For all further information, contact the Scientific Secretary of ICAM 98, Regione Piemonte, Settore Prevenzione Rischio Geologico, Meteorologico e Sismico, Servizio Meteoidrografico, C.so Unione Sovietica, 216, 10134 Torino, Italy. Tel.: 39-11-46.18.203. Fax: 39-11-31.81.709. E-mail: meteoidro@regione.piemonte.it

The year of the floods

Twenty-five years ago, in 1972, devastating floods hit the USA, taking almost 500 lives:

- On 26 February 1972, a coal-waste dam collapsed, releasing 500 million litres of water into Buffalo Creek Valley, West Virginia, completely destroying the town of Saunders, as well as all or part of 16 other small communities or mining caps: 125 dead;
- In June and July 1972, rainfall from *Agnes*, albeit an extremely weak hurricane, caused one of the worst natural disasters in Pennsylvania history. The Susquehanna River and tributaries along the New York-Pennsylvania border produced the most severe flooding there since 1784;
- A stationary group of thunderstorms over the Rapid City area of the Black Hills in South Dakota on 9 June 1972 produced more than 254 mm of rain over a 155 km^2 area. The resulting toll from the ensuing floods was 237 dead, more than 3 000 injured and total damage in excess of US$ 160 million.

Since the 1972 disasters, human casualties from floods in the USA have declined, thanks to advances in science and technology and to better partnerships among local, state and federal agencies working to provide advance warnings to citizens. Nevertheless, US Geologi-

Conference announcement and call for papers

Coastal Environment 98

Environmental Problems in Coastal Regions

Cancun, Mexico, 8–10 September 1998

Conference themes

- **Pollution management and decision analysis**
- **Hazard/mitigation risk analysis**
- **Environmental impact assessment and legislation**
- **Harbours, ports and marinas**
- **Littoral drift**
- **Coastal erosion**
- **Siltation and dredging**
- **Oil slicks and spills**
- **Acoustic pollution**
- **Pollutant transport and dispersion**
- **Remote-sensing**
- **Wastewater treatment**
- **Sewage and chemical pollution**
- **Atmospheric pollution and control**
- **Hydrodynamic and pollutant transport modelling**
- **Water-quality models**
- **Case-studies**

Abstracts of no more than 300 words should be submitted by 6 January 1998. Enquiries and abstracts should be sent to: Liz Kerr, Conference Secretariat, Coastal Environment 98, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton, SO40 7AA, United Kingdom. Tel.: +44 (0) 1703 293223. Fax: +44 (0) 1703 292853. E-mail: <liz@wessex.ac.uk>

cal Survey Chief Hydrologist, Robert Hirsch, warns: "We should not let our guard down. Floods continue to cost the nation an average of US$ 160 billion in damage and about 95 lives every year.". ❒

❒ *This item was extracted from an article concerning a US Geological Survey News Release in* Hydata—News & Views, **16** (3), *the newsletter of the American Water Resources Association* (Ed.).

News from the Secretariat

Secretary-General's visits

The Secretary-General, Prof. 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 extended to him.

South Africa

The Secretary-General visited South Africa from 6 to 8 April 1997, where he addressed the opening session of the Fifth Southern Hemisphere Meteorology and Oceanography Conference held at the University of Pretoria. He also gave a lecture entitled "Some issues related to climate change—a view from WMO".

During his visit, he met with HE Dr Peter Mokaba, Deputy Minister of Environmental Affairs and Tourism, the Hon. Ms Mabudgfhasi, Member of Parliament, and Mr G. C. Schulze, Permanent Representative of South Africa with WMO. Fruitful discussions were held on the development of the Weather Bureau and other matters of mutual interest.

Spain

The Secretary-General visited Spain from 13 to 15 April 1997 to address the International Symposium on Cyclones and Hazardous Weather in the Mediterranean, which was held in Palma de Mallorca from 14 to 17 April 1997. He also gave a lecture entitled "WMO and the academic and research community" at an academic ceremony organized in his honour at Salamanca University on 15 April 1997.

The Secretary-General met with Ms Isabel Torino, Minister of Environment, and had useful discussions on furthering the excellent cooperation between Spain and WMO. He had extensive discussions with Mrs Maria Jesus Prieto-Laffargue, Permanent Representative of Spain with WMO, on strengthening the collaboration between the National Meteorological Institute of Spain and WMO. At Salamanca University, the Secretary-General had rewarding discussions on matters of mutual interest with Mr D. Ignacio Berdugo Gómez de la Torre, *Rector Magnifico*; Mr D. José Antonio Fernández Delgado, *Vice-Rector Magnifico*; and Prof. Dr Moisés Egido Manzano, Director, Department of Atmospheric Physics.

Vanuatu

The Secretary-General visited Vanuatu from 20 to 22 April 1997. He was received by the Prime Minister, the Hon. Mr Rialut Serge Vohor, and the Deputy Prime Minister and Minister of Education, the Hon. Mr Donald Kalpokes, and had fruitful discussions on strengthening the excellent relationship between Vanuatu and WMO. The Secretary-General also met several high-ranking Government officials, including the Hon. Mr Demis Lango, MP, Minister of Civil Aviation, Tourism, Telecommunication, Meteorology and Postal Services. He joined in celebrations of World Meteorological Day with staff at the Vanuatu Meteorological Service and delivered an address.

During his discussions with national authorities, matters of common interest between Vanuatu and WMO were addressed, including the development of the Vanuatu Meteorological Service and its role in national socio-economic sustainable development and its participation in relevant WMO regional and international activities.

Solomon Islands

On 23 and 24 April 1997, the Secretary-General visited Solomon Islands. During the visit, he was received by the Prime Minister, the Hon. Mr Solomon Mamaloni, MP. He also met several high-ranking Government officials, including the Minister of Agriculture and Fishery, and the Acting Minister of Foreign Affairs, Mr Victor Ngele; Minister of Mines and Minerals, Mr David Vouza, MP; and the Minister of Finance, Mr Michael Maen, MP.

Prof. Obasi had discussions with the Permanent Secretary for Culture, Tourism and Aviation, Mr John Baura, and the Permanent Secretary for Development and Planning, Mr Donald Kudu. He visited the Solomon Islands Meteorological Service, where he exchanged views with the Director, Mr Mike Ariki. During his discussions with the national authorities, matters of mutual interest between Solomon Islands and WMO were addressed, including ways and means to further strengthen the Meteorological Service.

Singapore

On his way to Vanuatu and Solomon Islands, the Secretary-General took the opportunity, on 17 April 1997, to visit the ASEAN Specialized Meteorological Centre. The Director of the Meteorological Service, Mr Woon Shih Lai, made a presentation on the activities of the Centre, which is considered as a model of regional cooperation.

Saudi Arabia

From 2 to 7 May 1997, the Secretary-General visited Saudi Arabia, where he signed a trust-fund agreement for a study on cloud physics with the possibility for rain enhancement. He had discussions with HH Prince Fahad Bin Abdulla Al-Saud, Assistant to the Minister of Defence, Aviation and Inspector General for Civil Aviation Affairs, on strengthening the excellent collaboration between Saudi Arabia and WMO. Prof. Obasi visited the facilities of the Meteorology and Environmental Protection Administration (MEPA) and discussed its further development with Dr Abdulbar A. Algain, President of MEPA and Permanent Representative of Saudi Arabia with WMO.

During his visit, the Secretary-General presented the lecture "An overview of research, education and training activities of the World Meteorological Organization" at the Faculty of Meteorology, Environmental and Arid Land Agriculture, King Abdul Aziz University. He had discussions with the Dean of the Faculty, Dr Reda Ben Ali Kabli, on fellowships matters, and also visited the Marine Science Faculty.

Bahamas

The Secretary-General visited the Bahamas and addressed the twelfth session of Regional Association IV (North and Central America), which was held in Nassau from 12 to 21 May 1997. Prof. Obasi also took the opportunity to discuss matters of regional interest and concern to the national Meteorological and Hydrological Services having delegations attending the session.

The Secretary-General was received by HE Sir Orville A. T. Turnquest, Governor General, and HE Rt. Hon. Hubert A. Ingraham, Prime Minister, with whom he had fruitful discussions on the strengthening of the excellent relationship between the Bahamas and WMO. He also met HE Mrs Janet G. Botswick, Minister of Foreign Affairs; HE Pierre V. Dupuch, Minister of Consumer Welfare and Aviation; Ms Willamae Salkey, Permanent Secretary, Ministry of Consumer Welfare and Aviation; and Mr Kenneth Lightbourne, Permanent Representative of the Bahamas with WMO. The development of the Department of Meteorology and other matters of mutual interest were discussed.

Republic of Korea

The Secretary-General visited Seoul, Republic of Korea, from 25 to 28 May 1997 and had useful discussions with the Minister of Science and Technology, Dr Sook-il Kwun; the Minister of Environment, Mr Kyun-Wook Kang; and the Vice-Minister of Foreign Affairs, Mr Ki-Choo Lee, on strengthening the excellent relationship between the Republic of Korea and WMO.

Prof. Obasi visited the facilities of the Korean Meteorological Administration (KMA) and delivered the lecture "WMO's role in addressing some global environmental issues". He had discussions with Dr Jong-Hon Bong, Administrator of KMA and Permanent Representative of the Republic of Korea with WMO, and senior staff on the further development of the Administration.

The Secretary-General visited the Samsung Electronic Company Ltd., the Dae Chung Multipurpose Dam and the Korea Water Resources Corporation. He also had discussions with Mr Sung-Gil Hong, Head of the Meteorological Research Institute, concerning the Korean Monsoon Experiment (KORMEX) and a proposal for cooperation in the area of rain enhancement.

Paraguay

Prof. Obasi visited Paraguay on 2 June 1997. He was received by HE Juan Carlos Wasmosy, President of Paraguay, and had fruitful discussions on the development of the national Meteorological Service. The President took note of the necessary measures aimed at meeting the most pressing needs of the Meteorological Service. The Secretary-General was also received by the President of Congress, Dr Miguel Abdón Saguier, and his advisory team on natural resources. Action taken in relation to the law on water under study by the National Congress was reviewed. On

Asunción, Paraguay, 2 June 1997 — The Secretary-General (*centre*) with (*to his left*) General O. Faría Vergara, Vice-Minister, National Defence; (*to his right*) Dr A. Martin Avalos, President, Civil Aviation Administration; and (*from left to right of photo*): Mr G. Lizano, Director, Regional Office for the Americas; Ms G. Velázquez, Secretary General, Civil Aviation Administration; Mr W. Castro Wrede, Permanent Representative of Paraguay with WMO; and Mr E. Rousseau, WMO

this occasion, Dr Leila Rachid, Minister of Foreign Affairs a.i., and Prof. Obasi signed a Memorandum of Understanding on the cooperation between the Government of Paraguay and WMO relating to the preparation of the feasibility study for the Ibero-American Climate Project. The Project is based at the WMO Regional Office for the Americas in Asunción.

The Secretary-General met with the President of the Civil Aviation Administration, Dr Martin Avalos, and his Council and exchanged views on the development of meteorological activities and their contributions to the different sectors of the economy. The Secretary-General also had extensive discussions with Mr Wilfrido Castro Wrede, Permanent Representative of Paraguay with WMO and president of RA III, on the development of the national Meteorological Service and matters of regional interest. He visited the Regional Office for the Americas and discussed activities with the staff.

Argentina

The Secretary-General paid a short visit to the Argentine National Meteorological Service (NMS) in Buenos Aires, on 3 June 1997.

Comodoro Ramón Sonzini, Director-General of the Service and Permanent Representative of Argentina with WMO, briefed Prof. Obasi on the most recent developments, mainly those devoted to providing a better service to an extended range of user. Prof. Obasi also visited some of the facilities of the NMS. He had extensive discussions with Comodoro Sonzini on matters relating to the development of the NMS and other matters of mutual interest.

Hong Kong, China

At the invitation of the Governments of China and the United Kingdom, the Secretary-General visited Hong Kong, China from 29 June to 2 July 1997 to attend the handover ceremony of Hong Kong. During the course of the visit, he met with several high-ranking officials of a number of countries and heads of international agencies and exchanged views on matters of mutual interest.

Hong Kong, China, 1 July 1997 — (*From left to right*): Dr M. C. Wong, Dr R. L. Kintanar, Mrs Elaine Koo, Prof. G. O. P. Obasi, Mr E. H. Al-Majed (Director, WMO Regional Office for Asia and South-West Pacific), Dr H. K. Lam (Director, Hong Kong Observatory), Mr K. H. Yeung and Mr C. Y. Lam

He visited the new airport which is under construction, where he was briefed on the equipment that would be installed and the meteorological service that would be provided to civil aviation. Prof. Obasi also visited Hong Kong Observatory and held discussions with Dr H. K. Lam, Director of the Observatory and Permanent Representative of Hong Kong, China with WMO on the future role of the Observatory and its participation in WMO activities.

Staff changes

Departure

On 1 July 1997, Mr **T. Kimura** returned to Japan upon completion of his two-year assignment as Junior Professional Officer in the Satellite Activities Office, World Weather Watch Department. We wish him every success in his future career.

Appointments

On 1 May 1997, Mr **Tommaso Abrate** was appointed Scientific Officer in the Hydrology Division, Hydrology and Water Resources Department. Mr Abrate, who holds a degree in geology and a postgraduate diploma in environmental engineering from the University of Turin, worked as a geologist for two Italian private companies as of 1988. He joined WMO in 1994 as a Junior Professional Officer in the Division for Africa, Technical Cooperation Department.


Tommaso Abrate

On 1 June 1997, Mr **Cyril U. Gwam** was appointed Fellowships Officer in the Fellowships Division, Education and Training Department. Mr Gwam holds an M.Sc. in international relations from the University of Ife, Nigeria. Prior to taking up his duties with WMO, Mr Gwam had worked in the field of training since 1983 both as a civil servant and diplomat with the Government of Nigeria.


Cyril U. Gwam

On 1 June 1997, Dr **Daniel D. C. Don Nanjira** was appointed WMO Representative to the UN and other UN System Organizations in North America under a "loan" arrangement with WHO. Dr Don Nanjira holds an M.A. degree from Warsaw University; an M.Sc. from University College, London; a Ph.D. in development economics, law and the UN System; and diplomas in diplomacy, foreign policy and international relations from John Hopkins University, Washington, DC. Prior to taking up his duties with WMO, Dr Don Nanjira held various diplomatic positions with the Government of Kenya and was actively involved in the United Nations International Decade for Natural Disaster Reduction (IDNDR). He chaired the Preparatory Committee and several other committees relating to the IDNDR Yokohama Conference.


Daniel D.C. Don Nanjira

Anniversaries

Miss **Eliette Tarry**, Administrative Assistant, Education and Training Department, completed 25 years of service on 8 May 1997.

Miss **Anna Morawska**, Senior Secretary, Telecommunications and Monitoring Unit, World Weather Watch Department, completed 20 years of service on 26 June 1997.

Recent WMO publications

Agrometeorology of Grasslands for Middle Latitudes, by A. J. Brereton, S. A. Danielov and D. Scott. WMO-No. 839, Technical Note No. 197 (1996). English. 36 pp. Price: SFR 15.

Livestock production is a major element in the economy of many countries, while meteorological factors greatly influence grass production and grassland productivity and, hence, the quantity, quality and health of grazing animals. Moreover, enormous differences exist in animal production in temperate, subtropical and tropical regions. This Technical Note is the outcome of studies carried out by the authors in their capacity as rapporteurs of the Commission for Agricultural Meteorology. It describes the influence of climate and weather in the development, composition, productivity and utilization and global distribution of both natural rangeland and plantations of grass.

WMO Climatological Normals (CLINO) for the period 1961–1990. WMO-No. 847 (1996). ISBN 92-

63-00847-7. English/French. 768 pp (looseleaf). Price (with binder): SFR 124.

This publication was produced through the Development of Climate Databases Project of the World Climate Data and Monitoring Programme. The National Climatic Data Center, Asheville, North Carolina, USA, undertook the data-collection processing (including basic quality control) and editing, with the assistance of the WMO Secretariat. The volume contains statistical data for nearly 4 000 stations in more than 130 countries on maximum and minimum temperatures and wind speed, as well as atmospheric pressure, mean temperature, sunshine duration, vapour pressure, relative humidity, amount of precipitation, number of days with precipitation and frequency groups of precipitation amount. The data herein form a valuable basis for climate research, monitoring, diagnostic studies and for climate applications and services.

Weather and the Media: a Press Relations Guide. WMO-No. 861 (1997). ISBN 92-63-10861-7. English, French, Russian and Spanish; numerous illustrations in colour; 23 pp. Price: SFR 15.

Over the last few years, within the framework of its Information and Public Affairs Programme, WMO has been placing increasing emphasis on capacity-building efforts, particularly in improving the communications skills of national Meteorological and Hydrological Services (NMHSs) through training activities and by building alliances with the print and broadcast media. The purpose of this booklet is to serve as a practical guide for Information and Public Affairs focal points of the NMHSs of WMO Member countries, as well as for senior WMO staff who may have to deal with representatives of the media in the course of their work.

Corrigendum

Compendium of Education and Training Facilities for Meteorology and Operational Hydrology (seventh edition, 1996). WMO-No. 240. ISBN 92-63-07240-X. English/French/Russian/Spanish. Looseleaf. Price (including supplement service and binder): SFR 60.

The last line of the summary should read: "It is intended to update the publication every other year." (and not "at least twice a year").

Recently issued reports

WMO Annual Report, 1996. WMO-No. 859 (1997). ISBN 92-63-10859-5. English, French, Russian and Spanish. 60 pp. Price: SFR 15.

Commission for Basic Systems—eleventh session (Cairo, 28 October–7 November 1996). WMO-No. 854 (1997). ISBN 92-63-10854-4.

Obituaries

Bernard Lagarde

Bernard Henry Lagarde died on 21 May 1997 after a long illness. Born in Rabat, Morocco, on 30 November 1936, Mr Lagarde distinguished himself during the period of his work with the French National Meteorological Service (1959–1965) for his special technical skills and his particular knowledge of meteorological instruments and equipment, with emphasis on the operation of weather radars and accessory equipment.

This background and his field experience were to prove an asset in the various posts Mr Lagarde occupied in the WMO Secretariat from 1965 to 1992, all within the Technical Cooperation Department and mostly with the development and implementation of technical assistance programmes for Africa. His close working relationships with Members' representatives were appreciated.

Mr Lagarde retired from WMO on 30 June 1992. He is survived by his wife, Anna, and his children, Luc and Lilyane, to whom we extend our sincere condolences. ❒

David Ludlum

The following text is a slightly abridged and modified version of an obituary which appeared in the New York Times *(Ed.).*

David M. Ludlum, the foremost historian of American weather, died from complications of a stroke at his home on 23 May 1997. He was 86.

Long before he was calling the turn of battle in World War II as commander of a US Army Air Forces meteorological unit, David Ludlum was a small boy in East Orange, New Jersey, catching snowflakes on his tongue.

From the beginning, there was a scholarly component to his interest and, with no well-established meteorological career path to follow, Ludlum majored in American history at Princeton, New Jersey, receiving a master's degree from the University of California at Berkeley and then returning to Princeton for his doctorate.

He enlisted in the US Army in January 1941 and used his prerogative as a volunteer to secure a place in a meteorological unit. In 1944, military planners asked him to predict the weather for the assault on Monte Cassino, Italy. Ludlum shook his head so many times at the 5 p.m. briefing that the oft-postponed assault was given the official code name of "Operation Ludlum". On the 21st day, 14 February 1944, Ludlum said "yes".

After the War, Ludlum founded Systems Associates, in Princeton, the nation's first weather instrument sales company. He also founded *Weatherwise* in 1948, a magazine for weather enthusiasts, that is now published by the Heldref Foundation in Washington, DC. ❐

New books received

Gravity Currents in the Environment and the Laboratory (second edition), by J. E. Simpson. Cambridge University Press (1997). xiii + 244 pages; numerous figures and illustrations. ISBN 0-521-56109-4 (h/b). Price: £50/US$ 74.95.

Climate Trend Atlas of Europe—Based on Observations 1891-1990, by C.-D. Schönwiese and J. Rapp. Kluwer Academic Publishers Group, Dordrecht (1997). vii + 288 pages; numerous figures. ISBN 0-7923-4483-9. Price: US$ 112.

The Atmosphere and Ocean—A Physical Introduction (second edition), by Neil Wells. John Wiley & Sons, Chichester (1997). ix + 394 pages; numerous figures and equations. ISBN 0-471-96216-3. Price: £22.50.

Applied Climatology—Principles and Practice. R. D. Thompson and A. Perry (*Eds.*). Routledge, London (1997). xxiii + 352 pages. ISBN 0-415-14100-1 (h/b). Price: £60. ISBN 0-415-14101-X (p/b). Price: £18.99.

Gravity Wave Processes—Their Parameterization in Global Climate Models. NATO ASI Series I: Global Environmental Change, Vol. 50. K. Hamilton (*Ed.*). Springer-Verlag, Heidelberg (1997). viii + 401 pages; numerous figures. ISBN 3-540-62036-2. Price: DM 248.

Hurricanes—Climate and Socioeconomic Impacts. H. F. Diaz and R. G. Pulwarty (*Eds.*). Springer-Verlag, Heidelberg (1997). xii + 292 pages. ISBN 3-540-62078-8. Price: DM 98.

Global Environmental Change—An Atmospheric Perspective, by J. Horel and J. Geisler. John Wiley & Sons, Chichester (1997). viii + 152 pages. ISBN 0-471-13073-7. Price: £10.99.

Antarctic Meteorology and Climatology, by J. C. King and J. Turner. Cambridge University Press (1997). xi + 409 pages; numerous illustrations. ISBN 0-521-46560-5 (h/b). Price: £55/US$ 90.

Images in Weather Forecasting—A Practical Guide for Interpreting Satellite and Radar Imagery. M. J. Bader, G. S. Forbes, J. R. Grant, R. B. E. Lilley and A. J. Waters (*Eds.*). Cambridge University Press (1997). xxiii + 499 pages, numerous figures and illustrations. ISBN 0-521-62915-2 (p/b). Price: £35/US$ 59.95. ISBN 0-521-45111-6 (h/b). Price: £85/US$ 140.

Subsurface Hydrological Responses to Land Cover and Land Use Changes, by Makoto Taniguchi. Kluwer Academic Publishers, Dordrecht (1997). iii + 226 pages; numerous figures. ISBN 0-7923-9931-5. Price: US$ 125.

Scientific, Environmental and Political Issues in the Circum-Caspian Region. NATO ASI Series 2: Environment, Vol. 29. M. H. Glantz and I. S. Zonn (*Eds.*). Kluwer Academic Publishers Group, Dordrecht (1997). xvi + 312 pages. ISBN 0-7923-4626-2. Price: US$ 175.

Integrated Approach to Environmental Data Management Systems. NATO ASI Series 2: Environment, Vol. 31. N. B. Harmancioglu, M. Necdet Alpaslan, S.D. Ozkul and V.P. Singh (*Eds.*). Kluwer Academic Publishers Group, Dordrecht (1997). viii + 546 pages; numerous figures. ISBN 0-7923-4671-8. Price: US$ 227.

Reviews

Air Pollution IV: Monitoring, Simulation and Control. B. Caussade, H. Power and C. A. Brebbia (*Eds*.). Computational Mechanics Publications, Southampton (1996). 888 pages; numerous figures. ISBN 1-85312-422-2. Price: £245/US$ 368.

This 888-page (six-cm thick) hardcover book contains papers presented at the Fourth International Conference on Air Pollution, organized by the Wessex Institute of Technology of Southampton, United Kingdom, and held in Toulouse, France, from 28 to 30 August 1996. This volume continues a series of conference proceedings published by Computational Mechanics Publications. It is important to note that the individual papers were typeset by their authors and reproduced directly.

Until about 10 years ago, conference proceedings were considered "grey literature" and were usually distributed with soft covers. The papers were unreviewed, but were distributed because they reflected up-to-date status reports on ongoing research. If warranted, some of the papers were ultimately expanded and rewritten and submitted to refereed journals. Recently, there has been a trend, encouraged by for-profit publishers, to package these same types of conference papers in a nice glossy hardcover book and offer it for sale for about US$ 100 per volume. But the problem is, as demonstrated by the current book, the quality of many of the papers is still substandard, due to the lack of an adequate peer-review process.

This volume has all the good points and bad points of a conference proceedings. On the good side, there is a comprehensive representation of the types of work ongoing in the fields of air pollution monitoring, simulation, and control. A wide range of topics is covered, including emissions studies, control strategies and equipment, observations of air quality (instruments, analysis methods, and results), models (new and old types, applications), statistical methods, health effects, chemistry, fluid modelling, and deposition. Authors from 25 countries are represented and the observations and applications deal with most continents. On the bad side, the technical quality of the papers is spotty and there are many problems with figures and tables.

An analysis of the papers and their authors reveals that 31 of the 88 papers were authored by members of the local organizing committee or the scientific advisory committee. One member of the scientific advisory committee, Dr Longhurst of Manchester Metropolitan University, co-authored nine papers, which must put him in contention for the record for most papers co-authored at a single conference. Not surprisingly, well over half of the papers were from France (where the conference was held) and adjacent countries. It was disappointing to find that no papers at this "international conference" were given by researchers from India, China, Japan or Korea (one paper was from Hong Kong).

Since my expertise is in the area of air-quality modelling, I was naturally drawn to the papers on that topic. Dr Moussiopoulos gave a clear and comprehensive summary of the needs and trends in air pollution modelling. Dr Carmichael and his colleagues presented an excellent paper on the use of the new automatic differentiation method to carry out sensitivity analyses for air quality models. Dozens of other papers covered many interesting applications of models and many results of field observation programs in about 20 countries.

Several sessions were devoted to emissions and to pollution engineering and management. The emissions inventory determinations are important since all modelling predictions are proportional to the emission rate. Also, innovative new chemical analysis methods are being used to assess the possible contributors to observed concentrations at remote sites (e.g. Bylinska's analysis of data from Sudety Mountain in Poland).

It appears that authors were instructed to limit the length of their papers to 10 pages. This led to some ill-advised attempts to squeeze as many figures as possible on a single page. As perhaps the worst example of this practice, Fassi-Fihri *et al.* imbed 11 tiny figures with entirely illegible axes and legends within a larger figure (I could not read them even with a magnifying glass). The runners-up for most illegible figure are Cremades *et al.*, who attempt to present four detailed three-dimensional views on a half-page. The grey scales and legends are illegible. About one-quarter of the figures in the book suffer from these illegibility problems or from inadequate legends, axis labels, and captions, which should have been resolved by the editors prior to publication.

In conclusion, I feel that the book is useful as a grey-literature conference proceedings, accepting all the positive and negative aspects of those publications. However, I am concerned about the recent trend where glossy hard covers are put on these grey-literature reports with little attention paid to technical peer review or to standards for important details such as figures.

S. Hanna

Forecasts for Flying: Meteorology in Canada 1918–1939, by M. Thomas. ECW Press, Toronto (1996). ISBN 1-55022-303-8. 264 pages. Price: Can$ 14.95.

The title of this highly informative and delightful story of the growth of weather services in Canada reflects the critical importance of flying as the major patron of weather information in the development of Canadian society. Although this development came somewhat later than it did in the Big Neighbour to the south, it parallels US experience closely in building an aviation weather service. Morley Thomas tells the story in its most practical terms, highlighting the personalities who were central to this development, and sparing no criticism of bureaucracy's slow response to this new infant in the growing family of government services. His meticulous notes on every important development makes this book a valuable historic reference to the growth of meteorological services in a major "developing" country.

Until civil flying became a practical public service in Canada, it looked as though the needs of its vast forests would become the primary focus for the public weather service. But, as in Europe and elsewhere, the focus of aviation demands, greatly stimulated by wartime needs, quickly shifted to the safety of the more glamorous fledgling transport system. It is surprising to note, however, that, until after World War I, no Canadian government agency had responsibility for support to aviation. Hence there was little hope at that time of giving this new activity any specialized weather services beyond the daily weather maps already available to the general public. This situation continued even during Canada's involvement in World War I and its extensive training programmes for the United Kingdom's military needs.

Although a meagre weather service was "ordained" as early as 1871, the staff at the Toronto Central Office (the major facility of the Service) had grown to only 20 persons by the first decade of the 20th century. One of the first employees was Frederic Stupart, who joined as a map plotter in 1872. He became Director in 1894 and served in that capacity until 1929. He was the only Canadian Director to be awarded a knighthood by the Queen of England for his services to the Dominion of Canada.

The appointment of Dr John Patterson in 1929 to replace Sir Frederic brought a new direction to the Service. For many years, Dr Patterson was the only fully qualified scientific officer. Recognizing this serious deficiency, the Service encouraged the University of Toronto to begin Masters courses in meteorology starting in the 1933/1934 academic year. Patterson was a mathematics and physics major and stressed the need for a scientific background for all his principal officers. Most subsequent Directors had followed these courses and their academic qualifications assured the sound future development of the Service.

One of the advantages of Thomas's book is the details of staff members of the early period and the dates of opening of the new Service's offices. A valuable impression of the Service is given by the historical photographs of both offices and staff, including such well-known officials as Dr Andrew Thompson (a close colleague of the Chief of the US Weather Bureau) and Dr P. D. McTaggart-Cowan. The description of the early trans-Atlantic air services is a particularly useful record of these historic events in the beginnings of international aviation, which set precedents incorporated in the standards and practices adopted by the International Civil Aviation Organization (ICAO) a decade later.

The impact on the Meteorological Service of a trans-Canadian air-route system parallels in many aspects the similar struggles that had taken place a decade or so earlier in the USA and emphasizes the fundamental part aviation has had—and still has—in spreading meteorological services around the globe. The building of the AlCan Highway by the USA at the beginning of World War II provided not only vital landing fields for military flights to Alaska and Siberia, but also ideal locations for aviation observing stations. On this point, it would have been useful to have had more maps showing the locations of the offices that took part in these developments.

Of the Directors who followed Patterson, Dr Andrew Thompson was a particularly close colleague of the Chief of the US Weather Bureau, Dr Francis W. Reichelderfer. Similarly, Pat McTaggart-Cowan became well known in the USA for his pioneering work in developing the essential weather support for trans-Atlantic aviation, and particularly the great military air-ferry service that grew up around the Gander (Newfoundland) facility at the beginning of World War II. In the final chapter, Thomas says: "The remarkable developments of Canadian meteorology in World War II must be dealt with in another book." After reading Thomas's fascinating stories of the early years, one would hope that he might find time to take up that story as well.

An interesting aspect of Thomas's story is his accounts of the participation of the Canadian Meteorological Service in international developments. Stupart seemed to be well aware of the importance of such developments for his own Service. In fact, he seemed to seek closer contacts with the British Met Office than with the Americans and attended the early meetings of the International Meteorological Committee (IMC), a body formed under the aegis of the League of Nations in Europe. Even as early as the First Polar Year, 1882–1883, Canada was asked by the IMC to set up a station to the north of Hudson Bay. Lacking the necessary financial resources, it contributed instruments and special equipment to a British Station at Fort Rae. When the Second Polar Year was being organized in 1932–1933, Dr Patterson was a member of the Organizing Committee and ensured full Canadian participation.

More than half a century earlier, the Canadian Director had been invited to take part in the first meeting of the IMC of the International Meteorological Organization ((IMO), the predecessor of WMO) in Vienna in 1873 but declined because of "more urgent duties in Canada". Nevertheless, the Service did follow as far as possible the recommendations arising from that meeting. In 1896, Stupart was the first Director to attend a meeting of the IMO Conference of Directors and was subsequently elected as a member of the IMC. Thomas notes that in 1919, the League of Nations set up the International Commission for Aerial Navigation (ICAN) to regulate civil aviation. In the same year, the International Union of Geodesy and Geophysics was established, with an Association for Meteorology. These events created some uneasiness in the new IMO that other bodies would undercut its responsibilities for coordinating the work of meteorological services, a concern that is as alive today as it was nearly a century ago.

G. D. Cartwright

CALENDAR OF COMING EVENTS

(sessions to be held in Geneva, Switzerland, unless otherwise stated)

1997

4–7 November	**CAgM Advisory Working Group**
4–8 November	**Second Technical Conference on Management of Meteorological/Hydrometeorological Services in Asia *(Macao)***
10–14 November	**International Course on Sedimentology in Fluvial Streams *(Montevideo, Uruguay)***
10–14 November	**CBS Working Group on Data-processing—ninth session**
10–14 November	**Training Seminar/Workshop on User Requirements for Agrometeorological Services *(Pune, India)***
11–14 November	**Third International Conference on the Mediterranean Coastal Environment (MEDCOAST 97) *(Qawra, Malta)***
11–15 November	**International Symposium on "Hydrometeorology Science and Practice—Present and Future" and exhibition "Hydrometeorology and Man" *(St. Petersburg, Russian Federation)***
23–29 November	**Fourth Meteorological Conference for Eastern and Southern Africa *(Kampala, Uganda)***
24–27 November	**International Seminar on Climate and Hydrological Effects of the El Niño/Southern Oscillation (ENSO) Events at the Regional and Local Scales *(Quito, Ecuador)***
25 Nov.–1 Dec.	**ESCAP/WMO Typhoon Committee—thirtieth session *(Hong Kong, China)***
1–5 December	**CHy Advisory Working Group**
2–5 December	**International Symposium on Asian Monsoons and Pollution over Monsoon Environment *(New Delhi, India)***
3–5 December	**GAW Operations Support Group *(Zurich, Switzerland)***
16–19 December	**International Expert Meeting on the Participation of Women in Meteorology and Hydrology *(Bangkok, Thailand)***
17–18 December	**Kyoto and Beyond: Climate Change Policy Moves to Center Stage. Center for Environmental Information, Inc., thirteenth annual conference *(Washington, DC, USA)***

1998

23 Feb.–4 March	**Commission for Atmospheric Sciences—twelfth session *(Skopje, The Former Yugoslav Republic of Macedonia)***
24 Feb.–2 March	**WMO/ESCAP Panel on Tropical Cyclones—twenty-fifth session *(Dhaka, Bangladesh)***

MEMBERS OF THE WORLD METEOROLOGICAL ORGANIZATION*

STATES (179)

Afghanistan, Islamic State of
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
Kazakstan
Kenya
Kuwait
Kyrgyz Republic
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
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, Socialist Republic of
Western Samoa
Yemen
Yugoslavia
Zambia
Zimbabwe

TERRITORIES (6)

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

* On 15 August 1997

WMO BULLETIN—VOLUME 46 (1997)

INDEX

Items of general interest

News from the Secretariat

Obituaries

Reports of special meetings

Reviews

Technical cooperation

WMO programme news

Aeronautical meteorology

Agricultural meteorology

Atmospheric Environment and Research Programme

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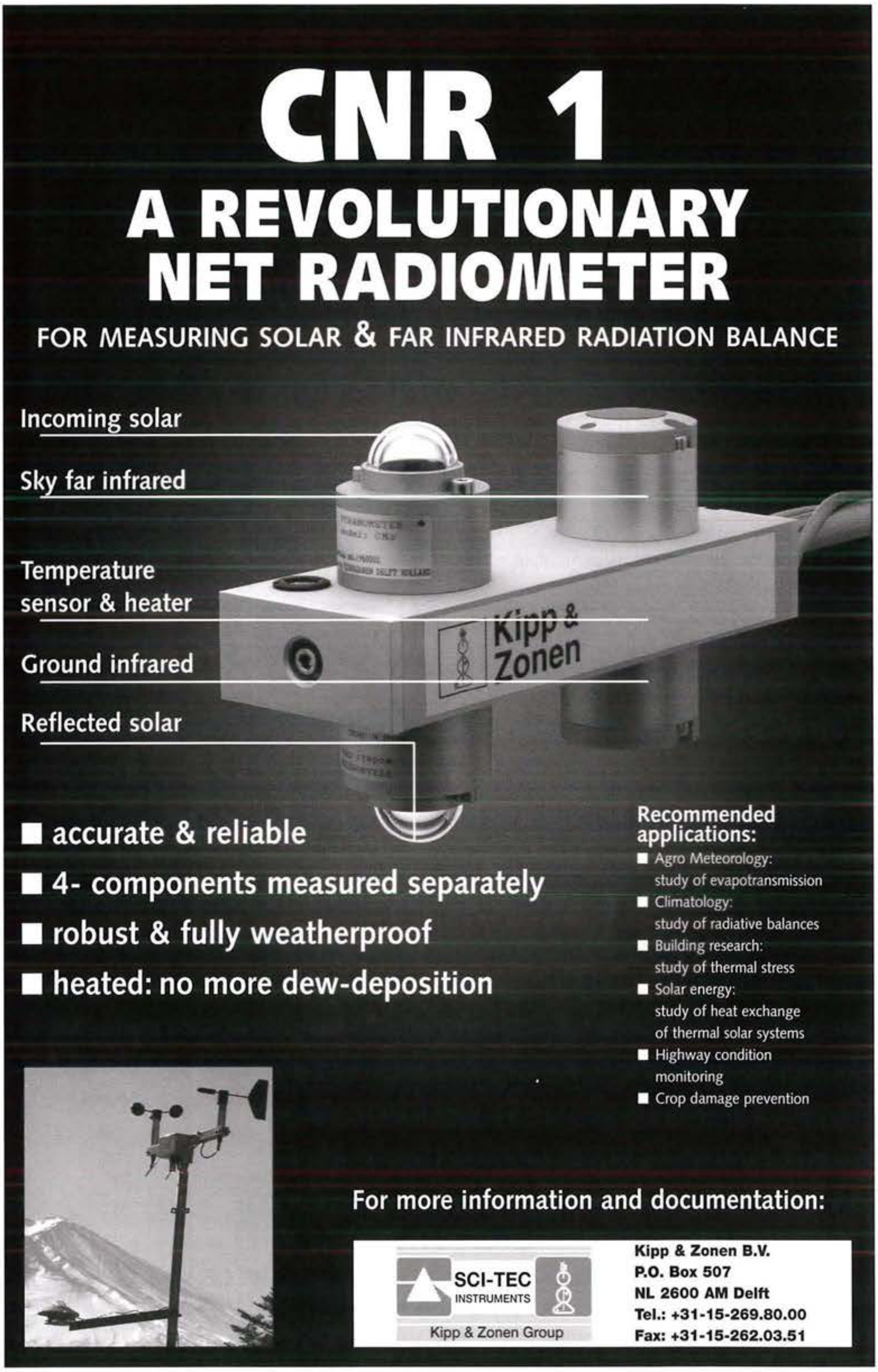
CNR 1
A REVOLUTIONARY NET RADIOMETER
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Temperature sensor & heater
Ground infrared
Reflected solar
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■ accurate & reliable
■ 4- components measured separately
■ robust & fully weatherproof
■ heated: no more dew-deposition
Recommended applications:
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■ Climatology: study of radiative balances
■ Building research: study of thermal stress
■ Solar energy: study of heat exchange of thermal solar systems
■ Highway condition monitoring
■ Crop damage prevention
For more information and documentation:
SCI-TEC INSTRUMENTS
Kipp & Zonen Group
Kipp & Zonen B.V.
P.O. Box 507
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Low Cost Atmospheric Measurements in the Palm of Your Hand

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MICROTOPS II delivers accurate readings at the touch of a button. Just aim the meter at the sun; align its image in the cross-hairs; and push the button.

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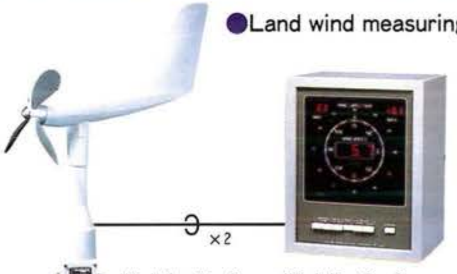
E-MAIL: info@solar.com • WWW: http://www.solar.com

Weather Observation System (Wind)

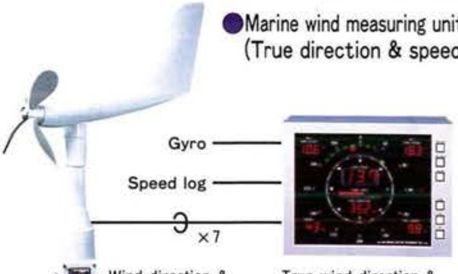
●Land wind measuring unit



Wind direction & speed sensor

Wind direction & speed indicator

●Marine wind measuring unit (True direction & speed)



Wind direction & speed sensor

True wind direction & speed indicator

SPECIFICATION

Wind Speed: Optical encoder, Resolution 0.1m/s
Wind Direction: Optical encoder, Resolution 360°/256, Fluctuating width 36 directions
Sampling Rate: 0.25sec
Threshold Speed: Less than 0.4m/s
Withstand Speed: 110m/s
Range: 0.5~90m/s, 360°
Accuracy: Speed Less than 10m/s ±0.3m/s
Over 10m/s ±3%
Direction ±3°
Weight: Sensor 5kg, indicator 4.8kg

Wind Speed: AC power generating type
Wind Direction: DC selsyn(Standard)
Vessel Speed: Electro magnetic log(0.1~60kt)
Course: Gyro compass(36bearings-360°)
Range: 1~90m/s or 2~175kt, 360°
Accuracy: Speed Less than 10m/s ±0.5m/s
Over 10m/s ±5%
Direction ±5°
Threshold Speed: 1m/s
Withstand Speed: 110m/s
Weight: Sensor 5.5kg, indicator 5kg

NEI
Automatic Weather Observation System

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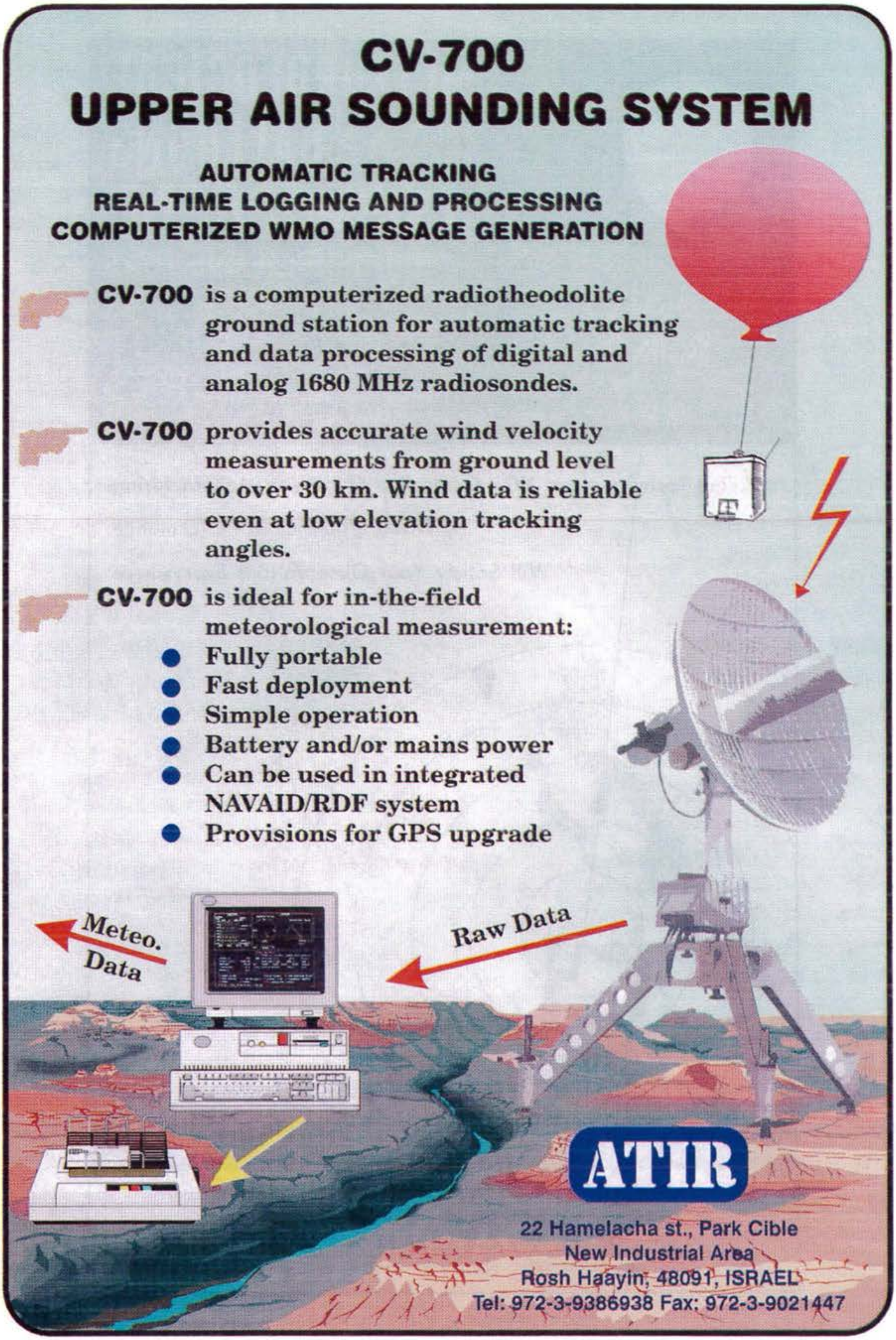
4-9, KAMINOGE 2-CHOME, SETAGAYA-KU, TOKYO, JAPAN 158

TEL 81-3-5707-8251 FAX 81-3-5707-8261


CV-700
UPPER AIR SOUNDING SYSTEM
AUTOMATIC TRACKING
REAL-TIME LOGGING AND PROCESSING
COMPUTERIZED WMO MESSAGE GENERATION
CV-700 is a computerized radiotheodolite ground station for automatic tracking and data processing of digital and analog 1680 MHz radiosondes.
CV-700 provides accurate wind velocity measurements from ground level to over 30 km. Wind data is reliable even at low elevation tracking angles.
CV-700 is ideal for in-the-field meteorological measurement:
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Fast deployment
Simple operation
Battery and/or mains power
Can be used in integrated NAVAID/RDF system
Provisions for GPS upgrade
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Raw Data
ATIR
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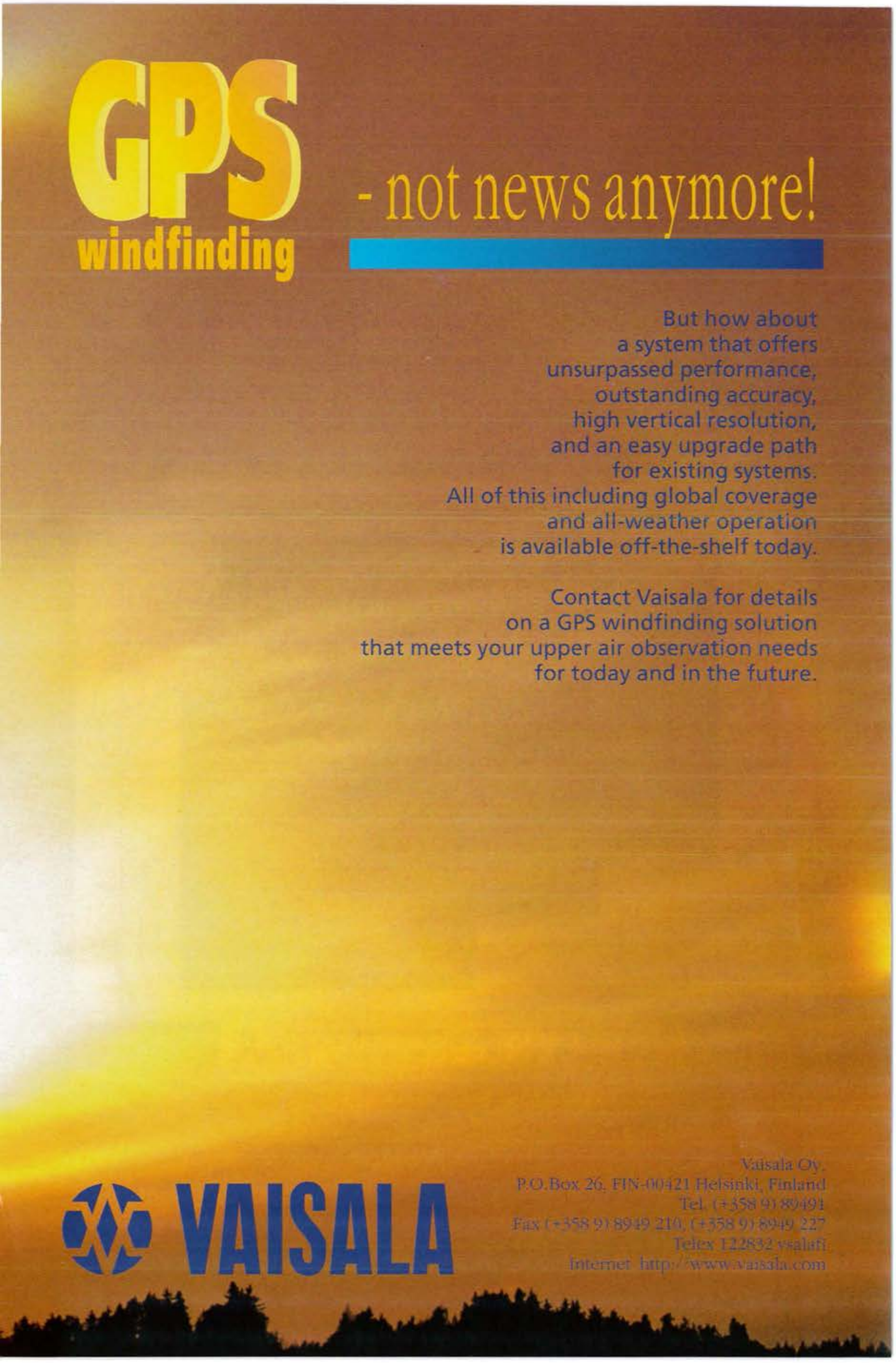
New Industrial Area
Rosh Haayin, 48091, ISRAEL
Tel: 972-3-9386938 Fax: 972-3-9021447



GPS
windfinding
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Internet http://www.vaisala.com

ABBREVIATIONS USED IN THE WMO BULLETIN

ACCAD Advisory Committee on Climate Applications and Data (CCl)
ACMAD African Centre of Meteorological Applications for Development
AGRHYMET Agrometeorology and operational hydrology and their applications
AREP Atmospheric Research and Environment Programme (WMO)
BAPMoN Background Air Pollution Monitoring Network (WMO)
CAeM Commission for Aeronautical Meteorology (WMO)
CAgM Commission for Agricultural Meteorology (WMO)
CAL Computer-aided learning
CAS Commission for Atmospheric Sciences (WMO)
CBS Commission for Basic Systems (WMO)
CCCO Committee on Climate Changes and the Ocean (SCOR/IOC)
CCD Convention to Combat Desertification
CCl Commission for Climatology (WMO)
CCWCP Coordinating Committee for the World Climate Programme
CHy Commission for Hydrology (WMO)
CILSS Permanent Inter-State Committee for Drought Control in the Sahel
CIMO Commission for Instruments and Methods of Observation (WMO)
CLICOM Climate computing (WMO)
CMM Commission for Marine Meteorology (WMO)
COARE Coupled Ocean–Atmosphere Response Experiment
COSPAR Committee for Space Research (ICSU)
CSD Commission on Sustainable Development
DCP Data-collection platform
DCS Data-collection system
DRS DCP retransmission system
ECMWF European Centre for Medium Range Weather Forecasts
ENSO *EL Niño*/Southern Oscillation
ESA European Space Agency
ESCAP Economic and Social Commission for Asia and the Pacific (UN)
ETR Education and Training (WMO)
FAO Food and Agriculture Organization of the United Nations
FCCC Framework Convention on Climate Change (UN)
GAW Global Atmosphere Watch (WMO)
GCIP GEWEX Continental-scale International Project (WCRP)
GCOS Global Climate Observing System (WMO/IOC/ICSU/UNEP)
GDPS Global Data-processing System (WWW/WMO)
GEF Global Environment Facility
GEWEX Global Energy and Water Cycle Experiment (WCRP)
GOOS Global Ocean Observing System (IOC/WMO/ICSU/UNEP)
GOS Global Observing System (WWW/WMO)
GTS Global Telecommunication System (WWW/WMO)
HOMS Hydrological Operational Multipurpose System (WMO)
HWR Hydrology and Water Resources (WMO)
IAEA International Atomic Energy Agency
IAHS International Association of Hydrological Sciences (IUGG)
IAMAS International Association of Meteorology and Atmospheric Sciences (IUGG)
IAPSO International Association for the Physical Sciences of the Ocean (IUGG)
IATA International Air Transport Association
ICAO International Civil Aviation Organization
ICSU International Council of Scientific Unions
IDNDR International Decade for Natural Disaster Reduction (UN)
IFAD International Fund for Agricultural Development (UN)
IGBP International Geosphere–Biosphere Programme (ICSU)
IGOSS Integrated Global Ocean Services System (IOC/WMO)
IGU International Geographical Union (ICSU)
IHP International Hydrological Programme (UNESCO)
IIASA International Institute for Applied Systems Analysis
IMO International Maritime Organization
IMO International Meteorological Organization (predecessor of WMO)
IOC Intergovernmental Oceanographic Commission (UNESCO)
IPCC Intergovernmental Panel on Climate Change (WMO/UNEP)
ISO International Organization for Standardization
ITU International Telecommunication Union
IUGG International Union of Geodesy and Geophysics (ICSU)
JSC Joint Scientific Committee for the WCRP (WMO/ICSU)
MDD Meteorological data distribution (METEOSAT)
NASA National Aeronautics and Space Administration (USA)
NIS Newly Independent States
NMC National Meteorological Centre (WWW)
NOAA National Oceanic and Atmospheric Administration (USA)
NWP Numerical weather prediction
OHP Operational Hydrology Programme (WMO)
RMC Regional Meteorological Centre (WWW)
RMTC Regional Meteorological Training Centre (WMO)
RSMC Regional Specialized Meteorological Centre (WWW)
RTH Regional Telecommunication Hub (WWW)
SADC Southern African Development Community
SCAR Scientific Committee on Antarctic Research (ICSU)
SCOPE Scientific Committee on Problems of the Environment (ICSU)
SCOR Scientific Committee on Oceanic Research (ICSU)
SCOSTEP Scientific Committee on Solar-Terrestrial Physics (ICSU)
SPARC Stratospheric Processes and their Role in Climate (WCRP)
STEND System for Technology Exchange for Natural Disasters (WMO)
TCP Tropical Cyclone Programme (WMO)
TOGA Tropical Ocean–Global Atmosphere programme (WCRP)
TRUCE Tropical Urban Climate Experiment
UNCED United Nations Conference on Environment and Development (Brazil, 1992)
UNDP United Nations Development Programme
UNEP United Nations Environment Programme
UNESCO United Nations Educational, Scientific and Cultural Organization
VCP Voluntary Cooperation Programme (WMO)
WAFS World Area Forecast System
WCASP World Climate Applications and Services Programme (WMO)
WCDMP World Climate Data and Monitoring Programme (WMO)
WCIRP World Climate Impact Assessment and Response Strategies Programme (WMO)
WCP World Climate Programme (WMO)
WCRP World Climate Research Programme (WMO/ICSU)
WFC World Food Council (UN)
WHO World Health Organization
WHYCOS World Hydrological Cycle Observing System
WMC World Meteorological Centre (WWW)
WOCE World Ocean Circulation Experiment (WCRP)
WTO World Tourism Organization
WWW World Weather Watch (WMO)