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THE NEW WORLD WEATHER WATCH

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Introduction

Meteorology provides one of the finest examples of effective international cooperation, driven as it is by technical enterprise and scientific ideals and relatively free from political disputation.

The World Meteorological Organization (WMO) is arguably the most cost effective of the UN Specialised Agencies and the World Weather Watch (WWW) is WMO's most important program.

In recent years however there have been increasing signs of tension, all of which have common roots. Who gains? Who loses? Who pays? Unless these problems are treated sensitively, and in a constructive spirit of compromise and goodwill, they could shake the foundations of the WWW.

In this address I will trace the development of WMO itself and of the WWW. I will give particular attention to the role of the WMO Commission for Basic Systems (CBS) which carries the responsibility for the operation of the WWW.

This will provide the backdrop against which to consider the emerging problems relating to:

- possible conflicts arising from incompatibility between the principle of free exchange of meteorological information between Members of WMO and the growing commercial activities of meteorological consultants and of National Meteorological Services themselves;
- measures to ensure the effective continuation and development of meteorological satellite systems;
- the operation and funding of other WWW systems (particularly observing systems) which are global or regional in nature (for example, drifting buoy networks, automated observing systems on aircraft (ASDAR, ACARS), and the automated shipboard aerological programme (ASAP);
- the operation and funding of systems for the collection of observations through satellite systems such as INMARSAT to prevent a disproportionate financial load falling upon some countries;
- difficulties in establishing and maintaining the most effective system of global and regional centres for analysis and prediction on global and regional scales;
- difficulties in integrating the WWW with other operational and research programs, in particular the World Area Forecast System (WAFS) for aviation and the Integrated Global Ocean Services System (IGOSS);
- the gulf between the technological and financial capabilities of developed and developing countries.

The plan for the new WWW as developed by CBS follows the ideals built up over more than a century in the international meteorological community. The spirit is still there. Each Member will contribute according to its capacity to do so and all Members will work towards the common good. The development will be based, as it always has been, on scientific endeavour and technological innovation. Major thrusts of the new WWW are expected to be:

- a continuation of the revolutionary development of satellites for the acquisition of observations and for communications;
- faster and more efficient communications;
- faster and more sophisticated computers and numerical prediction models;
- innovative concepts of data processing and data management.

But how will some of the new data management concepts sit with the traditional concepts of free exchange of information and the emerging commercialism?

The origins of WMO

It is interesting and instructive to look at the origins of the WMO because the basic reasons for its formation are still as valid today as they were in the earlier years. The forces that moulded WMO also inevitably led to the development of the WWW.

Over the years there has been an ever increasing demand for bigger and better meteorological services. The demands are insatiable because achievements in meeting them only serve to open up new applications for weather information and new horizons for weather predictions. We are spurred on to produce more precise, more accurate and longer range forecasts.

As we move forward striving to meet the demands, science and technology open up the avenues and provide the bricks with which to build the achievements. But if science and technology provide the bricks then it is international cooperation that provides the mortar. That was true 100 years ago and it continues to be true. Solutions will be found to the gathering problems and WMO and WWW will continue to prosper.

In the middle of the 19th century the time was ripe for the development of meteorological services to provide forecasts and warnings on an operational basis. The demand was there and growing and the invention and practical introduction of the telegraph in North America and Europe in the 1840s provided the means.

Safety of ships at sea was the driving force that led to the establishment of meteorological services. Two events were of particular significance:

1853 meeting of representatives of maritime countries in Brussels, to set up an international program for meteorological observations by ships at sea.

1854 (November 14th) a disastrous storm in the Black Sea which caused heavy losses to the Anglo-French fleet.

A detailed study was commissioned by Napoleon III to see whether the storm could have been forecast and the losses averted had there been a weather forecast service based on telegraphed reports. The answer from the famous French astronomer Leverrier was – Yes!

Thus the disaster in the Black Sea and the invention of the telegraph led to the establishment of official meteorological services in a number of countries including England in 1861, France in 1863 and Norway in 1866 and of a skeleton system for the exchange of observations and forecasts within Europe. It wasn't long before a network of storm warning stations in the British Isles was linked to the European network and the development of the system, which was later to be called the WWW, had begun.

By 1873 a number of meteorological services had been established and their Directors met at Utrecht in the Netherlands to found the International Meteorological Organization (IMO), the forerunner of WMO.

IMO developed steadily and initially concentrated on improving services provided by meteorologists for shipping and agriculture. In the years leading up to the Second World War, meteorological services began growing at a quickening pace. The development of aviation provided the spur and technology in the form of radio communication provided the means. IMO built up a system of Regional Commissions, Technical Commissions and Working Groups which provided the framework for a similar system which exists in WMO today.

During the war operational meteorology matured and its benefits became universally recognised. Technology and science were providing better 'bricks' and after the war the political climate was better than ever before to make the 'mortar' of international cooperation.

In 1947 Directors of National Meteorological Services met in Washington and drew up and adopted a World Meteorological Convention which provided for the transformation of IMO into a new World Meteorological Organization (WMO). The Convention came into force on the 23rd March 1950 (now celebrated as World Meteorological Day) and the first 44 Members opened their first Congress in Paris on 19 March 1951. We are now looking forward to the tenth Congress in 1987. Group Captain H.N. Warren, then Director of the Australian Meteorological Services was the chairman of the committee which drafted the Convention.

Given the tyranny of distance Australian participation in IMO was remarkable as is evident from the following extract from the Bureau of Meteorology brochure 'Australia's Role in International Meteorology'.

> *Australia and IMO*
>
> The first delegate from an Australian colony to an International Meteorological Conference was Clement Wragge. He attended the Conferences in Munich in 1891 and in Paris in 1896.
>
> Two other Australian meteorologists were also active in IMO affairs before 1908, though there is no record of them actually attending meetings. However, in those days, much of the work of the Organization was carried out by correspondence. R.L.J. Ellery of Victoria was a member of the International Meteorological Committee of IMO from 1891/1896 and R.C. Russell of NSW from 1896/1907.
>
> In 1919 the Commonwealth Meteorologist, H.A. Hunt attended the 4th International Conference of Directors in Paris. At the 1935 Warsaw Conference of Directors, Australia was represented by W.B. Watt, who also took part in the IMO Commission for Synoptic Weather Information.
>
> In 1936 the meeting of the IMO Regional Commission No. II (Far East) in Hong Kong was attended by

Mr E.W. Timcke. Watt, as Commonwealth Meteorologist, also took part in the Meteorological Conference for the South West Pacific in Wellington in 1937.

At the postwar Extraordinary Conference of Directors in London in 1946, Australia's representative was Group Captain H.N. Warren. He also attended the Conference of Directors in Washington in 1947 and the meetings of Regional Commission V (South West Pacific) in Melbourne in 1947 and Wellington in 1948.

W.A. Dwyer was a guest Observer and Advisor at the R.C. II meeting in New Delhi in 1948, and the Australian delegate to the session of the Commission for Aeronautical Meteorology in Paris in 1950. The final IMO Extraordinary Conference of Directors in Paris in 1951 was attended by E.W. Timcke.

Dr W.J. Gibbs, Director of Meteorology from 1962-1978, was a delegate to the meeting of the Regional Commission V in Wellington in 1948, and accompanied H.N. Warren to the meeting of the IMO Technical Commission in Toronto and the IMO Conference of Directors in Washington in 1947.

The origins of the WWW

The coming of the telegraph provided the technological drive for the formation of National Meteorological Services in the 1860s. In like manner, it was the advent of satellite technology which gave rise to the WWW one hundred years later.

The first satellite was launched by the USSR on 4 October 1957. One cannot help but be impressed by the speed with which WMO and the meteorological community reacted to this development and the new horizons that had suddenly been opened up. Here are a few dates:

1958 WMO Executive Committee (EC) adopts a resolution on the WMO contribution to the exploration of the atmosphere by means of satellites.

1959 WMO EC establishes a Panel of Experts on Artificial Satellites to study the feasibility of using satellites for meteorological purposes (V.A. Bugaev (USSR), H. Wexler (USA), W. Gibbs (Australia as CSM representative) and G. Robinson (CAeM representative)).

1961 20 December. The General Assembly of the United Nations adopts Resolution 1721 (XVI) 'International Cooperation in the Peaceful Uses of Outer Space'. In Section C of the Resolution it was stated that, thanks to the advances in outer space exploration, new opportunities arose in meteorology for improving the existing methods of weather prediction. It was recommended that WMO, in consultation with other international organisations and agencies, should prepare a report and submit proposals on the problem.

1961 At the invitation of WMO, Dr H. Wexler and Academician V. Bugaev met in Geneva to develop the WWW concept. (The title of the new system World Weather Watch (WWW) was coined by Dr Wexler.)

1962 The famous WMO First Report on the advancement of atmospheric sciences and their application in the light of developments in outer space.

1962 'First Report' considered by the EC Panel (Wexler, Bugaev, Gibbs, Robinson) and representatives of other international organisations (including UNESCO, ITU, ICAO, IAEA, ICSU) and approved by the WMO EC. The First Report was approved by the Seventeenth General Assembly of the United Nations and resulted in Resolution 1802 (XVII) calling for more detailed planning of WWW developments.

1963 WMO Fourth Congress adopts the concept of the WWW.

If the prompt reaction of the meteorological community was impressive then the vision of the plans was even more so. The following papers presented to the 24th Session of the WMO Executive Committee in 1972 to mark the 10th Anniversary of WWW, make very interesting reading.

'The origin of the World Weather Watch and its future prospects' – V.A. Bugaev.

'The impact of outer space technology on developments in meteorology' – S. Johnson.

'Numerical weather prediction within World Weather Watch – Past, present and future' – J.S. Sawyer.

Bugaev reviewed the success of the WWW but pointed to a number of problems that needed to be resolved and the important role that the Global Atmospheric Research Programme (GARP) might play in resolving them – what form should the observational system take, what degree of accuracy is required for the initial data, the use of non-synchronous data and the necessity for synchronous observations, the need to devise uniform methods of objective analysis and select a number of models of the atmosphere for operational numerical weather prediction, etc. Johnson analysed the 'First Report' and found that the expectations were, in general, conservative. In regard to satellites the 'First Report' accurately predicted:

- the application of images of clouds and the Earth's surface;
- the possibility of infrared observations at night;
- the determination of the extent of snow and ice fields;
- the continuing role of satellite measurements of incoming and outgoing planetary radiation in studies of climate;
- the determination of vertical profiles of ozone in the upper atmosphere;
- the use of satellites for meteorological communications (but the application of satellites for locating moving platforms (buoys etc.) was not anticipated).

On the other hand the 'First Report':

- did not refer to the possible use of geostationary satellites to obtain frequent cloud images;
- made a forecast of satellite-borne radar for precipitation observation which has not yet materialised;
- foreshadowed systems for observing thunderstorms by lightning flashes at night or by atmospherics which have not been developed and mentioned some expectation of measurement of surface pressures.

The 'First Report' was given a 'low score' for not predicting the spectacular development of methods for obtaining atmospheric soundings nor the derivation of wind measurements from geostationary satellite cloud images.

Johnson was courageous enough to make the following predictions of the role of meteorological satellites in 1982:

- four or five geostationary satellites and two polar-orbiting satellites will be in use;
- temperature soundings will have replaced radiosondes, except for special local and regional applications;
- hourly soundings will be made from geostationary satellites;
- winds will be automatically derived from cloud displacements;
- three-dimensional cloud analyses will be automated;
- the introduction of new technology for processing, interpreting, disseminating and displaying meteorological data to a variety of users, not the expected advancement in space techniques, holds the key for the largest improvements by 1982;
- significant investments by user nations in specialised training and new technology will be necessary if these nations are to realize the benefits of the satellites of 1982.

I would give both the 'First Report' and Johnson high marks. It would take considerable courage to attempt to predict the development of satellite meteorology in the next 10 years given the explosive development that is taking place. Johnson was able to look at his 'predictions' some ten years later when he produced *Twentieth Anniversary of the World Weather Watch: Opportunities and Outlook for an improved WWW* in 1983.

Sawyer's paper dealt with the other major development which had been given considerable emphasis by the architects of the WWW – computers and numerical analysis and prediction. He traced the history from the pioneering work of Richardson and Charney, Fjortoft, and von Neumann to the stage where in 1972, numerical forecasts of the pressure field for 24 hours or longer from primitive equation models were held by many to be as good as or better than forecasts produced by subjective methods.

In foreshadowing future developments Sawyer gave emphasis to:

- the possible improvements in predictability over periods of two to three weeks;
- the use of smaller mesh-lengths in models particularly for the prediction of weather phenomena within the planetary boundary layer and proper treatment of orographic effects.

The structure of the WWW

The basic structure of the WWW, as devised by its architects in 1962, remained relatively unchanged until 1985. The main components were the Global Observing System (GOS), the Global Telecommunication System (GTS) and the Global Data Processing System (GDPS).

Apart from the satellites the GOS was composed mainly of national surface and upper air networks. Observations from ships and aircraft were also important.

The GDPS was a three-tiered structure composed of three World Meteorological Centres (WMCs) (Melbourne, Moscow, Washington), and a number of Regional Meteorological Centres (RMCs) and National Meteorological Centres (NMCs).

The concept was that WMCs would provide meteorological analyses and prognoses for the entire globe and the RMCs would be responsible for more detailed analyses and prognoses for specified regions. These products would be provided as guidance to the NMCs thus avoiding the expense and duplication in having a large number of centres preparing analyses and prognoses for large areas.

The GTS initially was the main focus for international cooperation. Links were established and upgraded to exchange the increasing volume of observational data generated with the GOS and the 'processed data' generated by the WMCs and the RMCs.

WMO was (and still is) very aware of the technological gap between developed and developing countries. Emphasis was therefore placed on programs for training and transfer of technology.

Australia played a prominent part in the development of the WWW through the participation of W.J. Gibbs in the EC Panel of Experts on Artificial Satellites. Melbourne became one of the three WMCs and was one of the first meteorological services to acquire a computer and produce numerical analyses and prognoses. Melbourne and Darwin were also RMCs.

Through the 1970s and early 80s Australia, through the Commonwealth (later Australian Numerical) Meteorology Research Centre, was a world leader in research into numerical methods and models. This mantle has now been passed to the Bureau of Meteorology Research Centre.

Structure of WMO and the Commission for Basic Systems

The structure of WMO is illustrated by Fig. 1. The main components are:

Congress (meets every 4 years)
Executive Council (annually)
8 Technical Commissions (every 4 years)

Basic Commissions:

- Basic Systems (CBS)
- Atmospheric Science (CAS)
- Instruments and Methods of Observation (CIMO)

Applications Commissions:

- Aeronautical Meteorology (CAeM)
- Agrometeorology (CAgM)
- Climatology (CCl)
- Hydrology (CHy)
- Marine Meteorology (CMM)

6 Regional Associations

- Africa RA I
- Asia RA II
- South America RA III
- North and Central America RA IV
- South West Pacific RA V
- Europe RA VI

In addition there is a large number of panels and Working Groups and ad hoc bodies are established from time to time.

The Commission for Basic Systems (CBS) is the WMO body responsible for the planning, development and operation of the WWW. Its name was changed from the Commission for Synoptic Meteorology to the Commission for Basic Systems by the WMO Fifth Congress in 1967 in recognition of the fact that the WWW provides the basic systems that support all other WMO programs. CBS has five standing working groups: the Advisory Working Group and Working Groups on the GOS, the GTS, the GDPS, and Codes.

In the continuing development of the WWW it is very important that CBS endeavours to ensure that advances in technology and the science of meteorology are harnessed and introduced operationally to make the WWW more effective and efficient; and that there is agreement among the Member nations regarding the changes that are being made so that effective international cooperation will continue.

At times there is frustration among those who would wish to see changes introduced more rapidly and this becomes reflected in criticism of the ponderous machinery of CBS. However CBS has been very successful in maintaining the vital ingredient of consensus. It is no easy task to obtain the agreement of some 150 countries on something as complex as the WWW plan.

It would be possible to replace CBS with a system of small expert groups and thus move faster. The risk is that a gulf would open up between groups of countries and international cooperation which has served us so well would be damaged.

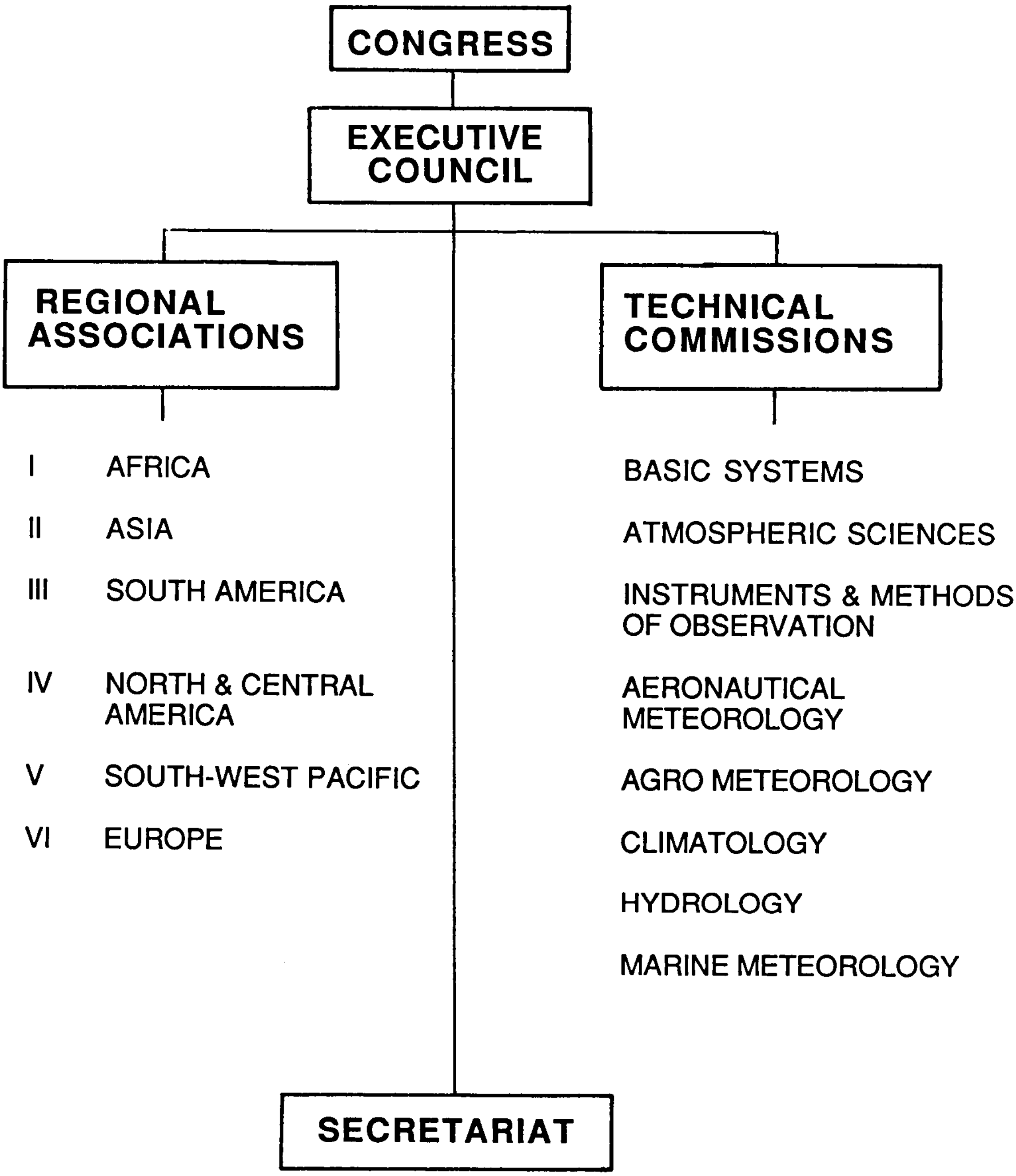
The changing scene

During the late 1970s and early 80s there was a growing feeling that a fundamentally different approach was required to the WWW because of three evolutionary developments:

- the emergence of new observing systems which, like satellites, are global or regional rather than national in nature;
- the demonstrated capability of centres to produce very valuable prognoses on a global scale for periods of 5 days or more ahead;
- the advances in computer and communication technology which opened up the concept of integrated systems and new possibilities for international cooperation in the processing and application of meteorological data.

These factors and the results of the GARP Global Weather Experiment 1979 led to WMO initiating an 'Integrated System Study' which resulted in the development by CBS in 1985 of a new WWW Plan – the WWW 2000.

Fig. 1 The structure of the World Meteorological Organization.



In 1967 an agreement had been signed between WMO and ICSU to develop jointly a research program, for which the abbreviation GARP was adopted.

The central core of GARP was the formulation of a model of the behaviour of the atmosphere and this required a study of:

- the degree of complexity with which the complex physical processes in the atmosphere need to be described to explain and predict the decisive features of weather development – this is fundamental to deciding the nature and detail of observing systems and networks;

- methods of computing the way in which the weather at a given instant changes as a result of the physical processes that it has been decided are the most important.

GARP consisted of a number of sub-programs (GATE, ALPEX etc.) but the outstanding achievement was the Global Weather Experiment, the largest international scientific field exercise ever undertaken. During the twelve-month period 1 December 1978 to 1 December 1979, technological resources of WMO Members were deployed on a massive scale to bring the Earth's atmosphere under more intensive surveillance than ever before. Special satellites, floating balloons, sounding balloons, aircraft, drifting ocean buoys, ships etc. were harnessed to form the most comprehensive meteorological observing systems seen to that time. The objectives of the Global Experiment were:

- to obtain a better understanding of atmospheric motions for the development of more realistic models for weather prediction;
- to assess the ultimate limit of predictability of weather systems;
- to design an optimum composite meteorological observing system for routine numerical weather prediction of the larger scale features of the general circulation;
- to investigate within the limitation of a one-year period of observation, the physical mechanisms underlying the fluctuations of climate in the time range of a few weeks to a few years and to develop and test appropriate climate models.

When the field phase of ALPEX, the last GARP sub-program, was completed in 1982, attention increasingly focused on the World Climate Research Programme. However research is continuing in scientific academies, universities and research institutions, using the comprehensive data sets generated by the Global Experiment and other GARP field experiments. It is on the fruits of this research that the historical judgement of the impact of GARP and the Global Experiment will ultimately be made.

Nevertheless the place of the Global Experiment in the development of meteorology is already secure. On many grounds it has been hailed as an outstanding success.

- The effective cooperation of so many nations (virtually all the Members of WMO) in such a complex sophisticated experiment was in itself an unparalleled achievement.
- The Experiment generated the most comprehensive global data set yet seen which will serve for many years as the basis of research aimed at achieving the objectives of GARP and the Global Experiment.
- It effectively demonstrated that satellites are essential to the future of the WWW, in their observing, data collection and communications roles.
- The cost effectiveness of new observing systems (drifting buoys, automated systems on commercial aircraft (ASDAR), and semi-automatic upper air observing systems suitable for use on ships of opportunity) was amply demonstrated.
- Very valuable experience was gained in data management on global and regional scales (quality control of data, compilation of data sets).
- Analyses and research based on Global Weather Experiment data have already resulted in:
  - an improved understanding of the circulation in the southern hemisphere (for example indicating more intense jet streams and cyclonic circulations than expected); and
  - a better understanding of large-scale features of monsoons and other tropical circulations.

Although research work on the Global Experiment was (and is) still continuing, there were great expectations in the early 1980s that the achievements should be reflected in a new WWW plan. Additional drive was provided by the rapid development of communications and computer technology and a desire to take advantage of concepts developing in data management.

Largely for these reasons CBS undertook the Integrated Systems Study aimed at producing a plan for an improved WWW to the year 2000 and an Implementation Program 1988-1997. In October 1985 an extraordinary session of CBS agreed to comprehensive drafts of the Plan and Implementation Program to be submitted to the WMO Executive Council and subsequently the WMO Congress.

The new WWW Plan

The major thrusts of the new WWW Plan are:

- incorporation of new observing systems (in particular satellite based systems, drifting buoys, ASDAR, ASAP);
- greater emphasis on support functions
  - WWW Data Management
  - WWW Implementation Support Activity
  - WWW Implementation Coordination

  while retaining the major elements

  - Global Data Processing (GDPS)
  - Global Observing System (GOS)
  - Global Telecommunication System (GTS);
- a somewhat more unstructured approach to the detailed definition of the GDPS and GTS through which the Regional Associations have been given greater responsibility for aspects such as:
  - the specification of the location and functions of Regional Specialised Meteorological Centres
  - the specification of the configuration of the GTS;
- the acknowledgment of the increasing dominance of numerical modelling in the forecasting process;
- the need to take advantage of advances in communication and computing technology, not only in large centres but also for providing output from the WWW to developing countries through the use of low cost technology;
- the incorporation of information on requirements for data with a distinction between what is required to permit optimum results from NWP by the late 1990s and what would be realistic goals at which to aim in the implementation of the GOS.

The new Plan gives emphasis to philosophy and principles, for example, the specification of objectives, major influences 1988-97, and design features. In framing the objectives the fundamental basis is the requirements of Members and 'end users' (e.g. agriculture, aviation, marine interests, industry, general community).

Two important initiatives bound up with the Integrated Systems Study and the development of the new WWW Plan were:

- a study by a WMO rapporteur Dr A.J. Gadd (UK) assisted by Dr W.A. McIlveen (also UK) on the application of improved forecasting techniques and the technology (particularly computer technology) required to implement these techniques. In the course of his study Dr Gadd visited Melbourne WMC and Darwin RMC;
- the development of bit orientated codes (or exchange formats) to facilitate computer to computer exchanges of data.

The development of bit orientated codes is a revolutionary step and will facilitate the application of computer based data management concepts. The desire to introduce new data management concepts was the main driving force for the Integrated System Study but there is considerable apprehension about the long term implications of introducing techniques which would, for example, facilitate computer access by Member countries to the data banks of other Members. As a result the treatment of data management in the new WWW Plan is general and rather vague.

This has no doubt been a disappointment to those who advocate a much more aggressive approach to the introduction of new technology and new concepts and has led to criticism that the new WWW Plan is a damp squib. Many expectations were raised but few were satisfied.

Criticism of this nature tends to overlook the great difficulty in obtaining international consensus on radically new ideas which at the beginning may be poorly understood except by the most expert in the field. Such ideas need to be gradually matured and their implications carefully assessed if they are to be accepted. WMO has no real alternative but to proceed cautiously and this caution has once again been reflected in the new WWW Plan.

On the positive side the Integrated System Study did provide a formal framework within which to consider the achievements of the Global Experiment and the impact of technological advances in communications technology. However, viewed in retrospect, the machinery may have been too formal and ponderous. It probably raised, unduly, expectations that the new WWW Plan would provide answers to the very complex questions outlined at the beginning of the paper.

The new Plan (WWW 2000) does not provide many of the answers to these difficult questions and it would be unrealistic to have expected it to do so. It does however, reaffirm the basic ideals and international cooperation on which the WWW has been based and provides the conceptual framework within which the questions can be addressed.

Data management concepts

The data management concepts in the WWW (2000) include:

- monitoring and quality control;
- the provision of operational information on the status of the WWW System (e.g. availability of various analyses/prognoses);
- the specification of standards for
  - data acquisition
  - data transmission
  - data bases, data processing, data storage
  - data access;
- facilitation of data access and applications.

The implementation of these concepts, particularly the facilitation of data access and applications, was a major driving force behind the Integrated System Study. Some of the concepts are non-controversial but others have implications for data security and the principle of free exchange.

Monitoring and quality control are obviously fundamental to the efficiency and effectiveness of the WWW. The specification of standards is a much more delicate area. In the age of computers it is obviously highly desirable that equipment used by various Members be compatible but it is by no means easy to achieve this end. Large sums of money can be involved if equipment used by some countries or manufactured by some organisations does not meet the prescribed standards.

At first glance it may appear highly desirable to implement any measures (such as transfer of computer data files) that would facilitate access by one Member to the meteorological data banks of other Members. The problem is that meteorological data (information) can be extremely valuable for commercial purposes and its value will grow rather than decrease in the years ahead. In the commercial world data are carefully guarded and access is often heavily restricted (except on payment) rather than facilitated.

The growing commercial activities of meteorological consultants and of National Meteorological Services themselves pose very difficult questions for WMO, for example:

- should there be some restrictions on the traditional free exchange of data between Members?;
- should data management techniques be implemented which would facilitate computer access to data by Members if this also facilitates access by commercial organisations which might be in competition with the Member's National Meteorological Service originally holding the data?

Funding of meteorological satellites

Meteorological satellite systems are now an essential part of the WWW and the challenge is to ensure the continuation and orderly development of these systems.

The cost of maintaining and operating a meteorological satellite system is already large compared to the costs of other components of the WWW and can be expected to increase. Major nations, particularly the United States, initially undertook the development of meteorological satellites as part of their space programs. GARP (particularly the Global Experiment) provided an additional incentive and accelerated the establishment of operational systems.

There is now a trend for the satellite operators to pass the cost of operating meteorological satellites from their Space Agencies to their National Meteorological Services and this has increased pressure for a more equitable sharing of the costs by countries who benefit from the satellite programs.

The WMO Executive Council has asked its Panel of Experts on Satellites to study the problem. Aspects being considered are:

(a) that WMO place a high priority on reducing the reliance on one operator (the United States) for such a large proportion of data and services from polar-orbiting meteorological satellites;

(b) that WMO assist the geostationary meteorological satellite operators and potential operators in the development of direct participation and/or cooperative arrangements among WMO Members within the geographic area of coverage. The European organisation (EUMETSAT) is a good example but several types of technical and/or financial cooperation are possible;

(c) that WMO take a more active role in identifying acceptable and practical means for Members to participate in the development and maintenance of a global meteorological satellite network. This could involve the co-ordination of design and implementation, particularly in relation to products and services for international use, and the promotion of the development of facilities for using satellite data and services for meteorology and hydrology;

(d) the development of an action plan to achieve the above objectives.

Sharing of funding would almost certainly mean a sharing of control and therefore proposals need to take account of the extent to which satellite operators would be prepared to share control of the program. The time is not ripe (and it may never be) for the funding and control of a meteorological satellite program to be undertaken by WMO with financial contributions being made by all Member countries. In the foreseeable future the funding of WWW satellite systems will probably be based upon a combination of the following:

(a) national systems which also offer data and/or services to other Members;

(b) national systems as in (a) in which other Members participate technically (e.g. by providing sensors);

(c) regional organisations, such as EUMETSAT, based on technical and/or financial cooperation.

Funding of other observing systems

The original concept of the GOS as a combination of nationally funded and operated observing systems has changed in recent years with the emergence of ASDAR, ASAP and drifting buoy networks. These networks which are global or regional rather than national in character, raise fundamental funding issues.

Following the Global Experiment, a consortium of interested Member countries (including Australia) was established by WMO to develop and fund an operational ASDAR system. Less formal cooperative arrangements were also made to develop drifting buoy and ASAP systems but these did not involve specific financial commitments as applied to the ASDAR development.

The ASDAR initiative encountered severe problems with the development of the prototype unit. At the time of writing the future of the ASDAR system is not clear but it does appear that if it does proceed, the cost of ASDAR units would be considerably greater than previously envisaged and this obviously affects the cost effectiveness of ASDAR relative to other observing systems.

It is particularly unfortunate that WMO's first venture into a consortium approach to funding should encounter such difficulties. Nevertheless the concept is sound and the ASDAR experience should not deter further efforts.

Satellite collection of observations

The operation and funding of systems for the collection of observations through satellite systems such as INMARSAT provides yet another example of the complex financial issues facing WMO. Some of the satellite systems are obviously efficient and cost effective but again the main problem is in endeavouring to ensure that the financial burden is borne as equitably as practicable.

In the case of INMARSAT there are at present a limited number of Coastal Earth Stations (Singapore is the only CES in the Southeast Asia/Southwest Pacific area). If an increasing number of meteorological observations from ships are lodged via INMARSAT, countries operating CESs may find themselves being asked to meet increased costs for the reception and onward transmission of these reports. The new satellite technology is disturbing the traditional arrangements where various Members met the costs of acquisition of ship reports from specified areas through coastal radio stations.

In endeavouring to draw up new arrangements aimed at equitable cost sharing, WMO needs also to ensure that ships' companies are not discouraged from making meteorological reports because of complex or unduly restrictive procedures.

Global and regional centres

The pre-1985 WWW Plan specified in detail the location, responsibilities and functions of World Meteorological Centres (WMCs) and Regional Meteorological Centres (RMCs). Some modification of the Plan seemed to be required to take account of:

(a) the emergence of centres other than the three WMCs undertaking analysis and prediction and related functions on a global basis;

(b) the apparently decreasing relevance of the RMCs because advances in computer and communication technology and in numerical analysis and prediction would enable global centres to carry out the role of the RMCs as originally conceived.

The European Centre for Medium Range Weather Forecasts (ECMWF) is a special case. It has been spectacularly successful in numerical analysis and prediction on a global basis and its products have been widely disseminated on the GTS as well as to its (European) Member States. ECMWF prognoses out to five days have proved very useful here in Australia. The ECMWF is intimately involved in the WWW in many ways (for example in monitoring and quality control of data as well as in the dissemination of prognoses) but paradoxically it does not have any formal role as a GDPS Centre in the WWW.

The new WWW Plan at present does not specifically propose any changes to the system of three WMCs nor does it exclude such changes. Three WMCs would be sufficient for practical purposes and would more than cover the need for redundancy. However the fact is that there are other centres operating on a global basis and consideration should be given to the dissemination of their products on the GTS. The formal nomination of a centre as a WMC brings with it an undertaking to meet specified responsibilities and priority would need to be given to those WWW responsibilities as well as to national needs (or to the needs of regional Member States as in the case of the ECMWF).

In the new Plan the concept of RMCs has been replaced by Regional/Specialised Meteorological Centres (RSMCs) which may have activity and/or geographic specialisation.

Centres with geographic specialisation

(a) Provide the interface between WMCs and NMCs by formatting and distributing global products to meet needs in a particular region.

(b) Undertake limited area fine scale analyses and provide fine mesh forecast products for 12 to 48 hours, for designated areas.

Centres with activity specialisation

Examples of functions are to:

(a) Provide long-range or medium-range forecasting products.

(b) Provide warnings for tropical cyclones, severe storms and for other dangerous weather phenomena.

(c) Provide tailored aviation or marine products to service international users in a particular area.

(d) Provide information on prolonged adverse weather conditions, including drought monitoring.

(e) Undertake activities relating to the World Climate Programme and other WMO or international programs.

The location of the RSMCs will be based on recommendations of the six WMO Regional Associations and at the time of writing this had not been finalised. The RSMCs may be either existing national or regional centres, which accept responsibilities by multilateral or regional agreement or centres implemented by a joint cooperative effort by several countries in a region.

Because of 'political' considerations and the introduction of the concept of 'specialised' centres it now appears that the number of RSMCs might exceed the number of RMCs (pre 1985).

Support for developing countries

There is a gulf between the technological and financial capabilities of developed and developing countries and with advances in technology there is a danger that the gulf will widen. This has been recognised for many years by WMO and in the new WWW Plan emphasis is given to the Implementation Support Activity (ISA).

It is essential that low cost technology is employed to the maximum extent practicable to enable developing countries to obtain full advantage of the data and products (analyses, prognoses, special forecast products, etc.) available in the WWW system.

Integration of WWW with other international programs

The WWW provides basic systems that are very useful and in some cases essential for the support of other international programs, in particular (IGOSS and WAFS). This obviously has implications for the design of the WWW (e.g. capacity of the GTS) and the priority which is given to the WWW and the other programs.

The WAFS is very heavily dependent on the WWW. It utilises the GOS for basic information and the GTS to carry products of the World Area Forecast Centres at Bracknell and Washington.

It is highly desirable that the international organisations involved with the WAFS (ICAO and WMO) cooperate effectively but unfortunately there have been problems in the past.

Concluding remarks

The new WWW Plan (WWW 2000) establishes the framework to take operational meteorology into the 1990s but there are many questions that need to be answered and much work still to be done.

The most difficult issues that WMO has to face relate to:

- possible pressure on the traditional principle of free exchange of data/information in the face of emerging commercialisation in meteorology;
- funding of WWW systems which are global or regional rather than national in character;
- the gulf between the financial and technological capabilities of developed and developing countries.

The common factor in these difficult issues is money and therefore what we need above all are:

(a) sound arguments that will convince national governments of the increasing value of meteorological services so that they will be prepared to provide adequate funding for their National Meteorological Services and for related international initiatives;

(b) a continuing cooperative spirit within WMO so that the financial issues will be attacked in a constructive way.

Given these two basic elements WMO and the new WWW will be as successful in the future as they have been in the past.