World Meteorological Organization

GUIDE ON THE APPLICATION OF NEW TECHNOLOGY AND RESEARCH TO PUBLIC WEATHER SERVICES

PWS-6

WMO/TD No. 1102

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NOTE

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Chapter 1
INTRODUCTION

As part of their mandate to provide reliable and effective services to the public in support of safety of life and protection of property, NMSs have continuously evolving requirements for observational data in order to produce forecasts, warnings and climate information which are similarly evolving according to user requirements and expectations, and to disseminate those products and information through increasingly more sophisticated and efficient dissemination means.

In order to provide guidance to support NMSs, especially smaller Services and those in developing countries, in their service delivery activities by keeping pace with developments in technology, a Technical Document (PWS-1, WMO/TD No. 1054) was prepared in 1999 under the auspices of the WMO Technical Commission for Basic Systems (CBS) by the Public Weather Services Expert Team on Product Development and Verification and Service Evaluation. The purpose of that Technical Document was to provide a framework for the requirements of public weather services for data and products.

At its twelfth session (Geneva, 2000), CBS re-established the expert team under the modified title of Expert Team on Product Development and Service Assessment and requested it to review the above-mentioned Technical Document in order to include the application of research to public weather services as well as to modify and update it as necessary where new technologies and their relevance to public weather services were concerned. The Expert Team duly prepared the present Technical Document at a meeting in Honolulu in 2001. This Technical Document has built on the original framework with notable additions to some already existing topics: (Chapter 2.2) satellite technology; (Chapter 2.3) radar technology; (Chapter 2.4) workstation technology. Other new topics include application of research to more effective production and delivery of public weather services (Chapter 3), which includes Computer Aided Learning (CAL). Chapter 4 discusses new and improved public weather products related to human biometeorology. Finally, Chapter 5 concentrates on exchange of all products related to PWS through a modernized WMO Information System.

It should be kept in mind that this Technical Document, like the other technical documents published under the WMO PWS series, is intended to provide guidance in the form of best practices that can be used by Members. Because of the diversity of NMSs with respect to size and stage of technological development along with the variability of weather types and climate, some practices may not have significant utility for a specific Member. However, this document does cover a wide range of guidance that should provide some form of assistance to every Member.

Chapter 2
NEW TECHNOLOGIES APPLICABLE TO PUBLIC WEATHER SERVICES

2.1 IMPACT OF CHANGING TECHNOLOGY

The last 10 years have seen an enormous increase in demand for meteorological data and products due to rapid advances in communications and computing technology, and especially the rapid growth in the Internet. These emerging technologies are having a marked impact on the information system of NMSs and WMO as a whole.

Technical developments have emphasized the need to focus not only on the standards for routine exchange of data and products under the World Weather Watch system, but also on the specific and changing needs for efficient and effective delivery for public weather services by NMSs to their domestic users. The "information revolution" has presented many challenges and is seen by some NMSs as a threat. However, the changing technology has also presented many opportunities to improve access to meteorological information and to provide more effective, timely and relevant public weather services products, including critical warnings.

In addition to significantly enhancing the ability to process, analyse and communicate meteorological information, continuing new technological development has also allowed for more accurate and higher resolution of weather observations. This new ability is most noticeable in the capability to obtain important meteorological data in remote locations.

In this chapter, a brief description is given of the key technologies that NMSs will need as a basis to meet the demands of the public weather services user.

2.1.1 Server hardware

2.1.1.1 High performance computing used for modelling in a large computer centre

Servers for high-performance computing are required for the processing of meteorological forecast models. The current generation of computers used for such purposes are Massively Parallel Processing systems (MPP). The architecture of these systems consists of hundreds of nodes, each with a shared memory and mostly two to 16 processors using a shared memory (SMP Nodes). The nodes are connected via a high-speed proprietary network in various topologies. Some of the MPP systems consist of vector processors which are very effective as regards the sustained performance necessary for meteorological models. Most of the MPP systems, however, have RISC processors which are less expensive than vector processors.

These RISC-based systems became more and more dominant in the last few years. In addition to RISC-based systems, MPP systems with "high-speed processors" are an emerging cost-effective alternative to classical MPP systems.

2.1.1.2 Modelling on a workstation level for a small computer centre

Today's workstations are powerful enough to run a local/regional high-resolution forecast model with appropriate parameters in an acceptable time frame. For example, the German Meteorological Service (DWD), distributes a model which can be run on a four-processor (R10000-MIPS) workstation with 512 megabyte memory, 25 gigabyte disk space and connection to the Internet.

2.1.1.3 Data handling and pre/postprocessing in a large computer centre

Servers for data handling and pre/postprocessing consist of high availability clusters of shared memory nodes. The nodes will have access to disks and cartridge silos via a storage area network based on fibre channel technology. The typical amount of data to be stored is in a range of several hundreds of gigabytes during daily production.

2.1.1.4 Data handling and pre/postprocessing in a small computer centre

If numerical forecast models can be run on a workstation level, it is also possible to generate the products on the same system. The workstation should have media such as a high capacity tape drive, RW CD, or other similar technology for archiving and efficient graphic hardware for the presentation of products.

2.1.2 Server software

In general, today's servers run UNIX or similar architecture as an operating system. There is a variety of "dialects" of UNIX-Systems, because every manufacturer adds enhancements and optimizations for specific hardware to the UNIX-code. LINUX as a highly standardized open source, manufacturer-independent UNIX-operating system is an attractive and inexpensive solution. Independent Software Vendors (ISV) regard LINUX as one of the top preferred platforms for their products. Meteorological models are primarily written in Fortran 90, using C-library programs.

2.1.2.1 Additional software for high-performance computing (HPC)

In order to run parallelized applications over all nodes, the servers for high-performance computing use the message passing interface (MPI). Within a SMP node it is easier to parallelize programs with the open MP application program interface (API).

2.1.2.2 Running models on a workstation level

In the case where the workstation running the forecast comprises more than one processor (but generally not more than four), a low-level parallelism should be used. Using Open MP, the program can be parallelized without losing the portability of the code.

2.1.2.3 Software for data handling at a large computer centre

Servers for data handling and pre/postprocessing must provide the users with a relational database or file-based system and facilities for archiving/retrieving meteorological data. The underlying software for archiving comprises a hierarchical storage management (HSM) system and access to silos of thousands of cartridges with capacities from 10 to 120 gigabytes. If servers for data handling are run as a cluster of SMP Nodes, the existence of a common file system for the cluster is essential, so that every process in the cluster can access files by the same path.

2.1.2.4 Software for data handling and pre/postprocessing at a small computer centre

If the forecast model is run on a workstation, the amount of data is several gigabytes per day. There are cheap archiving systems that can handle the model output. Products can be generated using program libraries which are in principle used also by the larger centres. Software for connection to the Internet is required, especially for sites which obtain the boundary values for their forecast models from other meteorological services.

2.1.3 Client hardware

Standardization of client hardware must be a top priority. Traditional workstations are UNIX-based. However, the x86-platform is becoming more powerful and has almost caught up with the former power standards of graphics workstations. It is on the way to being used as a graphics developing workstation.

Some of the major reasons for recommending the x86-platform as a potential replacement for traditional graphics workstations are as follows:

- x86 processors are reaching the working frequency of more than 1 GHz;
- Graphics adapters for the x86-platform support the major graphics standards in meteorology (e.g. OpenGL);
- Former graphics workstations would not be available in the price range of the x86 workstations;
- If more clients adopt the standard PC, the total support cost is reduced and, therefore, better support can be derived from allocated resources. A well-configured PC-based graphical workstation costs approximately US$ 3 000–4 000 (in 2001).

The decision as to which operating system will be the best in the future has not yet been made. The operating system Windows”, in the versions NT” 4.0 SP6 and 2000, has the advantage of being supported by more developers. However, these developers do not concentrate on developing products for meteorological needs. Historically, meteorological needs were fulfilled by developing programs at UNIX workstations.

By using one of the major graphics workstations with UNIX, e.g. IRIX” by SGI, no extra costs for the migration of meteorological applications will emerge. Using LINUX” at x86-platforms instead of Windows” could be the better choice for the following reasons:

- There are only marginal costs for licensing the operating system;
- There is no necessity for license management;
- There is support by major vendors today and in the near future;
- There is no necessity of extra training for UNIX developers.

2.1.4 Programming platforms

National Meteorological Services operate and maintain a variety of computer hardware and software. Some of these implementations are specific to the computer or the operating system itself. These installations are hard to maintain and require a significant amount of resources.

There is an obvious trend in today’s IT-world towards vendor and platform independence. This strategy allows the expenditure of limited resources for the development of new products. There are different approaches to create portable software:

- Develop on one platform (e.g. UNIX) and use a commercial software package to port to another platform (e.g. NT). This would require a runtime system, which one has to buy, on each installed computer;
- Use of Java as the computing platform. Java is a robust programming environment whose performance has been greatly improved over the last years. Java has evolved to a mature programming language with an extensive set of built-in libraries including defined data structures and methods supporting faster implementation time. Java development systems, runtime systems and some IDEs are available free of charge. Java allows the creation of applets, that have to be run inside browsers, client side applications, or server side applications.

For the sake of flexibility, scalability, and robustness multi-tier architectures separate clients, application logic, and data layers. Multi-tier architectures allow different hardware platforms, operating systems and application formats (e.g. objects written in different programming languages) to interoperate. This architecture is able to integrate legacy systems. But it requires additional resources to be set up and maintained.

A common standard, maintained by the Object Management Group, is CORBA. There are several CORBA implementations by companies like Borland/Inprise/IONA and BEA.

Integrated development environments help in coping with the increasing complexity of the software. They also allow rapid creation of graphical user interfaces.

It is likely that the convergence in the area of operating systems will lead to only a few major platforms like Windows, LINUX and very few other UNIX.

2.2 SATELLITE TECHNOLOGY

Environmental satellite and computer technology continue to provide the major improvements in the ability to more accurately and timely provide weather warnings and forecasts. The use of observations from both geostationary and polar-orbiting satellites have made and continue to make the quality of public weather services significantly better. In addition to enhancing the ability to observe weather elements on a global scale, these satellites have provided a low cost technology for providing data location and transmission from remote *in situ* observation systems.

2.2.1 Geostationary and polar-orbiting satellites

The big advantage of the geostationary satellites is their high temporal repetition rate, which is currently at least one hour or better. Polar-orbiting satellite images are especially useful for the identification of small, pixel-size features, low cloud features such as low stratus and fog, and dust storms. They are useful as single images for newspapers, but animation effects for television can only be achieved with imagery from geostationary satellites. These images are also useful in locating the presence of fires, in particular forest fires. A satellite pixel that exhibits high temperatures is known as a hotspot and these pixels are indicated by red dots on a hotspot maps showing the approximate positions of the fire. Hotspot maps are produced regularly by the Asean Specialized Meteorological Centre in Singapore as part of the Regional Haze Monitoring Program to provide an early warning service over the Asean region.

The most current information on the technical impact of changing technology on the PWS regarding satellite systems can be retrieved from the WMO home page (http://www.wmo.ch).

2.2.2 Ground facilities

The most significant change for the operators of ground facilities for the direct reception of satellite images is the change from analogue to digital picture transmissions. During the next 10 years there will be a transition from the present analogue low-resolution satellite services APT (analogue picture transmission from polar-orbiting meteorological satellite) and WEFAX (Weather FAXimile from geostationary meteorological satellites) to the digital Low Rate Picture Transmission (LRPT, polar-orbiting satellites) and Low Rate Information Transmission (LRIT, geostationary satellites). The transition will have a direct and potentially large impact on existing and planned ground receiving equipment, as it will no longer be possible to use the APT and WEFAX receiving systems for the reception of digital LRPT and LRIT data. Consequently, the APT and WEFAX systems will have to be replaced by new digital systems. In order to ease the adoption of the new digital services for the users, the majority of the meteorological satellite operators plan a transition period during which both analogue and digital services would be available.

An analysis of the satellite operators' plans for LRIT conversion indicates that in WMO Regions I (Africa) and VI (Europe) a three-year overlap, starting 2002/2003, of WEFAX and LRIT transmissions can be expected. WMO Regions II (Asia) and V (South-West Pacific) may also have an overlap period but presently there is some uncertainty. A transition period for Regions III and IV (South, Central and North America including the Caribbean) will start in 2002. Concerning the Indian Ocean area (RA II) the situation is somewhat uncertain, and it is possible that the WEFAX system will be continued for a longer period.

An analysis of the plans for LRPT conversion shows that the morning orbit satellite will commence using LRPT transmission in 2003/2004; whilst the afternoon orbit satellite will start using LRPT in 2009. There will not be a separate transition period for the morning orbit or the afternoon orbit, but a possible five to six year period when both APT (afternoon orbit) and LRPT (morning orbit) will be available. Therefore, if it were considered necessary to receive information from the morning and afternoon orbiting satellites, a dual capability (APT and LRPT) would have to be maintained during the period 2003/2004–2009. A description of the attributes of LRIT/LRPT and their implementation can be found in the technical document WMO/TD No. 910 entitled *Application and Presentation Layer Specifications for the LRIT/LRPT/HRIT/HPRT Data Format, 1998* (SAT-19). Valuable information can also be found in WMO/TD No. 660 entitled *A Description of a Standard Small Satellite Groundstation for Use by WMO Members, 1995* (SAT-13).

The introduction of the next generation of operational meteorological satellites will affect not only the APT/WEFAX systems, but also existing high-resolution digital satellite receiving equipment. The first high-resolution satellite receivers be affected will be the primary data user stations (PDUS) for the reception of digital METEOSAT image data. In comparison to the present METEOSAT system the volume of transmitted image data will increase by a factor of approximately 20 with the introduction of Meteosat Second Generation (MSG). The present PDUS cannot be used for the reception of MSG data and will have to be replaced by either a low rate user station (LRUS) or a high rate user station (HRUS). The launch of MSG-1 can now be foreseen for the year 2002 and there may be an overlap period of about three years between the present METEOSAT system and MSG. For the case of back-up operations, it is recommended that operators of PDUS maintain a dual capability (PDUS and, HRUS or LRUS) during the overlap period 2001–2003/2004. Further details can be obtained from the EUMETSAT home page: http://www.eumetsat.de. It is important to note that MSG image data will be encrypted, with the exception of the six-hourly images from 00, 06, 12 and 18 UTC. This applies to both the HRIT and the LRIT data stream. EUMETSAT decided to make MSG imagery also available via the Internet. However, details on this Internet service are still to be defined. The first considerations will be directed to a service which would be similar to the present Meteosat WEFAX service: hourly or half-hourly images from three spectral channels in near-real-time with an image size not larger than the present WEFAX images via the Internet.

It is also important to note that the introduction of Meteosat Second Generation (MSG) will influence the transmission of new data-collecting platforms (DCPs) data and meteorological data distribution (MDD) data. Operators of new DCPs may have to use different frequencies from those used currently. Operators of existing DCPs will, in all probability, not have to change their frequencies. But they will be allowed to do so if they so wish, e.g. if the DCP transmissions are currently affected by interference or if the assigned timeslot for the transmissions seems not to be fully satisfactory for the operator. Details on this have been made available by EUMETSAT, see www.eumetsat.de. As a consequence of the transition from WEFAX to digital data dissemination MDD data will become part of the LRIT and the HRIT data stream. Therefore, a HRUS or LRUS will be needed to replace the present MDD station.

Information on the status of the current satellite system and some indications on the future meteorological satellite system are contained in the Appendix to this document. The information is derived from the "Report of the 28th Meeting of the Coordination Group for Meteorological Satellites (CGMS), CGMS XXVII, Woods Hole, Massachusetts, 16–20 October 2000", which can be obtained from the CGMS Secretariat at EUMETSAT, or from the CGMS Web site at http://www.wmo.ch.

More detailed and valuable information concerning the impact of changing technologies and their use as regards meteorological satellites can also be found in the "Education and Training Material" section of the Satellite Activities pages on the WMO Web pages.

2.2.3 Use of satellite imagery for weather diagnostic, forecasting, severe weather warnings and NWP

Satellite imagery is important in the forecast, warning and NWP processes for the following reasons:

- Satellite data are important for short-term severe weather monitoring, especially in the case of developing super cells and line squalls. Images with a repetition rate of 10 – 15 minutes are especially useful. They are also especially important for the identification of cyclogenesis;
- Water vapour images are especially useful for identifying dry slots, which are a factor in super cell development;
- In the case of countries surrounded by wide ocean areas with little or no surface reports, satellite images are important to verify the NWP analysis and prognostic fields, and therefore play a role in forecast decision-making;
- Due to scant upper-air information in many areas of the world, satellite images aid in the analysis and verification of upper-air systems such as cut-off lows and jet streams. In addition, satellite-derived winds are an important tool for determining the movement of tropical cyclones and depressions;
- From a climate service provision point of view, satellite image data are among other purposes used to identify developing drought conditions, for the construction of rainfall maps or for an assessment of the solar irradiance at ground-level.

2.2.4 Product development

The output side refers to satellite imagery and products which are disseminated to the public and other users such as disaster and emergency management. Multispectral processing methods are desirable for the correct interpretation of infrared satellite imagery. However, as these methods may not be familiar to some NMSs, one of the issues about simple satellite imagery is to have products that distinguish between clear conditions and conditions with fog or low ceiling stratus or stratocumulus.

Among the newest products that are becoming available are three-dimensional satellite imagery. At present, these displays are rather crude, but more sophisticated techniques could be employed, such as the combination of satellite data, synoptic observations and radiosonde measurements to create a better three-dimensional image. These products present both a challenge and an opportunity for television presentation to better demonstrate the 3-dimensional nature of weather systems and to be able to explain to the viewers what is being demonstrated.

2.3 RADAR TECHNOLOGY

Over the past 50 years the use of radar technology has been a major component in the detection and warning of local severe storms including tornadoes and flash flooding, making it an essential tool for nowcasting. Most weather radars operate at wavelengths of 5 or 10 cm in order to maximize reflectivity return from hydrometeors. Newer model radars continue to operate at these frequencies, and now provide both analogue images and digital files that can be used to enhance graphical products and animation.

NMSs create, receive and store a wide variety of products, based on data sets from local radars. Radar products are generated from both reflectivity and doppler shift information. Reflectivity data is useful in generating products related to storm intensity, storm movement, and precipitation. Doppler Shift data can help derive products related to wind velocity and shear as well as turbulence in the atmosphere, thus allowing the estimation of tornado formation and other storm structures. Radar serves as complementary data source to the geostationary satellite and is most effective at higher resolution (i.e. 1 to 10 km) needed for nowcasting and short term severe weather warnings. Furthermore, radar is a much more precise tool in estimating important parameters related to land falling tropical cyclones, particularly when cyclones are within 200 km of land. The capability of radar to provide high-resolution rainfall estimates (i.e. 1 km) can be supplemented by actual in situ measurements that can be used to improve radar calibration and accuracy. Data from more than one radar can be combined into radar composites covering a large area. These composites which are also called mosaics can be exchanged in real time using the standard code form BUFR. Radar data can be depicted in both the horizontal and vertical and "looped" over a time period. These profiles can provide excellent information regarding the need for high wind warnings as well as those associated with storms. Many radar products serve as useful graphics to supplement the issuance of severe weather and flash flood warnings when disseminated in popular media such as television or on the Internet. In many countries, special software is available from vendors to generate special products. In the USA, for example, the implementation of a new network of digital Doppler radars has resulted in nearly doubling the accuracy and timeliness of tornado, severe thunder storm, and flash flood warnings.

2.4 AUTOMATED SURFACE OBSERVING SYSTEMS (ASOS)

Getting more information on the atmosphere, more frequently and from more locations is the key to improving forecasts and warnings. The ASOS information will help the NMSs to increase the accuracy and timeliness of forecasts and warnings.

The primary concern of the public as regards weather conditions is the threat to safety. A basic strength of ASOS is that many critical weather parameters are measured and reported at high temporal resolution (e.g. every minute). ASOS observes, formats, archives and transmits observations automatically via data distribution networks. It also transmits a special report when conditions exceed preselected weather element thresholds, e.g. the visibility decreases to less than 1 mile. In addition, ASOS detects significant changes, disseminating hourly and special observations. It can also, routinely and automatically, provide computer-generated voice observations directly to users. These messages are often available via a telephone dial-in port and radio link. ASOS reports the following basic weather elements:

- Sky condition: cloud height and amount (clear, scattered, broken, overcast) up to 12 000 feet;
- Visibility (to at least 10 statute miles);
- Basic present weather information: type and intensity for rain, snow, and freezing rain;
- Obstructions to vision: fog, haze;
- Pressure: sea-level pressure, altimeter setting;
- Ambient temperature, dew point temperature;
- Wind: direction, speed and character (gusts, squalls);
- Precipitation accumulation.

Other elements of importance to very short range forecasting and nowcasting are reflected in remarks including variable cloud height, variable visibility, precipitation beginning/ending times, rapid pressure changes, pressure change tendency, wind shift, and peak wind.

2.5 NEW WORKSTATION TECHNOLOGIES

With the advent of technologies both in the fields of remote sensing and numerical weather prediction, an ever-growing amount of meteorological information is provided to forecasters as input for their formulation of forecasts and warnings. Moreover, information not available from conventional telecommunication circuits such as scatterometer data and radar imageries are now readily available from the Internet. In order to assimilate the information effectively, it is very important that they are presented in an easily interpreted manner.

Personal Computers have been used in the preparation of weather forecasts, display of weather charts, satellite imageries and numerical products, generation of climatological reports, generation of Web products as well as in research. All these usage could be implemented on dedicated systems with separate systems for radar display, satellite imageries visualization, data storage and display of forecast maps. This approach has not been satisfactory because it does not allow for the overlay of different data sets. Moreover, in the monitoring and nowcasting of severe weather caused by mesoscale systems which are relatively small in spatial scale and relatively short in time scale, the traditional subjective assimilation of weather information by visual impact of a wide array of display units and charts is not sufficiently responsive. However, with the advent of modern technology and the multi-user, multiprocessing capabilities of the workstation, all these products can be integrated into one user-friendly system and provide all the necessary functionality on the desktop.

Most of today's meteorological workstation system (MWS) rely on a two-tier model where the data layer and parts of the application layer are implemented on servers while interaction, visualization and certain applications are run on clients. These MWS allow interaction with the data, e.g. by modifying certain values or gridded fields or enabling the forecaster to create customized products. Since clients are usually connected to the server via a network, meteorological information can be viewed in locations other than the forecasting office. This MWS design was developed during the early to mid-1990s.

Today there is a clear tendency to move to multi-tier architecture with balanced client/server implementations. Depending on the needs of applications, which might range from word processing to animated 3D-visualization, clients could range from ultra-thin (only a monitor running from server) to very fat (high capacity PC with a large memory). But there is still some discussion as to what extend computing intensive visualization applications could be run on servers. This clearly depends on the network bandwidths. But even with high bandwidths, animations with appealing frame-rates need clients that could handle and visualize data locally.

In order to make the generation of meteorological products more effective and consistent, many NMSs have developed a centralized database. This database is filled with interactively revised forecasts which allow the automatic creation of products. Many of these new integrated forecasting systems are now available in major centres. Some of these products are described in more details below.

2.5.1 Advanced Weather Interactive Processing System (AWIPS)

AWIPS is an integrated suite of automated data-processing equipment that supports complex analysis, interactive processing, display of hydrometeorological data, and the rapid disseminations of warnings and forecasts in a highly reliable manner. AWIPS is now being used in the USA at National Weather Service (NWS) Weather Forecast Offices, River Forecast Centers, and National Centers for Environmental Prediction to support weather and hydrologic forecast and warning operations. AWIPS is used to:

- Provide computational and display functions at operational NWS sites;
- Provide open access, via a satellite broadcast called NOAAPORT, to extensive NOAA data sets that are centrally collected and/or produced;
- Acquire and process data from an array of meteorological sensors (e.g. Weather Surveillance Radar-88Doppler, Geostationary Operational Environmental Satellite, and Automated Surface Observing System) and local sources;
- Provide an interactive communications system to interconnect NWS operations sites and to broadcast data to these sites; and,
- Disseminate warnings and forecasts in a rapid, highly reliable manner.

AWIPS has capitalized on recent advances made in relevant software and hardware technologies. AWIPS development activities have employed an incremental, evolutionary build approach where functionality is developed and implemented in multiple stages. This has allowed for more frequent integration and evaluation of system components and the realization of the benefits of this system as rapidly as possible. The AWIPS site architecture is an open system implementation. The use of open systems has been a key aspect of the AWIPS design and continues to influence design and implementation decisions. This approach has resulted in a standards-based, client/server system that provides isolation of applications, data, and system-level functions from hardware implementation and software services, thereby eliminating dependency on vendor-unique products. The system architecture emphasized the use of commercial-off-the-shelf (COTS) hardware and software and functional independence of components to deliver a system that is flexible, expandable, and portable. This approach maximizes the intended long-term life of the system.

All site systems are linked to the AWIPS Communications Network. A wide-area network connects sites for multi-point-to-point and point-to-point communications. A satellite broadcast network provides for point-to-multi-point communication of NOAA's centrally-collected and produced real-time environmental data. This satellite broadcast network, known as NOAAPORT, provides both internal and external users open access to this data stream. A Network Control Facility (NCF) is responsible for managing the AWIPS Communications Network and supporting the operation and maintenance of systems in the field. The NCF is operated by PRC 24 hours per day. The NCF acquires and distributes forecasts, warnings, observations, and model data from the NWS Telecommunications Gateway and geostationary satellite data from the National Environmental Satellite Data and Information Service. All data streams are transmitted to a Master Ground Station for uplink to SpaceNet 4, a GTE communications satellite. SpaceNet 4 then broadcasts these data to satellite receiver antennas at AWIPS sites and private sector sites.

In support of the field systems, the NCF:

- Manages systems maintenance;
- Restores site to operation in real-time, if failed;
- Dispatches Contract Maintenance to sites to maintain/repair hardware;
- Refers software discrepancies as appropriate;
- Distributes software;
- Provides central site support;
- Archives and replenishes data;
- Monitors site performance.

2.5.2 The Common Graphics System (CGS)

Meteorological Workstation Systems should support a multitude of tasks in a weather office such as monitoring, now-casting, forecasting, climatological report generation, batch production, application serving for the Web, verification, and research. There is also an intrinsic need to keep such systems open to implement new application scenarios or data sources. For example, the German Meteorological Service (DWD) has decided to choose a very flexible and portable architecture to assure this generic approach. The CGS, which is a multinational project, is intended to replace DWD's current workstation and batch production systems in the year 2004. It is implemented using the Java programming environment. Pure Java applications can be run on nearly every hardware or operating system. The CGS utilizes a multi-tier approach which separates client, server and data. This architecture enables participating partners to use their databases, whether they use flat files or relational databases or any other kind of environment.

The client tier offers a highly flexible design to configure the client. Clients can be configured from "radar animation only" to a full-blown Meteorological Workstation including 3D-visualization and interactive product generation. Due to the open design any project partner is placed in a position to add new functionality without affecting the base architecture.

2.5.3 The Australian Integrated Forecasting System (AIFS)

The Australian Integrated Forecast System (AIFS) is a workstation-based interactive software suite that brings modern technology to the forecaster's desk with its advanced capabilities in the processing, analysis and display of weather data. Using a modular "open systems" computing design which offers simplicity, flexibility and the ability to easily incorporate new technologies and software, AIFS is usually installed with the Australian Bureau of Meteorology's computerized meteorological message switching software, providing a seamless link between data reception, product preparation and subsequent dissemination.

AIFS is now being used in Australia at the major regional and some smaller forecasting centres and military establishments, the Regional Specialized Meteorological Centre in Nadi, Fiji, and the Malaysian Meteorological Service. Specific objectives of the AIFS include:

- Enabling the creation of a wider variety of products, with more specific content, in a more flexible format;
- Coping with the expanding volume and variety of meteorological data;
- Integrating the meteorological data and associated applications into a standard user interface;
- Incorporating improvements in scientific methodologies and new techniques;
- Increasing the efficiency of operations and decreasing running costs.

System design for AIFS coupled with the message switching software generally requires a back-end configuration of paired UNIX servers in an automatic fail-over configuration together with a shared disk array. Display terminals can range from either Unix workstations to Intel platforms running X-emulation. The modular approach to system design allows AIFS to be scaled to meet user requirements. For smaller remote offices, AIFS software can run on a single, mid range graphics workstation connected remotely via a TCP/IP connection to a larger regional office.

2.6 GEOGRAPHICAL INFORMATION SYSTEM (GIS)

The visualization of meteorological data requires geographical context information. Geodata are also needed for modelling processes in meteorology and related domains (e.g. hydrology) and for climatological analysis. It has been realized by meteorologists that a GIS is a powerful tool to support their work.

A GIS is designed for acquiring, processing and displaying geographic data. The first step can be achieved by scanning or digitizing maps. Various public and commercial organizations offer data in a variety of formats. Data processing includes format conversion and geodetic transformations, but it can also extend to more elaborate processes such as image analysis. For display on high-resolution screens and plotters, various graphical features may be attributed to geometric objects.

Most GIS support both raster and vector data. These are structured in layers, where user-defined information may be added. A commercial desktop GIS fulfils many of the meteorological requirements, but several additional features and extensions are needed. The system must be able to handle three-dimensional data, e.g. digital elevation models, and must have an interface to a relational database.

The collection and preparation of data requires a large, often underestimated effort. In addition, there is a considerable amount of software development necessary, in particular for data interfaces and algorithms. Data formats for GIS and weather processing systems are very different. Well-established meteorological formats are not yet supported by GIS. While vectorized geodata have a complicated structure, some features desired by meteorologists are missing.

Standardization efforts are welcome, especially the work of the OGC (Open GIS Consortium). The completion of data sets compiled by European organizations such as MEGRIN (Multi-purpose European Ground-Related Information Network) will fill a large gap. Valuable worldwide data are offered by the US Geological Survey. Data from the recent SRTM (Shuttle Radar Topographic Mission) will provide an excellent worldwide high-resolution elevation database.

2.7 INTEGRATION OF ALL DATA AND PRODUCTS

2.7.1 Speed and ease of access

The various types of data and products that can be generated, pre- and postprocessed or displayed by computers are extensive. This information can be roughly divided into two categories: real-time and non-real-time data and products. A detailed overview of data-management techniques is given by WMO-No. 788, *Guide to World Weather Watch Data Management*. Speed and ease of access are dependent on:

- Method of generating data and products (observing systems, forecast models such as global and local models with different grid resolutions);
- Volume of data;
- Representation of codes (e.g. BUFR, GRIB);
- Data exchange among NMSs (WMO Bulletins over the GTS);
- Database technology (e.g. relational or object oriented databases);
- Query languages (SQL – standard query language) for database access;
- Software techniques (e.g. programming languages Fortran or C) for processing and visualization (e.g. IDL);
- Networking (LAN and WAN);
- Computing equipment (high performance computing environment);
- Availability of information systems (especially World Wide Web).

2.7.2 Portability across systems

To ensure portability, it is important to introduce standards of data-handling techniques. One example is the use of standardization of database technologies and query languages such as relational database management system (RDBMS), (see. WMO-No 788). Data from RDBMS-type databases can be retrieved via a special query language called SQL. With the aid of SQL it is possible to work with databases from different vendors, even with databases that are available free of charge, such as mySQL, which allows storing and retrieving all kinds of data in a transparent way, especially data in commercially supplied browser format. It simplifies accessing data for using new technologies (e.g. the Internet) and guarantees portability across other databases.

In order to facilitate the usage of data in special computing and visualization environments, it is indispensable to store data in standardized data formats. There are several data formats, each of which is suited for different data types:

- BUFR: observations (e.g. FM 13, FM 35), radar imagery
- GRIB, netCDF: gridded fields
- T4-code, Tiff (e.g. Geotiff): Images.

2.8 DISSEMINATION

2.8.1 Television

Television is an effective medium to disseminate weather information to a large number of people. The weather presentation must be suited to viewer clientele and area (national and regional). The quality standards of the individual broadcast stations are variable and must be noted for production, as this will affect the possibilities of transmission. For maximum effectiveness of the production, a balance should be achieved between automation and flexibility.

2.8.1.1 Graphics quality

A production system for public weather services has to cover all television standards according to image size and image frequency (e.g. PAL or NTSC) and it must be open to new developments on TV sector (e.g. digital TV or 16:9).

The graphical quality depends on image import, compression rates of hardware and exported image format. To simplify the exchange of images between graphics designer and the production system it is useful to employ a standardized format such as tif. Images have to be easily understandable by the layman and all objects have to have a high resolution. Background landscape images should be recognizable for the viewer.

2.8.1.2 Audio-visual formats

There are various formats for images used for TV presentation, depending on quality demands (e.g. gif, jpeg, mepg) and frame rates. Many formats can be converted and edited in graphics software available on the market.

2.8.1.3 Animation

The length of animations depends on hardware, frame rate and time-step of meteorological data. Animations have to be smooth for the spectator. This is achievable by high frame rates, short time-steps within the data and interpolation to shorter time steps.

The interpolation of meteorological data to shorter timesteps can have various effects depending on interpolation algorithm. These effects have to be mentioned, especially when interpolation is used for clouds or precipitation.

Formats for animations may be mpeg, gif and others depending on hardware and the way the data are provided. Many formats can be converted to each other. Special hardware such as digital disk recorders and compression boards is also available for the dissemination of longer animations.

2.8.1.4 Individualized designs

For TV stations, an individualized design for weather presentation that is understandable for the layman, is as important as the content. A software for weather presentation should allow the possibility to import and export data for unique designs. Standard output formats such as tif are therefore useful. Graphics designers could use software from the market for their design. The weather presentation system should have a large variety of landscape and other geographical information. There are several possibilities to represent numerical weather prediction data, such as two-dimensional, three-dimensional, pictograms and cloud forecasts, which can be individually designed. Many software packages can be obtained commercially or through bilateral arrangements with other NMSs, thus making it unnecessary for each NMS to use resources to develop its own software.

2.8.1.5 Networked/local broadcasts

There are various ways to transfer data to the TV stations such as video wideband line (analogue) and ATM (digital).

Single images and short animations can also be transferred via the Internet or ftp-server, depending on capacity of network and size of data, both of which affect image quality.

2.8.1.6 Timely broadcast of warnings

The process of dissemination of warnings has to be defined very strictly, so that the warnings reach the viewer in a timely manner. When the warnings reach the TV stations there has to be a flexible system to edit a meaningful image very fast, for immediate broadcast. Such a flexible system could also be used for educational purposes and special events.

One method of displaying warnings in a timely manner is by the use of “trailers” or “scrolls” that can be placed on the edge of a TV screen either at the bottom or top and not interfere with the normal programming. In many cases the scroll can be initiated with an audio alarm.

2.8.2 Radio

2.8.2.1 Delivering of products

A variety of means are employed for the distribution of weather information to the radio sector for ultimate dissemination to the public. A standard method for the dissemination of products to radio stations is transmission by fax. This technique is available for nearly all stations and is suitable for a fast and direct dissemination of information as text, in tabulated forms or graphics. By prearrangement, narrative and graphical products can also be provided to radio stations as attachments to emails. Increasingly, radio stations obtain their weather information via the World Wide Web and, in some cases, from access-restricted web sites specifically designed to serve the media.

2.8.2.2 Broadcast quality voice lines

For smaller radio stations, normal telephone lines will be sufficient. For larger radio stations, special hardware is necessary to transmit live interviews in studio quality via an ISDN or other high-speed broad band connection.

For transmission of statements, special software on PC Platforms is available, which converts information in standard file formats (e.g. WAV files). Transmission is possible via modems and analogue or digital telephone lines or the Internet.

2.8.2.3 Value of immediacy

Radio is the most frequently used form of mass media for transmission of meteorological information. Therefore, only the latest observations and information, preferably not older than an hour should be used. Radio is the most suitable medium for the urgent and timely broadcast of severe weather warnings to the public. It also lends itself to the immediacy of nowcasting.

Encoding information within the warning message on the relative urgency for broadcast can assist radio station operators in the decision as to whether to interrupt a current broadcast segment for the broadcast of the warning message, or to broadcast the warning message after the current segment or to wait until the next routine news and weather break for the broadcast of the warning.

The trend towards remotely fed radio broadcasts and automation in the radio sector has presented additional challenges to getting warning messages out in a timely fashion. Special arrangements for interception of these remotely fed or taped radio broadcasts with broadcast quality voiced warning messages can ensure timely delivery.

2.8.3 Print

In recent years, the demands made on the media, especially for graphic presentation of weather information, have increased steadily. This has resulted in a high degree of automation using modern desk-top publishing tools to produce many weather pages for newspapers with individual layouts. Prior to setting up a new weather page it is necessary to contact the newspaper and check the technical standards (for example Macintosh or MS Windows personal computers, graphic software, transfer protocols used, etc.). The second step should be to find out the meteorological content that the newspaper is interested in.

2.8.3.1 Desktop publishing (DTP)

In the area of desktop publishing, certain products have established themselves as de facto standards. A few years ago, the only platform on which these tools were available was the Macintosh platform. Nowadays, these tools are available for both Macintosh and MS Windows.

In the area of layout software, there are two leading, quite expensive products: QuarkXPress and Adobe PageMaker. Both enable:

- Sophisticated layouts to produce brochures, magazines, newspapers, catalogues;
- Colour separation and professional colour management;
- Setting typography to professional standards;
- Creating templates for often-used layouts;
- Batch mode run for often-used layouts.

But there are also other DTP tools with a different scope. PageMaker is a high level DTP tool for the technical market. Corel Ventura and MS Publisher have limited functionality, but are located in the mid-price regions.

2.8.3.2 Graphics quality

Graphics quality depends on the solution of bitmap images, used types and colours. It is advisable to use fresh, clear colours for newspaper print. All colours should be given in the CMYK format. As a rule, the resolution of bitmap images (for example, tif) could be around 150 dpi (dots per inch). It is also possible to use vector images (for example, eps). Postscript fonts, for example, Times, Helvetica, and Excelsior, are available among the most widespread newspaper standard types.

2.8.3.3 "Ready to print" Weather Pages

In order to keep production costs low, manual work for producing a newspaper weather page should be minimized. Therefore it is important to develop a system which is on the one hand, compatible with the graphic systems and standards used by the print media, and, on the other hand, interconnected with all data sources used in the NMS. Good results are obtained with widespread desktop publishing programmes such as Illustrator or QuarkXPress.

2.8.3.4 Electronic delivery

Meteorological information such as images, maps or complete weather pages can be transmitted directly into the computer system of the newspaper, for example via ISDN Leonardo Protocol (Mac to Mac or PC to Mac) or via the Internet (ftp server). In the case of smaller data-files, it is also possible to use e-mail for delivery.

2.8.4 Internet

Of all the Internet services, the WWW (World Wide Web), FTP (File Transfer Protocol) and E-Mail (Electronic Mail) are the most important for public weather services.

Sections 2.8.4.1 to 2.8.4.4 discuss the use of the Internet and its application to public weather services as regards the required infrastructure, advantages and disadvantages, and possible services for different users.

2.8.4.1 Infrastructure

To use Internet services hardware, special software and a company to provide the Internet access (Provider) are needed on the part of the NMSs and other users (see table below).

2.8.4.2 World Wide Web (WWW)

The WWW as shown on page 12 is an information system that allows the worldwide exchange of digital data. It offers several possibilities to provide meteorological information – mainly visualized data (tables, pictures, graphics) – to private users and to business customers.

2.8.4.3 FTP

The ftp (File Transfer Protocol) service is an easy way to provide data to defined users (see table on page 13). High performance, security and the possibility of an automated delivery/download are the most attractive features. As the name implies, ftp is used to transfer files from one computer to another across a network, i.e. the Internet, and is an excellent way to distribute meteorological information such as weather reports, meteorological data files, radar, or satellite images in support of public weather services.

The ftp consists of two programs. There is a client program and a server domain program. An ftp client contacts a server on a remote machine and establishes a connection validated by user name and password. Once the validation is successful on the server machine, the ftp client can upload and download files, create and remove directories, etc. ftp client software for many operating systems (e.g. windows) is usually available at no cost through shareware or is already included in the operating software itself.

2.8.4.4 E-mail

The term "Electronic Mail" appropriately describes this service (see table on page 14). It is an efficient way to send information/products (mostly reports) to a customer. The integration of all kinds of files as attachment is possible.

2.8.5 Fixed and mobile communications systems

2.8.5.1 Fixed telephone lines

Telephone services are only suitable for pure speech transmission. They are mainly used for operating recorded announcement services in polling procedures. The analogue

Needed Infrastructure	Internet-Services: WWW,FTP, E-Mail
Other Users	*Hardware:* PC, WS Telephone+Modem, Telephone+ISDN, (Leased line, dedicated line) *Software:* WWW: Browser (e.g. MSIE, Netscape) FTP: ftp-client (e.g. ws-ftp), Browser E-Mail: e-mail-client (e.g. Outlook (Windows), Mail(Unix)), Browser *Provider:* Usually local company to provide the Internet access e.g. AOL, T - Online Others (Dependent on the Country)
NMS	*Hardware:* PC, WS Software: http-daemon (e.g. Apache) ftp-daemon (e.g. wuftp) email-daemon (e.g. MS-Exchange Server) *Provider:* Company to provide the Internet access; selection of company depends on: - Bandwidth - Prices - Traffic *Possibility of Web-Hosting:* Server is run by an external company!

Points of interest	Internet Services: WWW	
	Description	Additional Information
Parameters to be looked at while constructing the web site	*Performance:* High *Navigation:* Clearly structured *Content:* Well arranged; Adapted to usergroup *Design:* Attractive *Browser:* Independant	Besides the meteorological content the acceptance of a web-site mainly depends on the described parameters!
POSSIBLE SERVICES Free access	*Of interest for:* Private users Business customers	
	Content: Meteorological information of general interest	*Examples:* General forecasts for cities, regions, country; Warnings (only in addition to other media); Travel weather; Climatological information
	Advantages: Many users can be reached Everybody is able to access Image of NMS can be improved Advertising possible (banners, sponsoring)	
	Disadvantages: No direct income from users No direct contact with users	
Usergroups	*Of interest for:* Private users with special interests Business customers	*Examples:* Private pilots Winter road maintainance authorities Schools
	Access: Only with user-identification and password	User has to have a subscription; NMS has contract with user
	Content: Combination of special, user-group-specific, standardized information	*Examples:* Winter road maintainance: Detailed street weather reports; Hourly updated chart of 2m-temp.; Combination of a satellite-picture with actual observations *Schools:* Actual weather observations; Forecast charts; Analyses; Satellite pictures; Climatological information
	Advantages: Users known, Direct income, Products can be tailored to users needs	
	Disadvantages: Administration necessary, No spontaneous access possible	
Webshop	*Of interest for:* Private users Business customers	
	Content: Special but standardized products	*Examples:* Charts of windspeed/direction for special regions (e.g. for use by Windsurfers); Charts of wind-speed/direction at different heights (e.g. for the building industry); Detailed reports
	Access: Open to everybody, but products have to be paid for	E-Cash methods
	Advantages: Spontaneous access possible Single products can be ordered Direct, real-time access/delivery Direct billing, no invoice necessary	
	Disadvantages: No direct communication Has to be administered Costs for shop-software or administration	

magnetic tape used earlier has been replaced to a large extent by digital processes. Using this technology, speech is converted into so-called audio files and can be reproduced and transmitted without loss, even when a high degree of playback quality is required.

The special advantage of voice services is in the conversion from text to audio files. The development of software for the automation of this process is still primitive but enhancements are expected to be available in the near future. The best speech comprehension is for the time being still attained by the reading of a text by a trained speaker.

In principle, it must be borne in mind that the speech must be designed so that the listener can take in all the relevant information by listening just once. This requires comprehensive text formulation with a suitable choice of wording and phrasing.

2.8.5.2 Mobile telephone

As far as the provision of voice services is concerned, there is no fundamental difference between fixed and mobile networks. Mobile telephones do provide additional communication techniques however, which are somewhat similar to the Internet services.

The so-called SMS (short message system) allows a direct, economy-priced text transmission to another mobile telephone. This function is basically similar to sending an e-mail on the Internet and is to a large extent identical to that of a pager. (See also paragraph 2.8.5.3).

The WAP service (wireless application protocol) features basic elements of the World Wide Web. Similar to the Internet, information may be provided on a server that can be addressed worldwide by specifying a defined name (URL). As navigation, transmission and display are realized on mobile telephone hardware, there are major restrictions in use compared with the WWW. Currently available devices mainly allow presenting text information in a plain navigation structure.

2.8.5.3 Pagers/SMS

Pagers and mobile telephones (see also paragraph 2.8.5.2) allow short text messages to be sent to mobile devices that are

Points of interest	Internet Services: FTP	
	Description	Additional Information
POSSIBLE SERVICES Free access	*Of interest for:* Private users	
User: Anonymous	Business customers *Content:* Data files (No fees) Software of general interest *Advantages:* Interested users can access All kind of data can be provided Administration minimized compared to other ways of delivery *Disadvantages:* Users unknown Possible security problems	
Users	*Of interest for:* Partners Business customers	*Examples:* NMSs; Online services; Power industry; Met. Service providers
	Access: Only with user-identification and password	User has to have a contract with the NMS
	Content: Combination of products determined by user	*Examples:* Grid-/Grib data files Forecast charts Radar/satellite imagery Animations
	Advantages: Users known Easy to access Data can be sent or downloaded automatically Better security Higher performance *Disadvantages:* Administration necessary	

Points of interest	Internet Services: E-Mail	
	Description	Additional Information
POSSIBLE SERVICES Delivery to - single user - usergroups	*Of interest for:* Private users Business customers *Content:* User-determined meteorological data, products, and information *Advantages:* Easy way to deliver and access Automatic delivery possible Receipt possible Users known *Disadvantages:* Amount of data restricted Not secure Times of transfer vary within a broad range Administration necessary	 Reports Warnings (only in addition to other media) Users have to have a contract with the NMS
Newsletter	*Of interest for:* Private users Business customers Partners *Delivery:* Only after registration *Content:* Information concerning special subjects; News *Advantages:* Users known (At least e-mail-address) Marketing instrument Image of NMS can be improved Administration minimized *Disadvantages:* Texts (contributions) have to be produced	*Examples:* Independence of subject: NMS; Met. Service Providers; Universities; Key account customers; People interested in meteorology New products; New developments; International activities; Meetings

carried by the recipient and are addressed via special radio networks. The owner can adjust the device to indicate an incoming message by signal tone or vibrations.

These systems are ideal for transmitting warnings. Transmission time depends on the network, but is usually within the range of a few minutes. However, the sender receives no confirmation of reception, so a network with high system availability should be selected.

The number of transmittable characters per message is usually restricted; for SMS messages, for example, the limit is 160 characters. Longer texts can be broken up into several messages. This makes it much more difficult to read the messages, however, especially as the various messages can arrive out of sequence.

2.8.5.4 Fax on demand

In order to transmit meteorological information in telefax services, these have to be converted into a special graphic format which is standard worldwide. In manual operation fax machine does this by scanning a hard copy. To automate this operation, the telefax page has to be assembled by means of a word processor from the required text or graphic elements, then given out in telefax format and finally filed on the fax server.

2.9 STANDARDS RELATED TO NMS OPERATIONS

2.9.1 Data standards and formats

As far as data exchange within the GTS and the operability among spatial distributed data archives of NMSs are concerned, the standardization of data formats and data description (meta-data) is inevitable.

An important aspect of data management for the World Weather Watch (WWW) is the establishment of common procedures for data representation, i.e. character codes and binary representations. Such procedures serve to facilitate the timely national and international exchange of the vast volume of meteorological, geophysical, and environmental information required by individual Members to meet their specific operational responsibilities. National and international research and application programmes are also served by the availability of observations in common data forms.

These common procedures for international data representation are based on the concept of using codes to describe weather conditions, reports of instrumental readings, and processed data, thereby considerably reducing the length of messages, avoiding language problems and facilitating automatic processing.

Coded bulletins are used for the international exchange of meteorological information comprising observational data provided by the WWW Global Observing System and processed data provided by the WWW Global Data-processing System. Coded messages are also used for the international exchange of observed and processed data required in specific applications of meteorology for various human activities and for exchanges of information related to meteorology.

Messages may take the form of either a set of code forms, defined by standard procedures, for alphanumeric data exchange (character codes) or a set of representation forms with their specifications and associated code tables for binary data exchange (binary representations). Rules concerning the selection of codes and representation forms for international exchange are specified in the WMO *Technical Regulations*, Volume I, Chapter A.2.3 (WMO-No.49, 1988 edition).

Ideally, a self-defining binary representation form should be universal – capable of representing a required set of data. In practice, the last consideration in the previous paragraph has resulted in two forms being developed for the representation of meteorological data – FM 92 GRIB, used mainly for the representation of products, and FM 94 BUFR, used mainly for the representation of observational data.

In addition, for some applications, it would be of advantage to access data directly from databases without using decoding procedures. Data should be stored in simple readable formats, e.g. on the basis of relational data models, which take the information about and the relationships between the data.

The wide range of data and products that could be of potential use to the various WMO programmes creates a need for extensive meta-data to describe them independently of data formats.

2.9.2 Communication standards and protocols

The common protocol for communication between computers, the TCP/IP protocol, has become the worldwide standard protocol.

The most common applications based on the TCP/IP protocol are:

- DNS (domain name system) for translating computer names into the unique computer addresses in the TCP/IP protocol (IP addresses) and vice versa;
- Ftp (file transfer protocol) to transfer both binary and text files;
- WWW (World Wide Web) for presenting and retrieving any documents that are stored on servers;
- E-mail (electronic mail) for sending information to a group of recipients provided that the volume of information is not too large, and for receiving feedback;
- Newsgroups as a tool for exchange of information within a limited group of persons.

As today practically every computer supports them, all these standard applications can serve public weather services to develop more efficient methods for disseminating information to a far wider audience.

2.9.3 Computing standards

In an operational environment, especially in the area of nowcasting and warnings, it is indispensable to have reliable and robust hard-and software. This could be assured by setting up a support team for client hard-and software. It also makes sense to implement system management software (see paragraph 5.6) to ensure flawless operation.

2.9.3.1 Clients

Today's client computer at a NMS is either a Windows PC or a Unix workstation. The main task of a Unix workstation is to represent meteorological forecast models. This application needs high performance and quality for two-dimensional and three-dimensional graphics. The client should be able to show digital videos and has to offer other multimedia capabilities. At the DWD for example, SGI computers are used, where the standard client is a SGI O2 workstation having 128 Mbytes of main memory. The CPU is a R5000 processor. The file system is stored on two drives having 4 Gbytes capacity each.

Windows PCs based on the x86-platform are used for doing classical office work, i.e. writing documents, sending and receiving e-mails, or creating reports. If such a PC is enhanced with an extra graphic adapter supporting OpenGL" and if its frequency is beyond 700 MHz, the PC could also be used for displaying meteorological model data.

Again, as an example, at the DWD, meteorological products are presented on both Unix and x86-platforms. On the x86-platform, this is done by a browser using HTML. Furthermore, Windows" NT" 4.0 SP6 is used as the operating system. Both Netscape Navigator" and MS Internet Explorer" are employed as browsers.

2.9.3.2 Server hardware

At most NMSs, servers for high performance computing are MPP-Systems with RISC or vector processors. There are also solutions with a single parallel vector processing system (PVP).

Servers for data handling and pre/postprocessing are normally SMP-systems. These systems provide access to cartridge silos with thousands of cartridges. The corresponding drives are connected to the servers by SCSI. Widely used types of drives are Magstar (IBM) and Eagle (StorageTek).

The servers exchange data via high-speed networks, e.g. high performance parallel interface (HIPPI) – connections with 800 Mbit/s peak.

2.9.3.3 Server software

In general, servers run UNIX as an operating system. Main programming languages are Fortran 90, C, C++ and Java. The parallelized analyses and forecasts are mainly written in Fortran 90 using the MPI-Library. Forecast suites consist of batch-jobs, submitted via a network queuing system. In order to build up batch-jobs command languages like Korn shell, C-shell and Perl are used.

Data handling and pre/postprocessing are done by file-oriented or relational database-oriented applications. For archiving/retrieving data in a transparent way a hierarchical storage management (HSM) must be installed.

HSM software allows to view offline data (stored on tapes or DVDs) as a truly "online" direct access storage (e.g. disks). This facilitates the storage and retrieval of data sets.

2.9.3.4 Computing standards software

There is a wide variety of software standards. During the early to mid-1990s most software was developed using the structured analysis and design paradigm. Today most client and server-side software are developed using object-oriented (OO) programming techniques. In the area of numerical modelling, the transition from Fortran77 to Fortran90/95 has been made in more recent times. Object orientation is a technique for system modelling, ("system" being software system or a system in a more general context, such as the weather). OO models the system as a number of related objects that interact. An object might be a cloud, that has special attributes such as type, water content, cloud base, etc.

The early phases of OO software lifecycle development are covered by tools that use the unified modelling language UML, which is today's de facto standard. Several vendors provide quite expensive and massive tools for this phase.

Client- and server-side applications are written mostly in C, C++ and Java. C is still used in environments, where the transition to OO thinking has not yet taken place. This transition is quite a big change in the way software is developed and maintained and requires considerable resources. Java itself is gaining more and more importance, even on the server-side. The advantages of the Java platform is described in Section 2.1.4 (Programming platforms).

There are still two strategies to store data. Some NMSs rely on file-systems for the sake of performance and simplicity while others utilize relational databases (RDBMS). RDBMS allow the storage of all sorts of data and sophisticated queries. RDBMS vendors today offer more and more additional functionality (see also Section 2.6 on GIS) which might make proprietary developments redundant.

In the field of graphical user interfaces (GUI) development there are only a few defacto standards:

- Visual C++ or Visual Basic (MS-Windows only);
- Motif (Unix only);
- Java (Swing, AWT; all platforms);
- TCL/TK, Qt (all platforms, only minor importance).

Microsoft's Visual product line can only be run on Microsoft's operating systems and Motif only on Unix. TCL/TK, QT, and Java allow the creation of portable user interfaces. With the aid of GUIs, applications can be created that enable the customer easily to request or configure products.

Graphics programming is done using the four major application programming interfaces (API):

- Open GL (all platforms);
- X11 (UNIX only);
- DirectX (MS-Windows only);
- Java AWT, Java2D, Java3D (all platforms, on top of DirectX or OpenGL).

OpenGL, DirectX, and Java's graphics APIs allow creation of appealing, customizable graphics, that could well be tailored to the needs of customers. With the help of these APIs one could create fast (in the sense of image generation) or beautiful images, depending, for example, on the bandwidth of the network or the area of use (TV or newspaper).

2.9.4 Integrated system

As described in Section 2.5, most of today's Meteorological Workstation Systems MWS are implemented in C or C++, with some legacy code written in Fortran and with Java becoming more important. The operating system used is in most of the cases one of the major vendors UNIX (DEC Ultrix, HP UX, SGI IRIS, SUN Solaris). Certain NMSs are now evaluating LINUX more closely. LINUX is becoming a reliable and powerful operating system. Many companies compile stable "LINUX distributions". These distributions give good value for money. Most major hardware and software companies, such as IBM, SGI and HP invest a lot in LINUX. Windows NT plays only a minor role.

Due to the dominance of UNIX, the standard in the area of middle-ware is CORBA (see Section 2.1.4). Only few NT-based systems are using Microsoft-DCOM.

Most of the Graphics User Interfaces are implemented with OSF/Motif. The graphics API (application programming interface) is in certain systems still the graphical kernel system, while others use pure X11 or directly OpenGL.

Graphics APIs allow drawing on a virtual canvas. It is possible to draw lines, areas symbols and images in two or three dimensions. With primitives, it is possible to build a complex scene. A scene could be a newspaper weather chart or an animation for TV broadcasting.

2.9.5 Dissemination and access

2.9.5.1 Participation in the World Weather Watch

Knowledge of the state of the atmosphere in synoptic time scales is the essential precondition for the production of a whole variety of meteorological products. These products provide weather information of interest to the general public as well as forecasts for the development of the economic and social aspects of life. The most important components of meteorological products are warnings of severe weather in support of safety of life and protection of property.

The basis for all meteorological products is a worldwide network of different meteorological observing platforms, the data from which are distributed globally and in real time.

Through the Global Observing System (GOS), the Global Telecommunication System (GTS), and the Global Data Processing System (GDPS), data and products required in the preparation of public weather products and for the delivery of services are collected and disseminated.

The technical equipment employed in the international exchange of data is the Message Switching System (MSS).

The MSS receives international meteorological data from the GTS for use nationally, and routes national meteorological data through the GTS, for international exchange.

The data exchange via the GTS follows a set of rules and procedures that are WMO standards (see *Manual on the Global Telecommunication System*, WMO-No. 386). These regulations cover the details of the distribution of all kinds of data: measured, observed and processed, over all kinds of links in use. Included are most of the presentation forms, e.g. pictorial, graphical and textual. In smaller NMSs, the task of providing customers and the public with the appropriate services is done partly or in full via the MSS system. In larger centres, that are able to provide a higher level of service to the public, a variety of dedicated computer systems for different purposes are in use, e.g. workstations for processing satellite data, radar data or for controlling information systems. High-performance computer systems do the numerical weather prognosis on the basis of sophisticated models of the atmosphere. These systems also rely on the MSS for access to basic data.

2.9.5.2 Preparation of products for customers and the public

The rapid development of Information Technology (IT) continues to open new possibilities for producing and distributing new products. In parallel with these advances, the demands of the public to be supplied with actual and especially tailored meteorological data and information continues to increase. As a result, the task of providing the public with appropriate information continues to become more complex. The production of information for the public and customers is now delegated more and more to specialized systems such as workstations, so-called product servers. The servers of a centre are connected with the MSS and with each other via a local area network (LAN). These server systems process information such as:

- Synoptic observational surface data;
- Synoptic upper-air data;
- Results from remote-sensing (e.g. radar, satellite pictures);
- Output of numerical weather prognosis.

Products for the end user should meet the requirements of the public and paying customers. Such user-tailored products include:

- Warnings of severe weather conditions (e.g. hurricanes, severe local storms, heavy precipitation leading to flash floods, thunderstorms, etc.);
- Distribution forecasts of harmful air pollution (volcanic ash, smoke from forest-fires, accidental chemical releases, etc.);
- Nowcasting (weather development within the next hours) for public events and sports;
- Short-, medium-and-long range forecasts for the transport industry;
- Special forecasts for traffic (vertical cross sections, special routes, freezing conditions, snow fall, fog), for agriculture (precipitation, evaporation, soil humidity, hail forecast, wind), for construction (high wind speed, temperature), for power plants (temperature, wind prognosis);
- General forecasts for the public via mass media and other dissemination channels;
- Medical advice for people who are sensitive to changes in the weather.

Products that are prepared for the public and other users are normally produced in appropriate formats to be delivered via different media to the end users.

The product servers can handle the different procedures needed to deliver the products directly to the end users or use the services of dedicated information servers to distribute the products according to a scheduling table.

2.9.5.3 Distribution of products

There are many different services available now to provide the user with the appropriate information in an appropriate manner. Each of the services has advantages and disadvantages. In selecting the most suitable service the customer demands, the available infrastructure and the pricing of the telecommunication services have to be taken into account as well. The following is a list of those services:

- Bulletin broadcast
  A set of bulletins as available over the GTS is transmitted from the MSS to the broadcast station for transmission. It is important that the transmission follows a selected but timely fixed programme. Bulletin broadcast is expensive but useful for areas with weak communication infrastructure or for ships in coastal regions.
- Bulletin distribution service
  Bulletins as available over the GTS or compiled individually for distribution are sent to customers via leased lines or via dial-up connections according to a time schedule or when available. This is mainly the functionality of the MSS for some specialized customers who can accept the GTS coding.
- FAX service
  Any meteorological content prepared according to the customer's needs is coded into fax format and sent to the customers mainly via phone lines or ISDN.
- Fax on demand
  Any meteorological content prepared according to the customer's needs is stored on the server workstation, where it is available on demand, but the system does not take the initiative to transmit. The customer may apply for the fax using his own fax device for selection of the appropriate data set. The prepared information will then be coded into fax format and sent to the customer. The transmission costs are borne by the customer.
- File service
  A special software accesses files ordered by customers from the workstation where it is available and sends them via leased lines or via dial-up connections. Files are sent according to a time schedule or when available.
- Internet ftp server
  Any meteorological content prepared according to the customer's needs is coded and stored in files on an

Internet server. Customers have access to the files via the Internet using ftp.

- Internet home pages
  Any meteorological content prepared according to the customer's needs is coded into the HTML format and placed on the homepages of the NMS. The growing Internet community among the public, may access them according to its needs by using standard browsers. Access restrictions for special pages are possible, since it is possible to restrict access only to a special group of (paying) customers who hold passwords.
- E-mail
  Meteorological content that meets the customer's needs is coded as mail content or as a data file appended to a mail. The mail is sent to the customer's addresses when available or using a time schedule. The customer may access and read the mail as needed.
- One Stop Shop
  Any meteorological content available in the NMS is coded into special formats according to the customer's needs and is held available in a server's database using a DBMS. This server is named One Stop Shop because all the data of the NMS or the region are held available.

  The customer may search for datasets he needs using SQL or a HTML interface. If the customer decides to get the data, he may send a prepared form to the server applying for data. These orders are served by the One Stop Shop as soon as possible or in agreed intervals. It is also possible for customers to subscribe to classes of data and get them in a routine manner via e-mail or ftp.

  Different kinds of billing systems are possible, e.g.:
  – Sending invoices of fees to the customers;
  – Allowing customers to pay in advance, booking the fee for the data from the account;
  – Virtual billing applies to institutions that get the data for free.
- Satellite distribution services (e.g. German FAX-E, British SADIS (for aviation onlay), French RETIM)
  A fixed number of data-sets, thought to best meet the needs of most of the customers, is sent to the satellite for distribution following a schedule. Encoding may restrict access to open datasets or allow access only to those data-sets that the customer has subscribed to.

2.9.6 Feedback on systems performance and service quality

The IT architecture of an NMS is normally a distributed and heterogeneous environment. Centralized management and control of such an environment provides the best way to ensure continuous application availability. There are several software packages available that address these problems, including network management. IBM's Tivoli© , HP Open View and Computers Associates TGA Unicenter are the major commercial products. These kinds of package are very complex and need considerable effort to be implemented.

Tivoli© Distributed Monitoring is used at the DWD as the strategic management tool for this aim. Tivoli© surveys CPU and system loads of both UNIX and Windows NT servers. Other critical system and application parameters are monitored as well. Rules are specified which automatically detect, correct, and avert problems before they affect application and system availability.

Microsoft's Systems Management Server is used to distribute software to machines or to remove software from machines. Detailed technical information on client installation and inventory, software distribution, remote troubleshooting, upgrading, and third-party product information is collected and stored in the underlying database. This helps administrators plan, deploy, and diagnose a network of Windows PCs.

A user help desk system should support problem handling and document all failure and problems of the whole IT environment. As part of its functions, it coordinates and documents the actions taken for failure/problem solution and gives a failure/problem history. This forces a coordinated procedure of failure/problem handling and trails to a knowledge database useful for faster solution finding.

There are multiple different systems on the market. Normally these systems are in-stalled as a plug-in on existing system management, network management, asset management and/or network documentation systems. They can use existing databases over an interface and have the capability to generate trouble tickets automatically on incoming events of these systems.

Common products are, for instance, Action Request System (Remedy Corp.), Tivoli© Service Desk (Tivoli©), Solve:Central (Sterling Software).

Chapter 3
APPLICATION OF RESEARCH FOR MORE EFFECTIVE PRODUCTION AND DELIVERY OF PUBLIC WEATHER SERVICES

3.1 SEAMLESS USE OF SEASONAL, MEDIUM- AND SHORT-RANGE FORECASTS

The development of numerical weather forecasting began some 50 years ago, at a time when it was inconceivable for meteorologists to offer the general public, the media and special users products that would range from the very short-range forecasts to seasonal forecasts. The standard at the time was a 24-hour forecast compiled manually and an outlook for the following day. Longer-term predictions consisted of probability statements based on climatological statistics.

Nowadays, thanks to decades of international developments in science and technology, meteorology benefits from:

- More observations data round the clock from all over the world;
- Mathematical-physical models; and
- Fast computers.

These tools are used in combination for producing "seamless" weather forecasts.

These forecast products can be classified as follows in accordance with the WMO Definitions (*Guide to Public Weather Services Practices*, WMO-No. 834) as follows:

- Nowcasting:
  A description of current weather parameters and a zero to 0-2 hour forecast description of forecasted weather parameters.
- Very short-range weather forecasting:
  A description of weather parameters up to 12 hours.
- Short-range weather forecasting:
  Beyond 12 hours and up to 72 hours description of weather parameters.
- Medium-range weather forecasting:
  Beyond 72 hours and up to 240 hours description of weather parameters.
- Extended-range weather forecasting:
  Beyond 10 days and up to 30 days description of weather parameters, usually averaged and expressed as a departure from climate values for that period.
- Long-range forecasting (from 30 days up to two years):
  - monthly outlook: description of averaged weather parameters expressed as a departure (deviation, variation, anomaly) from climate values for that month (not necessarily the coming month);
  - three-month or 90-day outlook: description of averaged weather parameters expressed as departure from climate values for that 90-day period (not necessarily the coming 90-day period);
  - seasonal outlook: description of averaged weather parameters expressed as departure from climate values for that season.
- Climate forecasting(beyond two years):
  - *Climate variability prediction:* description of the expected climate parameters associated with the variation of interannual, decadal and multi-decadal climate anomalies;
  - *Climate prediction:* description of expected future climate including the effects of both natural and human influence.

The use of numerical weather forecasts began in the USA in the mid-1950s. From today's point of view, these were just simple barotropic models, but at that time it was the start of a new era. Other NMHSs followed suit at the beginning of the 1960s.

Rapid development in computer technology followed, which, in turn, provided the prerequisite for rapid development of numerical models. Baroclinic models followed the simple barotropic models, and hemispheric models became global models. In keeping pace with the development of ever more powerful computers, better communications networks, and more sophisticated observation systems, such as satellite technology, the numerical models continued to be improved. The spatial and temporal resolutions of the models became increasingly refined. Whereas at the beginning the forecasts were confined to a few standard parameters, such as altitude of the 500 hPa area or the temperature in selected areas, the models were developed further in the direction of "weather" forecasts models. A further step was the development of so-called "nest models", with grid lengths of only a few kilometres, for the regional forecast, which are driven by the large-scale models.

A logical step for the development of medium-range weather forecasting followed that of the short-range forecasts in the 1970s. This was followed by the development of "extended range" forecasts and climate models.

Today the meteorologists and forecasters have an abundance of data at their disposal to meet the many and diverse requirements of the users of the meteorological and hydrological services.

For the time being a seasonal forecast must necessarily be limited to a prognosis of average conditions. Seasonal forecasts based on atmospheric models alone are inconceivable. Only a complete system consisting of a coupled ocean atmospheric model and an ocean data assimilation system will make a real-time seasonal forecast possible.

First successes of these models are ascertainable above all for tropical regions. The best-known example is the successful prediction of the El Niño phenomenon in 1997/1998.

Over the past 50 years, technical developments on the one hand, and the increasing demands of society for safety of life and property on the other hand, have led to the development of an almost seamless forecast activity of NMHSs.

For longer-term forecasts, meteorology is just at the beginning of new and exciting developments. The following chapters deal with selected forecast scales in more detail.

3.1.1 Nowcasting

Apart from the need to provide short to medium-range forecasts, there is a growing demand for nowcasts of the immediate next two hours or so as well as seasonal forecasts of a few months ahead. Nowcasting is as difficult, if not more, as seasonal forecasting as nowcasts of a relatively "quantitative" nature are usually required by users. These "quantitative" nowcasts are often crucial in times of severe weather conditions for emergency organizations and the public in making decisions on the precautionary measures to be taken. Such decisions and thus the nowcasts have huge impact on public safety as well as economic development. Questions on more specific location, timing and degree of severity of the weather conditions are often asked. These questions sometimes come from the highest levels of the government. Nowcasts as input to weather warning services are thus the most visible output of NMSs. Accurate nowcasts often boost the image of an NMHS and are very good justification of the investment of public revenue in NMSs.

Apart from having a good understanding of the large scale weather systems, it is very important to be able to closely monitor the mesoscale systems in nowcasting. Since these mesoscale features are relatively small, it is practically impossible to capture them using conventional operational charts and NWP products. Their detection are now made possible by using near real-time data from a dense network of AWSs and raingauges, satellite, radar and other remote sensing equipment such as wind profilers.

With the advent of NWP and high speed computing facilities such as super-computers and PC clusters, it is now possible to run regional numerical models with resolutions down to a few kilometres. Predictions from these high-resolution models are now more accurate. Considerable strides in Quantitative Precipitation Forecasts (QPF) have also been made. These serve as valuable guidance to the relatively quantitative nowcasting.

Apart from having the capability to nowcast the weather in the next two hours, it is of equal importance to have effective dissemination channels in place so that nowcasts can reach the users in good time for taking prompt actions.

3.1.2 Short-range forecasting

Short-range forecasting (12 hours to 72 hours forecast) has become a high-demand forecast product used mainly for the daily planning of outdoor activities such as sports events and social events, as well as special purpose activities such as filming, tourism and construction. Forecasting tools used for short range forecasting include radar echoes map, satellite imageries, real-time weather charts and numerical guidance products.

Many short-range numerical guidance products are available either at the national/regional level or from a range of centres. These numerical guidance products are distributed over the WMO Global Telecommunication System (GTS) or available on the home page of the particular NMS concerned. Sources of available numerical guidance products include the following among others:

- European Centre for Medium range Weather Forecast (ECMWF) disseminates numerical products on the GTS;
- Japan Meteorological Agency (JMA) Tokyo distributes numerical guidance products on the GTS as well as provides numerical prognostic maps and data on the WMO Distributed DataBase (DDB) Web Site at the following URL: http://ddb.kishou.go.jp;
- United Kingdom – The Met Office disseminates numerical products on the GTS;
- National Weather Service, United States of America, disseminates numerical guidance products on the GTS;
- The German Meteorological Service (DWD) distributes numerical guidance products on the GTS;
- Meteorological Service of Canada disseminates numerical products on the GTS;
- Bureau of Meteorology Australia disseminates numerical guidance products on the GTS as well as provides numerical prognostic maps on their web site for registered users at http://www.bom.gov.au;
- US Fleet Numerical Models output products are available on the internet with the URL: http://www.fnmoc.navy.mil.

3.1.3 Medium-range forecasting

3.1.3.1 Recent developments

Medium-range forecasting is an initial value problem of global scale requiring comprehensive observational data to specify the model variables using a modern data assimilation system to provide the initial condition for the forward integration of the atmospheric model equations. Numerical weather prediction for the medium-range aims to provide forecasts for the range of 3 to 10 days and beyond. Forecasts up to 14 days are now available at some centres and developments are in progress to close the gap between medium-range forecasting and seasonal forecasting by running the models out to a month. The extension of the forecast range has been justified by progress in data assimilation and modelling techniques, improvements in the global observing system, in particular the increasing availability of high-resolution satellite data, developments in the parameterisation of sub-grid scale physical processes, and the subsequent improvements in the skill of global prediction systems. Several forecast centres now produce forecasts which in the northern and southern hemisphere with respect to the synoptic scale flow pattern are on average useful out to 7–8 days.

The approach to medium-range forecasting can be both deterministic and probabilistic. Until the early 1990s, the deterministic approach was the classical forecast technique, although forecasters already made use of the "poor man's" ensemble approach, i.e. using and comparing forecasts from different model runs and forecasting centres. Since the 1990s, the ensemble forecasting technique supported by the necessary computer resources has found its way into operational weather forecasting.

3.1.3.2 Observations and data assimilation

The backbone of the in situ observing system is still the world-wide radiosonde network supported by surface observations over land and the oceans and aircraft measurements at upper levels. Automation has resulted in a substantial increase of observations from aircraft over recent years, providing wind and temperature profiles at airports during take-off and landing as well as at flight level. A true global observing system was achieved by the end of the 1970s when data from a network of polar orbiting and geostationary satellites first became available.

In the 1980s, most data assimilation systems used all the available observations in a time window around a fixed analysis time. e.g. for 00, 06, 12 and 18 UTC, thus ignoring the time offset for most of the space-based data, but also for many of the in situ observations, mainly from aircraft. The observations were analysed applying statistical interpolation against the background of a short-range forecast (six-hour first-guess field), i.e. the dynamical model provided the global information on the atmospheric state which was updated by observations unevenly distributed in space and time.

Since then, the data assimilation systems have been developed substantially to make better use of the asynoptic data and quantities directly sensed from satellites, i.e. the radiance data. This was made possible by introducing the variational data assimilation technique which allows the assimilation of radiance data directly into the model through the use of appropriate observations operators.

With the four-dimensional variational analysis (4D-Var) system introduced at ECMWF in November 1997, the influence of an observation in space and time is controlled by the model dynamics which increases its realism by spreading out the information. This is achieved by having the background errors modified by the model dynamics over the assimilation period in a flow dependent way. Observations are thereby given larger weights near rapidly moving or deepening cyclones where the forecast uncertainty is larger.

3.1.3.3 Numerical formulation

It was well recognized in the 1970s that for successful medium-range forecasting a global formulation of the forecast system was required for which the appropriate computer resources needed to be available. The first ECMWF numerical model was a gridpoint model with 15 levels in the vertical up to 25 hPa. The horizontal resolution was 1.875 degrees in latitude and longitude, corresponding to a grid distance of some 200 km on any great circle. Gridpoint models continue to be in use, but several major NWP centres have since introduced a spectral formulation for handling the dynamics while the physical processes need to be computed on a grid. In addition, the use of semi-Lagrangian techniques improved the computational efficiency which, together with the enhancements in computer power, allows the running of forecasting systems at much increased horizontal and vertical resolution. The current operational forecasting system at ECMWF is run with a spectral model at T511 resolution with 60 levels in the vertical extending up to 0.1 hPa. The grid used for the computation of physical processes has a spacing of some 40 km.

3.1.3.4 Physical processes and parameterization

Even today's high-resolution medium-range forecasting systems cannot resolve all the scales and processes which are important for the forward integration of the state of the atmosphere. In particular for the longer forecast time scales, from the medium-range, through to monthly time scale to seasonal forecasting, the inclusion of physical and sub-grid-scale processes in the model through parameterisation becomes very important. Processes to be mentioned in this context are the sensible and latent heat flux, radiation, cumulus convection and stratiform precipitation, the vertical momentum flux, surface friction and land surface conditions. Detailed orographic effects are taken into account through characteristics of the sub-grid scale orography.

The calculation of the near-surface processes and the exchanges with earth's surface require a good definition of the initial state of the ground through a number of surface values, such as the land-sea distribution, the snow cover, sea-ice cover, land and sea surface temperature, soil moisture, albedo, vegetation and over the oceans the state of the sea. In the early years of numerical weather forecasting, these conditions were mainly inferred from climatology, since in situ measurements were rare, scattered and insufficient or not available at all other than from specific field experiments which provided valuable data for the calibration and validation of the parameterization.

In recent years the global satellite observing systems, including several satellites launched for research and development, have begun to provide valuable data describing surface conditions and also depicting moisture content and precipitation activity in the free atmosphere, all of which are important pieces of information for initialising the forecasting systems.

3.1.3.5 Capability of deterministic medium-range forecasting systems

The continuous development of the data assimilation systems, the models and the recent improvements in the global observing system, in particular the space-based component, have led to significant improvements in the skill of deterministic medium-range forecasting systems, i.e. resulting in an extension in forecast time of the useful NWP guidance and in a substantial increase in the number of products.

Figure 1 shows the evolution of the forecast skill from the ECMWF model for the northern and the southern hemispheres as measured by the anomaly correlation of the geopotential height at 500 hPa. Over the last ten years there has been an overall gain in skill of one day or more at all forecast ranges. It is also interesting to see that mainly due to the availability and efficient use of satellite data the skill in the southern hemisphere is almost comparable to that in the

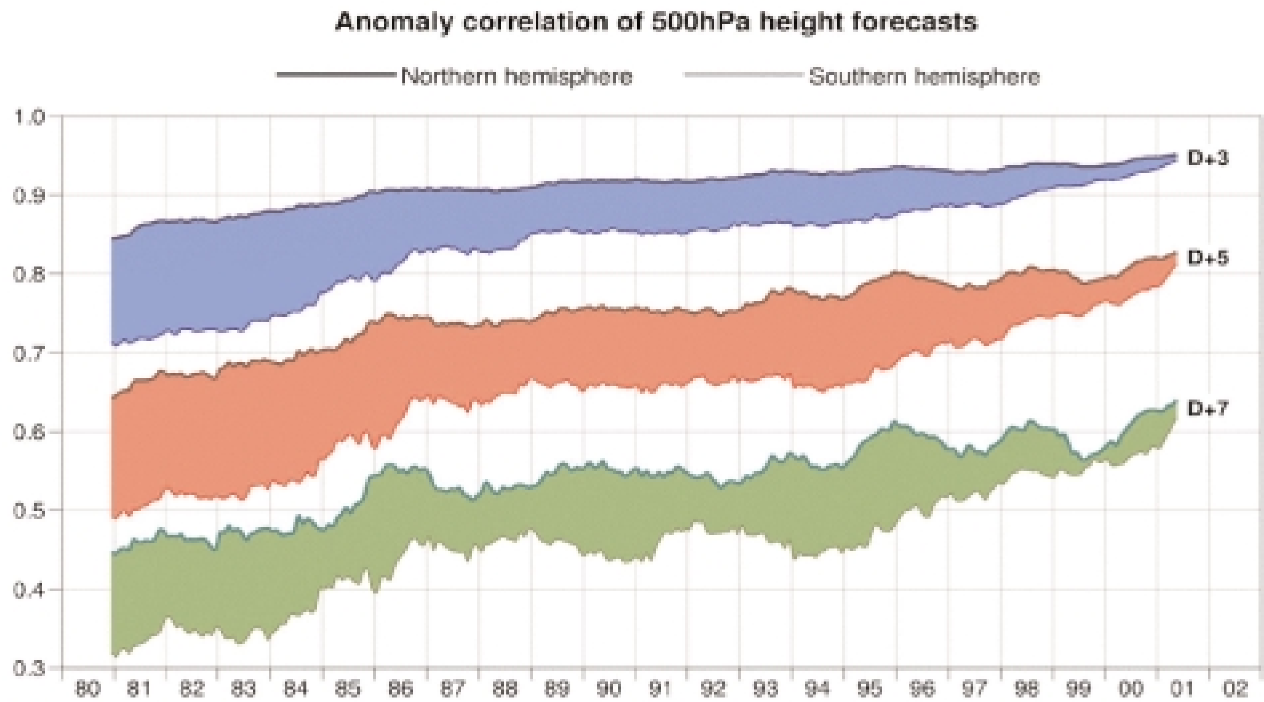


Figure 1. Evolution of the ECMWF forecast skill for the northern and southern hemispheres

northern hemisphere. Good forecasts of the flow pattern enable forecasters to predict major changes, e.g. the transition from a zonal to a blocked flow, the development of major cyclones, the onset or end of a heat wave, cold outbreaks or rainy periods. The latter examples are directly related to the model's capabilities to predict the 'weather' directly. Developments in model resolution, better model physics and a much improved formulation of boundary layer processes have resulted in the successful provision of model forecast guidance of near surface parameters like temperature and wind and wind gustiness, clouds, amount and type of precipitation. These parameters have a reasonable level of skill up to five days, even longer e.g. for precipitation when information of accumulated values in time and averaged over an area is required.

3.1.3.6 Limitations of deterministic forecasting

Regardless of the advances in numerical weather prediction in recent years, the deterministic approach to forecasting has its limitations which, depending on the application and the predictability of the atmosphere, may become apparent either at an earlier or later stage in the forecast length. Forecasters have a good deal of experience in interpreting single deterministic forecast runs and in filtering out the smaller scale features in the flow and weather pattern for which there is only little or no skill remaining. It is, however, difficult or even impossible to assess and quantify the uncertainty in the forecast based on single deterministic runs. Forecasters have in the past used mini ensembles of consecutive forecast runs from the same forecasting system or a combination of model results from different forecast centres to obtain a qualitative view of the most likely evolution of the atmosphere. However, such techniques are only of limited use and do not provide the quantitative information required by those users who need to assess the probability of occurrence of weather events.

3.1.3.7 Ensemble prediction systems (EPS)

To take into account the stochastic nature of the medium-range forecast problem and to provide forecast guidance that allows an objective quantification of the uncertainty in the forecast, ensemble prediction systems (EPSs) were introduced in the 1990s at some major forecast centres to complement the deterministic model runs.

At ECMWF, for example, an EPS has been in operational production since 1992. Together with the control, a 50-member ensemble is run from perturbed initial condition which reflect the uncertainties in the analysis. In addition, to simulate model errors, the concept of stochastic physics was introduced with a stochastic perturbation of the physical tendencies. Recently, perturbations in tropical regions were added with a particular focus on tropical cyclone forecasting, but with potential benefits also for extra-tropical developments. Since computer resources are limited, the EPS members are run at a reduced resolution compared with the deterministic forecasting system. At ECMWF, the spectral resolution of T255 (80 km spacing on a reduced Gaussian grid) is in use with 40 model levels in the vertical.

The output from the EPS spans a wide range of products, which can be tailored to the application and the need of the users, i.e. both forecasters and end-users:

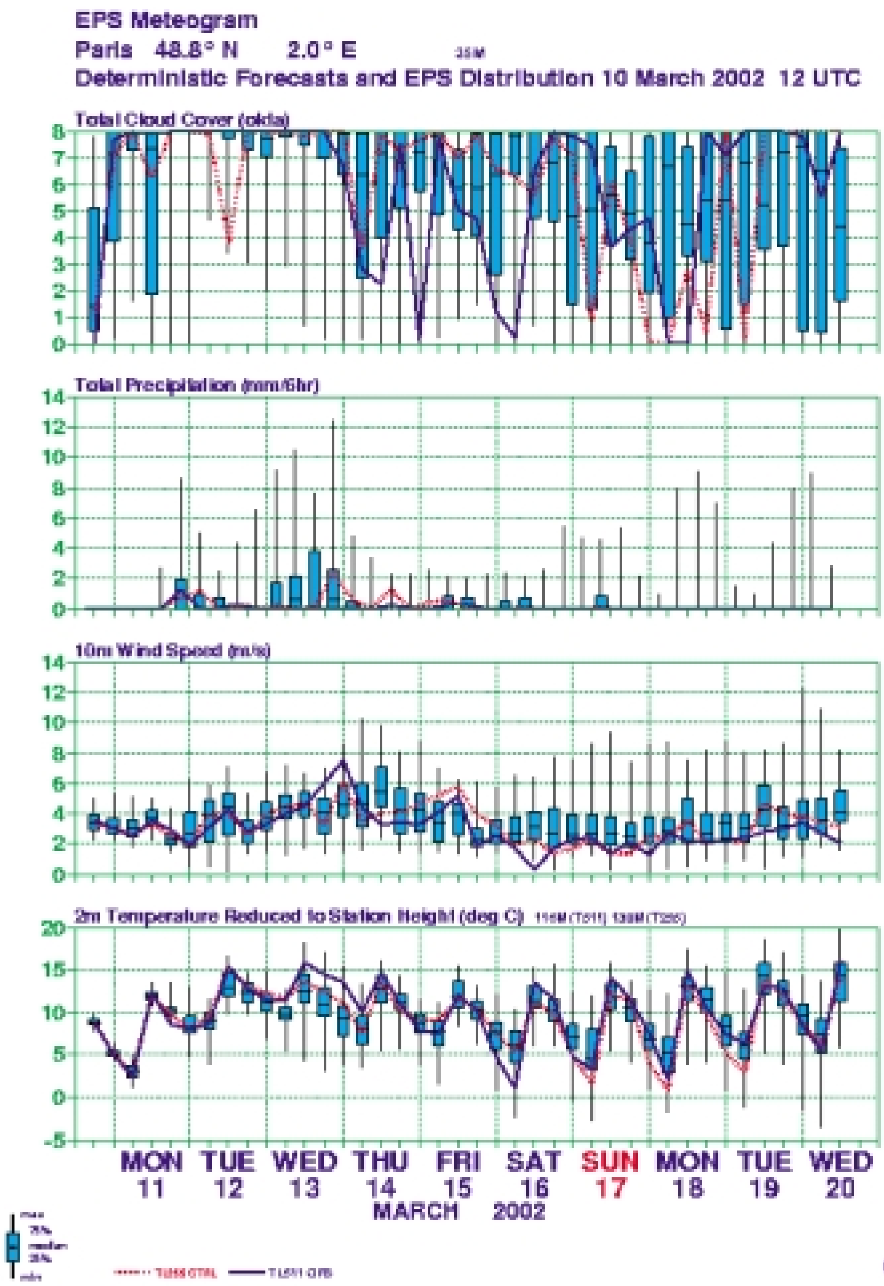


Figure 2.
EPS meteogram for Paris. The evolution of total cloud amount, precipitation, windspeed and temperature (top to bottom) with forecast time is shown every six hours. The spikes indicate the full range of the ensemble values, the rectangles the 50 per cent interval around the median of the distribution. The forecasts from the deterministic T511 (full) and EPS control (dotted) runs are also shown.

- Charts from the individual perturbed forecast runs; forecasters may be prepared to study such guidance in detail.
- Ensemble mean and cluster means; such charts compress the information and allow forecasters to assess the likelihood of alternative weather scenarios.
- Probability charts; indicating the probability of the occurrence of certain pre-defined weather events, e.g. precipitation amounts exceeding thresholds over a given period of time, occurrence of severe frost, exceedance of wind speed thresholds.
- Charts of extreme value indices; indicating the occurrence of extreme conditions in the forecast with respect to the model climate. Such indices can be used to provide early warning of severe weather events.

To make direct use of the forecast probabilities, the EPS needs to be an unbiased forecasting system. Otherwise it will be necessary to apply statistical adaptation and post-processing schemes tailored to the needs of the users.

Figure 2 shows a 10-day forecast at a gridpoint location displayed in a probabilistic meteogram. The time evolution of weather parameters is shown in one diagram for the deterministic model results and the EPS members. The EPS spread is indicated by the range of forecast values; the extreme values and the most likely solutions are depicted.

3.1.3.8 Severe weather forecasting

For successful predictions of severe weather events the forecasting system must have the attributes for detecting, simulating and forecasting the atmospheric features which lead to severe weather. The forecasting system can only simulate extreme or anomalous events which are at the scale of the prediction system (or larger). These events may be of mainly two types, i.e. large or medium scale persistent anomalies such as cold outbreaks or heat waves lasting for several days or small scale events with heavy rain, snow or strong winds. Suitable diagnostics of the model results, e.g. through the computation of extreme value indices related to wind speed, temperature and precipitation, can provide the early warning signal for the occurrence of extreme weather conditions in the EPS in the medium range. Further interpretation and post-processing of the direct model output may be required to determine whether the extreme conditions indicated by the forecasting system may constitute a severe weather event.

The combined use of guidance from the EPS and the high-resolution deterministic forecasting system is particularly beneficial for severe weather prediction. The EPS provides information on the probability of the event occurring and allows an objective risk assessment with respect to user applications, while the deterministic system because of its high resolution helps to further assess the intensity and severity of the event, such as gale force wind, high precipitation rates or the intensity of a tropical storm

3.1.4 Seasonal forecasting

3.1.4.1 Why seasonal forecasting?

The lower boundary conditions of the atmosphere such as sea surface temperature (SST) or soil moisture and snow cover often have a considerably longer memory than that of weather, and are at least partly predictable on a timescale of weeks to months.

One of the most important influences on weather patterns is El Niño, the irregular warming of sea surface temperature in the equatorial Pacific. When it appears, El Niño can have a strong impact on the weather worldwide, but even without El Niño there are many factors that influence the weather.

In recent years, both the ability to predict changes in SST and the understanding of their global impact has improved, and this has increased the interest in seasonal forecasting. The feasibility of such forecasts has also increased, for two principal reasons: firstly, the development of a fairly comprehensive in situ ocean observing system in the equatorial Pacific (the TAO array) which can measure upper ocean temperatures from the surface to depths of 500m. Help also comes from European, US and Japanese satellites, which provide wind, temperature and humidity data in the atmosphere plus surface stress and sea-level anomaly data at the ocean surface. The second reason for the feasibility of seasonal forecasting is the improvement in numerical models of the atmosphere and ocean. These are still flawed and require extensive further refinement, but they are good enough to use in developing a coupled forecast system.

3.1.4.2 A numerical seasonal forecasting system

The following sections describe the numerical seasonal prediction system at ECMWF. Seasonal forecasting at ECMWF is based on the use of numerical models, and is an example of the present state of the art. The system that has been developed consists of an ocean analysis system to estimate the initial state of the ocean, a global coupled ocean-atmosphere general circulation model to calculate the evolution of the ocean and atmosphere, and a post-processing suite to create forecast products from the raw numerical output.

The behaviour of the atmosphere is not predictable in a deterministic sense on seasonal timescales – small uncertainties in the initial conditions will always give a large uncertainty in the state of the atmosphere after some weeks. To produce a numerical seasonal forecast ensemble techniques are used. The forward calculation of the ocean-atmosphere system is repeated many times, with small differences in the initial conditions, and the overall statistics of its behaviour are considered. How many times the calculation needs to be repeated to give a good idea of likely atmospheric behaviour, depends on the place and time being considered. The size of some 30–40 ensemble members is enough to give a reasonable estimate of seasonal changes in many areas of the tropics, and some information in mid-latitudes.

A serious problem with using coupled models to calculate the behaviour of the ocean and atmosphere is that errors in the models are relatively large. In particular, there is a problem with what is called model drift. This is the continual tendency for the model to evolve towards an unrealistic state. In the ECMWF system this can be clearly seen in the tendency for many parts of the ocean surface to cool down, while in a few places the ocean surface systematically warms up. Since seasonal forecasting is largely based on the way in which changes in the ocean temperature affect the atmosphere, this model drift would be a serious problem if it were not dealt with in some way.

The strategy for dealing with model drift is straightforward. The ocean atmosphere and land surface are initialized to be as close to reality as possible. No ‘artificial’ terms are introduced to try to reduce the drift of the model, and no steps are taken to remove or reduce any imbalances in the coupled model initial state: the models are coupled together and integrated forward. The effect of the drift on the model calculations is estimated from previous integrations of the model in previous years. This mean drift is then removed from the model solution during the post-processing.

3.1.4.3 Post-processing and product generation

Seasonal mean climate anomalies are usually relatively small, for example temperature anomalies are often less than 1K. Since model errors are typically of a similar magnitude, the direct model output cannot be taken as a good indicator of what will happen. Allowance must be made for model errors. There are two basically equivalent ways of doing this. In the first, the mean bias of the model forecast is subtracted from the model output to produce an absolute forecast value, for example an SST of 26.1 C at a certain point in the ocean. The mean bias, a function of lead time and calendar month, is estimated from the difference between model forecast values and observations for a set of reference years. The absolute value can then be expressed either as it is, or as an anomaly from any chosen climatological reference value. This strategy is used at ECMWF for calculating values of Niño-3 SST from the model forecasts.

The second way of allowing for model errors is simply to ignore the true mean value of the field and to consider only anomalies. In this case, the values of the forecast ensemble are compared to the values of a climate reference ensemble (made up of model forecasts with the same lead time and calendar month, and covering a representative set of years), and the differences between forecast and climate are assessed and plotted. The advantage of this second approach is that no knowledge of the true climate is needed. In the case of 2m temperature, for example, the climatological value will vary on much smaller scales than the model resolves, and is not available on a global scale to ECMWF. Any local users, however, are assumed to know their own climate, and have the opportunity to interpret the forecast anomaly appropriately (but always carefully!).

The spatial distribution of near surface temperature anomalies or precipitation is often presented in absolute terms or as probabilities. Significance test may be used to present such information only for regions where the difference between the climate and the forecast ensembles is sufficiently large not to be due to chance.

3.1.4.4 How good is a seasonal forecast system

The answer to this question depends to a large extent on the user and his application. A user may describe a forecast system as 'good' if he can make good use of the information regardless of any quality assessment. There are three main elements in the objective assessment of the potential usefulness of a seasonal forecasting system, namely, the precision of the forecasts, their reliability and how they can be put to best use.

The precision of forecasts is related to the predictability of the system. Of course, anyone can make forecasts to arbitrary levels of precision – if one does not mind the forecasts almost always being wrong. Assuming, however, that one is aiming for at least some level of reliability, then the precision with which forecasts can be given is determined by the predictability of the ocean-atmosphere system. This is something which can be measured (or at least estimated) scientifically. In general terms, the predictability of mid-latitudes on seasonal timescales is low, whereas in some regions of the tropics it is moderately high. Estimates of predictability give an idea of the highest level of precision that will ever be possible in a reliable seasonal forecast.

The next question concerns the reliability of the forecast. Even if a prediction is not completely precise, it still might be very useful if it can be considered reliable. For example, reliable bounds on minimum or maximum temperature or rainfall in a coming season would be of benefit to many planning decisions. Reliable probability distributions can also be used in many decision-making or pricing processes. Reliability means that whatever predictive statement is produced from the forecast system is in fact correct: e.g. that a seasonal mean will be within a certain range, or will be above a given threshold with a certain probability. Direct use of numerical model output for seasonal forecasting is not likely to be reliable.

Unfortunately, it is very difficult to obtain meaningful estimates of reliability from the very short past records that are presently available. The amount of information available for this purpose needs to be increased. Once sufficient verification information is available, it should be possible to construct objectively estimated 'reliable' interpretations of the direct model output, but until then numerical seasonal forecast products should be used with caution.

The third question relates not to the scientific characteristics of a seasonal forecasting system but to how forecasts can actually be used in practical applications. A set of forecasts might be available with a range of precisions and estimated levels of reliability – but are the forecasts of any use to a particular user, how can their value be estimated, and how can they best be used? Various tools have been developed to help address such issues in medium-range ensemble forecasting.

Optimal use of forecasts can be facilitated by examining the Relative Operating Characteristic (ROC) curve, and economic value can be estimated with simple tools such as the Cost/Loss model. Although analyses such as these are a good starting point, in practice the detailed applications will have to be worked out with individual users or user communities.

3.1.4.5 Future directions

Numerical models still have significant errors which reduce their skill and reliability in seasonal forecasting to levels substantially below what should be theoretically possible. There are three ways in which this problem is being addressed. Firstly, model errors should be reduced. This is an ongoing long-term task. Secondly, results from different models (with different error characteristics) can be combined in a multi-model ensemble. Thirdly, appropriate mathematical and statistical tools can be used to apply numerical model output and observational data to user applications.

3.2 CLIMATE CHANGE AND NEW DEVELOPMENT ON CLIMATE MODELLING

As a result of the increasing interest in climate change and its impact on economic development, NMSs are often approached by the public, media and policy makers to give advice on this issue. Despite the fact that climate change is generally not regarded by many NMSs as part of the public weather services, as an enhancement or a continuation of their service delivery and more importantly, as the national meteorological authority, the NMS should be able to explain the observed climate changes and be prepared to give advice on possible future changes.

3.2.1 Present understanding of climate change

As a result of research on climate change in the past decade, it is now widely believed that the world is warming and there are other changes in the climate system. The global average surface temperature has increased over the 20th century by about 0.6°C. Globally, it is very likely that the 1990s was the warmest decade and 1998 the warmest year in the instrumental record since 1861. Satellite data show that snow cover and ice extent have decreased. Tide gauge data show that global average sea level has risen between 0.1 and 0.2 metres during the 20th century. There is also evidence that the global precipitation pattern is changing. Moreover, warm episodes of the El Niño/Southern Oscillation (ENSO) phenomenon have been more frequent, persistent and intense since the mid-1970s, compared with the previous 100 years. The ENSO phenomenon consistently affects regional variations of precipitation and temperature over much of the tropics, subtropics and some mid-latitude areas and attracts wide interest from the media and different sectors of the community. A more thorough discussion of the present understanding of the issue of climate change can be found in reports by the Intergovernmental Panel on Climate Chang (IPCC).

Changes in climate occur as a result of both variability in the climate system and external factors (both natural and anthropogenic). A positive radiative forcing such as that produced by increasing concentration of greenhouse gases, tends to warm the Earth's surface. A negative radiative forcing, which can arise from an increase in microscopic airborne particles tends to cool the surface. Natural factors, such as changes in solar output or explosive volcanic activity, can also cause radiative forcing. Characteristics of these climate forcing agents and their changes over time is required to enable the understanding of past climate changes and to project what climate changes could lie ahead.

3.2.2 Climate modelling

Physically-based climate models, such as Global Circulation Models (GCM) are required to estimate the change in climate. These models cannot yet simulate all aspects of climate and there are particular uncertainties associated with clouds and their interaction with radiation and aerosols. Nevertheless, confidence in the ability of these models to provide useful projections of future climate has improved due to their better performance on a range of space and time-scale. Some recent models produce satisfactory simulations of current climate without the need for non-physical adjustments of heat and water fluxes at the ocean-atmosphere interface used in earlier models. Some aspects of model simulations of ENSO, monsoons and the North Atlantic Oscillation, as well as selected periods of past climate, have also improved.

Although requiring more computational resources than Atmospheric General Circulation Models (AGCMs), coupled Atmosphere-Ocean General Circulation Models (AOGCMs) are now almost the standard tools for simulating climate change. These models allow the dymanics of the atmosphere and the ocean to continuously interact and evolve at the same time, thereby producing more realistic climate simulations.

As aerosols and chemical processes in the atmosphere also affect climate, some AGCMs and AOGCMs have incorporated them. Another trend in climate modelling is the use of "ensembles" whereby a series of simulations generated from slightly different initial conditions are averaged to smooth our errors resulting from inadequacies in initial conditions. Ensembles of forecasts from different models can also be generated to reduce errors introduced by inadequate model physics.

Further to address regional needs, regional scale simulations are obtained from AOGCM outputs through processes called "dynamical" and "statistical" downscaling.

3.3. CLIMATE INFORMATION AND BULLETINS

Climate information is usually presented on a daily and monthly basis. Most of the products are provided on the national level with some international cooperation to produce products on the regional or global level.

Sources of climate information include the following among others:

- The monthly CSM Bulletin published by WMO, also available on the Internet (The Climate System Monitoring (CSM) project of WMO provides access to global, regional and some national products on the Internet);
- A Climate Diagnostics Bulletin issued by the US National Weather Service comprising contributions of a number of institutes dealing with climate;
- The Annual Statement on the Status of the Global Climate published by WMO, also available on the WMO home page;
- A global summary published by the German Meteorological Service (DWD), comprises information from all parts of the world on a monthly basis;
- As a major activity, the Global Climate Observing System (GCOS), provides information on climate observations via the GCOS Monitoring Centres located at DWD, Offenbach, and the Japan Meteorological Agency (JMA), Tokyo;
- The CLIPS project of WMO will provide climate predictions on a seasonal to interannual time scale in the future;
- On the regional level, e.g. within Europe, a yearly monitoring report (RA VI Bulletin) based on an initiative of DWD is published. Similar publications are available for RA VI and RA V;
- Data and climate information are available from the World data Centres for Meteorology established at the National Climate Data Center (NCDC), in Asheville, USA and Obminsk, Russian Federation and also from specialized data centres such as the Global Precipitation Climatology Center (GPCC) located at DWD, Offenbach;
- It is envisaged to establish Regional Climate Centres within the WMO structure which will provide specialized products via GTS or the Internet;
- Special climate information results from Computer simulations are available from a range of centres e.g. the International Research Institute (IRI) located at the University of New York, USA, the Hadley Centre at Bracknell, UK, and the Max-Planck-Institute for Meteorology at Hamburg, Germany.

3.4 THE ROLE OF SATELLITES IN CLIMATE MONITORING

Satellite data has become increasingly important in observing and documenting the climate. Data representing the state of the atmosphere for a given area over a period of time provide the basis for climatology. Such data must be continuously generated in high resolution in time and space. Scientific and technological research has led to the development of various remote sensing methods and systems such as radar and meteorological satellites. Initially driven by requirements of forecasters, those systems can also meet many climatological requirements.

Climate data derived from satellite measurements are an important component in the climate observing system that consists of conventional observations, remote sensing data and data sets which are created by means of numerical weather prediction models. Satellite-derived data provide a high spatial coverage compared to conventional surface networks and especially fill gaps in areas with few data such as oceans or land regions with sparse conventional observations. They also provide information which cannot be measured from the ground, like the outgoing radiation at the top of the atmosphere.

The use of satellite data for documenting the climate and its changes is therefore an important research tool. As regards the requirements of climate monitoring, special attention has to be given to the operational long-term capabilities of the observing systems.

3.4.1 The aim of satellite applications support for climate monitoring

Several Satellite operating agencies such as EUMETSAT, NESDIS, JMA, etc. provide satellite applications support to various aspects of weather forecasting and in monitoring the climate. The support on climate monitoring provides the long-term monitoring of some important components of the climate system by generating and archiving high quality data sets of cloud and radiation parameters as well as atmospheric water vapour. For example, the EUMETSAT Satellite Application Support (SAF) on climate monitoring starts from a processing area covering Europe and parts of North Atlantic to serve regional climate activities, and is intended to eventually extend the area according to user requirements and available resources.

The product list of the EUMETSAT SAF on climate monitoring comprises merged satellite-derived water vapour fields and data sets of various cloud parameters consistent with radiation budget parameters at the surface and at the top of the atmosphere.

Output characteristics of the products with validated high accuracy are daily and monthly values, mean diurnal cycles and frequency distributions in an initial spatial resolution of 15 km for cloud and surface radiation parameters and 50 km for the other products. Intermediate and other products can also be made available.

EUMETSAT SAF is a theme-oriented, decentralized development and processing component of the agency's new ground segment. By launch of MSG –1 several SAFs will stepwise enter routine operations, e.g. the SAFs:

– In Support to Nowcasting and very short-range forecasting,
– On ocean and sea ice,
– On Numerical Weather Prediction,
– On ozone monitoring,
– On GRAS Meteorology (Global Navigation Satellite System Receiver for Atmospheric Sounding) and
– On land surface analysis.

Each SAF is located within the NMHS of a EUMETSAT Member State or other agreed entity linked to a user community.

The primary role foreseen for the SAFs is to develop services and products aimed at enhancing the value and use of satellite data for applications considered to be a common need for all, or at least a majority of Member States. All operational meteorological satellites are considered but the primary focus is on EUMETSAT satellites (MSG, EPS/METOP).

[For further information see WMO/TD No. 1054 (*Technical Framework for Data and Products in Support of Public Weather Services*), Section 3.2 and EUMETSAT WebPages: http://www.eumetsat.de.]

As of 2004 the EUMETSAT SAF on climate monitoring will operationally generate and archive high quality data sets on a continuous basis for the following application purposes:

– The monitoring of the climate state and its variability;
– The analysis and diagnosis of climate parameters to identify and understand changes in the climate system;
– Input for climate models to study processes in the climate system and for climate prediction;
– Validation of simulation models (climate and NWP);
– Planning and management purposes.

The products of the EUMETSAT SAF on climate monitoring will be helpful for the assessment of impacts on the environment and have the potential to contribute to the solution of problems, which can endanger the living conditions on earth. Some of these problems, such as droughts and floods are caused by seasonal to interannual climate variability, others are related to climate change as e.g. rising sea levels, desertification or availability of fresh water.

Climate monitoring products such as those of the SAF on climate monitoring will help politicians and business leaders to prevent or alleviate the consequences of climate-related disastrous events or developments.

Users of the products and services from the SAF on climate monitoring are NMHSs and oceanographic services. They can use theses products to perform tasks of climate system analysis and climate monitoring; to control model climatologies; for use in NWP models; and to serve customers with statistically evaluated data for planning and decision purposes. The SAF products on climate monitoring will be of value to specific user groups of NMHSs services, such as insurance companies, energy industry, agriculture (food management), water industry, aviation, human health and tourism.

Other users of the products and services of the SAF on climate monitoring are climate, environmental and climate impact research centres as well as institutes which carry out international research programmes. Operational agencies can use SAF products provided through the CLIPS Project of WMO for climate system monitoring, climate applications and to some extent for seasonal to interannual predictions. SAF products furthermore enhance the efforts to provide access to reliable time series of data and products in formats suitable for customers' use.

Similar complementary support is provided by NESDIS in the USA, the JMA, the CMA, and other satellite operating agencies.

3.5 COMPUTER-AIDED LEARNING

Computer-Aided Learning (CAL) is fast becoming a standard training tool. While there is not general agreement on the effectiveness of CAL as a training tool, it should be kept in mind that CAL is not meant to replace the traditional training programmes but rather to supplement them.

For many NMSs with remote offices and stations, CAL could be a useful solution to improved utilization of modern equipment and effective usage of software as well as provide the necessary expertise and guidance on the utilization of data. CAL software can be made readily available on the Internet or on a proxy server that could be easily accessible and downloaded. In addition, CAL can also be distributed to schools, used in exhibitions and be extended for use in public awareness campaigns to educate the general public.

Collaborative efforts on the development of CAL can be carried out on a regional basis in the form of case studies, regional research, and exchange of experiences and information.

Some examples of CAL type training programmes are described below.

3.5.1 European collaboration in meteorological CAL

The first initiative on the use of CAL in training within the European meteorological community came from ICWED in 1994 with the task of reviewing the needs for CAL training material and proposing the specifications for a future CAL programme.

EuroMET (http://euromet.meteo.fr/) was a European Commission (EC) funded project (1996–1998) to develop meteorological CAL building tools and finished training packages for universities and NMSs and to make them available on the Internet. When the project finished in 1998 it was awarded the European Academic Software Award and the University of Edinburgh and Météo-France generously maintained free access to the software through their Internet servers so that it remained available to the target audience.

In the absence of further funding EuroMET is becoming dated, can no longer be accessed by the latest Internet browsers and suggested improvements to the contents are not being implemented. However, the meteorological training community gained considerable experience in the use of CAL and distance learning packages and conceptual thinking evolved significantly.

In 1999 it became clear that the above situation was not stable. No single NMS could afford on its own the resources necessary to continue to provide this central source of material and, EUMETNET (http://www.eumetnet.eu.org/)was approached to help seek a way forward.

In the year 2000, EUMETNET established a working group to propose a way forward under the chairmanship of the Finnish Meteorological Institute (FMI).

The working group recognized that there was a common need for training material which could cost effectively be met through a cooperative effort and agreed that access to training material needs to be flexibly organized. The present EuroMET is composed of CAL tools and complete training packages. This is well suited to university-style training. However, NMSs, that are also training experienced forecasters in emerging meteorological techniques, additionally require access to modular segments of courses and data (e.g. satellite sequences) to incorporate into their own training courses. Additionally, this training material must reflect new developments in technology. The key new feature is the requirement for an evolving library of small teaching modules and raw data. The CAL tools remain an essential element as they provide a search, download and transfer facility and a capability to create custom packages to meet individual needs.

In 2001 the EUMETNET Council decided to establish the proposed new EuroMET Programme within EUMETNET. The main benefits resulting from the implementation of this programme are considered to be:

- Access to an expanding library of training material (e.g. satellite sequence, case studies, examples of classic meteorological occurrences);
- Tools to search the library, develop courses, and incorporate new material in NMS courses;
- A secure server to hold all material owned and produced by the proposed organization;
- Access to help and advice;
- Workshops and conferences to train instructors in the use of EuroMET.

The benefits from the programme increase greatly through integration with the training provided by other organizations, primarily EUMETSAT and possibly through links to EUMETNET`s other evolving training commitment. Such links would rapidly expand the range of material available.

More information can be found in the proposal from EuroMET-Working Group concerning the EuroMET Programme within EUMETNET (EMN/C12/Doc13, 16/03/2001).

3.5.2 Cooperative Program for Operational Meteorology Education and Training (COMET)

During the 1980s, the US National Weather Service (NWS) embarked on a major modernization programme. As a key part of this effort, NWS management emphasized strengthening the professional preparation and current qualifications of operational meteorologists to apply mesoscale data effectively. A second goal was to accelerate the incorporation of research findings into operational practices. The Cooperative

Program for Operational Meteorology, Education and Training (COMET) was thus established in 1989. The COMET Program was originally envisioned as a broad computer assisted learning effort to affect meteorological education and training in the United States. During the first decade of its existence, COMET produced CAL modules on almost all aspects of public weather forecasting and it has been one of the major training mechanisms for the modernization of the US NWS. The programme has recently been involved in activities to enhance meteorological education in universities and NMSs throughout the world. To meet the objective of improving mesoscale forecasting in the United States, an outreach component was developed at the COMET Program. This component currently provides financial support to universities for collaborative research projects, graduate student fellowships, postdoctoral fellowships, and other activities. Another way to meet this objective was the development of an education and training group. This group was assembled to design and produce teletraining, classroom instruction, case studies, and Web- and CD-based learning modules.

3.5.3 Simulated Forecasting Office

With the wide use of workstation systems by NMSs and because of the fact that these systems are usually connected to a central server by networks, it is now common that weather data from a variety of sources can be viewed and analyzed in locations other than the forecasting office. It is thus possible to develop a "Simulated Forecasting Office" with only a minimal investment in hardware and software. A "Simulated Forecasting Office" is very useful in the training of weather forecasters on the use of forecasting techniques and procedures under various weather conditions in a "virtual reality" environment.

The workstations in the simulated office can be downloaded with data of past significant weather events such as rainstorms, tornadoes, tropical cyclones and severe winter storms. Forecasters can then go through the historical events in either an accelerated time scale in the slow-changing phase of the weather event or slow-down time scale during the rapid development phase. The workstations will prompt forecasters for any missing procedural steps. Help menus are also available for forecasting techniques. The presence of a training staff is only required on request. In such manner, forecasting techniques and procedural actions can be taught and tested thoroughly. On the other hand, the workstations can be used to view real-time data so that forecasters can test their forecasting capability in real life.

E-learning in the form of a simulated forecasting office has a wide scope in the training of meteorological personnel in the future.

3.5.4 The Virtual Laboratory for Education and Training in Satellite Matters

Great strides forward can be expected with the planned and decided improvements to the space-based component of the Global Observing System of the WMO during the next decade. Well-informed users can benefit from the rapid developments – and a strong training component is required for a maximum utilization of satellite data for environmental applications. Meeting the demands of this challenge will be possible through the combined efforts of WMO and the world's producers of meteorological satellite data resulting in the formation of the Virtual Laboratory for Satellite Data Utilization (VL).

The VL is a collaborative effort joining the major satellite operators across the globe (EUMETSAT (Europe), JMA (Japan), NESDIS (USA) and NSMC (China)) with WMO "centres of excellence" in satellite meteorology. The centres of excellence are five WMO Regional Meteorological Training Centres (RMTCs): Nairobi in Kenya, Niamey in Niger, Nanjing in China, Bridgetown in Barbados, San Jose in Costa Rica as well as the Australian Bureau of Meteorology Training Centre. The various centres of excellence are sponsored by one of the major satellite operators.

Two streams of learning skills have been identified: a VL for Basic Skills and a VL for Specialist Skills. A virtual resource library (VRL) is of immense strategic importance supporting both VL skills. The VRL supports all three cornerstones of the WMO strategy to improve satellite system utilization:

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

The VL represents a vehicle through which the WMO and the Coordination Group on Meteorological Satellites (CGMS) will work to improve the utilization of satellite data world-wide. Effective interaction between Member States and their respective centre of excellence is required for Members to fully realize this benefit.

(This information is derived from the *WMO Bulletin*, Volume 50, No. 3, July 2001: "Virtual Laboratory for Education and Training in Satellite Matters", by J. Purdom).

Chapter 4
NEW AND IMPROVED PUBLIC WEATHER SERVICES PRODUCTS

4.1 HUMAN BIOMETEOROLOGY

4.1.1 Introduction

The atmosphere is part of the environment with which the human organism is permanently faced in maintaining the balance of life functions. Reactions of the organism can be comprehended as an answer to changes in the physical and chemical state of the atmosphere. As regards the effects of the atmospheric conditions on human health, well-being and performance, it is necessary to transform the "primary" meteorological information so that it becomes biologically relevant. For example, it is not only air temperature that is important for the human heat budget, but the complex conditions of heat exchange, which can only be completely described if information about wind, humidity, and short- and long-wave radiation fluxes is simultaneously available. Similarly, it is not generally solar radiation but a certain spectral wavelength (UV-B) that is responsible for the buildup of erythema. Another example concerns dust. It is not total dust, but a certain size fraction that goes down into the lungs, and among these particles, only those of certain origins possess a carcinogenic potency. The biological relevance determines whether a meteorological parameter will become a biometeorological one.

Human biometeorology is part of environmental meteorology. It covers a series of questions relevant to environmentally applied medical science. In investigating complexes of effects it uses almost the same epidemiological methodology to ascertain damaging potentials, to give information about limits of exposures which may affect human health, to discover the relationship between atmospheric conditions, diseases, and indisposition, and to define the importance of atmospheric environment factors for the transition between health and disease. Complexity is inherent in research into these effects. There are many confounding variables such as smoking, socio-economic factors, individual health behaviour, living conditions, etc., which are often dominant. Epidemiological research investigates the occurrence of effects on morbidity and mortality due to heat, cold, air pollution and changes in the weather. Concentrating on aspects of the environment relevant for health questions, three major complexes of effects can be distinguished: the complex conditions of heat exchange, the direct biological effects of solar radiation, and air pollution including allergens as pollen.

Research in human biometeorology has the task of finding out which clinical manifestations and other disturbances in human well-being are influenced by atmospheric environmental factors, and precisely which factors exert an influence on health and well-being, and to what extent. As regards risk factors, biometeorology has to inform and advise the public and decision makers in politics and administration with the aim of recognizing and averting health risks at an early stage, in the framework of preventive planning, for example by making recommendations for ambient standards, by evaluation site decisions, and by consultation of adapted behaviour.

The state of knowledge in the field of weather and human health allows to deliver a number of advisory services. Products and services such as pollen information service, UV-information service, forecasts of perceived temperature (heat load, cold stress) can help people to better handle atmospheric loads. These services are based on the specific adaptation of synoptical products to meet the needs of the users.

The benefits of meteorological information are usually not realized before their application. Human biometeorology already possesses numerous tools to meet the needs of the users, even if further improvements and adaptations are still needed. The general aim is always to avoid or at least diminish unfavourable effects, to take advantage of positive effects, and to improve the quality of life of the general public. Thus services for improving health and well-being of the population can be provided as a result of the work of the NMSs.

4.1.2 Human biometeorological advice

"Weather" is the description of the meteorological part of the physical environment of the human beings in the form of a state or a change of state. It is very significant in people's awareness due to its influence on so many aspects of life, including the health sector. Interfaces between the organism and weather can, on the one hand, be defined physiologically and thus causally via the meteorological elements. On the other hand, such stresses can be defined only via stochastic relations, whereby mostly the symptoms of the reactions can be explained. The influence of the weather usually does not take place via single elements, but as a collection of influences in which, some elements can carry more weight than others. The type and intensity of the influence, as well as the reaction of the organism and also the psyche depend on many different, often single, factors, but above all on condition (age, fitness) and the state of health of the individual and, in the case of morbidity, on the type and severity of the primary disease. When interpreting the weather in relation to its influence on the organism, one can differentiate between stressful atmospheric conditions (strong irritation, high degree of adaptability required), stimulating atmospheric conditions, and atmospheric conditions with neutral effect.

The basis for assessing the weather in respect to its influence on the organism are scientific studies based mostly on statistics with significant results that have a medical relevance. A relevant analysis of the weather brings recognition of its significance as risk factor, but also its preventive effect.

Up-to-date information on the effect of weather conditions such as stress and thus risk factor for organisms weakened by age or illness, or warnings of certain thresholds being exceeded (thermal pollution, chilling stress, considerable change in the physical environment) can be of help to a doctor in recommending prophylactic measures and to patients in adapting their activities (avoidance of additional stress). The effect of weather in the preventive area provides support in the conditioning of the organism and rehabilitation.

A number of countries currently issue biometeorological advice and warnings. One such example is Germany, which started in 1986 to provide public biometeorological advisaries for those individuals who are hypersensitive to changes in atmospheric conditions. Since 1992 these reports also appear in the print media, as well as in radio and TV. The basic feature of the biometeorological advice is that only those diseases and influences of these subjective conditions that have been agreed with the medical profession are mentioned and are formulated such as to encourage a sound doctor/patient relationship (for example by saying prevention according to the doctor's advice).

4.1.3 Thermal indices

4.1.3.1 Heat Index

Human bodies dissipate heat by varying the rate and depth of blood circulation, by losing water through the skin and sweat glands, and as the last extremity is reached, by panting, when blood is heated above 98.6 degrees. The heart begins to pump more blood, blood vessels dilate to accommodate the increased flow, and the bundles of tiny capillaries threading through the upper layers of skin are put into operation. The body's blood is circulated closer to the skin's surface, and excess heat drains off into the cooler atmosphere. At the same time, water diffuses through the skin as perspiration. The skin handles about 90 percent of the body's heat dissipating function.

Sweating, by itself, does nothing to cool the body, unless the water is removed by evaporation – and high relative humidity retards evaporation. The evaporation process itself works this way: the heat energy required to evaporate the sweat is extracted from the body, thereby cooling it. Under conditions of high temperature (above 90 degrees) and high relative humidity, the body is doing everything it can to maintain 98.6 degrees inside. The heart is pumping a torrent of blood through dilated circulatory vessels; the sweat glands are pouring liquid including essential dissolved chemicals, like sodium and chloride, onto the surface of the skin.

Heat kills by taxing the human body beyond its abilities. For example, in a normal year, about 175 Americans succumb to the demands of summer heat. Among the large continental family of natural hazards, only the cold of winter – not lightning, hurricanes, tornadoes, floods, or earthquakes – takes a greater toll. In the 40-year period from 1936 through 1975, nearly 20 000 people were killed in the United States by the effects of heat and solar radiation. In the disastrous heat wave of 1980, more than 1 250 people died.

And those are the direct causalities. No one can know how many more deaths are advanced by heat wave weather; how many diseased or aging hearts surrender, that under better conditions would have continued functioning. North American Summers are hot; most summers see heat waves in one section or another of the USA. East of the Rockies, they tend to combine both high temperatures and high humidity although some of the worst have been catastrophically dry.

Considering this tragic death toll, the US National Weather Service has stepped up its efforts to alert more effectively the general public and appropriate authorities to the hazards of heat waves – those prolonged excessive heat/humidity episodes.

Based on the latest research findings, the NWS has devised the "Heat Index" (HI), (sometimes referred to as the "apparent temperature"). The HI, given in degrees Fahrenheit, is an accurate measure of how hot it really feels when the relative humidity (RH) is added to the actual air temperature.

As an example, if the air temperature is 95°F and the relative humidity is 55 per cent, the HI – or how hot it really feels – is 110°F. *Important:* Since HI values were devised for shady, light wind conditions, exposure to full sunshine can increase HI values by up to 15°F. Also, strong winds, particularly with very hot, dry air, can be extremely hazardous.

The NWS will initiate alert procedures (advisories or warnings) when the Heat Index (HI) is expected to have a significant impact on public safety. The expected severity of the heat determines whether advisories or warnings are issued. A common guideline for the issuance of excessive heat alerts is when the maximum daytime HI is expected to equal or exceed 105°F and a nighttime minimum HI of 80°F or above for two or more consecutive days. Some regions are more sensitive to excessive heat than others. As a result, alert thresholds may vary substantially from these guidelines. Excessive heat alert thresholds are being tailored at major metropolitan centres based on research results that link unusual amounts of heat-related deaths to city-specific meteorological conditions.

The NWS alert procedures are:

- Include HI values in zone and city forecasts;
- Issue Special Weather Statements and/or Public Information Statements presenting a detailed discussion of (1) the extent of the hazard including HI values, (2) who is most at risk, (3) safety rules for reducing the risk;
- Assist state and local health officials in preparing Civil Emergency Messages in severe heat waves. Meteorological information from Special Weather Statements will be included as well as more detailed medical information, advice, and names and telephone numbers of health officials;
- Release to the media and over NOAA's own Weather Radio all of the above information.

4.1.3.2 Perceived temperature

The German Meteorological Service (DWD) assesses thermo-sensitivity in the open air physiologically-correct as the perceived temperature. The perceived temperature compares the actually existing outside conditions with the temperature that would prevail in a standard environment in order to experience an identical feeling of warmth, comfort or cold. The standard environment is deep shade, e.g. a forest, where the temperature of the surrounding surfaces, i.e. the leaves, is the same as the air temperature and where there is only a slight breath of air of 0.1 m/s. As the human being is usually active in the open air, activity is assumed that corresponds to walking at 4 km/h. The person concerned attempts to adapt his clothing in such a manner that he continues to feel comfortable. The perceived temperature then assesses in degrees C the thermal sensitivity of a man who is 1.75 m tall, weighs 75 kg and is approximately 35 years of age.

The perceived temperature is calculated by means of the Klima-Michel-Modell of the DWD. The model needs a complete weather observation or a corresponding numerical weather forecast, the date and geographical coordinates as input quantities. In warm, sunny summer conditions with little wind the perceived temperature rises far quicker than the air temperature itself. In an extreme case, it can amount to up to 15°C more than the air temperature in central Europe. In pleasant, mild conditions with light to moderate wind it can, however, sink to below the air temperature, as fast walking and adaptation of clothing is reckoned with. In a cold and especially windy environment the perceived temperature sinks by up to 15°C below the air temperature. Sun and lack of wind can, on the other hand, raise the perceived temperature to above that of the air temperature.

The perceived temperature is calculated daily on the basis of the numerical forecast model of the DWD and serves inter alia as basis for issuing warnings of thermal pollution for health resorts as well as for evaluating the thermal pollution in biotropic connection with the weather conditions.

4.1.3.3 Wind chill

Wind chill is the chilling effect of the wind in combination with a low temperature. Humans do not sense the temperature of the air directly. When humans feel that it is cold, they are actually sensing the temperature of their skin. Because the skin temperature is lower when it is windy (humans lose heat from the skin faster than the body can warm it), humans feel that it is colder when there is wind. This sensation is what the wind chill index attempts to quantify. Each year, in Canada, more than 80 people die from over-exposure to the cold, and many more suffer injuries from hypothermia and frostbite. Wind chill can play a major role in such health hazards because it speeds up the rate at which the body loses heat. A recent survey indicated that 82 per cent of Canadians use wind chill information to decide how to dress before going outside in the winter. Many groups and organizations also use the system to regulate their outdoor activities. Schools use wind chill information to decide whether it is safe for children to go outdoors at recess. Hockey clubs cancel outdoor practices when the wind chill is too cold. People who work outside for a living, such as construction workers and ski-lift operators, are required to take indoor breaks to warm up when the wind chill is very cold.

Canada and the USA agreed to collaborate on the development of a new wind chill formula, and developed a process for its scientific verification and implementation. There was also agreement to use only a temperature-like index to report and forecast wind chill. The new formula, developed by Randall Osczevski of Canadian Defence and Civilian Institute for Environmental Medicine and Maurice Bluestein of Purdue University in Indiana, USA, makes use of advances in science, technology and computer modelling to provide a more accurate, understandable and useful formula for estimating the dangers arising from winter winds and freezing temperatures. Thereby, the new index has been harmonized with that used in the United States (where the Fahrenheit scale is used), thus giving a consistent index used throughout North America.

The new index is expressed in temperature-like units, the format preferred by most Canadians as determined through public opinion surveys. It must be noted that although the wind chill index is expressed on a temperature scale (the Celsius scale in Canada), it is not a temperature: it only expresses a human sensation. The index likens the way human skin feels to the temperature on a calm day. For example, if the outside temperature is -10°C and the wind chill is -20, it means that the exposed face will feel as cold as it would on a calm day when the temperature is -20°C.

The equation to determine the new index is the following:

$$W = 13.12 + 0.6215*T_{air} - 11.37*V_{10metre}^{0.16} + 0.3965*T_{air}*V_{10metre}^{0.16}$$

where: W= the wind chill index, based on the Celsius temperature scale, T_{air} = the air temperature in degrees Celsius (°C), and $V_{10metre}$ = the wind speed at 10 metres (standard anemometer height), in kilometres per hour (km/h).

The new index is based on a model of how fast a human face loses heat. The face is chosen because it is the part of the body most often exposed to severe winter weather, assuming the rest of the body is clothed appropriately for the weather. The new index has been validated in clinical trials held in Toronto in June 2001, in a climate controlled wind tunnel with human volunteers. This index is expected to be much closer to what people actually experience when exposed to wind and low temperatures.

In addition, specifically, the new wind chill index has the following features:

- It uses wind speed calculated at the average height of the human face (about 1.5 metres) instead of the standard anemometer height of 10 metres. The correction is effected by multiplying the 10-metre value (what is indicated in weather observations) by a factor of 2/3;
- It is based on a model of the human face, and incorporates modern heat transfer theory, that is, the theory of how much heat is lost by the body to its surroundings during cold and windy days;
- It uses a calm wind threshold of 4.8 km/h; this value has been obtained by observing the speed at which people walk at intersections;
- It uses a consistent standard for skin tissue resistance to heat loss.

Additionally, an equation to approximate minutes to frostbite has also been developed for the 5 per cent most susceptible segment of the population. It is considered valid for winds of more than 25 km/h and times of less than 15 minutes:

$t_f =$
$\{ (-24.5 \cdot [(0.667 \cdot V_{10}) + 4.8]) + 2111 \} \cdot (-4.8 - T_{air})^{-1.668}$

where: t_f = time to frostbite, in minutes, for the 5 per cent most susceptible segment of the population, V_{10} = Wind speed, in km/h, at the standard anemometer height of 10 metres (as reported in weather observations), T_{air} = Actual air temperature in °C.

More information on the wind chill programme in Canada can be found at the following web site: http://www.msc.ec.gc.ca/windchill/index_e.cfm. Also at this site charts, on-line calculators and downloadable calculators are available.

4.1.3.4 Net effective temperature (NET)

As an example of a heat index suited to local weather conditions and requirements by public, the net effective temperature (NET), routinely monitored by the Hong Kong Observatory can be considered. The NET takes into account the effect of air temperature, wind speed and relative humidity on human beings. For example, heat loss by a human body will be faster under lower temperature, higher wind speed and higher relative humidity conditions in winter and, as such, the feeling of coldness will also be more severe.

NET is calculated as follows:

$NET =$
$37 - (37-T)/(0.68 - 0.0014RH + 1/(1.76+1.4v^{0.75})) - 0.29T(1-0.01RH)$

where T= the temperature (°C), v = the wind speed (m/s), and RH = the relative humidity (%), and has a higher value when the temperature is higher, but its value will be lower at higher wind speed and relative humidity. Taking acclimatization into account, it is believed that people of a particular place will feel stressfully cold and hot when the value of NET is at the lowest and highest 2.5 per cent respectively. In Hong Kong, China, the Cold (or Very Hot) Weather Warning will be issued when the NET is forecast to be lower (or higher) than 2.5 per cent (97.5 per cent). Samples for the Cold and Very Hot Weather Warning can be found overleaf.

4.1.4 Pollen flight forecast

In Europe, a study carried out in North Rhine-Westphalia showed that medicine can be put to more efficient use with the aid of the pollen information service, thus maintaining the performance ability in schools and at the workplace, resulting in a reduction of absenteeism due to hay fever complaints.

More than 10 per cent of the population are allergic to pollen and the tendency is increasing. In Germany for example, the DWD collaborates with the German Pollen Information Service Foundation, to provide forecasts for the flight of the six most important pollen allergens: hazel, alder, birch, the grass family, rye and artemisia. The timing of the forecasts allows for the fluctuation of flowering in Central Europe. The concentration of released pollen is entirely dependent on the prevailing weather situation, hence a direct prophylaxis for those allergic to pollen can, be considerably improved by a daily update of the pollen flight forecast.

The forecasts are based on the regional short- and medium-range weather forecasts of the DWD, the pollen concentrations measured and evaluated by the German Pollen Information Service Foundation in various clinics, and the latest phenological data of the Deutscher Wetterdienst from the agrometeorological data acquisition.

4.1.5 UV index

The UV index is a simple means of measuring the strength of ultraviolet rays that cause sunburn and is given as a daily maximum. The index which is standard worldwide, takes cloud cover and the thickness of the ozone layer, which have a direct influence on the ultraviolet rays reaching the ground, into account. In central Europe the index has winter values of between 0 and 1. In the summertime, the index values are in the range of 5 to 7 in the northern, western and central Europe, whereas the values in the southern mainland Europe and islands such as the Canary Islands can be as high as 9 to 11.

Long exposure to high doses of UV-B causes acute sunburn in human beings. This is a sign of overdosage and thus an overtaxing of the protective mechanism of the skin. Further acute effects are a deterioration in the organism's condition of immunity and the effect on the eyes, e.g. snowblindness. Healthwise, the consequences of excessive exposure to sunlight are of special significance. These range from premature ageing of the skin to skin cancer, which has become one of the most common types of cancer. Frequent and intense exposure to sunlight with sunburn, especially in infancy and childhood, encourages the formation of malignant melanoma. The number of new growths of malignant melanoma has doubled every 7 to 8 years over the past 40 years. This can be attributed to the change in leisure behaviour which equates a sporty suntan with good health. Because of this basic tendency and the type of activity dependent on age, the human being receives approximately 50 per cent of life dose of ultraviolet rays in the first 20 years of life.

Nevertheless, ultraviolet rays also have positive properties. They stimulate the formation of vitamin D3, which is important for formation of bones. A very low dose of ultraviolet rays is, however, sufficient for this and lies far below the threshold of sunburn.

Canada has been measuring the thickness of the ozone layer since 1957. Today there are 13 monitoring sites across Canada: 10 across southern/central Canada and 3 in the high Arctic at Resolute Bay, Eureka, and Alert. Exposure to ultraviolet radiation from the sun has always been a risk to human health. In the last twenty years, however, those risks have increased as man-made chemicals have caused a thinning of

Cold Weather Warning

Cold Weather Warning Special Announcement:

(First issued)

* The Cold Weather Warning has been issued by the Hong Kong Observatory at _____________a.m. / p.m.

(Re-issued)

* The Cold Weather Warning issued by the Hong Kong Observatory is now in force.

****

* The Hong Kong Observatory is forecasting cold weather / Cold weather is expected / in Hong Kong / today / tomorrow / tonight / during the overnight period / in the next couple of days / in the next few days.

* The / minimum / temperatures in the urban areas / for tonight / for today / for tomorrow / during the day / overnight / will be / around / in the region of _____________degrees / or below. It will be / a couple of / a few / several / degrees lower in / the northern part of / the New Territories / and on high ground.

* As Hong Kong is being / will be / continuously / affected / by a cold winter monsoon / today / tomorrow / in the next couple of days / in the next few days, people are advised to put on warm clothes and be aware of low body temperature due to the cold weather.

* If you must go out, please avoid prolonged exposure to wintry winds.

* If you know of elderly or persons with chronic medical conditions staying alone, please call or visit them occasionally to check if they need any assistance.

* Make sure heaters are safe before use, and place them away from any combustibles.

Cancellation:

* **The Cold Weather Warning was cancelled at _____________a.m. / p.m.**

WCOLD – 22 Dec 1999	Originator	Day / Time of Dispatch
* Delete as appropriate		_________ H ________ ________________ ________

Very Hot Weather Warning

(First issued) * The Very Hot Weather Warning has been issued by the Hong Kong Observatory at ____________a.m. / p.m. *(Re-issued)* * The Very Hot Weather Warning issued by the Hong Kong Observatory is now in force. ** * The Hong Kong Observatory is forecasting very hot weather / with / high humidity / and / light winds / in Hong Kong today / tomorrow / in the next few days. The risk of heatstroke is high. * When engaged in outdoor work or activities, do drink plenty of water and avoid over exertion. If not feeling well, take a rest in the shade or cooler place as soon as possible. * The Hong Kong Observatory advises that prolonged exposure under sunlight is to be avoided. Loose clothing, suitable hats and UV-absorbing sunglasses can reduce the chance of sunburn by solar ultraviolet radiation. * Swimmers and those taking part in outdoor activities should use a sunscreen lotion of SPF 15 or above, and should re-apply it frequently.

Cancellation:

* **The Very Hot Weather Warning was cancelled at ____________a.m. / p.m.**

WHOT – 20 Jan 2001	*Originator*	*Day / Time of Dispatch*
** Delete as appropriate*		________ *H* _______ ______________ _______

the ozone layer. With the depletion of the ozone layer there has been a corresponding increase in the ultraviolet radiation reaching the surface. Since 1982 a gradual thinning of the ozone layer has been observed. Measurements show that the ozone layer over southern Canada is today about 7 per cent thinner than it was before 1982. Ozone depletion is most pronounced in the springtime when photochemical activity is greatest in the stratosphere. At this time of the year, depletion rates as high as 10 to 20 per cent have occurred over central Canada.

It is estimated that more than 71 000 new cases of skin cancers were diagnosed across Canada in 2000 and over 800 people died from a particular kind of skin cancer known as melanoma. Skin cancers take a long time to develop – anywhere from 10 to 30 years – so early prevention is very important. About 80 per cent of the lifetime exposure to UV radiation occurs before the age of 20. In 1998, Environment Canada in partnership with Health Canada started the Children's UV Index Sun Awareness Program. The programme teaches students under the age of 14 about the UV Index and how to use it to minimize the risk to their health from solar ultraviolet radiation.

In Canada, the UV Index ranges from 0 to 10 and is issued for 48 locations. The UV Index forecast is the maximum value expected for a given day usually around solar noon and are included as a routine forecast element in the public forecast bulletins from April through September. Generally, the further south the higher the UV Index. However, the UV Index is also dependent on altitude, reflection, and clouds. Generally, the process for forecasting the UV Index is as follows:

1. The thickness of the ozone layer across North America is forecast using the computer weather prediction models.
2. These values are then corrected based on observations from the 12 ozone-monitoring stations across Canada.
3. This information along with variables on latitude and time of year, is then fed into mathematical algorithms to produce the clear sky UV Index for each desired location.
4. The cloud and precipitation forecasts are generated by meteorologists in each of the regional forecast centres across Canada and are assigned a transmission factor, which is then used to adjust the clear-sky UV forecast.

Chapter 5

EXCHANGE OF PUBLIC WEATHER SERVICES PRODUCTS THROUGH A MODERNIZED WMO INFORMATION SYSTEM

5.1 THE WMO INFORMATION SYSTEM

5.1.1 The actual system

The WMO Information System comprises a combination of the private Global Telecommunication System (GTS) and the public Internet. The GTS consists of a private telecommunication network, satellite broadcast and collection systems and an evolving set of managed network 'clouds'. It can accommodate a variety of protocols (e.g. X.25 and TCP/IP) and supports the current GTS message switching system as its single most important application. The Internet is playing an increasingly important role, particularly for the exchange of non-real-time products, and supports a variety of applications, some of which are pertinent to WMO requirements. Most GTS centres now have links to the Internet and a few GTS circuits have recently been implemented over the Internet.

Figure 3 illustrates the actual WMO Information System.

An ultimate system would see the WMO coordination of an integrated approach to meeting the requirements of:

- Ad hoc non-routine applications (e.g. requests for, and insertion of, non-routine data and products);
- Routine collection of observed data;
- Automatic dissemination of scheduled products, both real- and non-real-time.

The system would rely upon a combination of public and private networks as shown in Figure 4, and would ensure coordinated development and operation of the participating systems through reliance on international protocols and standards and off-the-shelf software.

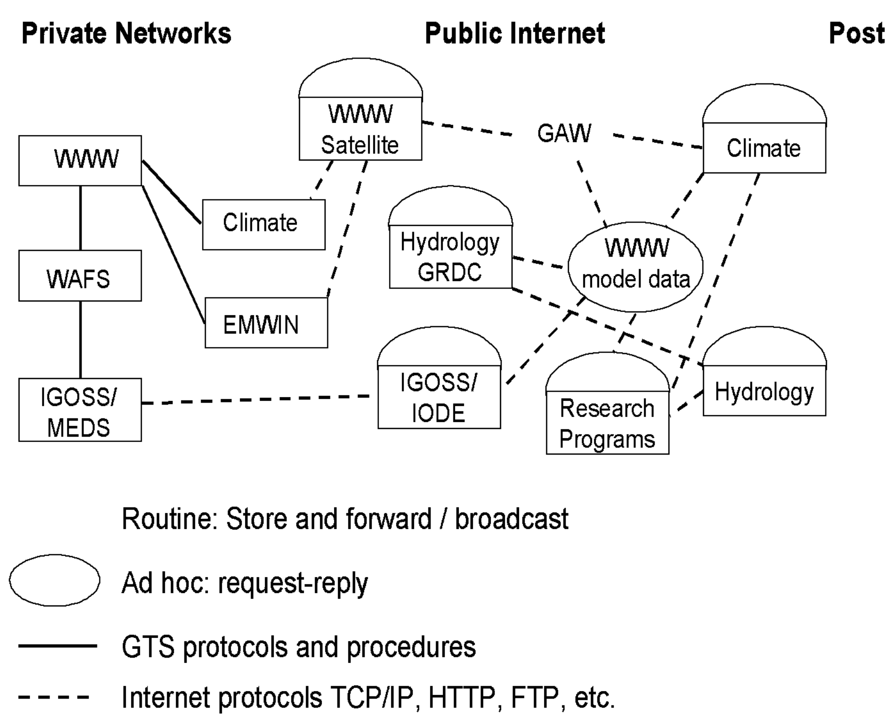
Figures 3 and 4 highlight some of the key points regarding the two systems as follows:

- There is now limited utilization of the Internet for operational store and forward applications;
- There are a large number of different applications whose development has not been coordinated, making the integration of data sets a technically challenging task;
- Multidisciplinary application of meteorological, hydrological and oceanographic data is hampered by lack of agreed standards needed to effectively identify, acquire and use all the relevant data;
- Greater use of commercially accepted standards and off-the-shelf hardware could increase the responsiveness and decrease the costs of operating current systems.

5.1.2 Standards related to PWS use of future information systems

The activities in relation to future information systems have been heavily influenced by the ever- increasing importance of

Figure 3. Current WMO Information System



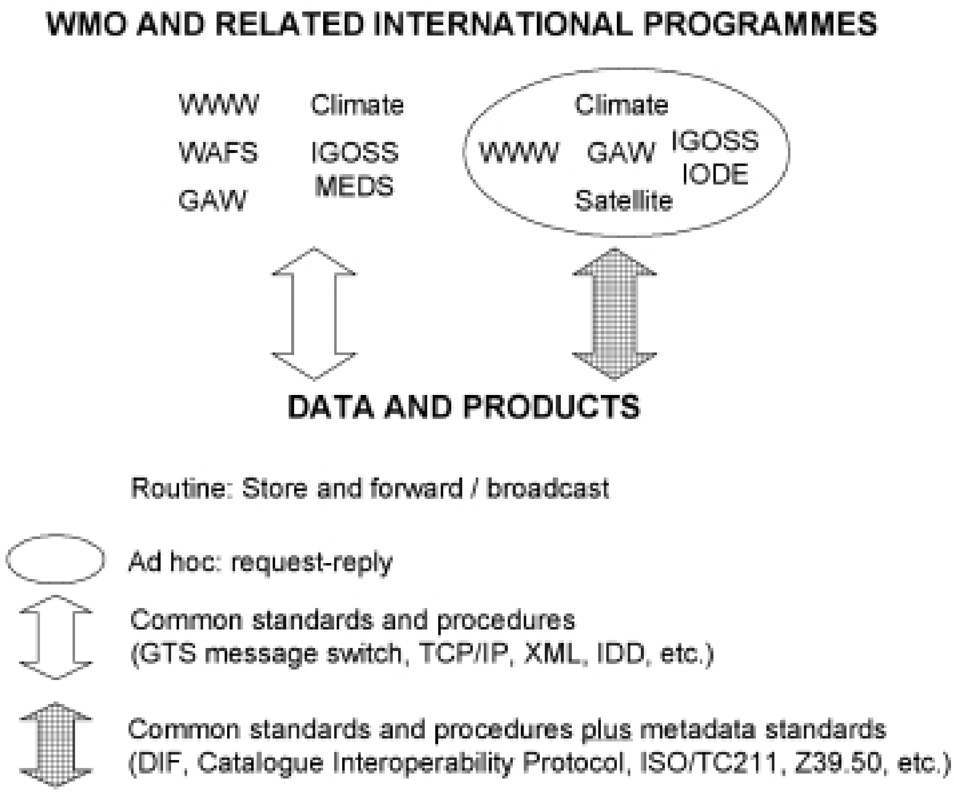


Figure 4. Future WMO Information System

the Internet. The emerging common view of the future networks at each NMS is depicted in Figure 5.

In this scenario, it will be possible to retain the GTS connections for real-time data and to use the Internet for less time-critical products and for the supply of data to other users. Over the GTS, the WMO TCP/IP-based protocols for ftp and socket connections will prevail, while, for the Internet, the commonly used World-Wide-Web services should be provided. The development of meteorological "portals" is still in its infancy and will be prototyped by some NMSs in the future.

An Internet portal is built preferably by larger Internet access or information providers to offer to users a single homepage address. Starting here, the user is led to a variety of different services offered. A meteorological portal may lead the users to services that allow access to:

- A tree of pages with different kinds of forecasts;
- Warnings (severe weather conditions);
- Actual news pages;
- Download-areas comprising larger sets of data such as satellite or radar imagery using the ftp protocol;
- Meteorological databases directly with and without billing using SQL;
- Active distribution offers (e.g. as e-mail) of pre-defined sets of information routinely or at irregular times;
- Climatic information;
- Links leading to further and related topics;
- E-mail addresses to be used for detailed questions to the NMS experts.

5.1.3 Internet

The Internet, as a connection of computer networks, provides worldwide connectivity to every site connected to it. It is thus possible to use it as a dissemination (broadcast) medium, as well as a medium for sharing information available on Internet servers. It can be used as a fundamental communications tool to improve and expand the information dissemination methods of public weather services. By using the Internet, a far higher number of recipients can be reached.

However, there are no policies on the Internet that would ensure e.g. a guaranteed delivery time for products or reachability of every recipient. Depending on the use of the Internet, dissemination of products can be delayed, and it is also possible that information is lost.

It is also the responsibility of every connected site to set up appropriate security mechanisms to protect the Internet servers themselves, as well as their contents. Without any protection mechanism in place, it is easy to alter digital information.

WMO has published a Guide on Internet Practices, which is available at: http://www.wmo.ch/web/www/reports/Internet-Guide.html.

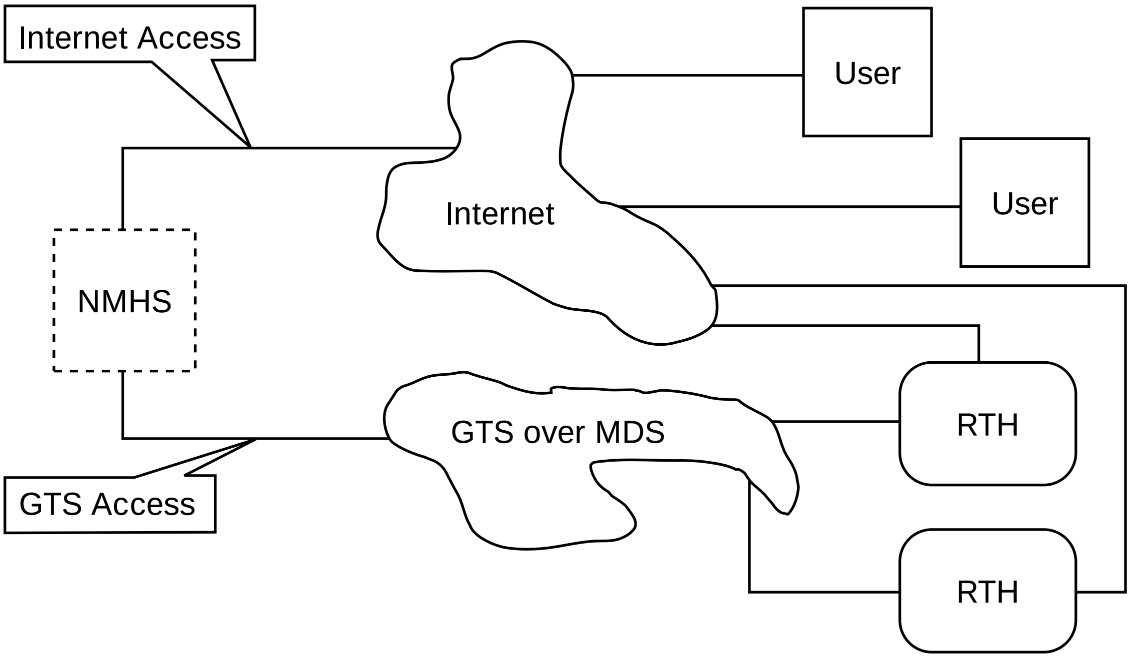


Figure 5. Schematic view of future network accesses for NMS

GLOSSARY

AFD	Automated File Distributor
API	Application Programming Interface
CORBA	Common Object Request Broker Architecture
DAVID	Datenaustauschs-, Verwaltungs- und Informationsdienste
DBMS	Data Base Management System
EMWIN	Emergency Managers Weather Information Network
FTP	File Transport Protocol
GAW	Global Atmosphere Watch
GIS	Geographical Information System
GOS	Global Observing System
GTS	Global Telecommunication System
HPC	High Performance Computing
HTML	Hypertext Markup Language
IDE	Integrated Development Environment
IGOSS	Integrated Global Ocean Services System
IP	Internet Protocol
ITT	Invitation To Tender
LAN	Local Area Network
MAP	Meteorological Application and Presentation System
MSS	Message Switching System (following WMO standards)
MWS	Meteorological Workstation System
OGC	Open GIS consortium
OO	Object Oriented
OSF	Open Software Foundation
PWS	Public Weather Services
RDBMS	Relational Database Management System
SQL	Structured (Standard) Query Language
TCP	Transport Control Protocol
USGS	United States Geological Service
WAFS	World Area Forecast System
WAN	Wide Area Network
WWW	World Weather Watch and World Wide Web