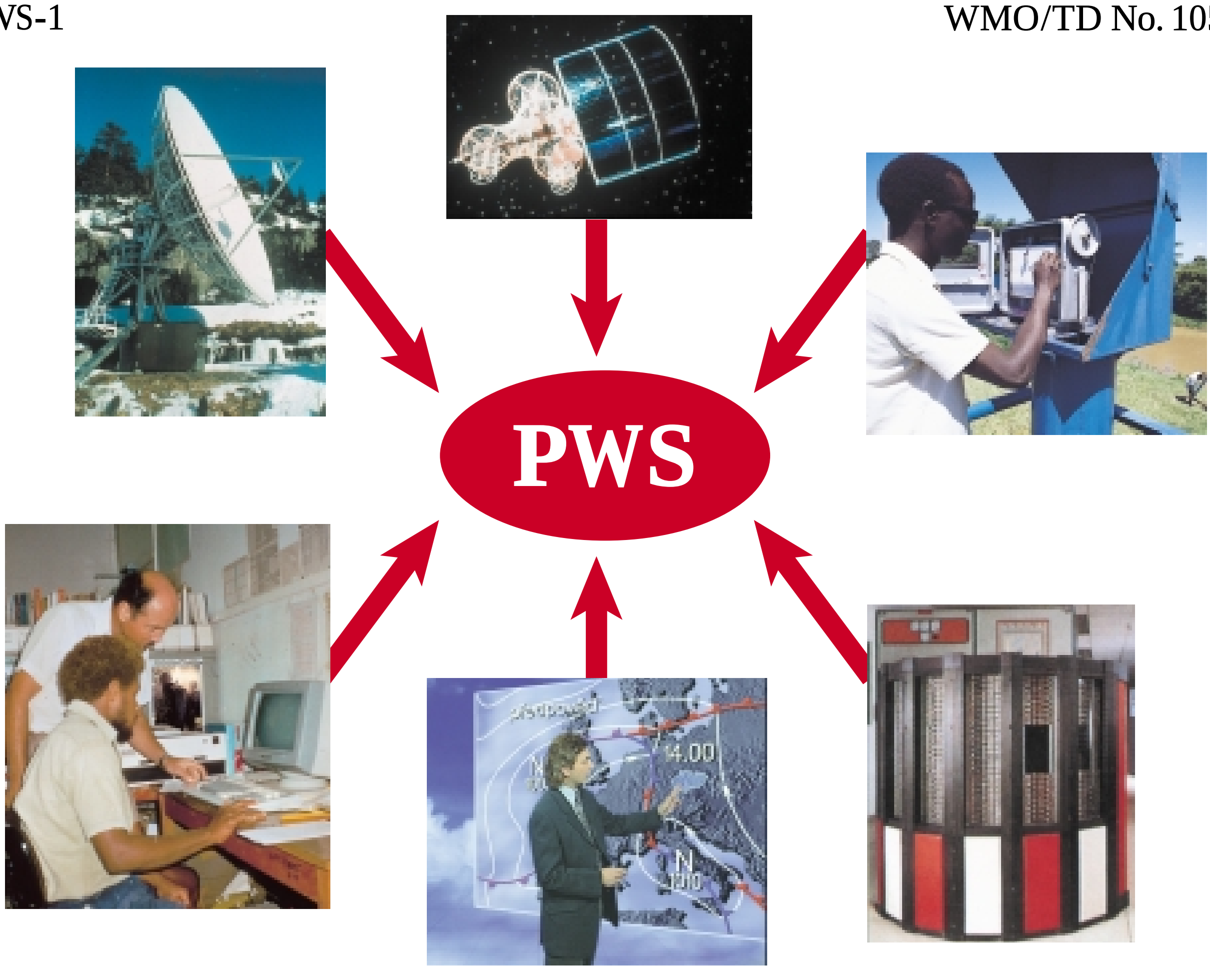
World Meteorological Organization

TECHNICAL FRAMEWORK FOR DATA AND PRODUCTS IN SUPPORT OF PUBLIC WEATHER SERVICES

PWS-1

WMO/TD No. 1054



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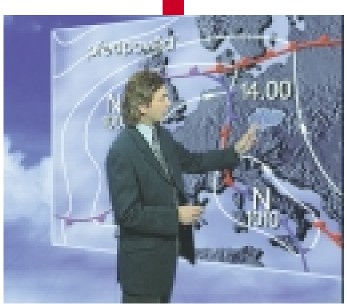

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NOTE

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Chapter 1
INTRODUCTION

One of the most important roles of NMSs is to provide reliable and effective weather and related products and services to ensure the safety of life, protection of property and the well being of their nations' citizens. To fulfil this mandate, NMSs rely on progress in both science and technology as applied to meteorology. Modern observational, computing and communications systems, steadily improving numerical prediction models and growing application of artificial intelligence, together with improved understanding of atmospheric sciences continue to contribute to the enhancement of weather forecasting capabilities. Similarly, new and emerging technologies are having a marked impact on the ways in which NMSs achieve their objectives of providing crucial information in an accurate, timely and useful manner.

Technical requirements for provision of public weather services span a very broad spectrum ranging from observational data (including real-time data, satellite and radar data), to forecast and warning products, climate information, telecommunications and computing and communication standards. This acknowledgement has given rise to a need for more detailed guidance to support NMSs, especially smaller Services and those in developing countries, in their service delivery activities by keeping pace with developments in technology.

This Technical Document is based on an outline developed at a meeting of the Public Weather Services Expert Team on Product Development and Verification and Service Evaluation, held in Hong Kong, China, in November 1999. The document was developed under the term of reference to "Investigate and document, with the other CBS Open Programme Area Groups (OPAGs), the particular technical requirements of data and products to support public weather services".

The purpose of this Technical Document is to provide a framework for the requirements of public weather services for data and products, and the supporting hardware and software that are necessary to service those requirements. As such, this is a preliminary document, based on current available information, which will evolve with the further endeavour from experts within the Public Weather Services Programme, in cooperation with other OPAGs.

Chapter 2 gives a broad outline of types of data and products that are needed to support public weather services. Chapter 3 highlights some of the advances in technology that have impacts on provision of those services, and chapters 4, 5 and 6 discuss the standards that are related to both public weather services and the operation of NMSs and the globalization of media. Finally the improvement of international cooperation on technical aspects of public weather services is reviewed in Chapter 7.

Chapter 2
SCOPE OF PUBLIC WEATHER SERVICES DATA AND PRODUCTS

2.1 DATA

2.1.1 Observations

The first requirement in the provision of public weather services is the availability of local and regional surface observations. Actual weather, temperature (including maximum and minimum temperatures), wind speed, wind direction, and precipitation are essential.

In addition, for business and travel purposes surface observations covering a larger area are needed. The actual weather and temperature (including maximum and minimum values plus the water temperature) will be sufficient for such purposes. For radio broadcasts, actual observations made within the previous hour are needed.

2.1.2 Satellite data

Satellite pictures give a good overview of the current weather occurrences and are essential for nowcasting and warnings.

Satellite imagery is especially important in tropical areas as it often becomes the single most important tool for monitoring the development of severe weather and formation of convective storms. For the purposes of print media, satellite pictures are required to contain additional information such as location and names of some cities and political boundaries. Satellite pictures are very important for TV broadcasting stations and can be used in different forms such as stills, loops or in combination with other information, e.g. with observations or pictogrammes. Of particular interest are satellite imagery loops, normally in the form of Infra-red pictures, to allow the animation of of images captured during the night. For the purpose of smooth animations, pictures with small time-steps (e.g. every 30 minutes) are desirable. Otherwise, morphing software can improve the quality of animation for pictures with longer time-steps.

2.1.3 Radar data

Radar pictures can also be used for the print media. For regional newspapers, images from single (regional) radar stations would be adequate, whereas for national newspapers, composite radar pictures would be more appropriate.

For TV broadcasts, radar animations, e.g. for the previous day, would provide extra information on the actual weather conditions experienced. If it is possible to have a live feed from the radar directly to the television station, then it will be possible to view the near-real-time evolution of the weather situation. As with satellite information, radar graphics will have to include locations and names of cities and political boundaries for better orientation of the viewers. Radar information could also be helpful for the preparation of weather forecasts for radio broadcasts. For nowcasting purposes, local and regional radar information from the last few hours could be very helpful.

2.1.4 Numerical weather prediction (NWP) data

Of interest to all media are the following products of the NWP models:

> surface pressure, surface temperatures, maximum and minimum temperatures, precipitation amount (accumulations for 12 or 24 hours), with information about the type of precipitation (snow or rain). Also of interest to some users are fields of wind speed and direction, 500 hPa geopotential, 850 hPa temperatures and 700 hPa relative humidity. For outlooks, all prediction data up to 7 days ahead are required.

2.2 AUTOMATION OF OBSERVATIONS AND PWS REQUIREMENTS FOR SYNOPTIC OBSERVATIONS

A surface observation network (mesh-size, frequency, parameters, etc.) is expected to support:

- Provision of data for numerical weather prediction;
- Quasi-real-time methods of supplying information to the climatological service for timely climate monitoring;
- Provision of data for operational weather forecasts, in particular the very-short-range-forecasts for purposes of:
  - very rapid identification of short-term weather changes
  - analysis and forecast of small-scale weather phenomena;
- Provision of high frequency data for continuous weather monitoring in support of warning services as follows:
  - analysis and forecast of dangerous hazards (thunderstorm, hail, ice, fog, storm, etc.)
  - issue of warnings in a timely manner
  - timely adjustment of actual forecasts and warnings
  - timely provision of actual data and information to users (media and other customers)
  - support for safety of aviation, marine and land transport;
- Provision of data for agricultural, hydrological and biometeorological advice;
- Verification of forecasts;
- Calibration of radar and satellite data.

Progress in technology, and the tendency of governments to reduce the operating budgets of NMSs, are influencing an increasing number of NMSs to redesign and upgrade their observation systems. In particular, with efficiency and economy in mind, they are planning to automate surface observations. Automation will necessarily entail the redefinition of requirements for surface observations, especially in the light of the increasing demand for high frequency, high quality data in time and space.

A major concern of NMSs over recent years is how to react to increasing automation, as well as the increasing demand for meteorological data exchange. Similarly, providers of public weather services are also concerned about the definition of minimum requirements for synoptic observations in order to serve the public best. These issues require in-depth investigation by NMSs.

2.3 FORECAST PRODUCTS

Requirements for forecast products include those indicated below:

2.3.1 Forecasts

- TV:
  - graphical products (stills, two-dimensional and three-dimensional animations)
  - supplementary text information — e.g. for weather presentations without meteorologists
  - "ready to air" productions: weather shows (produced in a TV-studio) presented by media or NMS meteorologists;
- Radio:
  - text forecasts: for local, regional or national scales, depending on the transmission range of the radio station
  - statements
  - live interviews
  - city forecasts (significant weather, temperatures)
  - travel forecasts;
- Newspapers:
  - text forecasts: for local, regional or national scales, depending on the dissemination area of the newspaper
  - city forecasts
  - travel forecasts
  - "ready-to-print" weather pages including weather and climate statistics.

2.3.2 Warnings

All severe weather warnings (e.g.):
- Strong wind;
- Thunderstorms with gusts or hail;
- Heavy rain or snowfall;
- Freezing rain, etc.

2.3.3 Special forecasts

- Snow conditions;
- UV-Index;
- Road conditions;
- Pollen forecast;
- Bio-weather conditions.

2.4 INFORMATION PRODUCTS

2.4.1 Weather summaries

Special summaries for press agencies (e.g. weather highlights of the previous day, forecast for the present day, outlook for the next few days), international weather highlights (e.g. extreme temperatures, precipitation, hurricanes, tornadoes).

2.4.2 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;
- 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 climate 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 newly established 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 IV 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.

Chapter 3
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 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.

3.1 ADVANCES IN COMPUTER TECHNOLOGY

3.1.1 Server hardware

3.1.1.1 *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 Intel-processors are an emerging cost-effective alternative to classical MPP systems.

3.1.1.2 *Modelling on a workstation level for a small computer centre*

Today's workstations are powerful enough to run a forecast model with appropriate parameters in an acceptable time frame. For example, 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.

3.1.1.3 *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.

3.1.1.4 *Data handling and pre/postprocessing in a small computer centre*

If forecasts can be done on a workstation level, it is also possible to generate the products on the same system. The workstation should have a tape drive for archiving and efficient graphic hardware for the presentation of products.

3.1.2 Server software

In general, today's servers run UNIX as an operating system. There is a variety of "dialects" of UNIX-Systems, because every manufacturer adds enhancements and optimizations for his 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 written in Fortran 90, using C-library programs.

3.1.2.1 *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).

3.1.2.2 *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.

3.1.2.3 *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.

3.1.2.4 *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.

3.1.3 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$ 3000-4000.

The decision as to which operating system will be the best one 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.

3.1.4 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.

3.2 SATELLITE TECHNOLOGY

3.2.1 Use of satellite data as input and output for PWS

There is a need to make a distinction between the use of satellite imagery and other satellite data/products as INPUTS in the preparation of products for PWS, and their use as OUTPUTS as additional information provided directly to the public. For example, a major focus of PWS is the preparation and delivery of severe weather warnings. In this area, there is clearly valuable information in satellite imagery which forecasters will use to monitor the development of severe weather, and which is used and assimilated by numerical models as guidance to the forecasters.

3.2.2 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. Future 15-minute images will be 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 spaces 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 imagery is used to identify developing drought conditions and for the construction of rainfall maps.

3.2.3 Product development

The output side refers to satellite imagery and products which are disseminated to the public and other users such as emergency management. Multispectral processing methods are desirable for the correct interpretation of infra-red 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.

3.2.4 Geostationary and polar-orbiting satellites

Geostationary satellite information is particularly useful in the tropics, where it is currently available on an hourly basis.

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 more useful as single images for newspapers, but animation effects for television can only be achieved with imagery from geostationary satellites.

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).

3.2.5 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 satellites) 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 in 2001, 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. WMO Regions III and IV (South, Central and North America including the Caribbean) have not yet identified a transition period. 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 to 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 2001 and there will be an overlap period of about three years between the present METEOSAT system and MSG. In 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 time-slot for the transmissions seems not to be fully satisfactory for the operator. Details on this will be made available by EUMETSAT in the near future. 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 27th Meeting of the Coordination Group for Meteorological Satellites (CGMS), CGMS XXVII, Beijing, People's Republic of China, 13-18 October 1999" 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 its 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.

3.3 RADAR TECHNOLOGY

NMSs create, receive and store a wide variety of radar products, based on data sets from local radar stations. These data can be combined, either nationally or internationally, into radar composites covering a large area, and are exchangeable using BUFR as the common standard. Radars deliver data in three dimensions, comprising various vertical layers. Data can be on reflectivity or wind velocity, the former allows the determination of actual precipitation values while the latter allows the detection of wind shear. Radial and vertical wind products can be generated only from Doppler radar data. Doppler radar technology also allows more effective filtering of clutter, e.g. the removal of erroneous data introduced by topography or special atmospheric conditions. A common application of radar data is the projection and representation of the data on a two-dimensional plane, which can be easily handled by most users.

In addition to standard products, NMSs can provide customised radar products to meet the requirements of specific users. For instance, for hydrological offices interested in water run-off or for TV stations interested in showing areas of rainfall to viewers, specialised radar products can be generated. Additionally, in case of extreme weather situations, warning products can be distributed. Radar data or imagery can also be sent to users for use in their own systems. Some users may be interested in special radar presentation software that is supplied by the producer of the radar data.

3.4 THE WMO INFORMATION SYSTEM

3.4.1 The actual system

The WMO Information System comprises a combination of the private 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 1 illustrates the actual WMO Information System.

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

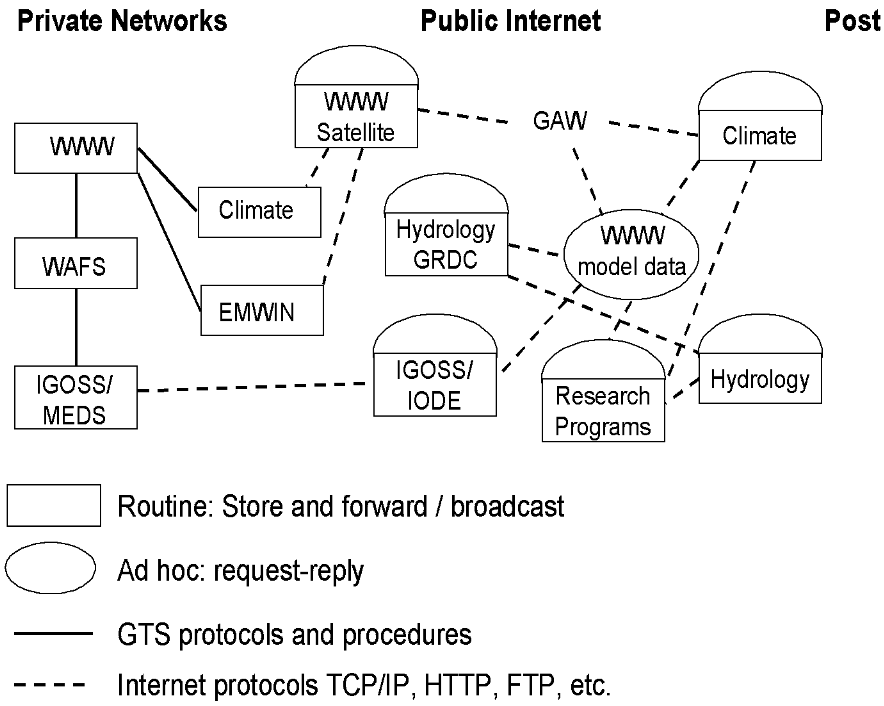

Figure 1 — Current WMO Information System

- 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 2, and would ensure coordinated development and operation of the participating systems through reliance on international protocols and standards and off-the-shelf software.

Figures 1 and 2 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 datasets 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.

3.4.2 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 the Internet. The emerging common view of the future networks at each NMS is depicted in Figure 3.

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 home page 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 data-bases 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.

3.5 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

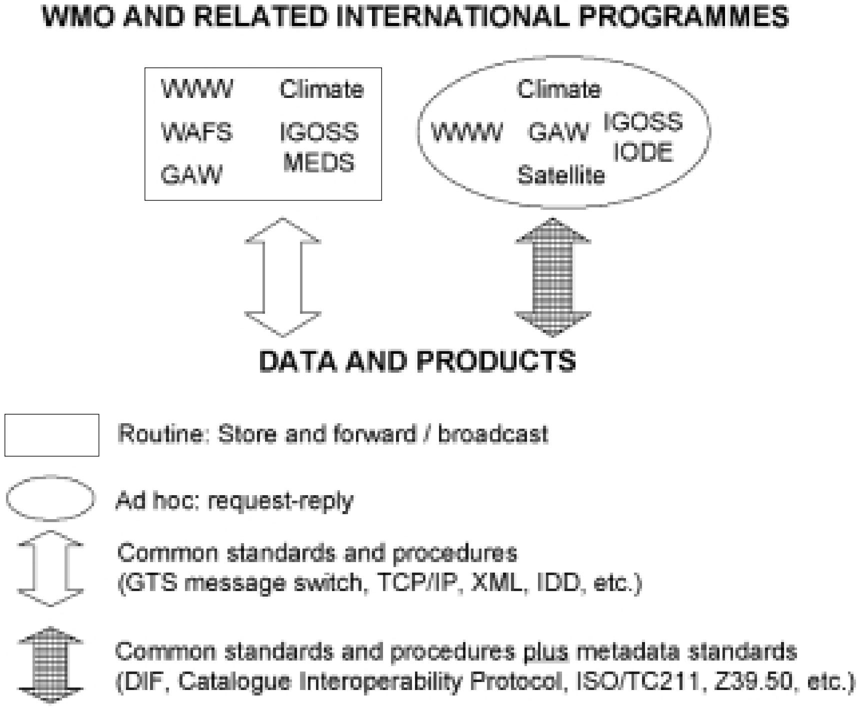

Figure 2 — Future WMO Information System

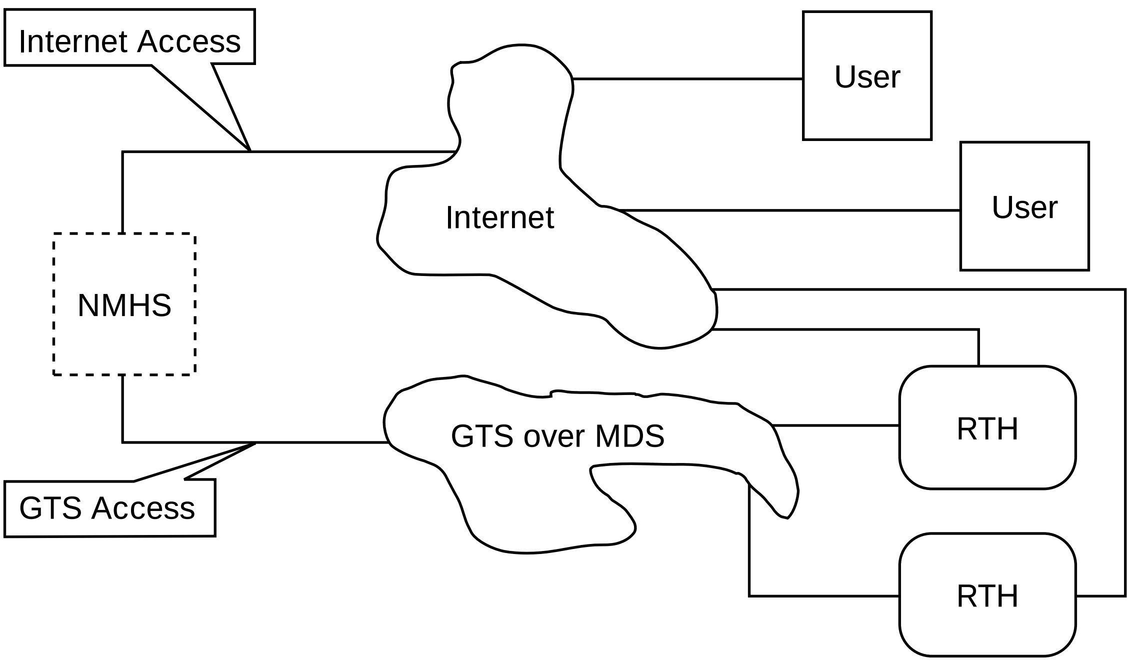

Figure 3 — Schematic view of future network accesses for NMS

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.

3.6 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 datasets 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.

3.7 INTEGRATED SYSTEM

The preparation and presentation of meteorological data is a multi-stage process. All these stages could be implemented on dedicated systems. One could have decoding and data storage on one server with several clients dedicated to different visualization jobs, e.g. there could be a screen for radar, one for satellite imagery, another for observation plotting, and finally one for the display of forecast maps. This is not a desirable configuration, because there is no overlay of different datasets.

Most of today's meteorological workstation systems (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. This MWS design was developed during the early to mid-1990s.

Today there is a clear tendency to move to multi-tier architectures with balanced client/server implementations. These implementations show all the advantages that were addressed in section 3.1.4. Depending on the needs of applications, which might range from word processing to animated 3D-visualisation, 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 extent 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.

A recent report prepared on workstations, which contains information relevant to this chapter can be accessed at the following:

http://www.wmo.ch/web/www/DPS/Workstation-Applications.html

Chapter 4
STANDARDS RELATED TO THE NEEDS OF PUBLIC WEATHER SERVICES

4.1 INTEGRATION OF ALL DATA AND PRODUCTS

4.1.1 Speed and ease of access

The various types of data and products that can be generated, pre- and postprocessed or displayed by computers are manifold. They 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).

4.1.2 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.

4.2 DISSEMINATION

4.2.1 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.

4.2.1.1 *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 tiff. 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.

4.2.1.2 *Audio-visual formats*

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

4.2.1.3 *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 time-steps 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.

4.2.1.4 *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 tiff 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.

4.2.1.5 *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 a ftp-server, depending on capacity of network and size of data, both of which affect the image quality.

4.2.1.6 *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.

4.2.2 Radio

4.2.2.1 *Delivering of products by fax*

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.

4.2.2.2 *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 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.

4.2.2.3 *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.

4.2.3 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.

4.2.3.1 *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.

4.2.3.2 *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, tiff) 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.

4.2.3.3 *“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.

4.2.3.4 *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.

4.2.4 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 4.2.4.1 to 4.2.4.4 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.

4.2.4.1 *Infrastructure*

To utilize these 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).

4.2.4.2 *WWW*

The WWW, as shown on page 14, 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.

4.2.4.3 *FTP*

The ftp (File Transfer Protocol) service is an easy way to provide data to defined users (see table on page 15). 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 daemon program. An ftp client contacts a server on a remote machine and establishes a connection validated by user name and password. Once the

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	

validation is successfully done on the server machine, the ftp client can upload and download files, create and remove directories, etc. on this machine. A popular ftp client program for a windows PC is ws_ftp which is a freeware product.

4.2.4.4 E-Mail

The term “Electronic Mail” appropriately describes this service (see table on page 16). 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.

4.2.5 Fixed and mobile communications systems

4.2.5.1 *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 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 in full swing, but the best speech comprehension is 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.

4.2.5.2 *Mobile telephone*

As far as the provision of voice services is concerned, there is no fundamental difference between fixed and mobile

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

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 4.2.5.3).

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.

4.2.5.3 *Pagers/SMS*

Pagers and mobile telephones (see also paragraph 4.2.5.2) allow short text messages to be sent to mobile devices that are 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.

4.2.5.4 *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.

Chapter 5
STANDARDS RELATED TO NMS OPERATIONS

5.1 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 standardisation 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.

5.2 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.

5.3 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.

5.3.1 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.

5.3.2 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.

5.3.3 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 Fortan 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 datasets.

5.3.4 Computing standards software

There is a wide variety of software standards. During the early to mid nineties 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 3.1.4.

There are still two strategies to store data. Some NMSs rely on file-systems for the sake of performance and simplicity while others utilise 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 3.6 on GIS) which might make proprietary developments redundant.

In the field of graphical user interfaces (GUI) development there are only a few de facto 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).

5.4 INTEGRATED SYSTEM

As described in Section 3.7, 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 hard- 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 3.1.4). 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.

5.5 DISSEMINATION AND ACCESS

5.5.1 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.

5.5.2 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.

5.5.3 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 home pages 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 data-base 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 data-sets 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 only), 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 data-sets or allow access only to those data-sets that the customer has subscribed to.

5.6 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 installed as a plug-in on existing system management, network management, asset management and/or network documentation systems. They can use existing data-bases 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 6
GLOBALIZATION OF MEDIA

Most national Meteorological Services have a long tradition as providers of meteorological information for the mass media. A major goal of NMSs is to meet the expectations of the society at large through the provision of comprehensive weather information, as well as providing additional services with particular emphasis on public safety and welfare.

Information technology has developed dramatically during the last 30 years and has supported on the one hand, the development of numerical forecast models, satellite technology and meteorological information and presentation systems and on the other hand, the communication technology. But during the same period, more has changed than just the technological basis for meteorology and the communication technology. More and more people travel, business and economics have developed on a global level and today's sophisticated public expects meteorological services of higher quality for travel destinations as well as at home.

The presentation of weather information has kept pace with globalization, giving rise to the creation of global media. There are two aspects to the globalization of the media. The first aspect concerns the global media organizations. The second concerns national media which need global weather information to meet the demands of users.

The most important means of dissemination of global weather information is television. Only television can deliver news and information in words, pictures and animation. Following the trend towards a global society, one can find the same TV channels all over the world; at home or in other continents. Users obviously expect high-quality information wherever they are. The same expectation also applies to weather information.

The public expects a comprehensive coverage of weather information spanning the regional as well as the global scale. For a national Meteorological Service this means the delivery of the following types of information for each continent:

- A short description of the weather situation;
- A short-range forecast;
- A medium-range forecast;
- City forecasts;
- Background information;
- Climatological information; and
- Hazard warnings.

Hazard warnings are the most important of all the information and should be given very high priority. Global TV channels expect to get the best information available about hazards such as tropical cyclones, tornados etc. in order to inform the travelling public about local weather situations at their intended destinations.

It is a major challenge for NMSs to deliver the most accurate and up-to-date warning information worldwide. For example, in the case of tropical cyclones that normally cover a large area and involve the operational responsibility of several NMSs simultaneously, proper coordination among NMSs is essential in order to avoid dissemination of different or contradictory warnings and forecasts for the same hazard. The challenge is to develop an information system for the exchange of weather warnings with an aim to:

- Informing each other and working together in a timely and coordinated manner;
- Avoiding contradictory forecasts which have a potential for public confusion; and
- Protecting the "single-voice" principle.

Based on such a system it will be possible to deliver to the global media and to the public clear, timely and correct information, especially with respect to hazards.

The second aspect of the globalization of the media which was mentioned above concerns national TV stations. Public or private channels have the same demands as the global news channels as regards worldwide weather information and hazard warnings. This fact makes the task of developing an appropriate system for the exchange of weather warnings and related information a challenge for the whole meteorological community.

The globalization of the media will continue to progress at a rapid pace and NMSs have to use and apply the available technology described in the previous chapters to design, package and disseminate weather products and services in a manner that meets the requirements of the users. Additionally, NMSs need to use the latest technology to develop and improve international cooperation with the media and among the meteorological community, in order to inform the global public in the best possible way.

Chapter 7
IMPROVING INTERNATIONAL COOPERATION ON TECHNICAL ASPECTS OF PUBLIC WEATHER SRVICES

7.1 COOPERATION ON PUBLIC WEATHER SERVICES DATA AND PRODUCTS

WMO has for many years assisted in the international coordination of exchange of tropical cyclone warnings, and, since the first cases of cross-border pollution arising from nuclear radiation, has been involved in establishing improved international arrangements to provide relevant information on these events. However, the arrangements for the routine exchange of public weather services data and products are relatively undeveloped. This is due to the fact that public weather data and products have been seen as primarily of national interest. The major impacts of advances in communications technology and the increasing globalization of media coverage have given rise to new expectations and demands on NMSs. The WMO Public Weather Services Programme is seeking to assist NMSs to respond to this issue by giving it increased priority in its future work. The following material is therefore indicative of early directions in these efforts rather than fully developed guidelines.

7.1.1 Coordination on public weather services data and products

Under the operations of the World Weather Watch, large amounts of data are exchanged daily on observed weather conditions. While this information is used extensively to feed into weather forecasting operations of NMSs and into the global numerical prediction models, comparatively little of the information is used directly in the delivery of public weather services. On the other hand, increased interest and demand for recent, current and forecast information for locations beyond the boundaries of the country concerned are becoming more evident.

In newspapers there are often lists of weather information for a collection of world cities and television weather presentations are increasingly including information on cities in neighbouring and other countries in their region and for the whole globe.

Another emerging trend is that increased media coverage of international weather-related disasters is leading to a need for additional current and forecast information that can be used in a "news" story context rather than the "weather segment" of the radio, television, Internet and newspaper concerned.

NMSs typically produce daily summaries of the previous day's local and perhaps national weather that give information about weather, wind, rainfall, and maximum and minimum temperatures. However access to similar information for neighbouring countries is not so straightforward. Providing access to such bulletins is not necessarily the required solution, because the local and national products will usually contain more information than is needed for international exchange.

Routine public weather forecasts are similarly produced by NMSs with their local and national audiences in mind, while, on a regional and global basis, it is not easy to access information such as forecasts for major cities.

For individuals and organizations with a special interest in the weather in one or more other countries, the Internet has provided part of the solution in that authoritive current and forecast information may be available from the NMSs of the countries concerned via the World Wide Web. However, national approaches to the content of information on the World Wide Web are not consistent and the need to search each site individually does not meet the needs of the media for access to a wide range of information in an easily accessible collective.

The gap between what the media and the international community need and what is provided by NMSs has led to a number of less optimal approaches. These include:

- The compilation of unofficial collectives by national and international news agencies;
- The compilation of collectives of recent data extracted from routine synoptic information by NMSs or private meteorological organizations that are then presented as "international weather" lists. It is often not clear whether these are "yesterday's weather" or "forecasts for today";
- The provision of lists of predictions for other international cities by NMSs or private meteorological organizations that are based on direct model output from global numerical prediction models. While these may be useful guidance, they do not always coincide with the official forecasts for the cities produced by the respective NMSs.

There is clearly a need and an opportunity for NMSs to modify their public weather services programmes to begin to meet this need more effectively, and to work more effectively with other NMSs to produce valued regional and global products. These products could include simple listing by day and date of "yesterday's actual" and "today and tomorrow's " summary forecast weather and temperatures for selected cities. WMO's role is to assist in the coordination and standardization of this work through the WMO Public Weather Services Programme.

7.1.2 Coordination of warnings

In comparison to international access to routine public weather information, arrangements are somewhat better for exchange of information among NMSs on certain types of severe weather warnings.

Arrangements for exchange of information on tropical cyclone warnings provide the best example of an effective system for exchange of warnings on a regional basis. The

WMO Tropical Cyclone Programme and the NMSs involved in the different regional tropical cyclone bodies have worked well to make good regional arrangements and procedures.

Another example where some international arrangements have been put in place is in relation to the cross-border exchange of weather information related to hazardous events.

As discussed in the next section, the arrangements for tropical cyclones and cross-border pollution events are less effective on a global basis, because, prior to the growth of the global media there was not a strong demand on a global basis for such information to be exchanged that widely. Efforts to improve the exchange of routine public weather information will contribute to improved arrangements for coordination and exchange of information on relevant public weather warnings.

7.2 COORDINATION WITH GLOBAL MEDIA

7.2.1 Routine Products

Weather information is a major programme content consideration for the global media because of the high level of interest by the public in international weather related to their holiday or business plans. It is also valued by the international media as a way of emphasising their "internationality" and, in the case of 24-hour radio and television coverage, to provide ever-changing programme "content".

As described above, the need for global weather information and the comparative lack of such information from the official NMS and WMO-coordinated sources has led to a number of approaches, each of which is less than optimal from an NMS and WMO perspective.

WMO has had increased dialogue with the global media groups in recent years, but this now needs to be matched by improved efforts to make the needed information more easily accessible and packaged in formats that allow it to be readily used by the media.

Efforts as described in the previous section, to improve the availability of routine weather information, will do much to meet this need. WMO and NMSs now need to develop more fully the needed technical and procedural arrangements.

7.2.2 Warnings

The issue of information broadcast on severe weather events by international and global media is an especially important one that has been discussed at the level of WMO Congress and Executive Council meetings. The broadcast of less than up-to-date information, or information different from official local warnings is potentially life- threatening. The potential undermining of the efforts of the responsible NMS though not the intention of the media, could be damaging and will certainly be detrimental to the visibility and authority of the NMSs concerned.

The WMO Public Weather Services Programme is developing options to address this issue, including the option of NMSs placing their warnings on a number of agreed regional World Wide Web sites, where they can be accessed by the international media. This has much potential, though some NMSs wish to ensure that such arrangements are strong enough to reinforce, rather than undermine, the official role of the NMSs.

7.2.3 PWS on the Internet

A closely related and increasingly important consideration for NMSs and WMO is the rapid growth of the Internet and the popularity of weather information on the Internet. Current and forecast (numerical model output) information on both national and international levels is now routinely provided by a number of private sector meteorological and news organizations, as well as some of the NMS Web sites.

The explosive growth and potential of the Internet is both a challenge and an opportunity for NMSs to provide ready access to relevant public weather information.

WMO is currently examining the potential of the Web and its successors to improve the existing telecommunication systems. It is important that NMSs address the needs for the exchange of PWS products, as well as utilization of the Web for exchange of real-time data.

Technical and other considerations include:

- Capability of the NMS to access the Internet;
- Capability of the NMS to maintain a Web site, perhaps in partnership with another agency, to provide information nationally and globally;
- Provision of real time information (type and frequency of update);
- Provision of numerical data, text and graphical information;
- Relevant computing and telecommunications infrastructure and costs;
- Suitable data collectives and ready-to-use products needed by national and international media.

APPENDIX

Current polar-orbiting meteorological satellite system (as at December 2000): The Chinese FY-1C was successfully launched on 10 May 1999. The most notable change in comparison to the previous satellites is the number of channels of its imaging radiometer which has been increased from 5 to 10. The High Resolution Picture Transmission of FY-1C is named CHRPT and can be acquired by other countries without any restriction. TV image data are available in APT mode (137 MHz) from the Russian Federation Meteor-2 and –3 satellites and the RESURS-01 N4. The operational polar-orbiting satellites of the US are NOAA-14 and NOAA-15 with two secondary and one stand-by spacecraft. Direct broadcast data of the Defense Meteorological Satellite Program (DMSP) are encrypted but are available from NOAA in near-real-time.

Current geostationary meteorological satellite system (as at December 2000): EUMETSAT operates METEOSAT-7 at 0° and METEOSAT-5 at 63°E with METEOSAT-6 in a stand-by mode. The current generation of Meteosat satellites will continue until at least the end of 2003, in order to allow time for many thousands of Meteosat users to transfer to Meteosat Second Generation and to provide a back-up satellite throughout the transition period. The INSAT (Indian National Satellite) system provides a Cyclone Warning Dissemination Service (CWDS) and a Meteorological Data Dissemination (MDD) service, which delivers 3-hourly WEFAX-type imagery and meteorological data to some 90 domestic stations. INSAT also performs data collection and re-transmission from more than 100 DCPs. INSAT wind products are available on the GTS of the WMO. The Japanese GMS-5 with its position at 140°E is the operational satellite for the western Pacific area. The experimental FY-2A of China with a position at 105°E cannot be operated continuously but provides regular imagery. GOES-10 at 136°W and GOES-8 at 75°W are the operational satellites of NOAA with GOES-9 and GOES-11 being the stand-by satellites. The GOES satellites have in addition to the imaging mission an operational temperature and humidity sounding capability.

Future polar-orbiting meteorological satellite system: The Joint Polar System will be the future system of operational meteorological polar-orbiting satellites which will be operated by NOAA and EUMETSAT to provide global meteorological and climate data from a series of European and American satellites, replacing the current NOAA-K, -L, -M series. The EUMETSAT Polar System (EPS) with the so-called METOP satellites will be the European contribution to the Initial Joint Polar System established with NOAA. The EPS system is dedicated to the acquisition, processing and dissemination of observational data from the morning orbit with the launch of METOP-1 planned for the end of 2003. China plans to launch FY-1D in 2001, which will have the same function and specification as FY-1C. The second generation of Chinese polar-orbiting meteorological satellite FY-3 is now in the concept design phase. The Russian Federation will develop the next series of METEOR-3M satellites with launches planned for mid 2000 and the beginning of the second half of the year 2002. These satellites will have an imager in the VIS and IR range, a microwave imager and IR and microwave sounders. With the launch of NOAA-15 in 1999 the US put into operation the new fifth generation of polar-orbiting satellites, now named Polar-Orbiting Environmental Satellites (POES). NOAA-L is scheduled for launch in April 2000, NOAA-N in December 2003 and NOAA-N’ in January 2008. They carry upgraded imaging and sounding instruments including microwave sounders. The question of the continuation of direct broadcast services from the future US polar-orbiting satellites after 2008 remains for the time being an open item.

The launch date of EUMETSAT’s first satellite of the Meteosat Second Generation (MSG) has been rescheduled for 2001. Impacts from the transition of the present Meteosat system to the new one are described in the sections above. Japan lost the first satellite of its new generation of geostationary satellites named the Multifunctional Transport Satellite (MTSAT). MTSAT-1R is planned to be launched in 2002 and MTSAT-2 in the summer of 2004. China plans to launch FY-2B in 2000 and FY-2C, -D, -E will be the 3 succeeding geostationary satellites. The number of spectral channels of the imaging radiometer will be increased from 3 to 5 and the S-FAX (similar to WEFAX) transmissions will be cancelled. Russia plans to launch the GOMS-Electro-N2 spacecraft in 2001 with an IR and VIS imager as core payload. Direct broadcast will be available in WEFAX format, the satellite will be positioned at 76°E. The US will continue to launch and operate a series of geostationary satellites (launch GOES-L in April 2000 up to GOES-Q in 2010).

GLOSSARY

Abbreviation	Explanation
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
MWS	Meteorological Workstation System
MSS	Message Switching System (following WMO- standards)
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 / World Wide Web