II. WORKSHOP REPORT

1. <u>INTRODUCTION</u>

ECMWF has, over the years, organised and benefitted from a series of workshops covering a variety of aspects of its operational and research activities. The discussions during these workshops have had a substantial effect on the activity of ECMWF in many of the areas which have been taken as topics.

The subject of this workshop, meteorological operational systems, was chosen because significant progress has been made during the last decade in the fields of numerical weather prediction and the analysis and assimilation of meteorological data. To obtain maximum benefit from such progress it is essential that the numerical models be supported by effective operational systems to generate, pre-process, post-process, monitor and display the data.

The objectives of this workshop were to examine these support functions, focusing on five principle aspects:

- overall design and implementation of meteorological operational systems;

- observational data acquisition and monitoring;

- archiving and data management;

- application of binary representation standards;

- graphical systems and products.

Emphasis was given to systems appropriate for the support of meteorological centres using supercomputers for global modelling, although many of the systems described were of general interest and could provide a basis for future co-ordination and co-operation.

The workshop consisted of a series of presentations which were attended by the participants in plenary sessions. On Wednesday afternoon three working groups were formed to discuss:

(i) monitoring of observational data;

(ii) graphics standards in meteorology;

(iii) presentation and visualisation of meteorological products.

The programme of the workshop and the list of participants are shown at the beginning of these proceedings.

Reports from each of the working groups were prepared and finalised. The reports were presented at a plenary session held on Friday morning and are included in these proceedings in addition to all the papers presented at the workshop.

2. DISCUSSION AND RECOMMENDATIONS

2.1 Monitoring of Observational Data

2.1.1 Defining the Data Problem

Numerical analysis and forecast systems, to perform at levels at which they are capable, require initial and verification data which match both the resolution of the model and the parametrised physical processes. Within one year some global models are likely to have a resolution of less then 100 km. This requires a high resolution observing system which in the free atmosphere provides 3-dimensional profiles of the mass, wind and moisture fields.

At the same time national meteorological services are confronted with an increasing demand for a denser meteorological observational network, both in time and space, to satisfy their requirements for high resolution analyses and now-casting systems. The inhomogeneity of the meteorological observational network is recognised. Surface observations are not uniformly distributed over the globe, in particular there is a paucity of ship data from tropical and southern hemisphere oceans, but also from desert and polar regions. Measurements from polar orbiting and geostationary satellites provide the required global data coverage at the appropriate resolution but conventional upper-air data, from radiosondes and aircraft for example, which serve as reference data for the space based measurements, are also concentrated in the northern hemisphere. Furthermore, the quality of such data is often inadequate.

However, there are untapped sources of data which exist but which are not routinely available. These data include required conventional observations which are generated for national applications but not exchanged globally at present such as marine measurements, aircraft observations and additional satellite products.

Improvements in the quality, quantity and the timely availability of meteorological data within the World Weather Watch seem possible through an achievable upgrading of the data collection, processing and dissemination scheme and by introducing standard methods and procedures for real-time and non-real-time monitoring of the availability and quality of observational data.

2.1.2 Addressing the Data Problem

There is ample evidence that much progress has been made in the development of numerical forecasting systems. However, further improvements in operational forecasting may well be seriously impeded by the current data deficiencies, both in availability and quality.

Since these data deficiencies cause great concern and have an adverse effect, in particular on forecasting in the medium range, ECMWF organised a meeting on 4-6 March 1987 with external participants from major operational centres and from EUMETSAT, to discuss the data problems and the measures/actions to be undertaken to improve the present situation.

The main objectives of the meeting were:

(i) to review current plans for the development of global forecasting systems;

(ii) to discuss the requirements, future production prospects, data monitoring, quality control, and communications in relation to observational data, with particular reference to space-based data and new observing techniques, for global atmospheric models;

(iii) to produce recommendations on action to be taken to secure the production and efficient real-time distribution of data of sufficiently good quality and with a coverage and resolution compatible with the data requirements of current and projected global data assimilation and forecasting schemes.

The meeting produced a final report which contained detailed recommendations to overcome the data deficiencies.

At this workshop the data problems were addressed again and, based on the recommendations from the March meeting, the issues were discussed in detail.

It was emphasised that there is a need for increasing the data density of the Global Observing System and to achieve a higher time resolution of the observations in order:

(i) to serve the needs of global models;

(ii) to meet the requirements of national meteorological centres preparing specialised products.

2.1.3 Improving the Data Situation

The recommendations made by the data meeting in March were endorsed and some additional recommendations were made. A summary follows:

Rec. 1: Transmit all existing GTS data globally, including:

- all conventional data from the basic regional network;
- surface data at 3 hour intervals, upper air soundings at 6 hour intervals;
- exchange of all parts of TEMP and PILOT messages.

Rec. 2: Provide additional data for exchange on the GTS globally, including:

- aircraft observations over land and at constant time intervals;
- bogus data in the vicinity of tropical cyclones;
- research observations in real time.

Members of WMO should be encouraged to make the necessary arrangements to ensure that observations from research experiments are put on the GTS.

Rec. 3: Develop and implement new techniques of data production and collection, including:

- good quality (and high reaching) radiosonde data from a baseline network;
- exchange of information on newly implemented observation platforms and techniques;
- data collection by satellites;
- automatic stations, e.g. wind profilers.

Rec. 4: Intensify the data monitoring at all levels, using automation where applicable and introduce global real-time monitoring.

Rec. 5: Review the guidelines for quality control and intensify the quality control at all levels, in particular nationally.

Rec. 6: Gradually introduce real-time feedback on faulty or suspect stations or data sets.

Rec. 7: The exchange of monthly quality statistics between GDPS centres should take place with the minimum of delay using modern communication techniques where possible.

2.2 Graphics Standards in Meteorology

2.2.1 Objectives

The objectives of this working group were to discuss the relevance of graphics standards to meteorology under the following headings:

1. Implementation level
2. Metafiles
3. Graphical representation of meteorological data
4. Application system level

2.2.2 Background

Significant progress has been made during the last decade in the fields of numerical weather prediction and the analysis and assimilation of meteorological data. This is mainly due to the advent of super computers. To benefit from such progress it is essential that effective graphical systems are made available to monitor and display data. There have been major advances in computer graphics in recent years including new technologies such as Laser, Inkjet, Thermal transfer etc. Workstations have added a new dimension to graphics in meteorology. There is now a need to look at the connection between meteorology and graphics and, in particular, to examine the need for graphics standards in meteorology.

An increasing number of meteorological services are now using computer graphics, of some sort, to plot meteorological data. There are recommendations for plotting standards by WMO but these need to be reviewed as new types of data, e.g. radar and satellite, and new plotting facilities appear.

In recent years the computer graphics industry and graphics users have been very anxious to establish standards in the graphics area. The Graphics Kernel System (GKS), for 2-dimensional data, and the Computer Graphics Metafile (CGM), for the storage and transmission of graphical data, have become standards. They are intended to be the first members of a family of compatible standards, including GKS3D and PHIGS for 3-dimensional graphics.

New standards for the transmission formats of meteorological data have emerged recently, i.e. GRIB and BUFR. GRIB code is already established and BUFR will become established in the near future. It is essential that further graphics standards in meteorology be established at this stage as it seems that we are about to begin a new generation of computer graphics and meteorological models.

2.2.3 Graphics implementation level

It was generally agreed that GKS was acceptable as a graphics standard even though there were some shortcomings, e.g. problems displaying satellite imagery. As no standard has existed until now, GKS should be welcomed rather than criticised. It was considered that using GKS now could possibly mean a short term loss but would mean a long term gain. The gain would be made in future by being able to have a wider choice of hardware. It was thought that the prices of the GKS packages were too large, considering that the manufacturers of graphics devices frequently include a free graphics package as part of the purchase. However, some people felt that GKS would become a 'standard' graphics package after a short time and would be included free with devices. At least one person thought that GKS may be a step backwards in the sense that it cannot supply all the features that current packages offer, e.g. some text facilities. Some people said that they would need to examine other proposed standards before deciding, even though these standards were not established yet. It was generally felt that it takes too long for standards to become established and that one would always be waiting for the perfect standard. The variability of early GKS implementations has led to some problems in porting applications software but these problems are expected to disappear as the quality of implementations improve.

2.2.4 Registration of meteorological marker symbols

Graphical standards allow for the registration with ISO of various graphical items for international use. A suggestion was made that some meteorological symbols should be registered as standard marker types. To register graphic items, it is necessary to officially apply to the ISO Standards committee specifying the relevant marker types and requesting specific item numbers. In particular, it was felt that station circles should be included in GKS. There are approximately 10 such circles where each one contains a different cloud amount. It was also suggested that specialised line styles should be registered. These are lines representing weather fronts on a map. It was felt that it would not be proper to request that meteorological symbols be registered. There are well over 100 symbols. However, special hatching patterns could also be registered. WMO should be requested to make the request to the ISO11 committee (ISO reference TC97/SC24). The advantage of this registration would be that the computer industry would be made aware of meteorological needs.

2.2.5 ISO text extensions

There was a proposal that all meteorological symbols, apart from those mentioned in the previous section, should be registered in the ISO standard ISO2022. This would facilitate the plotting of meteorological observations considerably. It was suggested by another that, in fact, this would complicate observation plotting. This proposal should be considered to be independent of graphics standards. It was also suggested that WMO should co-ordinate this proposal to the ISO committee.

2.2.6 Plotting of wind flags

There was some support for the inclusion of wind flags in ISO2022 (see previous section) and a description of how this could be achieved was given. It was pointed out that, even though it would be easy enough to define the wind speed symbols required, it would be necessary to rotate them on the map according to the wind direction. Also, the other plotted observation symbols for station plots may need to be adjusted according to the wind direction. It would be impractical to define all the symbols taking wind speed and direction into account.

2.2.7 Metafile standards

The CGM has recently been established as a standard for metafiles. The computer graphics industry, as well as users, has been waiting a long time for it. There was a suggestion that CGM should have the ability to define certain 'sub pictures' with different attributes and it was pointed out that segmentation will achieve this when, as is planned, it is added to the CGM standard. It was suggested that a paper on CGM should be prepared at the Centre and sent to all member states. This was in response to the fact that metafiles will be sent to member states in the future and that the CGM will be used.

2.2.8 Graphical representation of meteorological data

It was suggested that the WMO recommendations on map plotting were now out of date and that a new set of recommendations were urgently required. It is necessary to review the standard for the way meteorological data is represented on maps, whether on paper or computer displays. This standard refers to colour, linestyles etc. No WMO standard is currently available for plotting of upper air observations (there is a very good standard for surface observations). It is important that WMO recommend a standard for upper air plotting. It was also suggested that the standards for projections and scales of meteorological maps should be reviewed. This would simplify the task of reading maps from different countries and would facilitate comparisons. There was a suggestion that the orientation of polar stereographic maps would be difficult to standardize, as each country would require that the vertical longitude of the map be in or close to their country. There should also be a standard for plotting imaging data.

2.2.9 Application systems

There are a few application systems existing at present, e.g. AMIGAS, METIS, McIDAS etc. However, it seems too early yet to decide on a standard application system but this should not be ruled out in the future. Any applications package considered in the future should conform to the other standards mentioned by the group.

2.2.10 Summary of Recommendations

(i) GKS should be accepted as a standard at the implementation level. Future graphics standards should be studied carefully for their relevance to meteorology.

(ii) The metafile standard CGM should be accepted as the meteorological standard.

(iii) The backing of WMO should be sought in registering meteorological symbols as marker types and in the registration of special line styles and hatch style. Similarly, WMO backing should be requested for registering other meteorological symbols in ISO2022.

(iv) WMO should be requested to review standards for the representation of meteorological data on plotted maps and to make available a standard for plotting of upper air observations. Standards for projections and scales of meteorological maps should be reviewed.

(v) There should be a standard for plotting imaging data.

2.3 Presentation/Visualisation of Meteorological Products

2.3.1 Objectives

Weather forecasting models produce large amounts of data, which can only be analysed using graphical techniques. The presentation of meteorological products using advanced presentation/visualisation is an area which is yet to be exploited.

2.3.2 Background

Modern supercomputers can handle and produce data at rates beyond human comprehension. Thus it is essential to isolate significant data properties and depict them in a readily recognisable form. Graphical techniques must be developed to enable meteorologists to comprehend their data, and to understand the mechanisms at work within their models; without such comprehension and understanding further progress is difficult to realise.

The working group tackled this problem by firstly trying to pin down exactly how modern visualisation techniques could be used in the field of meteorology. It then tried to determine how to achieve this goal.

2.3.3 Discussion

Three principal types of users of meteorological animated sequences were identified:

1. the researcher;
2. the forecaster, or operational meteorologist;
3. the general public.

It was considered that the demands of the general public, who set their standards by powerful commercial graphics, were beyond the scope of the working group, and were not discussed in any depth.

The working group contained about 10 members who considered themselves to be operational meteorologists. In an operational environment forecast data has to be passed onto the end user totally automatically, i.e. with no human intervention. Also, this must be done in a very short time period as a late forecast is operationally worthless. Any graphics that are relevant to the forecaster must therefore also be completed in a short time slot. However, due to operational constraints, a large amount of data is not looked at by the forecaster. So this is an area in which graphics could play a large role when the required computing power is available.

The researcher is not bound by the same critical time constraints as the forecaster, and is therefore able to obtain a superior presentation of meteorological data, if required, than would otherwise be available. This is an area in which the greatest use could be made of visualisation techniques.

2.3.3.1 Meteorological requirements

The ultimate purpose of computer visualisation, particularly animation graphics, is to provide the viewer with motivation which cannot be obtained using any other display techniques. The animation of two-dimensional raster images has proved effective in the analysis of data from complex numerical models in a variety of disciplines (e.g. astrophysics, meteorology, applied mathematics). The unique aspect of such models is the provision of data with high spatial and temporal resolution, and thus a first step towards better understanding the data is the application of well-understood two-dimensional animation techniques. For example, it may prove effective to animate derived quantities which provide information about the 3D structure of the atmosphere, but which can be displayed using 2D animation techniques (e.g. raster images of differential vorticity advection). Such a sequence would provide data which are not routinely available, and would do so in a way which is easily comprehensible.

Recent progress in graphics workstations has made these techniques more widely available. Unlike other fields a good general circulation model cannot be run interactively. What can be done is to permit the meteorologist to work interactively with the analysed and forecast fields. In the process, colour and detail must be used sensibly and effectively. Throughout such presentations, one must take care that the level of analysis is appropriate to the problem. Three-dimensional presentations of inherently two-dimensional problems add little to one's comprehension.

Videos presented during the main workshop provoked a number of interesting comments, the bottom line of which was "what exactly is it that a meteorologist wants to look at and how should it be presented?". To a great extent, this depends on which meteorologist is asked the question.

Some say that they have no requirements for animation techniques, others that they would like to see full weather systems in three dimensions. The types of weather features that are of greatest interest also vary a great deal, e.g. tornados, typhoons and trajectories, according to the part of the world that is being studied and/or if operational support is being provided.

As the amount of data coming out of a model is vast, it is not possible, even with graphical techniques, to examine all the information in detail. Some intelligent pre-selection of the relevant data must be performed.

It is not clear how various fields should be represented. The lay person has pre-defined ideas about what, for example, clouds, rain and fog look like and as such can be tackled head on using graphical techniques. But how should wind, pressure, temperature and vorticity be represented? The main technique being used is the use of false colours, but are there better more realistic presentation methods? It is clear that new areas of research make better use of graphics as there are no pre-conceived ideas about data representation. In meteorology, there is a lot of tradition concerning data presentation. A few years ago the researcher showed little enthusiasm for the use of colour. This has changed now that new methods of presentation have emerged. The same inertia now seems to apply to the use of animation.

It is also possible to look not at raw fields, but differences between various fields. This could be between forecast and analysis data, so that errors could be detected and traced to their origin, or between today's forecast and tomorrow's. It could be between different forecast models, so that a comparison can be made between them, which would assist with the verification of a forecast. It is possible, however, that the researcher could be satisfied by looking at such fields using traditional methods, without resorting to animation techniques.

The researcher needs the ability to control and dynamically change what he wishes to look at, such as the area, and obtain results within a reasonable amount of time. He should not need to systematically return to the super computer to perform such simple tasks, although tightly coupled workstations make this easier.

2.3.3.2 Presentation/visualisation techniques and tools

Given that animation is required by the meteorologists, what does the technologist, or tool designer offer to realise this need?

One problem associated with graphics, and especially animation, is the volume of data required to move images from one site to another, for example between ECMWF and its Member States. Network speeds are increasing all the time, but are still far too slow to handle real time animation. One solution would be to bypass networks and to broadcast sequences directly. Experiments have been suggested in this area, but have been limited by inadequate funding and, in Europe, by the inertia of the PTT's. On the other hand local workstations will soon be able to produce animation sequences, in real time, from pre-processed data.

The developments in the workstation area are very exciting, with falling prices and improving performance/power bringing them within reach of many more users (meteorological institutions generally being run on very tight budgets). The power of PC's is also improving dramatically, with the top end of this market now touching the bottom end of the workstation market.

There is however a lack of suitable software in the visualisation area that is directly applicable to the meteorological community. Any package must conform to a number of criteria before it is usable. It must do what the user requires, it must connect to existing hardware/software standards, and it must be programmable. It should always be borne in mind, that even standards vary according to their implementation, especially on workstations (e.g. UNIX, C). However standards are necessary, and meteorology is now well advanced embracing GRIB, BUFR, GKS, CGM and FORTRAN. ECMWF hopes to promote MAGICS as a sort of standard among its member states, and possibly outside.

2.3.4 Summary of Recommendations

Funding is a problem in the area of meteorological visualisation. Maybe industry and/or the European Community could be persuaded to help in this area? This applies not only to hardware, but also to software and knowledge. The software area could be eased by the provision of more public domain visualisation and/or rendering packages.

More interaction between tool designers and tool users will help to provide better solutions to the needs of the meteorological community. It is only by such interaction that good systems can be built.

It was suggested that a global user group concerned with meteorological visualisation be started, an idea that was received with interest. Maybe some affiliation to Siggraph or Eurographics could be established.