III. WORKSHOP REPORT

1. INTRODUCTION

The Sixth Workshop on Meteorological Operational Systems was held at ECMWF, 17-21 November 1997. The programme and the list of participants are given in the front part of these proceedings.

The objective of the workshop was to review the state of the art of meteorological operational systems and address future trends in the use of medium-range forecast products, data management and meteorological workstations. The workshop was organised under the following main subjects:

Use and interpretation of medium-range forecast guidance

The session addressed the problems and solutions related to the use of numerical guidance in medium-range weather forecasting. The operational ECMWF Ensemble prediction System was upgraded in December 1996 and now provides the users with the appropriate means of combining deterministic weather element forecasts with estimates of the event probability. Operational procedures for estimating in advance the uncertainty in the numerical forecast guidance and to indicate alternative flow scenarios in the forecast were reviewed.

Operational centres presented their approaches to medium-range weather forecasting and reported on their experiences with a combined use of output from deterministic models and ensemble prediction systems. The concept of probability forecasts and tailored products for certain categories of end users was also addressed and discussed further in a working group.

Operational data management systems

Operational database and archive systems were reviewed showing how use of standard software utilities and languages facilitates the development and portability of such systems. Special attention was given to ease of use and speed of access to data, as well as data transformations performed by retrieval systems on behalf of the users. User interfaces and higher level language interfaces were considered, requirements for standards in the context of distributed data bases were addressed and discussed in a working group.

Meteorological UNIX workstation applications

Further progress had been made in this area since the previous workshop in 1995. Meteorological UNIX workstation applications had become available and others were being developed including the use of JAVA. Current and planned meteorological workstation applications were presented and demonstrated at the exhibition during the workshop.

The power of workstations had continued to increase and the use of 3D visualisation had become practical from a technical point of view. A working group discussed 3D graphics in terms of requirements and applications in different meteorological areas.

The reports from the Working Groups are summarised in this section of the proceedings while the papers from the presentations are given in Section IV.

2. REPORT OF THE WORKING GROUP ON THE USE AND EVALUATION OF MEDIUM-RANGE FORECASTS

Deterministic and probabilistic forecasts

It was agreed that medium range forecast should be delivered to the end-user more and more in the form of probability statements of weather elements, although some users may still require deterministic forecasts which can also be extracted from the EPS. This deterministic information however results from integrals in probability space, e.g. ensemble means, whose weighting may in principle differ from one application to another.

Guidance should also be given in the form of weather scenarios (including alternatives when needed); this "weather" description should only involve those scales that are predictable for the range/situation of the day.

A simple way to introduce some probabilistic information in the forecast is through confidence indices or intervals.

Training of forecasters is an essential issue to allow them to cope with intrinsic synoptic scale unpredictability in the medium range - e.g. understand there is no hope that the "best" of the ensemble members can be identified in advance, or to always associate medium-range forecast errors to model or observation errors. Training courses have already successfully been organised by some Weather Services, and should be generalised.

Education of the general public should mainly be delivered through the media. Weather services should take the initiative in promoting the use and understanding of probability forecasts by this route. It was felt that such an education was much needed in order for the public to understand that some low probabilities (e.g. 30 or 50%) may be quite a strong signal when associated with rare events (e.g. big storm, or severe convection). How much the forecasted PDF[1] departs from climatology should therefore be expressed.

Education of the professional users should allow them to get direct use and benefit from EPS direct output, e.g. under the form of weather event probabilities. Some users can make immediate use of them, while others want advice from meteorologists to use this information in a decision-making process, and some users even prefer this process to be completed by the forecaster. In the latter case, the forecaster has to be well aware of the user needs (cost/losses thresholds).

The EPS can signal an early warning of the possibility of an extreme event. Some users can benefit from this information immediately, provided there is good temporal consistency in the evolution of the forecasted probabilities.

For both the general public and professional users, it is important to show that the stochastic information that is delivered to them in the form of probabilities, confidence indexes or error bars can be evaluated objectively .It was felt by many participants that the dissemination to the forecaster of both T213 and EPS forecasts beyond Day 5 can provide conflicting information, and that it was not very useful to provide forecasters with a deterministic forecast having more resolution than the EPS in the medium range. In practice, EPS products dissemination lags well behind T213 dissemination, which is quite detrimental in terms of the respective weight given by forecasters to the two systems. The working group discussed the possibility that the national meteorological services presented the forecasters with the EPS products as the primary guidance. The consensus was that in any case, higher resolution deterministic forecast in the medium range could only be taken as supplementary information - e.g. a difference between the control and the high resolution reference might point to a model problem associated with insufficient resolution.

Evaluation criteria

The inclusion of EPS mean fields in ECMWF deterministic verification scores should be considered.
Fields from the EPS are used both by forecasters in terms of synoptic guidance, and as input to perfect-prog-type post processing. Therefore the evaluation in terms of field patterns (e.g. EOF indexes or neural network classification) as presented in some lectures this week was felt necessary.

More investigation of how EPS performs according to geographical or weather pattern configuration is suggested (e.g. spatial maps of Brier skill scores or stratification according to weather regime). Case studies may be seen as a tool to get a better interpretation of probabilistic scores (e.g. what is the threshold value of the Brier Skill Score beyond which a probabilistic forecast is useful). However ,it is difficult to evaluate a probability system on a small number of cases.

EPS time consistency should be evaluated. "Desirable behaviour" should be when the PDF smoothly evolves as lead time decreases.

A common set of verification procedures should be defined for the purpose of exchange and comparison of results from different EPS.

[1].Probability Density Function

3. REPORT OF THE WORKING GROUP ON METEOROLOGICAL DATA BASES

Metadata

Metadata means different things to different people. One is the methodology of description of data and standards in classification of such data. The World Meteorological Organization is currently active in this area and aims to produce guide-lines for cataloguing observations and products. A second meaning is local metadata necessary to access data in a database or archive and this type of metadata was really the only one discussed.

The metadata for an database/archive has a number of roles: to describe data and where to find it. The description has to be usable by archival software and by human users, either directly or through a browser program.

For some smaller databases, the role of metadata may be covered by a suitable file-naming convention which identifies file contents. However, for very large databases, the metadata can become large and is a potential point of failure in a database.

The maintenance of metadata can be approached in a number of ways. It can be duplicated on separate machines providing a 'hot' standby which can be switched in rapidly if the primary archive computer fails. Metadata can be written into data files with the archive data. It must be possible to rebuild the metadata from the data itself; data must be self-defining, as it is for fields encoded in GRIB code (local extensions are necessary with GRIB Edition 1, hopefully this will not be the case in future). For such purposes, it has been necessary to add additional information to the headers to ensure that all fields are distinct; for example, operational and research fields for the same events must be separable. Backup dumps of the metadata can be taken periodically to provide checkpoints to limit the amount of rebuilding. The rebuilding process will be very long if large volumes of tapes have to be reread and the frequency of backups has to be carefully considered.

For human users, there is a need to be able to read and browse metadata. Any useful facility should allow the addition of comments or description in, say, ASCII characters which can be located by a suitable search engine hunting for keywords. This raises the prospect of making database descriptions available

online and in real-time on the World Wide Web. Careful consideration needs to be given to wider prospects for accessing the data after it has been located by a browser. Common schemes should be developed to define metadata for global searches, to specify data, documentation and to control subsequent processing. The schemes have to address issues of naming schemes and standards for distributing files (e.g. ftp).

Viewed from in-house, metadata reflects the hierarchical or class structure of the stored data and may be constrained by the retrieval 'language' used to address data. Retrieval languages need to be flexible enough to allow approximate or 'vague' references to translate into searches for matching data; as an example, a precise time might in fact be allowed to locate data within a time range. The language and metadata need the ability to grow over time in ways which may be impossible to anticipate.

Viewed externally, metadata may need to be accessible via menus defined from data dictionaries specifying attributes such as accuracy and precision. Data should be available across disciplines without the need for detailed knowledge of its format.

Metadata for observations presents a particular challenge. Codes such as BUFR provide excellent compression to the extent that metadata for individual observations may be larger than the observations themselves. Probably, observation data will be archived in blocks with metadata describing the extent

in time and area and the nature of the data in the block. Provision should be made for adding metadata as an afterthought to indicate reprocessing or feedback from analyses or perceived problems and limitations in observations. BUFR is a flexible format and can, in principle, be used for anything. Station histories and characteristics of reporting platforms (such as radar) are candidates for including in metadata but there are acknowledged difficulties in obtaining up-to-date information to create and maintain these.

Year 2000

There are two parts to the potential Year 2000 problem: the changeover from December 31, 1999 to January 1, 2000 and the leap year day February 29, 2000. The date changes may be mishandled by existing programs or by embedded hardware in processing or observing platforms. Estimates of the scale of the problem by Member States range from 'relatively straightforward' to '250 man-years effort affecting up to 30 percent of programs'. Efforts to handle the problem focus on replacing or rewriting key software and progressively updating hardware during planned maintenance. Computer suppliers will play their part by providing Year 2000 compliant platforms and database programs. Some software tools are available to automate the scanning of existing software in some computer languages which carry out date manipulations.

WMO data codes for GTS, BUFR and GRIB are not seen to be majorly affected by the new century dates but there will be a need to generate datasets covering several months, December to March, to allow testing of operational software. Datasets can be generated from data from early years suitably edited. Thebehaviour of transmission and networking software which inspect and retransmit data will be harder to anticipate and test.

An alternative to insisting that all dates in data have 4 digit years may be to provide front-end processing programs which 'correct' data before input to applications. It may be possible to buy time in this way where large data sets already exist.

Decisions are required as soon as possible on approved methods for handling dates in the next century in BUFR, GRIB and satellite codes.

The World Meteorological Organization (WMO) has a lot of information about the year 2000 on the World Wide Web (http://www.wmo.ch/ under World Weather Watch in Year 2000 Problem). Participants were encouraged to use this information and to submit to WMO their own findings with regard to the year 2000 problem.

Data formats

BUFR can be effectively used for image and satellite data and also for fields. Compression factors from one to two orders of magnitude have been demonstrated by translating codes (such as McIdas, RTOVS) into BUFR with run-length encoding. As far as satellite data is concerned, WMO is in liaison with the Committee on Earth Observation Satellites (CEOS) to find a solution.

Application interfaces often still use ad-hoc data formats rather than WMO standard BUFR and GRIB. Use of non-WMO formats (McIdas, NetCDF, CDF, HDF) is fairly widespread. They are perceived as 'easier to use' than BUFR/GRIB in some application environments because of the availability of helpful tools suited to the formats. Emerging code formats accompanied by ready-made software have a clear advantage. It was felt that not only coding/decoding software for the WMO code forms should be made available, but also visualisation software.

The WMO approach is to use table-driven codes based on numbers which are readily suitable for internationalisation; relational databases can transform data into local formats. However, keyword searches, for example across the World Wide Web, present a problem unless the language is standardised. There was discussion as to whether this may cause pressure to adopt a standard language in the way that English has been adopted in some international forums, such as ICAO.

There were discussions on possible changes to the GRIB code to address acknowledged shortcomings in the Edition 1 format. All the usual problems were raised, but a solution to the needs for ensemble forecasts seemed to be the most pressing. Serious concern was expressed that GRIB Edition 2 should not be too complicated but should have enough flexibility built in to enable easy expansion.

Although data formats were not part of the topics for discussion by the Working Group on Meteorological Workstations, they nevertheless felt there was a need for standardisation of formats, especially for satellite images where TIFF, netCDF or McIDAS as well as GRIB for geo-stationary satellites were in use at different sites. Examples of header information required in a common image format are: navigation (geographical control points etc), time dimension, calibration, processed data, mapped images and compression. It should be possible to read the actual data matrix with minimal overhead.

4. REPORT OF THE WORKING GROUP ON METEOROLOGICAL WORKSTATIONS

Working Group on Meteorological Workstations

Benefits of using 3D in operational meteorology

Changes during the last two years

The biggest change seems to be the reduction in price of tools required for 3D i.e. hardware and software, which makes the use of 3D more feasible now. The availability of 3D software such as Vis5D, AVS and IBM- Data Explorer has enabled researchers to gain experience. Vis5D, which is freely available, has had an API implemented in it. Also 3D systems have been developed in Germany (DWD). Computer users are becoming more mature and, therefore, more open to new technologies.

Usage of 3D in operational meteorology

The use of 3D in research is becoming well established but most sites do not use 3D in operational meteorology at present. There is some use of 3D as a diagnostic tool. However, there seems to be a feeling that, even though there is not a demand for 3D at the moment, the trend is moving in that direction. In particular, 3D is very useful for local scale problems.

Future usage of 3D in operational meteorology

There is general agreement that 3D would be used in the future.

Some suggested uses are:

- frontal analysis
- aviation meteorology
- finding forecast errors
- identifying moisture sources
- TV presentations
- use with ensemble forecasting
- trajectories
- general meteorological training.

Forecasters in general are not trained for using 3D and would need training in its use. The innovations will mostly come from outside sources such as scientists or software developers, but it is desirable that forecasters are involved in the development work as much as possible. New systems which may not fit into the bench forecasters normal routine could very well prove to be valuable forecast production tools. Graphical interaction would probably be a requirement and the use of macros will also be important as operational work is more time critical. Software based on OpenGL can spark off a slow move towards 3D now that technique and tools are available.

Visualisation of meteorological data using Java

What is currently possible with Java

Java is used more in the USA than in Europe. There have been few efforts to write in pure Java and it is seen as "wrapping" for existing systems. VisAD is being implemented in Java and the Swiss Meteorological service is currently in the middle of implementing a Java based system. Also, the meteorological services of Sweden, Germany, France, Sweden and Finland are developing software in Java. There is a prototype in the United States, called FXNET, using Java for meteorological visualisation and UNIDATA is using pure Java for netCDF files.

Performance is a problem at the moment but this should improve. There is also a problem with standardisation and with compilers.

When can we expect to see full featured visualisation systems for meteorological data implemented in Java

The benefit of Java is that, as well as enabling platform Independence and connecting all computers to one another, it allows the exchange of programs and data between sites and this is the direction to be aimed at in the future.

It is possible thatJava or some similar package will ultimately replace X, Motif etc. There seems to be a general agreement that Java, with improvements in performance, compilers and standards, could be the language for future "major" systems. Java2D and Java3d, Java API's for 2D/ 3D, are expected to be released soon.

Platforms: UNIX workstations, X-terminals, PCs...

Which platforms are currently use for visualisation of meteorological data?

Unix platforms (mainly workstations) are being used for visualisation in operational meteorology at present as also are non-Unix platforms running NT and Windows95.

Which platforms will you be using in the future?

Many sites are contemplating a move to PCs and some sites are now buying PCs only. It Is thought that PCs will become as powerful as workstations but will cost less. Currently neither Windows NT or 95 are felt to be stable enough to support a 24 hour operational environment but reliability is getting better. Note that It is possible to use INTEL processors for running Unix, e.g. with Linux and Sun Solaris. Recently network computing has been introduced i.e. central computing with many desktop terminals connected.

There was general agreement that the meteorological industry was still ahead of many other industries in terms of cooperation, data and information exchange, and workstation develpoment. However, a lot of work is duplicated and there is a need for even more cooperation. In particular standardisation of formats that could encourage interoperability of visualisation systems would be beneficial. Interoperability is the ability of different systems to work in cooperation and to exchange raw and processed data.

Examples of data/information that would be desirable to exchange between visualisation systems are:

Data

- Fields, observations
- Images (geo-stationary, polar-orbiting, radar)
- Vector data (e.g. coastlines, topography)

Information

- Significant weather charts
- Data coverage - Scores

Programs

- Common API - application programming interfaces (like OpenGL or Vis5I3)
- Macro programs (languages like SQL for data bases)

Although data formats were not part of the topics for this working group, the satellite image for~ mat was discussed because it is an important area where standardisation is required. Some sites use GRIB for geo-stationary satellites but also many other formats are in use, e.g. TIFF, the netCDF or McIDAS formats. Examples of header information required in a common image format are:

- navigation (geographical control points etc.)
- time dimension
- calibration
- processed data mapped images
- compression

It should be possible to read the actual data matrix with minimal overhead.

Note: Topics relating to graphical 'Interaction for nowcasting were raised during the final discussion but were not further discussed within this working group.