III. WORKSHOP REPORT

1. INTRODUCTION

The Second Workshop on Meteorological Operational Systems was held at ECMWF, 4-8 December 1989. The programme and the list of participants are given in the annex to this report.

The objective of the workshop was to review the progress made in establishing standards for the representation and presentation of meteorological data. Operational systems, which are essential to support numerical models in order to generate, preprocess, postprocess, monitor and display data were examined with a special view towards utilising such standards. The workshop was therefore organised under the following main subjects:

1. The use of binary data representation in meteorologial systems

2. Observational meteorological data - requirements and monitoring

3. Visualisation of meteorological data.

This report summarizes the discussions and recommendations from the working groups and the final plenary session while the papers submitted for these proceedings are given in Part II.

2. REPORT OF THE WORKING GROUP ON DATA REPRESENTATION

2.1 Non-standard data

The first of these related to the problem of data forms now being observed, or expected to be observed in the future, for which there are no extant official (WMO) character based codes (or no transmission lines capable of X.25 binary protocol) to transmit the information to centres who would like to have such data. There was general agreement that the use of tabular forms, such as the proposed BUFR Tabular Format (BTAB), was well worth pursuing, particularly as an alternative to attempting to design and implement unique character codes for each new data type. Better to design and implement one general character code, BTAB, once and be done with it than to continue to create yet more specialized codes.

Strong concerns were expressed about the prospect that BTAB would be used to replace current WMO codes. This can present considerable difficulty because of the relative inefficiency of BTAB, in some cases, with respect to rather compact WMO codes. The group agreed that this was indeed a concern and that such a replacement is not to be recommended. BTAB is good for the new, not so good for the old, even though it would be perfectly capable of representing the old data forms.

There was some disagreement as to whether BTAB decoding programs would be difficult to construct - this matter was left to the practitioners to sort out.

Another prospective use of BTAB was brought up: that of using BTAB to assure a "standardized" display of (BUFR transmitted) data at various stations. Since BTAB can accommodate itself to any users requirements, including using different units for the display of data, this was not viewed as a problem and indeed should be considered as a definite value to the BTAB approach.

2.2 ISO standard GRIB & BUFR?

The prospect of having GRIB and BUFR become ISO standards brought forth some concerns about the amount of work involved in seeking such standardization (is it worth the bother, particularly since they are now WMO standards?), and concern that if ISO standardization was achieved we, in the meteorological community, would have difficulty in making alterations that later became necessary. It was agreed that we should certainly "finish" the codes to our own satisfaction first but then it would be appropriate to take some initial steps to seek ISO blessing. The approach should be to make use of the ISO "fast track" method of standard acceptance; as an interim measure, it was recommended that GRIB and BUFR be submitted for recognition as "registered forms" within FTAM and X400.

2.3 Further developments in data representation

Some consideration was given to the incorporation of various major new data forms into GRIB and BUFR, in particular satellite imagery and wave spectra at grid points. With respect to satellite imagery, currently used forms include the McIdas representation forms, CGM for mapped imagery, and a variety of ad hoc formats; EUMETSAT expressed the desire to avoid creating an additional non-standard form. The radar community have produced additions to BUFR to enable radar imagery to be represented. It was recommended that one universal standard be pursued for the representation of radar and satellite imagery.

There was general agreement that the wave spectra might be able to be incorporated into GRIB. There was concern, however, that the nature of the wave spectral data (large sparse matrices) would present substantial difficulties.

2.4 Augmentations to GRIB

The group considered a collection of proposals for changes to the current GRIB code. These were:

a) Complex/Row by Row Packing of grid point data;

b) Packing using of First Differences;

c) Inclusion of the Century in the PDS;

d) Indicating a Version Number for the Parameter table, and setting aside a range of version numbers for local use (129-255);

e) Re-doing the parameter table to set all the units to SI units, eliminate redundant entries, allow for decimal scaling of the variables prior to encoding, and include the decimal scaling exponent in the GRIB message;

f) Placing the total length of the message right up front.

b) met with considerable opposition on the part of the current GRIB practitioners. They viewed the simplicity of the present method as more important than the 15% or so improvement in packing efficiency possible with the more complicated systems. The other proposals met with general approbation and they were recommended to the WMO/CBS Working Group on Data

Management (and its Sub-Group on Data Representation) to look into the details.

2.5 Augmentations to BUFR

The specific augmentations to BUFR comprised a shorter list:

a) Introduce a new descriptor for the length of data sub-sets;

b) Require that the Section Number appear in the high order bits of the 4th octet of each section (excepting sections 0 and 5).

Both of these serve, among other things, to help keep track of where one is when working through a BUFR record and to move about more efficiently. They were both recommended to the WMO Working Group for the details.

Concern was expressed about the appearance of variables with more than one set of units in some of the tables. It was agreed that this was indeed a problem but one for which no immediate solution was apparent, given the human propensity to want to think in terms of different units in diverse circumstances.

The question as raised about the necessity of (WMO) communications headers on BUFR (and GRIB) messages in that the message content is fully described within the message. It appeared that the communication people were quite adamant about requiring such headers (they would not transmit bulletins anywhere without them) so the matter was dropped.

2.6. Representation of quality control information in BUFR

Concerning the question of how to represent quality control (QC) information in BUFR, it was pointed out that there appeared to be two major classes of QC information arising out of two disparate process.

One type is generated by the originator of the data before and during the passage of the data through various (operational) observation, monitoring, and editing stages. The results of these steps is usually either some statement that a particular observation element is good or suspect in some way and/or the replacement of a bad, garbled, whatever, observation with a proper value. There may be more than one such monitoring/editing step as the data pass to their final destinations. The purpose of these steps is to generate the best possible data set for later use by others. It is also important to track the various changes to check back on the quality of the observing equipment and the skill of the editors and monitors. Such processes are often carried out during the production of level IB data in non-real time.

The other type of QC arises when the data are used, generally in an analysis and forecasting context. There the information generated is again often a statement about "quality", but there is additionally such information as analysis rejections , departures from first guess fields, statistics, and other more diagnostic material. This information is very dependent on the application that generated it and is often used in the study of the application's performance. It is not intended to improve the data quality (except in the long run); indeed the data, as received, are usually left untouched for comparison with later studies.

These two classes of QC generation require two different methods of representation in a BUFR record. In the first the interest is in having the best possible data be immediately available in the BUFR message as received along with the history of changes, and in being assured that the "best possible" data is not overlooked or lost as messages move about through the telecommunications system; in the second the interest is in retaining the received data as is while collecting an associated set, or sets, of QC information for later study.

Two QC representation systems have been developed for BUFR that respond to these two sets of requirements. The "QC for data in transit" system is that developed by the oceanographic community originally for the QUIPS program but applicable to all kinds of data. The "QC for data at rest" system is, of course, that developed at the ECMWF for its ongoing meteorological studies, but equally applicable to other kinds of data.

On a first side-by-side inspection of the technical details of the two QC representation systems, it appears that they are orthogonal, in the sense that either (or both at once) can be applied to a set of observations without mutual interference. Both can also represent most types of QC information (in this they are redundant) but the methods of representation are sufficiently different that they cannot meet the usage requirements of the two QC generation processes.

The group gave consideration to the proposal for a dual QC representation system in BUFR and recommended that the WMO Working Group work out the technical details so that both can be given adequate study to decide whether they both should become part of the BUFR specifications.

The group then reviewed the record of its deliberations, found them to be an adequate representation of their thoughts (albeit in a character encoded format) and adjourned at 1815 hours.

3. WORKING GROUP ON DATA MONITORING

In the context of the exchange of monitoring information between NWP centres, some currently outstanding questions related to the identification of poor quality observing platforms were discussed. As recommended by CBS-IX, the three appointed lead centres have started to collect and compile monitoring results from other NWP centres in addition to their own results. Two consolidated lists were produced for the period January to June 1989 (for ship pressure observations and for radiosonde and pilot wind and geopotential reports). At the same time, the monthly exchange of lists of "suspect" stations is going on; it is expected that the number of centres participating in the exchange will continue to increase.

For each data type, both the consolidated lists and the monthly lists were considered; the main conclusions are summarized below.

3.1 Upper-air and marine observations

3.1.1 The reports attached to the consolidated lists sent to WMO should be short. They may have a technical attachment, and it should also be made clear that detailed information can be provided by the lead centre on request.

3.1.2 In the monthly lists, gross errors should be handled by all the centres in the same way; their number should be indicated and they should not be taken into account in the percentage of rejected data (in neither the numerator nor denominator).

3.1.3 The RMS-based criteria used for the monthly lists of suspect upper-air stations are not efficient for all types of problems; for example, they do not pick up those stations with a large bias but small standard deviation. To improve this it is recommended:

- for height, to add tests based on the standard deviation and mean departures from first-guess, and to make all tests dependent on the pressure level;

- for wind, in addition to the current test on the vector RMS departure, to explore the introduction of a test based on the speed and direction departures.

ECMWF as a lead centre should make a proposal in that direction during the first half of 1990 to the other centres participating in the exchange.

3.1.4 Concerning the consolidated list of stations reporting suspect height values, it is recommended to add a list of stations with consistently large bias but small standard deviation, i.e. the stations whose data can easily be corrected and then used normally in data assimilation.

3.1.5 In the list of suspect drifting buoys, the mean position of the buoy during the month should be indicated.

3.1.6 It is also recommended that the WMO Volume A list of stations be brought up to date as many entries are incorrect.

3.2 Aircraft and satellite observations

3.2.1 The way of monitoring these data is very different and not as well defined as in the case of marine and upper-air data. NMC Washington (the relevant lead centre) has not yet provided WMO with results. Furthermore, no standard format for exchanging information has been defined yet between NWP centres. As a first step, the table below gives a list of products that should be sent every month to NMC. When applicable, NMC will pass relevant information on to the data producers.

3.2.2 Concerning the quality of satellite sounding and cloud-track wind data, it would be useful for every centre to be informed of the pre-determined data exclusion practices in use elsewhere. This information should be sent to NMC for further distribution.

3.2.3 When monitoring aircraft data, it is important to be able to distinguish true AIREP reports from PIREP encoded in AIREP format. The practice of using XX as the identifier of these pseudo-AIREP should be generalized. It will also be important to have the capability of monitoring the performance of automatically transmitted reports (e.g. ASDARs) as opposed to the normal AIREPs.

3.3 Exchange of CBS standard verification scores

3.3.1 As agreed by the GDPS meeting in April 1989, an update of the list of radiosonde stations to be used for the computation of the standard scores against observations has been proposed by ECMWF. It is recommended that this update be implemented on 1 January 1990.

3.3.2 The need for exchanging standard scores by electronic means in addition to the current exchange of printouts was recognized at the same meeting. It appears that electronic mail cannot easily be handled by all the participating centres. As suggested by the UK Meteorological Office, the use of the GTS should be exploded further.

3.3.3 The standard format of the tables to be exchanged every month (CBS Ext85) does not include the mention of the forecast centre, and some centres indicate it only in the covering letters. It should be indicated in the heading of the tables or at least on each page.

NMC - Lead Centre for Aircraft and Satellite Observations

Monitoring information requested from NWP centres

(Averaged over all data times)

	DIGITAL	GRAPHICAL
AIREP	Wind direction and speed RMS difference from FG, separated by carriers and geographical areas (to be specified). An indication of the number of calm reports to be included.	
SATOB	Mean difference from FG for direction (minimum speed 3 ms^{-1}) and speed, separated by layers: 1000-700 hPa 700-400 hPa 400-100 hPa **and** by areas: north of 20°N south of 20°S **and** 10 ms^{-1} speed classes, **and** producer.	Global chart of mean vector difference from FG, in 10° x 10° boxes, separated by layers. (At least 10 obs per box).
SATEM	Thickness RMS and mean difference from FG for the layers: 1000-850 hPa 300-100 hPa 50- 30 hPa in 10° x 10° boxes, for each satellite. Observation count.	Thickness RMS and mean difference from FG for the layers: 1000-850 hPa 300-100 hPa 50- 30 hPa in 10° x 10° boxes, for each satellite.

4. WORKING GROUP ON IMAGING

4.1 Introduction

There is now a great deal of interest in satellite imagery display, especially in Europe and the USA. The number of presentations displaying satellite images at this workshop shows this very clearly. The time is now ripe for discussions on the future of satellite imagery display, particularly in relation to standards of formats, configurations etc.

4.2 Source of data

Satellite data is now available from many sources, e.g. GOES, METEOSAT, TIROS, GMS etc. INSAT data is not readily available at present. No one site has access to all data. However, SSEC at the University of Wisconsin has access in real-time to GOES, METEOSAT and TIROS and, within the next month, will have real-time access to GMS data. Their aim is to make the list as complete as possible. It was stressed that real-time access to data, in a unified format, was very important. Apparently, the intention of the satellite operators is to make real-time exchange of satellite data available in the near future. Radar information was also considered as important, especially by some of ECMWF's Member States.

4.3 Data formats for exchange

No true international standard for the format of satellite imagery exists and there is a necessity now for establishing a true standard. The format for international exchange of satellite imagery should be based on data after processing as it is unreasonable to expect satellite designers to change their formats. There are plans at EUMETSAT to change from analogue to digital information for preprocessed data. This will be ready for the next generation of satellites at EUMETSAT. The current WMO standards, BUFR and GRIB, could be used with extensions, e.g. the addition of run-length-encoding to GRIB. GRIB code can hold details of projection etc. and BUFR code for radar already exists. CGM allows imagery with run-length-encoding and a just announced ADDENDUM 1 enables transformable imagery using CELL ARRAY and efficient display using PIXEL ARRAY. However, location of the picture relative to the earth is not included. It was suggested that there was no difference between satellite imagery and model output and that an amendment to GRIB code would make it easy for WMO to adopt the system. ANSI have agreed to investigate a relatively low-level programming interface for image processing. The committee is ANSI X3H3.8 Imaging Task Force. The standard will be called 'Programmer Interface Kernel (PIK)'. They aim to have a draft by 1990. They will acknowledge the existence of GKS, PHIGS etc. and will encompass edge detection, contrast enhancing, convolution etc.

4.4 Functions of the system

4.4.1 Navigation

Resolution of the satellite data is important as the navigation is acceptable for low resolution but not for high. If the correction for an orbitting satellite is missed, the picture cannot be used. Provision should be made for navigation information to be put in the data file or pattern recognition (e.g. coastlines) should be used.

4.4.2 Remapping to standard projections

It is easy to remap contouring to satellite projections but not many people wanted to look at such projections. There was some disagreement as to the necessity for remapping south of 45°N (in the Northern Hemisphere). Some maintained it was necessary as there is a need for all fields to be on the same projection. Satellite projections should be remapped to a well known projection, e.g. polar-stereographic. Remapping parameters should be documented.

4.4.3 Graphics functions

4.4.3.1 User interface

There are many forms of user interfaces in use at the moment for similar systems. Using a menu, which could be a pull-down menu, and a mouse is regarded as one of the most desirable types of interface. The interactive use of buttons etc. to control colour should be avoided. XWINDOWS should be recognised as de facto standard and could be suitable to be used as a basis for the user interface.

4.4.3.2 Area selection/zooming

Zooming may depend on whether there are other graphical fields overlayed on the satellite images, e.g. observations. True stereo is not going to be used for some time yet as all our tools are 2-dimensional. Zooming depends on hardware - a low resolution screen is not useful. Non-standard software zooming techniques may be used on workstations, but local hardware should be used for zooming on PCs. Averaging and sampling are two techniques that could be used to reduce resolution. Averaging is more compliant but there are problems as too many 'grey areas' occur at cloud edges.

4.4.3.3 Animation

Animation is a vital requirement. The important factors are speed and real-time access. The speed is hardware dependent. The minimum speed should be one frame per second as a lower speed would not be acceptable by users. For some applications, e.g. several levels of cloud, a speed of 10/15 frames is desirable. The ability to vary the speed of animation was also seen as desirable. Time interpolation of satellite data, to improve animation, was considered to be not successful. However, it may be possible to use wind from model data to interpolate between satellite steps.

4.4.3.4 Classification/colours

No real standards exist for colour classification of satellite data. WMO has defined a colour standard for contour lines of thickness. A colour scheme such as that for the perceived metal temperature could be used; black=cold, red=hot. Spectral colourisation does not convey temperatures. Colour correspondence to temperature will vary and is not standard. Shading could be used instead of colour as some people are colour blind. It is desirable to be able to see the colour table being used during the display. Application programs based on X-WINDOWS could prove to be useful for colourisation. Colours could be chosen interactively, e.g. to locate ice.

4.4.3.5 Overlaying with analysis/forecast fields

This was regarded as being a necessity, as was the inclusion of observational data. The problem of matching satellite data with model data was discussed and 'closest in time' was considered the best solution as the interpolation of satellite data is not considered good enough. However, post-processing of model data at the times and resolutions required for matching satellite data will be available in the not too distant future.

4.4.3.6 Extra functions

1. Mixing infra-red and visible satellite data and radar data.

2. Calculating the speed of echoes.

3. Different colours for different types of cloud.

4. Calculate speed of thunderstorms by pixel marking.

4.5 System configuration

4.5.1 Hardware

The minimum requirement is a PC 286/386 with EGA/VGA. Workstations were considered as a better alternative but some participants thought that a PC with high resolution graphics could be better than a workstation.

4.5.2 Resolution

A resolution of 250,000 pixels (4 bits per pixel) was a minimum for satellite data used in meteorological applications - less for radar data. However, the minimum requirement depends on the type of data and also on the application. Square pixels were considered important. A resolution of 4000 x 4000 (or 400 DPI) was considered a maximum as this was the limit for the human eye to perceive. If more windows are required, a higher resolution (1000 x 1000 x 8 bits) is required. It was also suggested that the software of a system should be able to query the hardware and be able to reconfigure the data to fit the existing hardware.

4.5.3 Performance

A PC/AT requires five minutes for acceptable real-time remapping, a 386 requires 2-3 minutes. These speeds are too slow for real-time usage. There are boards available commercially for PCs which can do remapping in one minute and some, which will become commercial soon, which can do it in five seconds. Special remapping boards on a PC was considered to be not a good idea and it was thought that it was better to to straight to a workstation. X-WINDOWS software was not yet ready for PCs under DOS and needs about 6 megabytes of memory on PCs with UNIX. VGA is now the standard graphics board.

4.5.4 Data storage

All available storage will be required as the data sets are very large. For large centres, a storage capacity in the region of 20 GIGAbytes is desirable. There is also a requirement for archiving data after use, e.g. optical disks.

4.5.5 Hardcopy

This was considered very important. The discussion centred on the advantages of a SCREENDUMP or sending a metafile to a plotting device. SCREENDUMP was considered more expensive but immediate whereas the metafile system was cheaper but prone to delays. Metafiles could also be sent around the world. Another consideration was that electrostatic colour devices were getting cheaper. The desirable size for hardcopy is A3/A4 and the paper should be capable of being written on.

4.5.6 Operating system

The majority favoured UNIX as being the standard system for the future but some felt that DOS still has a role to play.

4.5.7 Network access

A network with fast access to a database was considered important. Networking standards should be adhered to. The existing standard TCP/IP is a suitable standard at the moment but future, improved standards should be adopted as they emerge.

4.5.8 General requirements

All non-standard special hardware features used by these systems should be clearly documented. This will aid portability to other environments.