II. WORKSHOP REPORT

1. INTRODUCTION

In co-operation with the World Meteorological Organization, the European Centre for Medium-Range Weather Forecasts organised a joint ECMWF/WMO Workshop on Radiosonde Data Quality and Monitoring, which was held at ECMWF, Shinfield Park, Reading, U.K., 14-16 December 1987. Instrument experts, including representatives from the Commission for Instruments and Methods of Observations (CIMO) and manufacturing companies, as well as members of the Commission for Basic Systems (CBS) and operational users of radiosonde data came together to discuss the data deficiencies, both in the availability and the quality and to make recommendations for improvements of the performance of the observational radiosonde network.

The Workshop was opened by the Deputy Director of ECMWF, Dr. D. Söderman, who welcomed all the participants, expressing his appreciation of the favourable response which had been received to the Workshop, which was also reflected in the large attendance. Dr. Söderman highlighted the progress made over the last years in developing the numerical analysis and forecast systems, supported by ever more powerful computer systems. Further improvements appeared to be seriously impeded by data deficiencies both in quality and availability. He noted that ECMWF had over the recent years implemented a sophisticated monitoring system which, in particular for radiosonde data, but also for data of other observation types, proved to be a powerful tool for identifying data deficiencies. He stressed the importance of a dialogue between the data users and the producers and the need for a more efficient feedback of data monitoring results to the producers which would ultimately lead towards improvements in the observational network.

On behalf of Prof. G.O.P. Obasi, the Secretary-General of WMO, Mr. S. Klemm welcomed the participants of the Workshop on Radiosonde Data Quality and Monitoring organised by ECMWF and co-sponsored by WMO. He stressed that this Workshop was much appreciated by WMO as it brought together, for the first time, experts of CIMO, of CBS, representatives of data processing centres operating global or hemispheric models, representatives of major

radiosonde manufacturers and users of upper-air data of national services. This was done in order to consider all aspects of different actions for improving upper-air data, the major component for producing high quality global analyses of the state atmosphere and of weather forecasts. On the basis of the final results of the WMO Radiosonde Intercomparison (1984/85), the largest ever held, with data from more than 200 soundings with seven different radiosonde types, the Workshop should propose effective procedures for using these results by Members for improving upper-air data.

He was convinced that ECMWF would continue to contribute to this aim with its activities of real-time upper-air data quality monitoring. He wished the Workshop very successful deliberations.

2. ORGANISATION OF THE WORKSHOP

During the first two days of the Workshop lectures were given in three sessions with time reserved for discussions:

Session 1: Quality of radiosonde data inferred from radiosonde intercomparisons and trials
Chairman: S. Huovila

Session 2: Quality of radiosonde data inferred from operational data monitoring at major data processing centres
Chairman: F. Finger

Session 3: Operational approach to achieve the desired performance of the global radiosonde network
Chairman: P. Ryder

Each chairman provided a summary of the presentations and the discussions in his session (see para. 3).

The last day was reserved for plenary discussions, chaired by D. Söderman, and for establishing an action plan resulting in recommendations for improving the performance of the observational radiosonde network. The discussions are summarised in para. 4 and the recommendations are listed in para. 5.

3. THE PRESENTATIONS

The following summaries of the Workshop presentations and related discussions were compiled by the chairmen of each of the sessions.

3.1 Operational approach to achieve the described performance of the radiosonde network

3.1.1 Intercomparison results

Results obtained from WMO radiosonde intercomparisons in 1956 and in 1984-85 indicate that the mean performance of operational radiosondes, in terms of temperature and geopotential errors, is today at the 10 hPa level as good or better than it used to be at the 100 hPa level thirty years ago. This significant improvement is mainly due to evolution of electronics and sensor technology, as well as automation of radiosonde operations.

Monitoring methods developed by some meteorological centres have turned out to be reliable and economic alternatives to in situ comparisons of radiosondes. Serious systematic errors in the performance of individual radiosonde stations can thus be detected by monitoring whereas radiosonde intercomparison is still the best method to study the compatibility of different radiosonde types in all details.

3.1.2 Test results using temperature corrections

Development of corrections for the radiative error that were applied to the US radiosonde's thermistor have shown that the magnitude of differences between daytime and nighttime geopotentials were significantly reduced. More observations are planned in order to increase the sample size and enhance confidence in the corrections. Furthermore, the results have shown that long-wave emissivity of the white-coated rod thermistor is more dominant than previously considered.

3.1.3 Representativeness errors

Representativeness errors for temperature and wind observations used in synoptic analysis are larger than the measurement reproducibility (for good quality radiosonde systems).

3.1.4 Digital radiosonde system with open architecture

(i) Improved Sondes

Radiosonde intercomparisons reveal that there is room for improvement in radiosonde accuracy. The burden is on the manufacturer to make these improvements at a time when there is a downward pressure on margins and volume. There is a need for cooperation with the user community to work towards both increased volume and additional funding appropriations.

(ii) Fragility of the Radiosonde Source of Supply

Static or shrinking markets and narrow margins make radiosonde manufacture unattractive for new entrants. It is unlikely that there will be any additions to the small number of existing manufacturers because of the large investment that has to be made with a low probability of an adequate return. Current manufacturers must be considered as a global asset until alternative means for atmospheric sounding are operational and proven.

(iii) Achievable Economies

With the economies described for station operation, the purchase of locally manufactured equipment, service by electronic communication, and licensed manufacture of sondes, it is suggested that there can be a revitalization of the global sounding program. It is further suggested that this can be done whole preserving the integrity and profitability of the suppliers. This would appear to be timely on the basis of the premises laid out in the introduction to this paper.

3.2 Quality of radiosonde data inferred from generation data monitoring at major data processing centres

It is clear that the operational upper-air data base, especially at the higher level, requires careful examination before use. Meteorological analysis centres have developed monitoring programs ranging from completely cataloguing the receipt of reports from the global GOS upper-air network to the full application of data quality control procedures in order to provide the most useful data base, especially for forecast model operations. There is a considerable effort being expended by the centers at the present time to build systems for such monitoring. At the same time there is another effort to fully describe the problems of the operational radiosondes through the International Radiosonde Intercomparisons. Some of the following represents the points of interest throughout by speakers and the general participants:

- the upper-air operational data base must be carefully checked for errors and biases before being used
- the upper air base must be monitored for missing reports
- the data monitoring systems should be able to evaluate the cause of the error if possible (i.e. random or systematic)
- monitoring systems are more valuable for data rich areas
- different data adjustment systems may treat errors differently, which complicates development of required accuracy statements
- radiation errors of radiosondes have generally been decreased over the years, but still is a primary problem
- some centres apply adjustments to upper air reports in order to attain data base compatibility
- adjustments are not official data changes, but only allow more viable analyses

- adjustments can be different for different centres

- official corrections are being determined from intercomparison and other instrument studies

- corrections should be applied at the stations by the operator

- adjustments applied at analysis centres require more information than now given by the operational GTS reports (e.g. instrument type used at station)

- the upper-air code should be amended to include information on sondes in use

- adjustment systems should be used by analyses centres until the development of official corrections

- a mechanism for feeding back monitoring information to the responsible groups should be devised

- International Radiosonde Intercomparisons are important experiments for evaluating sonde errors

- a tidal climatology should be devised in order to more thoroughly determine radiosonde errors

- we should know more on the accuracy of reported winds

- stratospheric data becoming more important but are relatively sparse above 50 hPa

- exchange of monitoring statistics between centres would be very helpful

- the availability of data varies from region to region. Is this a GTS problem?

- wind data should be evaluated and used as independent radiosonde data evaluation tool.

3.3 Operational approach to achieve the desired performance of the global radiosonde network

The proposal to test the Basic Upper-Air Network (BUAN) concept through an operational trial was welcomed in principle, but some concern was expressed that lessons about the performance of radiosonde types and individual, candidate station, which have emerged from recent sonde intercomparisons and ongoing data monitoring respectively, may not be being applied in the planning and evaluation phases of the trial. NMC/NESDIS were urged to note and act upon available information on:

(i) day-night biases in radiosonde temperature measurements discernable from the WMO intercomparison and sustained by data monitoring;

(ii) the current availability and reliability of data on the GTS from candidate stations.

The current CBS recommendations concerning data monitoring and the exchange of information between data processing centres and members operating radiosonde stations was noted. Whilst these undoubtedly provide the necessary basic framework, it was considered that closer liaison between data users and providers may be beneficial at the detailed design and implementation phases. The designation of a single lead monitoring centre for the global radiosonde system and the recognition of real-time, short-period (weeks) and long-term (months to years) time-scales for monitoring and remedial action were accepted as helpful, important ideas.

Mr. Kellomäki expressed the view that simplification of some preparation procedures and automation of data reduction were essential to achieve consistent upper-air soundings. He believed that reliance on operator skill might be appropriate in some parts of the world, but not all.

John Nash reported the results of the recent WMO intercomparison of radiosondes and demonstrated that they exhibited a high degree of consistency internally and with time series data. However, he pointed out that it was necessary to take account of changes in procedures for applying radiosonde radiation corrections to understand them fully. He also advanced the thesis that bias errors in forecast fields of geopotential at 100 hPa or so were comparable with the observational errors being achieved by the best sonde systems. For this reason he believed that any correction procedures should be based upon:

(i) a physical understanding of the need for such correction;

(ii) a statistically significant set of intercomparison of the kind sponsored by CIMO.

He enunciated a set of recommendation based on these ideas.

Horst Böttger described the essential features of real-time monitoring, preparation of monthly statistics and studies of long-term trends, as carried out at the Centre. He showed how these techniques were able to identify gross performance errors and described the specific actions which were being taken and planned by the Centre. These included the production and distribution of:

(i) international reports

(ii) monthly summaries

(iii) lists of suspect stations

(iv) long-term, country packages.

Finally, Mike Nicholls described procedures for optimising the availability and quality of data from automated observing systems in operational service and planned. The essential characteristics include an assessment centre receiving a range of relevant performance information and able to initiate appropriate remedial actions.

4. ACTION PLAN DISCUSSIONS

4.1 The data situation and requirements

Major improvements in the numerical analysis and forecasting systems have led to a significantly higher quality of the numerical products: today's 5-day forecasts are of the same quality as the 3-day forecasts less than ten years ago. The numerical systems are supported by better observations. It was noted that the quality of today's radiosonde observations at 10 hPa equals that at the 100 hPa level thirty years ago. However, the lack of radiosonde data from large areas, the variable quality of the equipment used and the inadequacies in the procedures lead to severe deficiencies in the overall performance of the radiosonde network which are the cause of great concern.

Monitoring studies give evidence of the large spread in the quality of radiosonde observations which can only partly be explained by instrument differences. The equipment, and its calibration as well as ground procedures including the application of corrections and the timely distribution of the data are equally important for a well performing radiosonde network.

4.2 Application of the results of the WMO Radiosonde Intercomparison

Members wish to receive high quality radiosonde data for use in their analysis and forecasting systems. While the existence of systematic differences in the upper-air data as produced by the global radiosonde network is noted, a performance improvement is expected from the application of corrections derived from the WMO Radiosonde Intercomparison. The final results of the WMO Radiosonde Intercomparison (1984/85) were published in the WMO Instruments and Observing Methods Series No. 30. The envisaged RA II/RA IV regional radiosonde intercomparison, which has not yet been carried out should be taken into consideration. The aim must be to improve the performance of all radiosondes to the highest standards. One step in that direction would be taken by applying the results of the recent WMO intercomparison and bringing them into operational use (Rec. 5/1(CBS-IX) shown in Annex I as submitted to WMO/CBS under Agenda Item 5, which is the Status of WWW Implementation and Operation, including Monitoring.)

4.3 Technical information required in code

The more sophisticated use of the radiosonde data requires that additional real-time information on technical aspects of each radiosonde observation is made available. At present, details on the timing of the launch of the sonde, the position and instrument types are not distributed over the GTS in real-time.

Meteorological analysis centres require such information for defining the need and the numerical value of temperature/geopotential height adjustments for application to radiosonde reports in order to compensate for radiation and other systematic errors. Such adjustments are quite necessary in order to ensure the consistency of the radiosonde thermodynamic data. They require real-time information on instrument types and computational methods in use for a particular observation. Also information about the precise release time and ascent rate of the balloon is required. The WMO Commission for Basic Systems should take the appropriate action tht the radiosonde reporting code be amended to provide the needed information for each report.

4.4 Enhancements of data availability

There is an increasing need for stratospheric data up to the 10 hPa level. Such data is required for the numerical models and for the calibration of satellite sounding data. The present operational procedures for obtaining the radiosonde observations fall short of these requirements and all efforts should be made to improve the present situation (Rec. 5/2(CBS-IX) in Annex 1).

Radiosonde observations together with data from other observation types suffer from serious deficiencies in the data exchange on the GTS. There is evidence that valuable observations which were made and had been inserted on to the GTS disappear between automated switching centres. It is strongly recommended to monitor the GTS traffic in detail and identify the problem areas (Rec. 5/3(CBS-IX) in Annex 1).

4.5 Pilot study to improve the performance of the global radiosonde network

Much beneficial impact is expected from an enhanced information flow between the data producers and the users. Data users are lacking the up-to-date information on the instrumentation, operating schedules and performance objectives. Similarly, the data producers should have more feedback on the system performance and notification of any operational incidents or degradation in the observations. A pilot study to evaluate the beneficial impact of such real-time two-way feedback between the data producers and the users is outlined in the Rec. 5/4(CBS-IX) in Annex 1. Such exchanges would be complimentary to those envisaged in paragraphs 20 and 21 of Reference 2, which were authorised by CBS-Ext(85).

4.6 Action

It was agreed that the recommendations from the Workshop be brought to the attention of WMO by submitting a document with the recommendations and required actions to the WMO Secretariat for the IX. Session of the Commission for Basic Systems CBS-IX, Geneva, Jan.-Feb. 1988.

ANNEX 1

Draft recommendations as they were sent to the WMO Secretariat for submission to CBS-IX, Geneva, 25 January to 5 February 1988.

Draft Recommendation

Rec. 5/1 (CBS-IX) - COMPATIBILITY OF RADIOSONDE DATA

THE COMMISSION FOR BASIC SYSTEMS,

NOTING:

(1) The final report of the WMO Radiosonde Intercomparison (1984/85) published as the Instruments and Observing Methods Series No. 30,

(2) The existing systematic differences in upper-air data produced by the global radiosonde network,

CONSIDERING:

The importance of high quality radiosonde performance to Members for improving their analysing methods and quality of forecasts,

RECOMMENDS:

(1) To bring the results of the WMO Radiosonde Intercomparison to the attention of Members,

REQUESTS:

(1) The president of CIMO to take the necessary steps in order to specify proper corrections derived from the Intercomparison for each of the tested radiosondes and to arrange for distributing these corrections to all Members,

URGES:

(1) Members to apply as appropriate these corrections at their national radiosonde network,

(2) Members in co-operation with their national radiosonde manufacturers to report on all changes of radiosonde types and/or performance characteristics to the Secretary-General for inclusion in the WMO Monthly Letter as well as in the WMO Catalogue of Radiosondes and Upper-Air Wind Systems in Use by Members,

INVITES:

The Secretary-General to arrange for a regional radiosonde intercomparison of RA II/RA VI as a supplementary part to the WMO Radiosonde Intercomparison.

Draft Recommendation

Rec. 5/2 (CBS-IX) - STRATOSPHERIC RADIOSONDE REPORTS

THE COMMISSION FOR BASIC SYSTEMS,

NOTING:

The increasing needs for radiosonde reports including stratospheric data to the 10 hPa level for forecast model operations,

CONSIDERING:

(1) that radiosonde observations, in many cases, terminate at lower levels of the stratosphere,

(2) that the radiosonde remains as the prime supplier of information for stratospheric use,

(3) that satellite retrievals, which are a useful supplement to stratospherics radiosonde data, are presently based on statistics generated with the use of raiosonde data;

(4) that most radiosonde systems are capable of producing usable information from levels as high as 10 hPa.

RECOMMENDS:

That members make every effort to provide radiosonde data up to the 10 hPa level from at least 60 per cent of the observations.

Draft Recommendation

Rec. 5/3 (CBS-IX) - GTS MONITORING STUDY

THE COMMISSION FOR BASIC SYSTEMS,

NOTING:

That the data exchange on the GTS suffers from serious deficiencies namely many bulletins not reaching their pre-described destinations;

CONSIDERING:

That efficient monitoring of times of receipt and dispatch of individual bulletins at switching centres would enable the identification of problem areas;

RECOMMENDS:

That a GTS monitoring study as defined in the Annex to Rec. 5/3 be undertaken;

REQUESTS:

The Secretary-General to make the required arrangement for the monitoring study as specified in Annex to Rec. 5/3.

GTS MONITORING STUDY

Automated switching centres on the GTS will provide ECMWF as the monitoring centre for a pre-defined period with details of the bulletins received and dispatched and the corresponding times. Such information should be provided in a computer processable form and in an agreed format (on magnetic tape). Initially, the monitoring should be undertaken within RA VI but be extended to other regions as appropriate.

A report should be prepared by the monitoring centre and the result should be made available to CBS and the participating centres.

Draft Recommendation

Rec. 5/4 (CBS-IX) - A PILOT STUDY TO ESTABLISH THE VALUE OF INFORMATION EXCHANGE BETWEEN ECMWF AND NATIONAL FOCAL POINTS FOR RADIOSONDE SYSTEMS

THE COMMISSION FOR BASIC SYSTEMS,

NOTING:

(1) Paragraph 20 of the Plan for Monitoring the Operation of the WWW, Attachment II-14 of the Manual on the Global Data Processing Systems, concerning the monitoring of the quality of observations;

(2) The willingness and capability of ECMWF to monitor and report on the quality and availability of radiosonde data received at the Centre;

(3) That the full potential of current radiosonde systems for generating high-quality data is not being achieved consistently;

CONSIDERING:

(1) The great importance of high quality radiosonde observations for numerical weather prediction;

(2) That information on apparent deficiencies in the performance of their radiosonde stations would assist system managers to achieve optimum performance;

(3) That up-to-date information on the characteristics of radiosonde systems in use, their planned operating schedules and performance objectives would assist monitoring centres to better assess the quality and availability of data being received.

RECOMMENDS:

That a pilot study, as defined in the attached Annex to Rec. 5/4, be set up to establish the value of information exchanged between ECMWF and national focal points for radiosonde systems, for their respective operations;

INVITES:

Members to participate;

REQUESTS:

Participants to prepare a report of their work and conclusions for the next session of CBS.

PILOT STUDY TO ESTABLISH THE VALUE OF INFORMATION EXCHANGE BETWEEN ECMWF AND NATIONAL FOCAL POINTS FOR RADIOSONDE SYSTEMS

Information will be exchanged, routinely on a monthly basis and occasionally as necessary, between ECMWF and nominated focal points of participating Members. Preferably such focal points will have responsibility for national or regional radiosonde operations.

To each focal point, ECMWF will provide, in graphical and tabular form, summaries of differences between radiosonde data (geopotential and wind) and relevant first-guess fields, for land based and marine stations for which the focal point is responsible.

Each focal point will specify to ECMWF, the planned observing programme, sonde systems to be used and the performance objectives of his radiosonde stations. He will also report any actions taken partially or wholly in response to monitoring information.

III. WORKSHOP PROGRAMME AND LECTURES

SESSION 1: Quality of radiosonde data inferred from radiosonde intercomparisons and trials (Chairman: S. Huovila)