RADIOSONDE DATA QUALITY - A USER'S PERSPECTIVE

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1. INTRODUCTION

The development of automation at Meteorological Analysis Centers has brought an increasing need for relatively error free data. In order to diminish the possibility of errors affecting the operations, users must devise elaborate schemes for checking various aspects of the data base. We will review some of these problems as well as various methods that have been developed to deal with them. Further, we will recommend actions which we feel would contribute to improving the quality and usefulness of radiosonde data.

2. RADIATION ERROR PROBLEMS WITHIN RADIOSONDES

Radiation errors of operational radiosondes have been investigated for many years, with a view of reconciling day to night incompatibilities of temperature and geopotential height. Several methods have been used to gain information on radiosonde compatibility. Intercomparisons of instruments are a very good source of information while indirect studies utilize the data base for computing day-night differences of large numbers of reports (McInturff and Finger, 1968). Other indirect methods include comparing differences between station reports and an analysis (Spackman, 1978) or model forecast (Bottger, et al 1987). All studies conclude that systematic radiation errors are a cause for concern.

Emphasis has been placed on the solar type errors, but studies have suggested that infrared radiation errors of radiosondes may be larger and more complicated than has been assumed. Schmidlin (1987) finds long wave errors of .4C at 100 hPa and about 2C at 10 hPa for conditions at Wallops Island. McMillin et al (1988) suggest long wave radiation errors of up to 2C at 100 hPa and 4C at 10 hPa, depending on conditions (e.g. atmospheric temperature profile, clouds, surface conditions, etc). Clearly more work is necessary to address these problems.

A view of the progress made to diminish the effect of radiation errors is indicated in Figure 1. This shows day-night differences in reported upper-air temperatures as derived from data studies (Finger, 1968 and McInturff et al 1979) and also from the recent WMO International Radiosonde Intercomparison (Nash and Schmidlin, 1987). Significant improvement in quality of measurements occurred during the 1970s, as operators realized that some sondes exhibited large radiation errors. New sondes were designed, with special emphasis on temperature sensor material and placement. Also, data from several sondes were more effectively corrected for radiation effects. Differences between the WMO Intercomparisons and the 1979 study do not indicate further improvement during the 1980s. Although radiation problems have been decreased in some instruments, other problems associated with the pressure cell or with manual data reduction procedures are still evident.

The present data base, especially at higher levels, still lacks the internal consistency to properly drive the newer, more sensitive forecast models. A few Meteorological Centers have developed data adjustments, or taken actions to attain a more consistent data base. Present adjustment systems compensate for the radiation errors and require information that is not included in the regular teletype report. Knowledge of the radiosonde instrument in use at a given station is a prime requisite. Presently such information is only available through the WMO Catalogue of Radiosonde and Upper-Wind Systems in Use by Members, which unfortunately can not be updated and distributed in a time frame to fit the needs of operational Meteorological Centers.

3. RANDOM TYPE ERRORS

In many cases, users can compensate for systematic radiosonde errors by suitable adjustment schemes. Random errors are more difficult to correct, but also cause major problems. We define random errors as those which cannot be predicted, even if caused by a systematic sonde error. Random errors may be detected by data quality assurance systems. However, it may be difficult to determine whether anomalous appearing values are due to errors or to real meteorological changes. An example of damage caused by a single erroneous report can be seen in Figure 2. This error in reported height at a California station resulted in an initial analysis of an intense trough on the west coast of the United States. Model predictions indicated circulation and precipitation patterns based on the erroneous system. Fortunately, the problem was corrected for subsequent analyses and forecasts. Such problems probably occur regularly, but many remain undetected.

Random errors can increase the temporal variability of a reported meteorological parameter. Time series of geopotential height values from three participants of the WMO Wallops Island Intercomparisons are shown in Figure 3. Good compatibility is evident at 500 hPa. At 50 hPa, however, large Indian short-term variability is evident, with a somewhat smaller variability of the VIZ values. In contrast the random variability of the Vaisala reports appears negligible. To determine if the VIZ variability was connected with a systematic radiation error, we applied adjustments with values regularly used by NMC (McInturff et al, 1979). These adjustments diminished the VIZ variability, but to a point still somewhat larger than the Vaisala values. This remaining variability may be related to manual techniques used by the observers to derive VIZ data.

4. NEEDS FOR UPPER-AIR DATA QUALITY-CONTROL PROCEDURES

When radiosonde data problems are considered, it becomes obvious that an effective integrated quality-control system must consider all aspects of an upper-air observation. The logic behind this statement is that proper quality assurance can best (or sometimes only) be made during specific points of the message generation, communication, or use. The flow diagram shown in Figure 4 presents some information on stages of quality control application. The figure emphasizes interdependence of all stages of data flow and needs for feedback of information.

5. QUALITY CONTROL AT CENTERS

The purpose of this section is to highlight techniques for quality control of radiosonde data in use at various Meteorological Centers. We should add that exchange of information among Centers has improved the systems of all in recent years (Bottger et al, 1987, DiMego et al, 1985 and Finger et al, 1985).

5.1 Monitoring Data Receipt

Monitoring of data receipt is basic to Meteorological Center operations, since missing reports diminish the quality of numerical forecasts. The WMO has emphasized the need for systematic monitoring of data receipt as part of the World Weather Watch effort by publishing monitoring guidelines in various manuals and guides. The WMO also sponsors an annual October exchange of information among Meteorological Centers and serves as the focal point for gathering and analyzing the surveys. This identifies the differences in the availability of data at the participating Centers. Thus, positive actions can be set in motion to alleviate or eliminate certain data shortages at many of the Centers.

Data receipt for a typical synoptic time during October 1987 is shown in Figure 5. The steady fall off of available reports with decreasing pressure might be expected from balloon performance. However, there is a rather sharp drop between the 100 and 70 hPa levels, suggesting that some higher level messages were not received.

5.2 Monitoring Data Accuracy

Data errors must be identified and corrected, if possible, before analysis begins. The general process of quality control depends heavily on redundancy (e.g. being able to compare an observation with others nearby) and also on internal consistency. At the NMC (McPherson et al, 1979), and many other Centers at least three separate steps are followed.

5.2.1 Internal Consistency

Incoming reports are scanned for errors (e.g. bulletin and message integrity, station identification, coding, transmission errors, etc) and also for meteorological content. Another major check is for hydrostatic consistency. This is done by comparing the geopotential with values recalculated from the temperature profile. Questionable data may be examined by a meteorologist before analysis, if time permits.

5.2.2 Gross Error Check

Reports are subjected to comparison with the latest available forecast. This "gross error check" is done with caution, since the areas where suspicious differences occur may be the areas most needing adjustment. This step is used to delete reports which are not climatologically possible and to identify suspicious reports for further examination.

5.2.3. Temporal and Horizontal Consistency Checks

These checks compare station values with time, or each report with neighboring values, and is accomplished by deriving an interpolated value from neighboring observations. If the difference is larger than a threshold acceptance value, the report is deleted. Even so, devising an automated system to fit all possible scenarios is very difficult. A flexible program, allowing various checks to be applied according to the situation, can provide valuable information. Figure 6 illustrates an effective check of reported geopotential height values. The large variability and gaps in the reported Indian data when compared to Chinese reports makes analysis over the Indian subcontinent very problematic.

The NMC defines the quality of data from pre-analysis checks. Heights, temperatures, and winds aloft are tested for consistency as well as analysis "fit". Manually altered reports, are flagged as are those held or rejected in the objective analysis. The flags are summarized monthly and results applied in evaluating the total performance of stations. A comprehensive system is now under development in which all actions taken relative to each observation will be recorded. Summaries will provide information on the relative quality of data in the NMC system.

6. CONCLUSIONS

Problems of operational radiosonde inaccuracies have become more important since the introduction of more sophisticated forecast models, which are less tolerant of data errors than previous systems. As indicated throughout this paper, there are two major problems. The problem that has had most visibility is that of systematic errors of the 15 different types of radiosondes presently in use. The expectation for solution of the radiosonde problem is through a combined effort by users, designers/manufacturers and operators. In addition, there is currently an effort to develop a reference sonde, leading the way for sonde manufacturers to deal with radiation errors. An ideal, but seemingly politically impossible, solution is the use worldwide of a single type of instrument. At present, however, the task is to overcome the problems of instrumental incompatibilities, with hope of greater instrumental accuracy.

The second data problem is minimizing random type errors, which also can have profound effects on the meteorological operations. Problems may even take the form of missing reports from known operating stations. Monitoring programs are needed at a variety of locations, including observing sites, communications centers, and Meteorological Centers. They can perform the valuable service of increasing data flow to the users, as well as increasing the accuracy of the reports.

The following recommendations should accelerate the attack on problems of upper-air reported data. Some of these recommendations are already indicated in the various handbooks and guides, but are restated here to indicate their importance.

- Quality-control systems should be carried out by operators. The systems should consider stringent pre-flight instrument checks, proper and prescribed data reduction procedures (automated if possible), testing the report for internal and temporal consistency and assurance of proper report transmission.
- Radiosonde data corrections for station application should be developed for each type of instrument used for operations. Steps should consist of defining sonde data differences through continued intercomparisons, as well as defining sonde accuracy through special laboratory and atmospheric tests.
- Results of the International Radiosonde Intercomparison should be applied to the upper-air data base, initially as data adjustments by the user and when validated, as corrections applied at stations.
- The upper-air reporting code should be amended to include information on the type of instrument used at the station and on the correction procedures applied.
- Meteorological Centers should continue, in cooperation with the WMO,

to monitor the receipt of data. Evaluations should be completed and exchanged as soon as possible. Problem areas should be vigorously pursued and corrected.

- WMO Members should be made aware of problems with their reported data, as should the users of the data.

7. References

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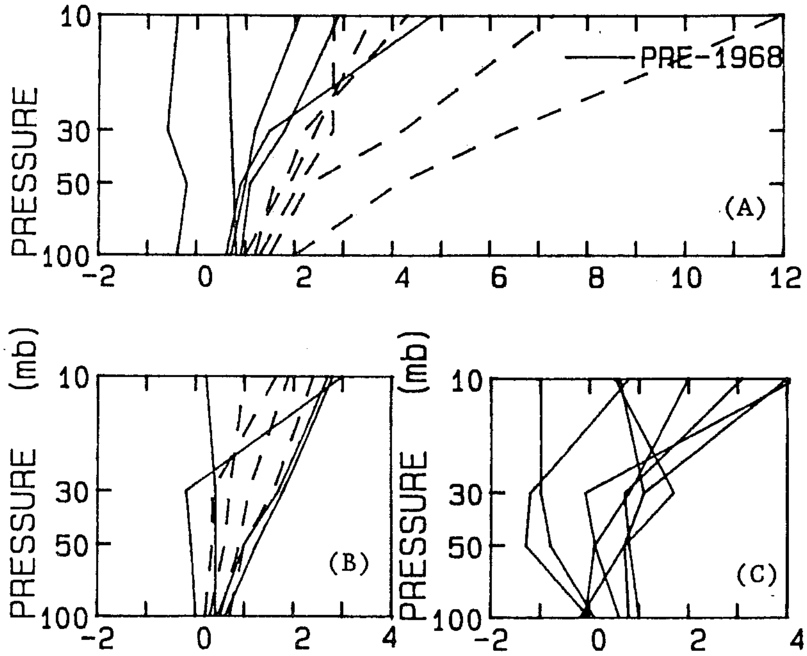

Figure 1. Day-night temperature differences (Degrees C) of various operational radiosondes for periods before 1968 (A), before 1979 (B) and as derived from the International Radiosonde Intercomparisons (C). Heavy lines represent results from countries that have been involved in the intercomparisons.

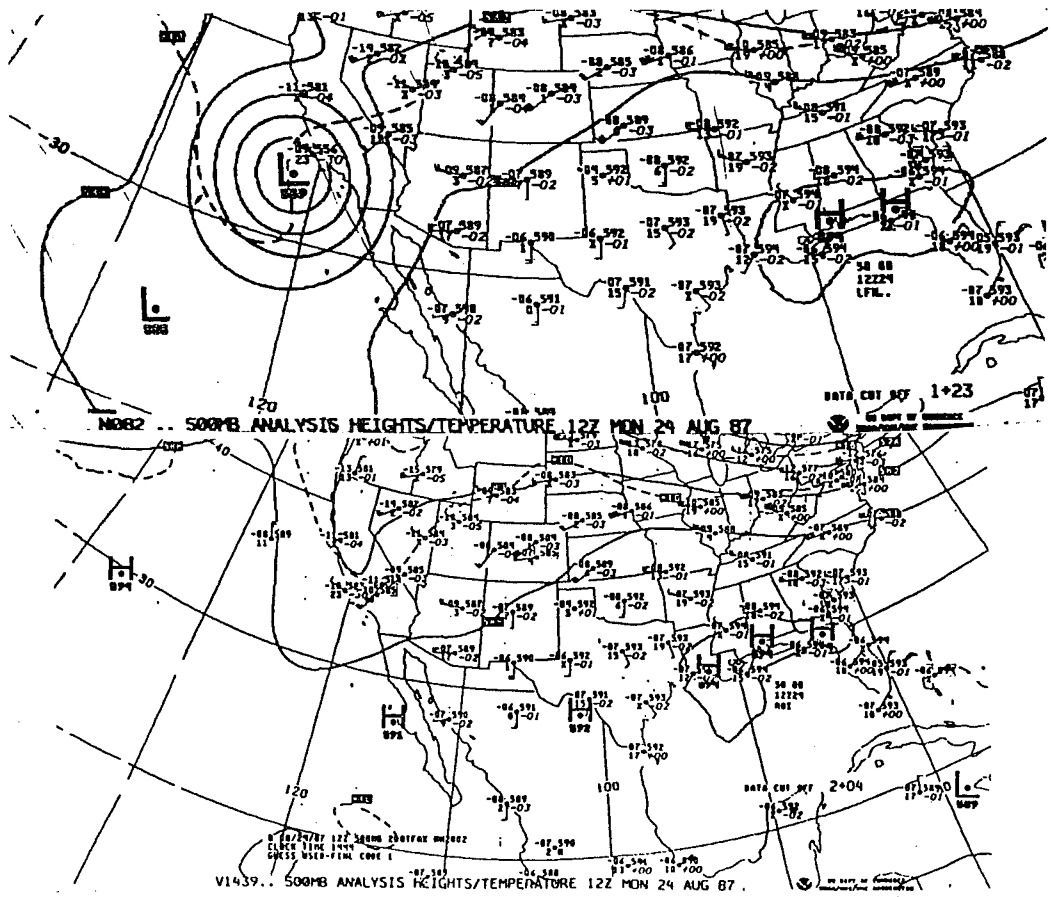

Figure 2. Example of operational analysis with undetected height error (top) and an analysis (bottom) after elimination of erroneous report. Analyses are for 500 hPa, performed 1 hour and 23 minutes (top) and 2 hours and 3 minutes (bottom) after 1200 GMT, 24 August 1987.

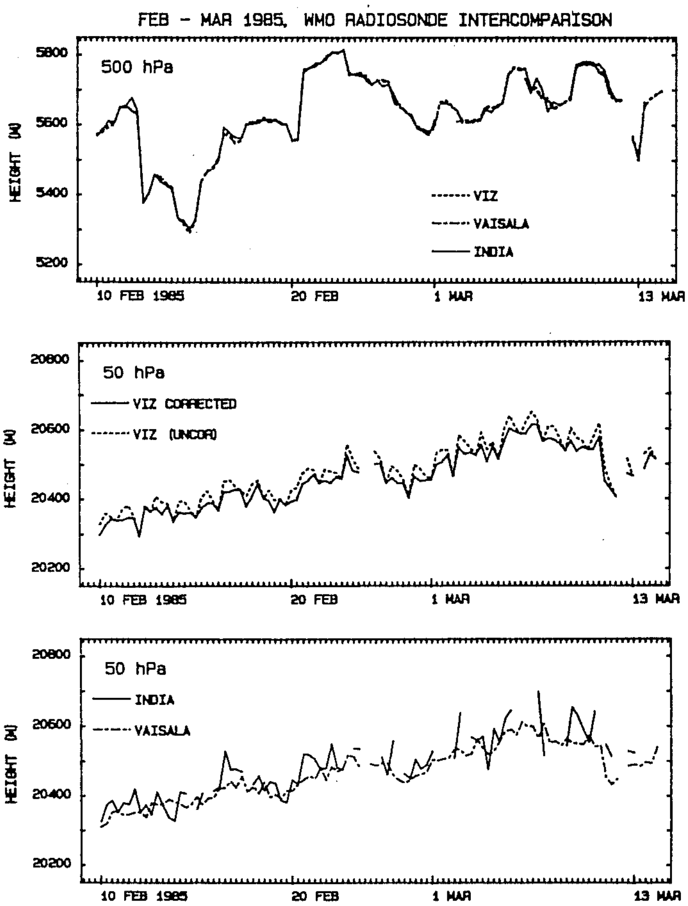

Figure 3. Time series of geopotential height at 500 hPa and 50 hPa for three instrument types (Vaisala, VIZ and Indian) involved in the WMO Radiosonde Intercomparisons during February to March, 1985.

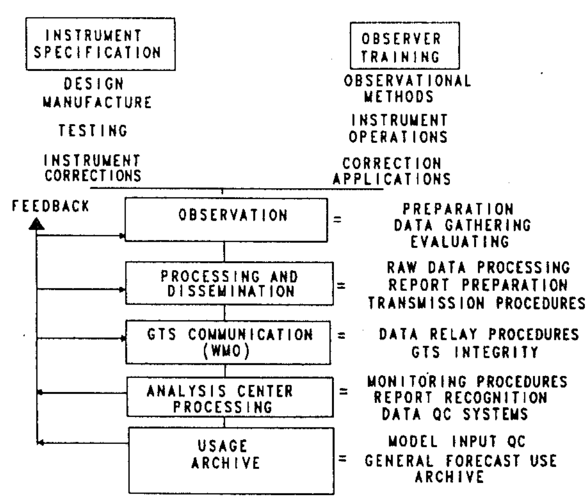

Figure 4. Flow diagram showing areas in need of quality control procedures.

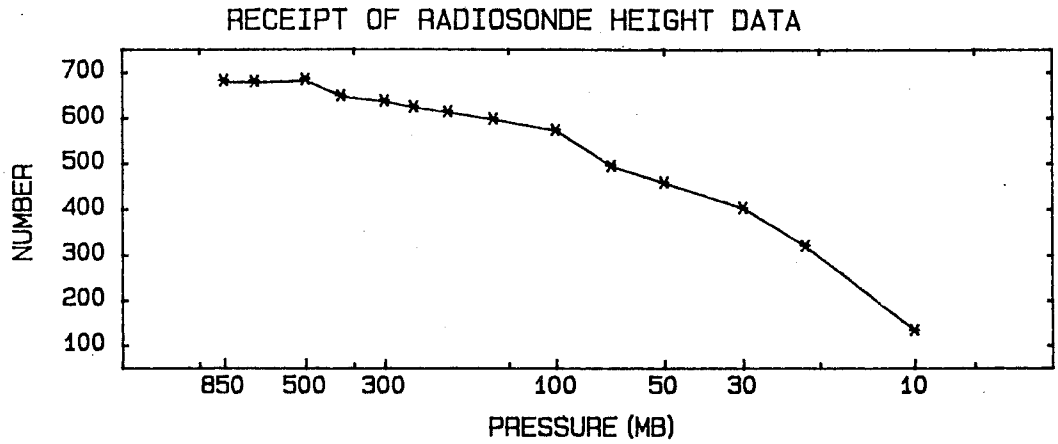

Figure 5. Number of radiosonde height reports received at NMC for a typical synoptic time during October 1987.

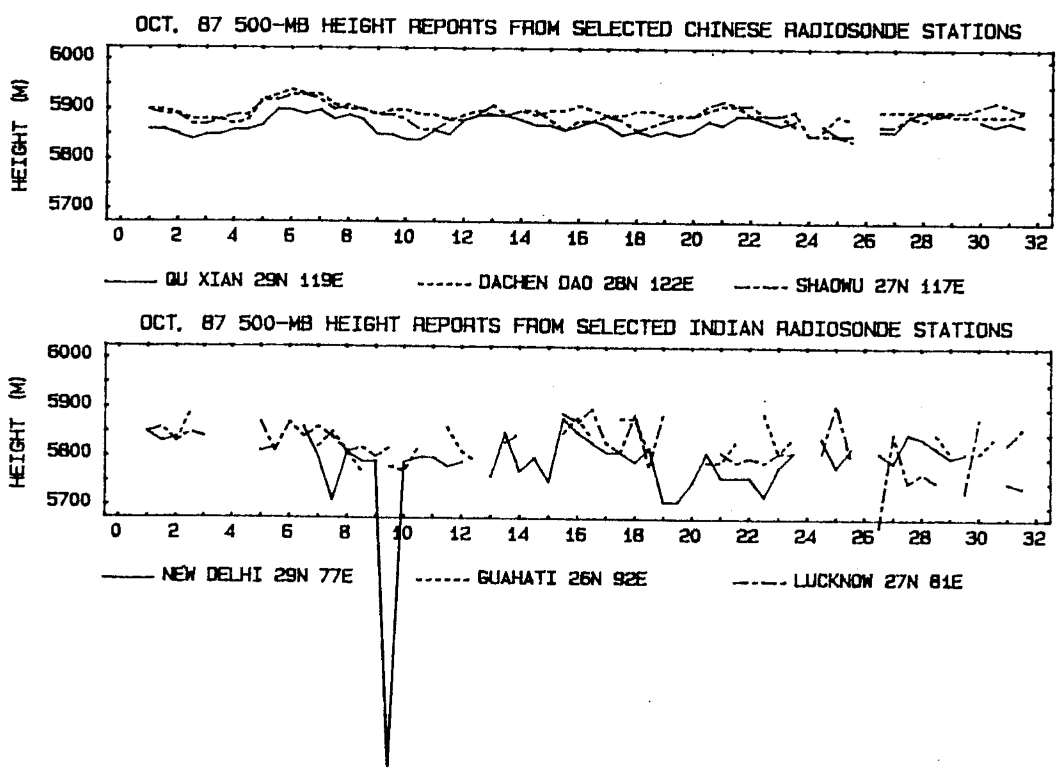

Figure 6. Time series of 500 hPa height from operational radiosonde reports during October 1987 for selected stations in China and India.