# MONITORING OF REMOTE RADIOSONDE OBSERVATIONS IN THE ATLANTIC BY THE UNITED KINGDOM METEOROLOGICAL OFFICE

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Abstract

Monitoring of timeliness, data availability and quality of radiosonde observations from remote locations in the Atlantic ocean by the Meteorological Office Quality Evaluation section are described.

## 1. INTRODUCTION

The United Kingdom Meteorological Office is responsible for the operation of radiosonde sounding systems at three remote locations in the Atlantic Ocean, the Falkland Islands, St Helena and Ocean Weather Ship 'Lima'. In addition, support has been provided to the Finnish Meteorological Institute in the deployment of an ASAP system on the Canmar Ambassador. Recently the UK has also commenced operation of two ASAP systems.

The Quality Evaluation team of the Observational Requirements and Practices Branch is charged with monitoring the performance of these sounding systems, including such aspects as the timeliness of receipt and the availability of messages received at Bracknell and the quality of the upper air measurements.

Evaluation of the quality of temperature and geopotential height observations from these sounding systems is hampered by the lack of radiosonde observations in the vicinity which would reduce errors in numerical analysis and forecast fields in the area. This study investigates the effectiveness of monitoring the measurement quality by two different techniques,

a) the analysis of time-series of observations of 100hPa geopotential heights at the station to estimate the reproducibility, eg see Hawson and Caton, 1961.

b) the comparison of the observations of 100hPa geopotential height with ECMWF 'first guess' and analysis fields.

## 2. METHODS OF ASSESSING THE QUALITY OF RADIOSONDE TEMPERATURES AND GEOPOTENTIALS

### 2.1 Estimating Reproducibility using a time series of 100hPa geopotential height measurements

The 100hPa geopotential height observation is obtained from an integration of the detailed virtual temperature observations with ln(pressure) from the surface to 100hPa. The quality of this measurement provides an assessment of the radiosonde temperature measurements averaged through this layer.

Consider an N day continuous time series of observations of 100hPa geopotential heights at 00 and 12 UTC at a station.

A quantity $\hat{E}$ is defined where

$$\hat{E} = \sqrt{2/3}\ \sigma_d$$

and $\sigma_d$ is the standard deviation of the N values of $d_i$ where $d_i$ is the difference between the 12 UTC observation and the interpolated value based on the 2 observations 12 hours either side (Hawson and Caton, 1961). If the rate of change of geopotential in the atmosphere is linear from midnight on one day to midnight the next then $\hat{E}$ will correspond to the reproducibility of an individual height measurement, where reproducibility is defined as the scatter of the data of individual sondes about their population mean.

Departures from linearity due to atmospheric variability will cause $\hat{E}$ to be larger than the reproducibility. Experience with the analysis of time-series for land stations in the United Kingdom has shown that $\hat{E}$ provides a realistic estimate of reproducibility in summertime when day to day changes in geopotential height are relatively small. In wintertime $\hat{E}$ can be biassed to higher values when larger and more rapid changes in geopotential are taking place.

For stations that report 6-hourly it is possible to calculate $\hat{E}$ for values of $d_i$ based on 12-hourly rather than daily interpolations. In the tropics ascents are only made once a day at some stations. Rates of change of geopotential are generally slower than in mid latitudes and the $d_i$ can be based on interpolations over 2 days.

## 2.2 Estimating Reproducibility using a Numerical Forecast Model

An independent estimate of radiosonde reproducibility can be made using the standard deviation of observation minus analysis or observation minus first guess field, $\sigma_{an}$ and $\sigma_{fg}$ respectively, where the analysis and first guess fields are interpolated to the upper air station position. The first guess field is the T+6 forecast (Böttger, Radford and Söderman, 1987). For upper air systems values of $\sigma_{an}$ and $\sigma_{fg}$ for temperature, geopotential and wind component are made available by ECMWF for monthly periods.

The $\sigma_{fg}$ results from a combination of instrumental, representativeness and forecast errors. The latter are expected to be larger in data sparse areas and will vary according to the frequency of radiosonde measurements in the vicinity of the station. The limitations of using values of $\sigma_{fg}$ to quantify instrumental errors are that it is also necessary to know the representativeness and forecast errors. To some extent the errors in the analysis field will be correlated with the observational error at the station in data sparse areas. Use of $\sigma_{an}$ may therefore lead to an underestimate of the observational error.

The reproducibility of the temperature measurement of a radiosonde could in principle be assessed using derived $\sigma$ values for temperature at various levels. However the representativeness errors for temperature are typically 0.5 to 1.5 deg C for layers up to 100hPa. This compares with the representativeness error in the 100hPa geopotential height measurement of 12m (Kitchen, 1987) which corresponds to approximately 0.2 deg C in equivalent mean layer temperature from the surface to 100hPa. Since radiosonde temperature errors are generally much less than 1 deg C the representativeness errors for temperature mask the instrumental errors on a given level. For this reason it is better to use geopotentials. In this paper $\sigma$ values refer to the geopotential height of the 100hPa level.

## 3. PERFORMANCE OF REMOTE RADIOSONDE SYSTEMS

### 3.1 Ocean Weather Station Lima

The weather ship Cumulus is on station at 57 deg N and 20 deg W. It makes full upper air ascents at 00,06,12 and 18 UTC. The current upper air system was installed during 1985 and it is believed that the radiation corrections correspond to those used by Vaisala in the WMO Radiosonde Intercomparison of 1984 (Hooper, 1986).

A modified CORA ground station is used with the Vaisala RS80 sondes. During the 12 month period November 86 to October 87 observations were produced on station for approximately 75 per cent of the year. Messages are received at Bracknell on the GTS after about one hour for Parts A, C and D and after about 2 hours for Part B. 12 Monthly values for $\sigma_{an}$, $\sigma_{fg}$ and $\hat{E}$ are given in Figure 1. Also shown are $\overline{x}_{an}$ and $\overline{x}_{fg}$ which are the mean values of observation minus analysis and observation minus first guess fields respectively; $\overline{D}$ is the mean of each of the midday geopotentials minus the interpolated values for the midnight points either side.

In January 1987 the figures for $\sigma_{fg}$ and $\sigma_{an}$ at 00 UTC where 51.5m and 60.0m respectively. An examination of the time-series of 100hPa heights from the station for January has revealed that there were no gross errors in the reported midnight heights. The explanation for these large $\sigma$ values is either that there were one or more occasions when the ECMWF model fields contained very large errors or that the $\sigma$ values themselves were incorrectly evaluated. These points have been excluded from Figure 1.

The values for $\hat{E}$ are based on interpolations between observations 24 hours apart, as described in section 2.1. Because the weather ship makes 4 ascents per day an estimate for $\hat{E}$ can also be made based on interpolations between observations 12 hours apart. Two sets of values of $d_i$ are found thus -

$$d_{06,i} = \emptyset_{06,i} - 0.5\ (\emptyset_{00,i} + \emptyset_{12,i})$$

$$d_{18,i} = \emptyset_{18,i} - 0.5\ (\emptyset_{12,i} + \emptyset_{00,i+1})$$

From these $\hat{E}_{06}$ and $\hat{E}_{18}$ are found. The estimate of $\hat{E}$ using 6-hourly data is then found from

$$\hat{E} = \sqrt{\frac{\hat{E}_{06}^2 + \hat{E}_{18}^2}{2}}$$

It is not possible to calculate $\hat{E}$ using the set of values of $d_i$ comprising of consecutive 6-hourly observations because the 06 and 18 UTC data come from 2 distinct populations (see Figure 2).

The above calculation has been performed for data in June and July 1987. It can be seen in Figure 1 that by using half the interpolation period there is only a slight reduction to $\hat{E}$. This is because the geopotential height varies slowly with time in the summer (see Figure 4).

Diurnal tides produce a difference in geopotential height measurements between 18 and 06 local time which is a function of latitude (see Nash, 1984). This diurnal variation is shown in the analyses of Nash based on the observations from Phase I of the WMO International Radiosonde Intercomparison held at Beaufort Park in June and July 1984 (Hooper, 1986). In Figure 2 the diurnal curve in this publication has been reproduced, with the phase shift of $1^1/_3$ hours due to the longitude of OWS Lima, and is taken to represent approximately the solar tide expected at that position. The points shown are derived from the average of the 00, 06, 12 and 18 UTC 100 hPa geopotentials for the months of June and July 1987. It can be seen that the amplitude of the wave at Lima is about what is expected at $\pm$17m and the points at 06,18 and 00 UTC fit well to the curve. The midday observations appear anomalously low relative to the 00 UTC observations when compared with the figures for the previous year (see Figure 1). This implies that the downward trend in $\bar{x}_{fg}(12Z)$ and D in Figure 1 may represent a real change in radiosonde performance at OWS Lima and may not be due to the model first guess fields. Further investigation is to be initiated into the origin of this discrepancy.

### 3.2 Finnish ASAP, VSBV3

The Finnish Meteorological Institute has provided a Vaisala ASAP (Automated Shipboard Aerological Program) system onboard the Canmar Ambassador with the call sign VSBV3. The system comprises of the Vaisala RS80 sonde which applies the 1986 radiation corrections, the Digicora Ground Station and Synergetics DCP.

Data have been received on the GTS since October 1986. The ship makes regular crossings of the Atlantic between Felixstowe and Montreal at about 50 deg N. The upper air sounding program consists of 00 and 12 UTC ascents made when the ship is clear of land. The number of observations actually received on the GTS at Bracknell falls markedly short of the potential number available (see Figure 3). It is extremely rare for an ascent not to be made from the ship; the prime reason for the shortfall in received observations lies with the communications uplink to the satellite. To make sure that there was no problem with the receipt and monitoring of these observations at Bracknell, the Meteorological Office and ECMWF monitored all incoming ASAP bulletins during the 3 week period commencing 16 February 1987. It was found that there was complete agreement between the bulletins received on the GTS at ECMWF and by the Meteorological Office. The mean delay between data being received on the GTS and the nominal data time of midday or midnight was about 1 hour 15 minutes.

In order to do the interpolations necessary to find $\hat{E}$, groups of at least 3 consecutive points are needed. The number of such groups that could be formed from the 44 data points was only 11 because there was a large proportion of single points and isolated pairs. The value for $\hat{E}$ obtained based on midnight to midnight interpolations was about 16m. The average monthly values for $\sigma_{an}$ and $\sigma_{fg}$ calculated over approximately the same periods of time within the 12-month period were 20 and 25m respectively.

The problem with using $\hat{E}$ in the quality evaluation of ASAP observations, is that there are currently too many gaps on the time series of observations which are transmitted on the GTS. However, this does not preclude the operators from using $\hat{E}$ analysis to check the quality of the observations in transit.

### 3.3 St Helena

This land station is in the tropics in the South Atlantic at approximately 15 deg S and 5 deg W. Full upper air ascents are made at 12 UTC daily and PILOT ascents (winds only) at 00 UTC. It uses Vaisala RS80 sondes. The upper air messages are compiled by hand from a chart recorder diagram and could therefore be subject to operator errors. The mean availability of midday ascents is about 85% and the mean delay between receipt of data on the GTS at Bracknell and the nominal data time of midday is approximately 3 hours. A similar figure for availability is obtained for the midnight PILOTS but the delay in their receipt at Bracknell is normally approximately 11 hours, occasionally reducing to about $3^1/_2$ hours. As a result of this monitoring steps are being taken to improve communications between St Helena and the GTS.

Monthly values for $\sigma_{an}$, $\sigma_{fg}$ and $\hat{E}$ are given in Table 1 for a 3 month period. The value for $\hat{E}$ is based on interpolations between observations 2 days apart. The values for $\sigma_{an}$ are significantly lower than those for $\hat{E}$. This may be because $\sigma_{an}$ is correlated with the observational error. Figure 4 shows part of the time series of 100hPa geopotentials for June 87, where the variation of geopotential with time is both slow and of small amplitude.

### 3.4 Mount Pleasant

This station is on the Falkland Isles in the south Atlantic at approximately 50 deg S and 5 deg W. A Microcora ground station is used with the Vaisala RS80 sondes. Upper air ascents at 00, 06, 12 and 18 UTC have been available on the GTS since June 1987. Prior to their release onto the GTS the upper air data were assessed to ensure that they were of acceptable quality. This monitoring was done by hand, since the data were not in machineable form, and involved comparing the reported winds and geopotentials at several levels, with estimates from Southern Hemisphere analysis charts prepared by the Central Forecasting Office. The values for $\hat{E}$ obtained in September and October 1987 was 34m by interpolating between consecutive observations 24 hours apart, and 17m for observations 12 hours apart. A significant reduction in $\hat{E}$ when the shorter interpolation period was used is expected since there was considerable variability in reported geopotential on short time scales (see Figure 4). The values of $\sigma_{fg}$ and $\sigma_{an}$ were 30m and 15m respectively.

## 4. SUMMARY AND CONCLUSIONS

Table 2 summarises the results of the earlier discussion. It can be seen that the estimates of $\hat{E}$ are closer to the values indicated for $\sigma_{an}$ than for $\sigma_{fg}$ for 3 of the 4 systems. For the station in the tropics, St Helena, $\hat{E}$ and $\sigma_{an}$ are significantly different. Further investigation is recommended to determine whether $\hat{E}$ is seriously underestimating the quality of the radiosonde observations at this station or whether $\sigma_{an}$ is correlated with the observational error.

The lowest values obtained for $\hat{E}$ are about 10m and are obtained with fully automated upper air systems during the summer months at mid-latitude stations (Nash and Schmidlin, 1987). The figures for OWS Lima in Table 2 are consistent with this result.

Estimating the reproducibility using $\hat{E}$ is a quick and easy alternative to using model fields. It has the advantage that it is not affected by changes to the model and it is not influenced by the density of the observing network. Thus it should always be used in interpreting the validity of values of $\sigma_{fg}$ and $\sigma_{an}$.

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## References

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| Month | $\hat{E}$(m) | $\sigma_{fg}$(m) | $\sigma_{an}$(m) |
|---|---|---|---|
| May | 19 | 22 | 9 |
| June | 16 | 20 | 9 |
| July | 23 | 30 | 11 |

Table 1 Values of $\hat{E}$ and $\sigma$ for St Helena over a 3 month period

| System | Time Series m | $\hat{E}$ | ECMWF Statistics n | $\sigma_{fg}$ | $\sigma_{an}$ | Period | Comments | Estimated Reproducibility |
|---|---|---|---|---|---|---|---|---|
| ASAP | 11 | 16 m | 77 | 25 m | 20 m | Nov 86– Oct 87 | 1 yr's data | ≦ 16 m |
| OWS Lima | 261 | 13 m | 545 | 18 m | 14 m | Nov 86– Oct 87 | 1 yr's data | see below |
| OWS Lima | 48<br>49 | 11 m<br>$8^1/2$ m | (1) 95 | 15 m | 10 m | June + July 87 | 2 summer months | ≦ 9 m |
| St Helena | 39 | (2) 19 m | 70 | 25 m | 10 m | May – July 87 | 3 month's data | ≦ 19 m |
| Mount Pleasant | 47<br>53 | 34 m<br>17 m | (1) 114 | 30 m | 15 m | Sept + Oct 87 | 2 spring months | ≦ 17 m |

Table 2. Values of $\hat{E}$ and $\sigma$ for 4 remote radiosonde systems

Notes m = number of interpolations
n = number of data points used
1 = interpolation based on observations at 6-hourly intervals
2 = " " " " " 24 " "

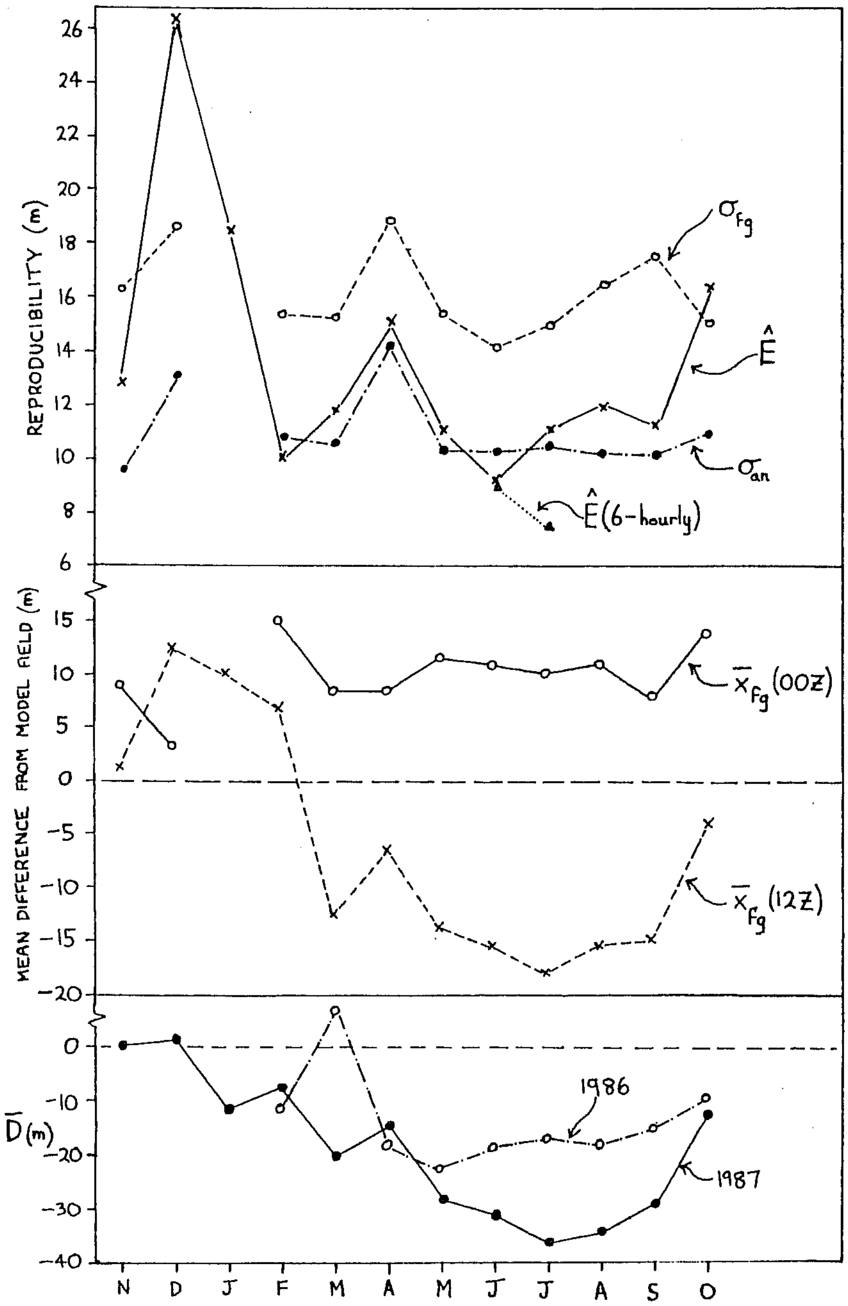


Fig. 1 Monthly values of $\hat{E}$, σ $\bar{x}$ and $\bar{D}$ for OWS LIMA from Nov 1986 to October 1987.

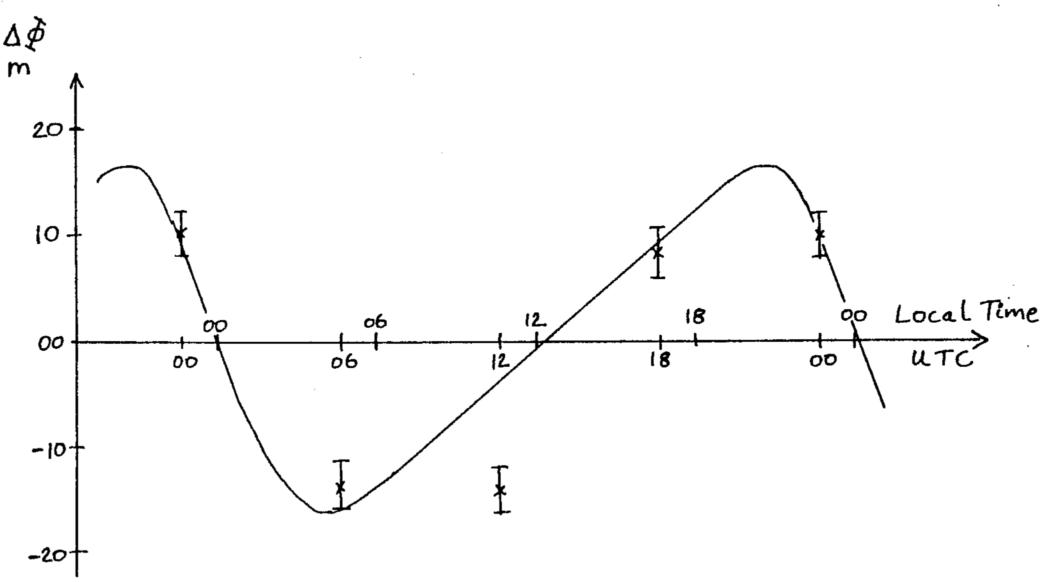


Fig. 2 Diurnal variation of 100hPa geopotential (smooth curve) with departures from the mean 100hPa height superimposed for OWS Lima (June and July 1987).

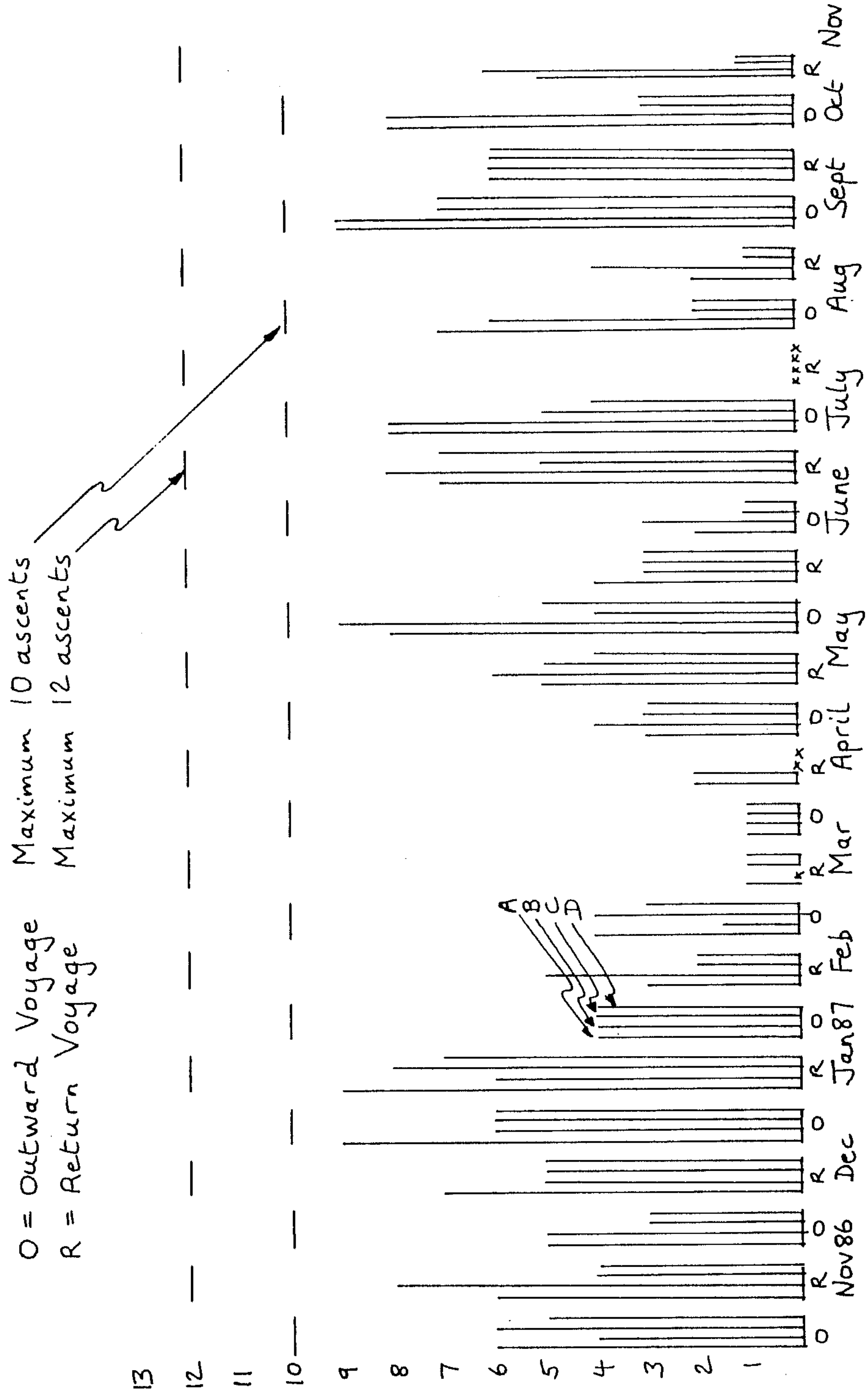


Fig. 3 Number of Parts A, B, C and D received on the GTS from Oct 1986 to Nov 1987 from the ASAP, VSBV3.

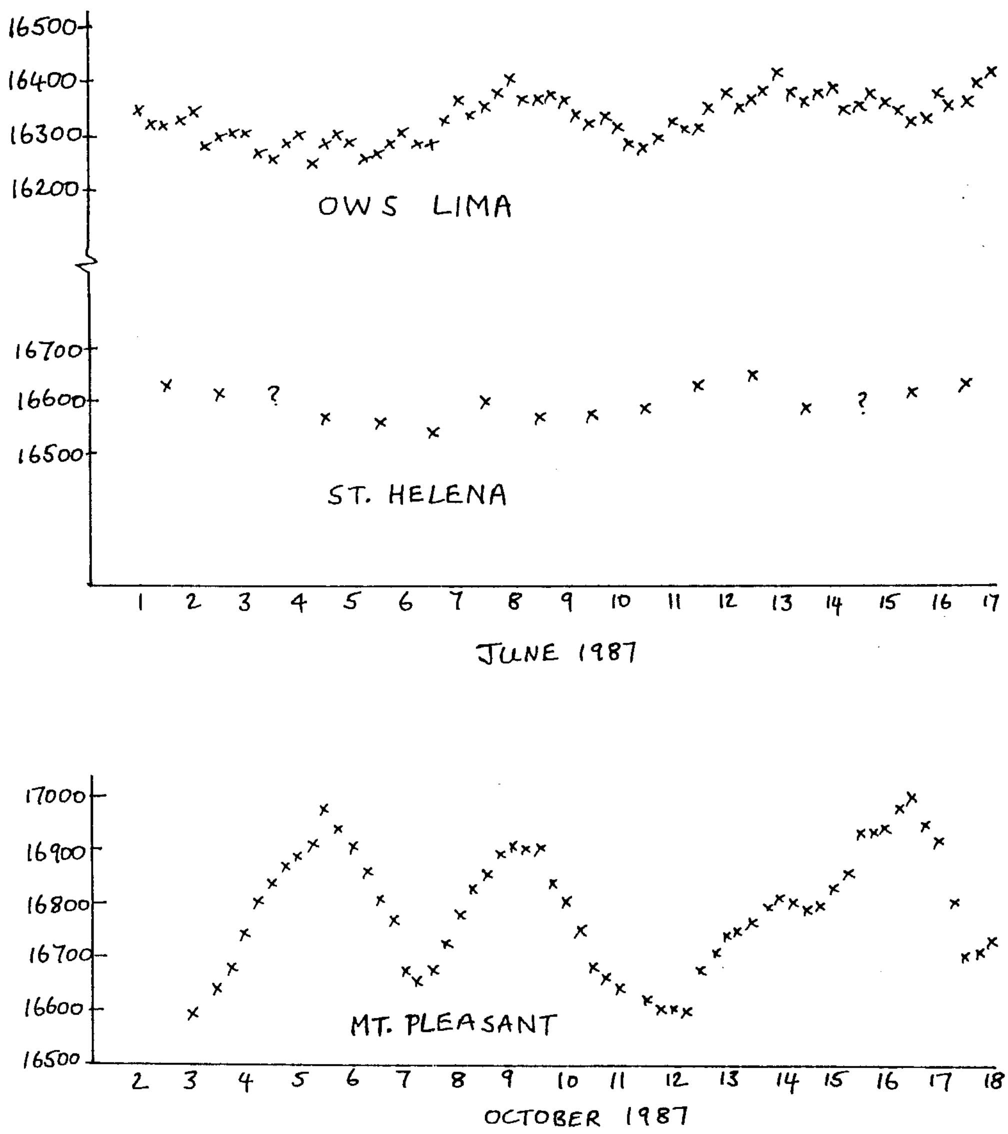


Fig. 4 Examples of 100hPa geopotential time series for 3 fixed upper air stations.

SESSION 3: Operational approach to achieve the desired performance of the global radiosonde network
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