ECMWF RADIOSONDE MONITORING RESULTS

A. M. Radford

European Centre for Medium-Range Weather Forecasts

Shinfield Park, Reading, U.K.

1. INTRODUCTION

ECMWF undertakes regular monitoring of the availability and quality of data from the Global Observing System (GOS) and has on various occasions made the results available to the WMO, data producers and other GDPS centres. WMO/CBS has endorsed such monitoring activities and recommended the exchange of results between monitoring centres (WMO, CBS Ext(85)).

One of the most important conventional surface-based data sets is provided by the global radiosonde network. Its performance has been studied in detail at ECMWF and monthly statistics on availability and quality of individual reporting stations are accessible by the 17 member states via computer links. Recent papers demonstrated the tools ECMWF uses to monitor the radiosonde observations (Böttger, Radford and Söderman, 1987a) and presented the long-term trends of radiosonde availability and quality over the North Atlantic area (Böttger, Radford and Söderman, 1987b).

This paper describes some of the different tools that ECMWF has at its disposal to monitor the performance of the global radiosonde network, and presents some recent results concerning both the availability and quality of the data on the monthly timescale.

The diagnostic facilities for the data monitoring activities at ECMWF are provided by the data assimilation system described by Lorenc (1981), with recent revisions documented by Shaw, Lönnberg and Hollingsworth (1984) and Lönnberg, Pailleux and Hollingsworth (1986). Hollingsworth et.al. (1986) provided the rationale for using modern data assimilation systems as the appropriate tools for monitoring the quality of observations. Further details on the ECMWF monitoring system may be found elsewhere in these proceedings in a paper by Böttger.

2. AVAILABILITY OF DATA

Day to day monitoring is essential in order to react quickly to problems but does not provide a good understanding of the systematic deficiencies in the availability of the data. An accumulation of statistics over a longer period of time, such as a month, is needed. It should be noted that the monthly availability of data reflects the number of observations received via the GTS and successfully decoded at ECMWF.

In this section two aspects of radiosonde data availability are examined, namely reception rate and average maximum height attained.

2.1 Reception Rates

Figure 1 displays the reception rate of 100 hPa geopotential height at 00 UTC during the month of November 1987. The information is presented in symbolic form, each symbol representing a category of reception percentage as defined in the top right corner of the figure. A symbol is plotted for each radiosonde station which should report at 00 UTC, as specified in WMO Publication No. 9 Vol. A.

The 100 hPa height was received more than 90% of the time over much of south-east Asia and Europe, whereas over India, Africa and South America the reception was mostly less than 30% and often zero. Poor reception rates at 100 hPa can be due to either the radiosonde ascents not reaching that level, or few ascents being made, or data not reaching ECMWF because of GTS problems.

When compared with the equivalent results for January 1987 it is possible to discern some improvement. For example the number of stations received more than 90% of the time in November was 355 compared with a figure of 285 in January. The greatest improvement was over South America with small changes elsewhere.

Table 1 summarises by WMO region the geopotential reception rates at three atmospheric levels for November 1987 (00 and 12 UTC combined).

WMO Region	850 hPa	500 hPa	100 hPa
Africa	50	51	46
Asia	73	81	70
South America	36	44	41
North/Central America	83	86	77
South-West Pacific	74	73	65
Europe	90	90	82
Antarctica	64	69	64

Table 1: Geopotential reception rate in per cent (November 1987)

Figure 2 displays the reception rate of 100 hPa wind (including PILOTs) at 00 UTC during the month of November 1987 in the same symbolic form as figure 1.

A total of 602 stations reported no 100 hPa wind, most of these being in India, Africa and South America. Once again though an improvement is noticed when compared with the equivalent results for January 1987. For example the number of stations received more than 90% of the time in November was 312 compared with a figure of 233 in January.

Table 2 summarises by WMO region the wind reception rates at three atmospheric levels for November 1987 (00 and 12 UTC combined).

WMO Region	850 hPa	500 hPa	100 hPa
Africa	29	18	13
Asia	52	60	49
South America	23	29	27
North/Central America	62	74	63
South-West Pacific	55	45	31
Europe	70	74	68
Antarctica	54	69	57

Table 2: Wind data reception rate in per cent (November 1987)

2.2 Average Maximum Height

A different way of investigating the availability of radiosonde data is to look at the maximum height attained at individual stations. Figure 3 displays these values, again in symbolic form, averaged over the month of November 1987 at 12 UTC. All stations received at least once at 12 UTC during the month are included. The values were calculated using parts A and C of the TEMP reports only.

Only 28% of stations averaged more than 25 km (approximately 30 hPa) which is the WMO recommended height for most regions. Over the Indian sub-continent many stations averaged below 14 km (approximately 150 hPa).

3. QUALITY OF DATA

As discussed in Hollingsworth et.al. (1986) there is good evidence that in areas where an adequate observational network ensures a sufficient data coverage, the 6-hour forecast error is quite low and allows the evaluation of data quality by comparison with the first-guess. In data sparse areas, however, a more cautious approach is required before any conclusions on the data quality are drawn from the comparison with the first-guess alone, as the model errors could be dominating. Only if additional independent comparisons, such as results from collocation statistics of radiosonde ascents and atmospheric soundings derived from satellite radiance measurements corroborate the data versus first-guess findings may they be accepted with confidence.

In this section the quality of radiosonde data is examined using two techniques. First some area maps of observed minus first-guess quality statistics are used to infer results concerning the global observation network. Then several stations where problems have been noted are investigated in detail using tools such as long-term trend graphs and vertical profiles of observed minus first-guess differences.

3.1 Area Maps

Figure 4 displays the mean observed minus first-guess difference (henceforth called bias) at 100 hPa for 12 UTC in November 1987. As in the availability diagrams each station is represented by a symbol depicting the category within which the bias lies. The categories (in metres) are defined in the top right corner of the figure. Only stations which were received at least five times for 12 UTC during the month are plotted.

The most striking features of the diagram are the large positive bias values over South-East Asia, and the uniform negative bias evident over most of the United States of America. The problems of day-night differences evident in the US radiosonde measurements are discussed in detail elsewhere in these proceedings, but the effect can clearly be seen using this technique. Figure 5 shows the 100 hPa bias values over North America at 00 UTC and 12 UTC. At 00 UTC there is a clear division between small biases in the west and large negative biases in the east, closely corresponding to the division between daylight and darkness in November. At 12 UTC this area is almost completely in darkness and the bias values are uniformly negative. This effect is studied more closely in the following section when the quality statistics of the radiosonde station 72694 (Salem/McNary) are investigated.

The quality of wind observations may also be studied using this method. Figure 6 shows the root mean square (RMS) vector differences between observed values and the first-guess field of 250 hPa wind for 12 UTC averaged over the month of November 1987. A symbol depicting the RMS value is plotted for every station received at least 5 times during the month and the units are metres per second. 90% of the global network has a RMS difference of less than 10 m/s at 250 hPa. Many of the stations exhibiting differences of more than 10 m/s are situated in South America but it should be remembered that the quality of the first-guess field in this area is likely to be poorer than in the Northern Hemisphere.

3.2 Single Station Investigations

Three stations are now considered in more detail in order to demonstrate additional software tools developed at ECMWF.

Firstly the day/night differences over the United States (referred to in section 3.1) are highlighted by investigating one particular station. Figure 7 shows the evolution of the mean monthly differences (in metres) between observations and first-guess over the 13-month period November 1986 to November 1987 for the station 72694 (Salem/McNary). Separate curves for 500 hPa, 100 hPa and 50 hPa are shown; 00 and 12 UTC data are displayed in different graphs. The number of observations shown above each time graph box are the number of 500 hPa height reports received during each month. The graphs clearly demonstrate the day/night difference, the geopotential bias being generally positive at 00 UTC and negative at 12 UTC throughout the year. It is also clear that there is an annual cycle in the magnitude of the bias, particularly at 00 UTC when the radiation effect on the radiosonde instruments depends on the solar angle.

In order to obtain a clearer picture of how the structure of the bias changes with height, vertical profiles of observed minus first-guess and analysis differences may be used. Figure 8 shows an example for station 72694 using statistics averaged over the month of June 1987. The differences between height and wind observations and the ECMWF first-guess and analysis are presented for each of the standard pressure levels. The figures give standard deviation (left) and bias (right) of u-component wind (top), v-component wind (centre) and geopotential height (bottom) of the differences in the units m/s for wind and m for height. The numbers in the centre give the number of observations used for calculations (TEMP/PILOT for the wind components). Dashed lines denote deviations from the uninitialised analysis, solid lines deviations from the first-guess fields. The character of the geopotential bias profiles is typical for United States radiosonde stations with the 00 UTC bias positive increasing with height while the 12 UTC bias behaves similarly but with a negative sign. The main effect is in the stratosphere. It is interesting to note that the difference between the first-guess profile (solid line) and the analysis profile (dashed line) is significant indicating that the data assimilation is adjusting the geopotential fields to fit the observation.

The second example demonstrates a case where a radiosonde station behaves in a dramatically different way for a short period and then returns to normal. Figure 9 shows the 13-month time series of mean observed minus first-guess geopotential height differences for station 32061 at 00 and 12 UTC between November 1986 and November 1987. The most striking feature is the extremely high value of bias in August 1987, particularly at 100 and 50 hPa, contrasting markedly with the normal performance in July and September. The sharp change can also be seen in figure 10 which shows the vertical profiles of observed minus first-guess and analysis differences for the successive months of July and August 1987. It is clear from these diagrams that it is not a pure bias problem because the profiles of standard deviation are also very different.

The final example demonstrates that the monitoring of wind quality at ECMWF also provides useful results. Figure 11 shows the 13-month time series of mean observed minus first-guess differences of the westerly, or u-component of the wind for the Spanish station 08430 at 12 UTC between November 1986 and November 1987. Curves are plotted for two levels, 700 hPa and 250 hPa. Between December 1986 and May 1987 the negative bias of the westerly component of the wind increased steadily to become much larger than the previous normal level. It is assumed that on the evidence of the monitoring results action was then taken and the quality of the wind observations returned to normal within a month.

4. CONCLUDING REMARKS

The availability of radiosonde data at ECMWF varies widely from region to region. The WMO regions I and III (Africa and South America) are particularly poor in this respect although some improvement is evident since January 1987, especially over South America. The maximum height reached by radiosonde ascents is also very variable; over India very few ascents reach 20 km and many fail to reach 14 km.

When compared with the ECMWF first-guess fields the US radiosonde network displays significantly different mean differences at 00 and 12 UTC, reflecting the known problems associated with correction for solar radiation.

South American observations have larger vector wind differences from the ECMWF first-guess fields than observations from other areas.

The plotting of long-term trends of mean or RMS differences of observed minus first-guess field values provides a powerful tool for detecting radiosonde quality problems, particularly when a change occurs in the performance of the station.

REFERENCES

Böttger, H., Radford, A., and Söderman, D., (1987a): ECMWF monitoring tools and their application to North American radiosonde data, ECMWF Technical Memorandum No. 133 (available from ECMWF)

Böttger, H., Radford, A., and Söderman, D., (1987b): ECMWF radiosonde monitoring results for OWSE-NA evaluation July 1986 to July 1987, ECMWF Technical Memorandum No. 140 (available from ECMWF)

Hollingsworth, A., Shaw, D.B., Lönnberg, P., Illari, L., Arpe, K., and Simmons, A.J., (1986): Monitoring of observation and analysis quality by a data assimilation system. Mon. Wea. Rev. (114) 861-879

Lönnberg, P., Pailleux, J., and Hollingsworth, A., (1986): The new analysis system, ECMWF Technical Memorandum No. 125 (available from ECMWF)

Lorenc, A.C., (1981): A global three-dimensional multivariate statistical interpretation scheme. Mon. Wea. Rev. (109) 701-721

Shaw, D.B., Lönnberg, P., and Hollingsworth, A., (1984): The 1984 revision of the ECMWF analysis system, ECMWF Technical Memorandum No. 92 (available from ECMWF)

WMO (1985): Commission for Basic Systems, abridged final report of the extraordinary session, Hamburg 1985.

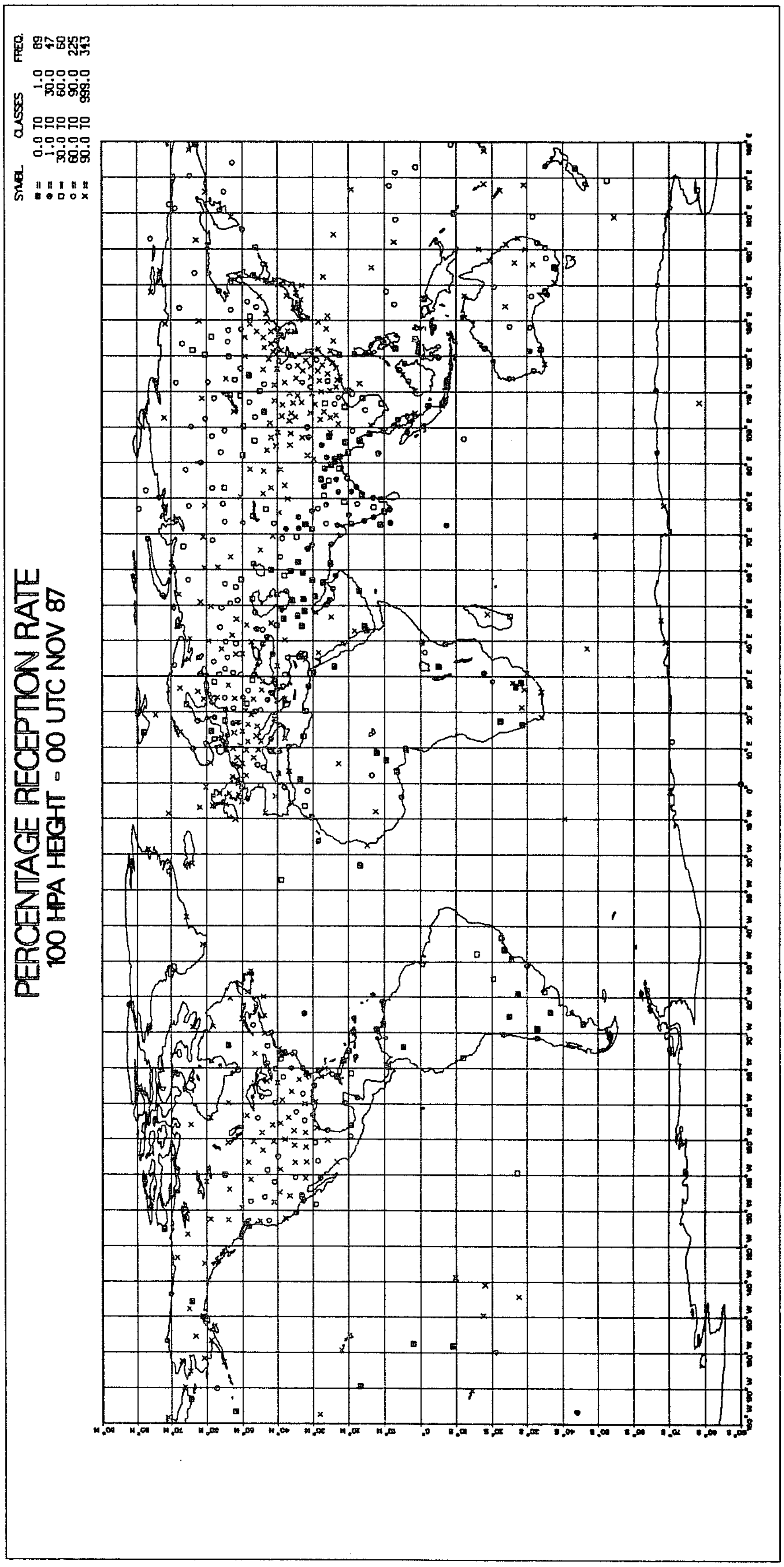


Fig. 1 Reception rate of 100 hPa geopotential height at 00 UTC for November 1987 (per cent)

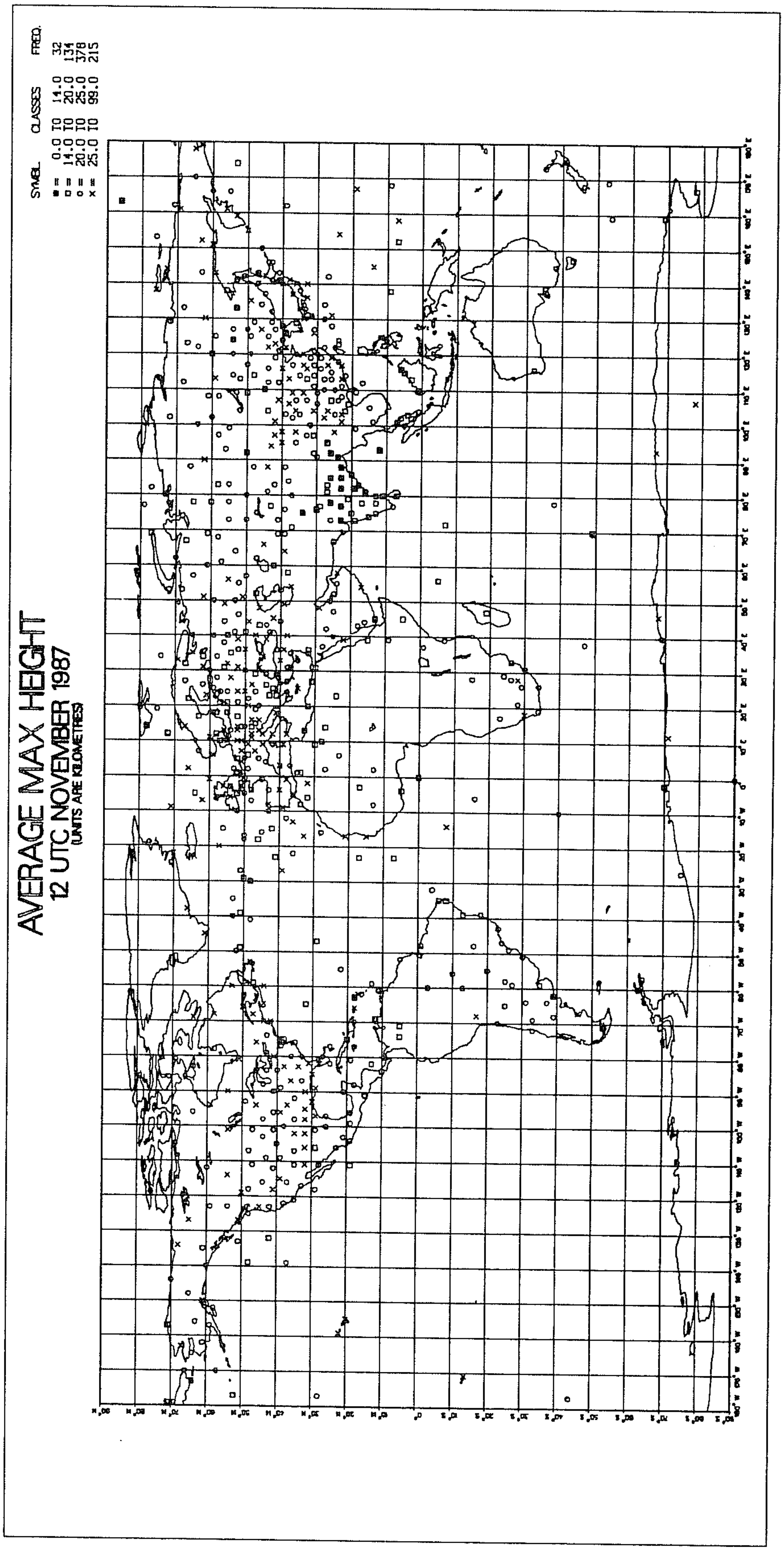


Fig. 3 Maximum height reached by radiosondes averaged over November 1987 for 12 UTC data (kilometres)

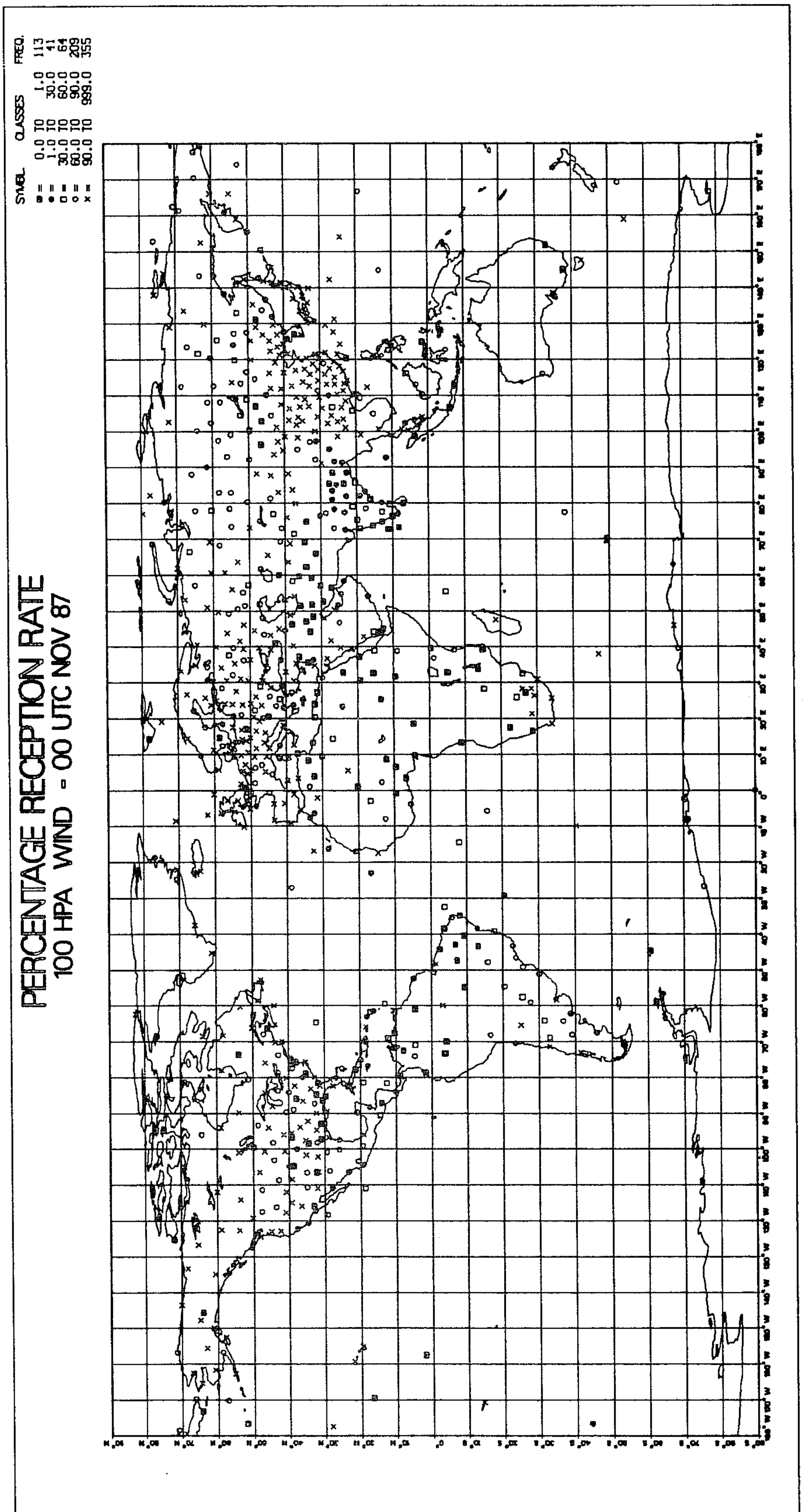


Fig. 2 Reception rate of 100 hPa wind at 00 UTC for November 1987 (per cent)

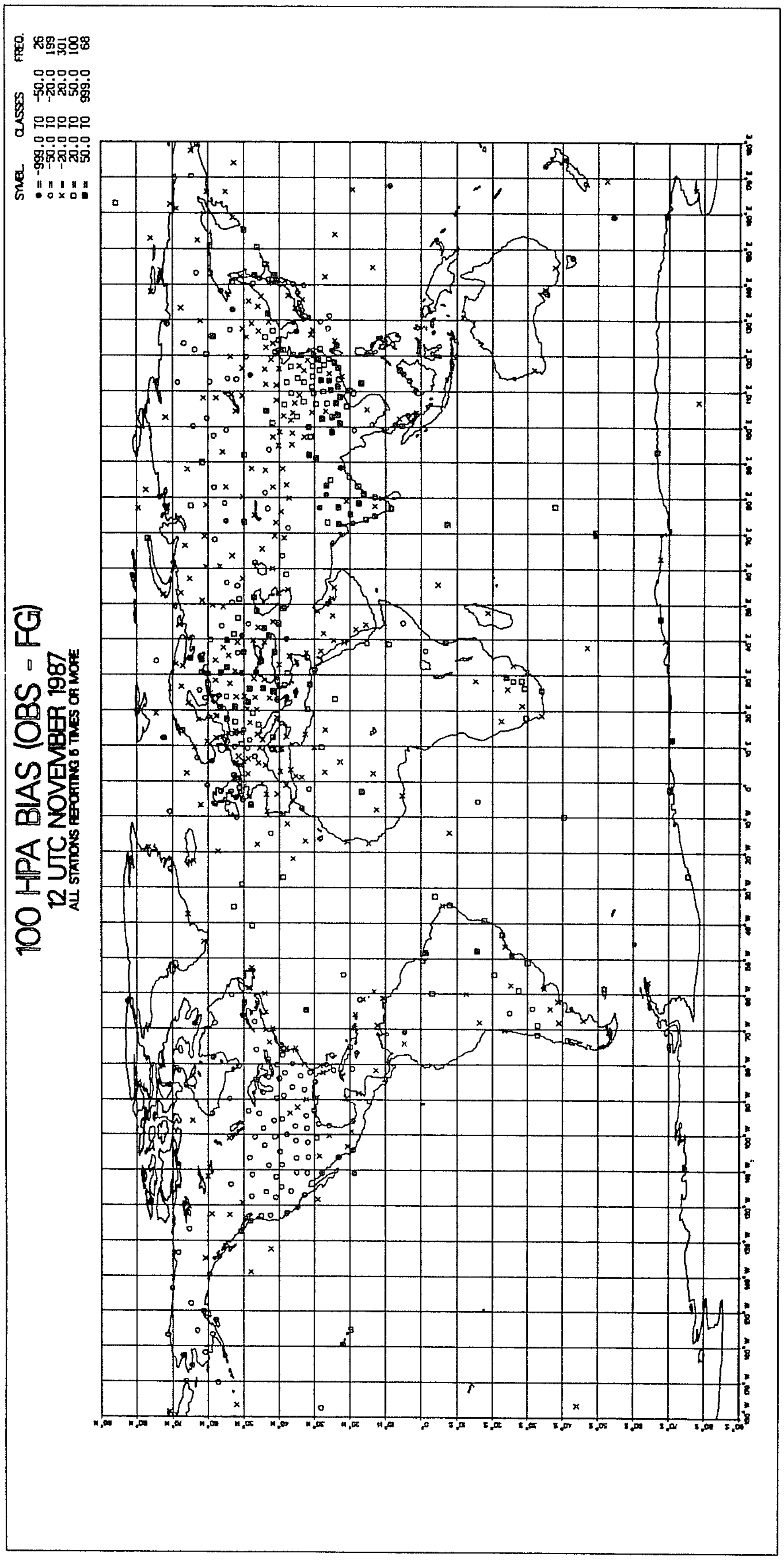
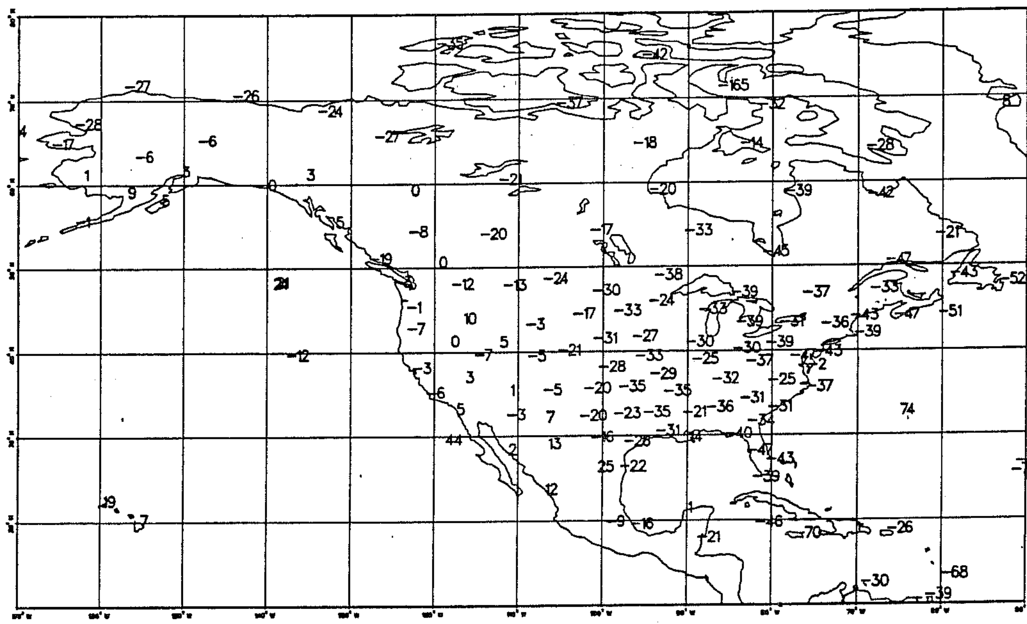


Fig. 4 Mean observed minus first-guess difference at 100 hPa for November 1987 12 UTC data (metres)

100 HPA BIAS (OBS - FG)
00 UTC NOVEMBER 1987
ALL STATIONS REPORTING 5 TIMES OR MORE



100 HPA BIAS (OBS - FG)
12 UTC NOVEMBER 1987
ALL STATIONS REPORTING 5 TIMES OR MORE

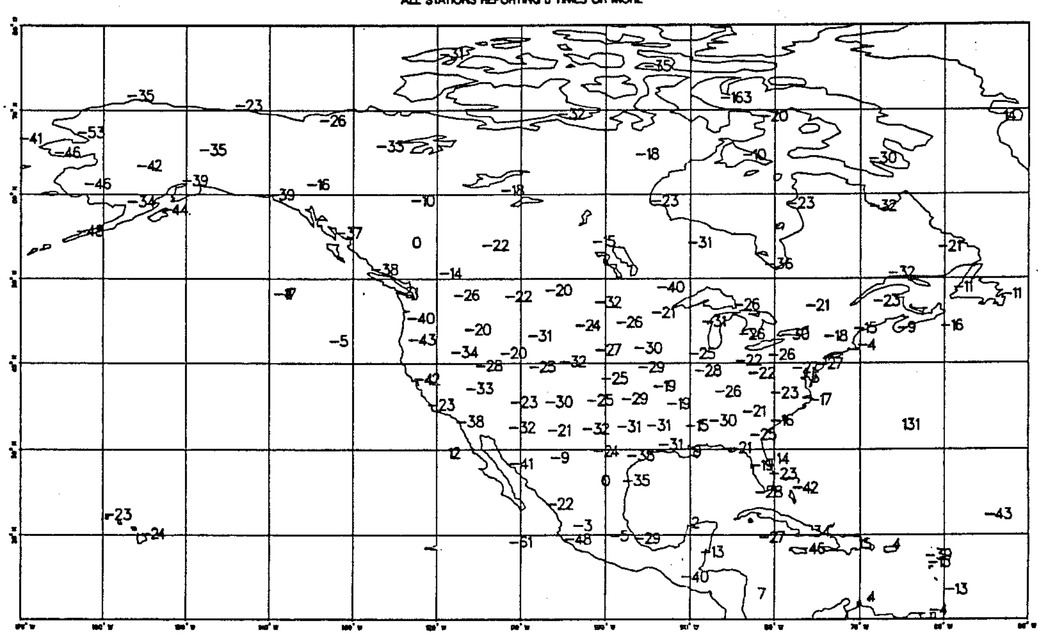


Fig. 5 Mean observed minus first-guess difference at 100 hPa for November 1987 (metres), 00 UTC data (above) and 12 UTC data (below)

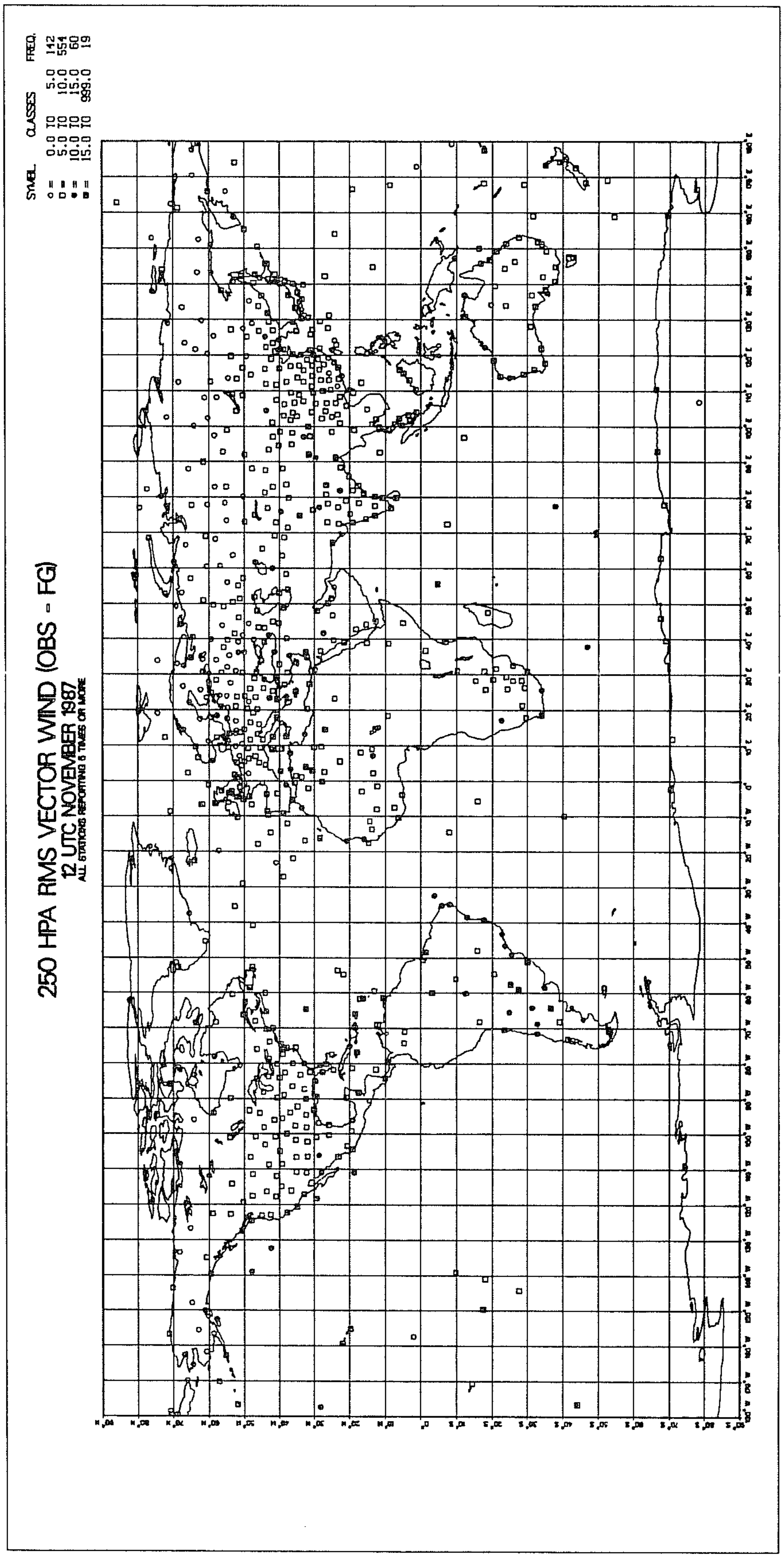
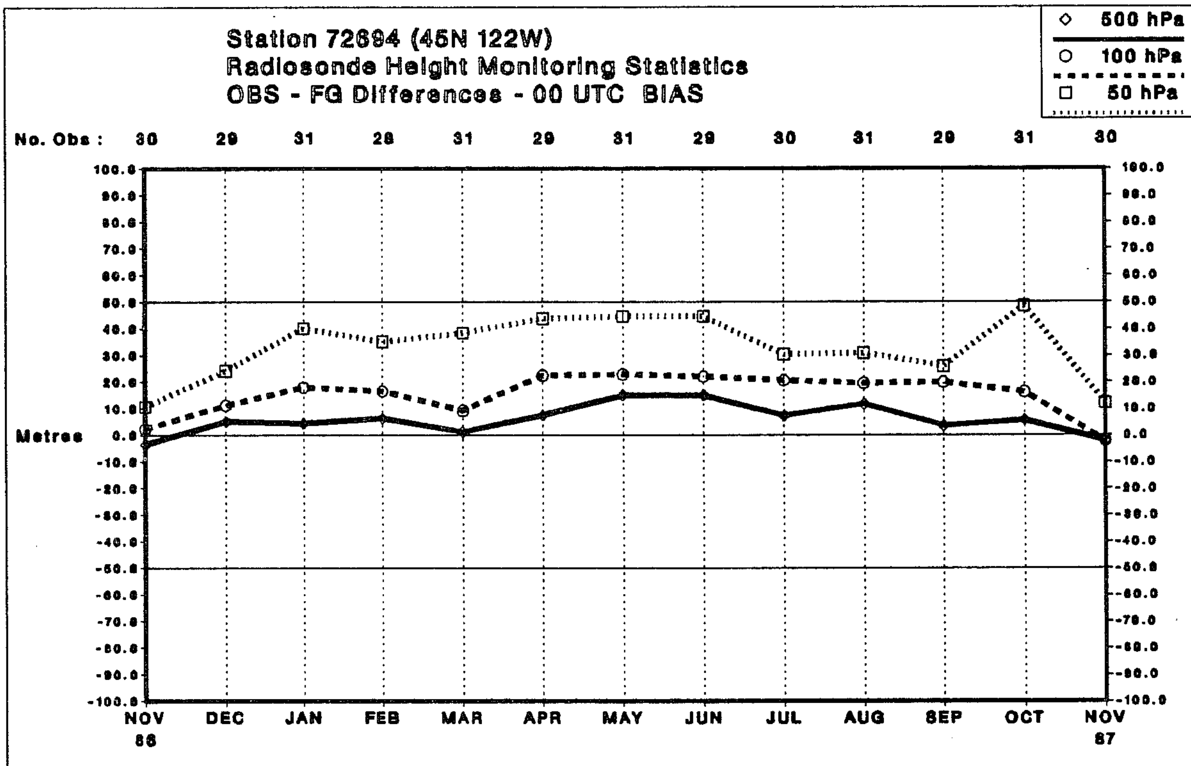


Fig. 6 Root mean square vector wind difference between observations and first-guess at 250 hPa for November 1987 12 UTC data (metres per second)



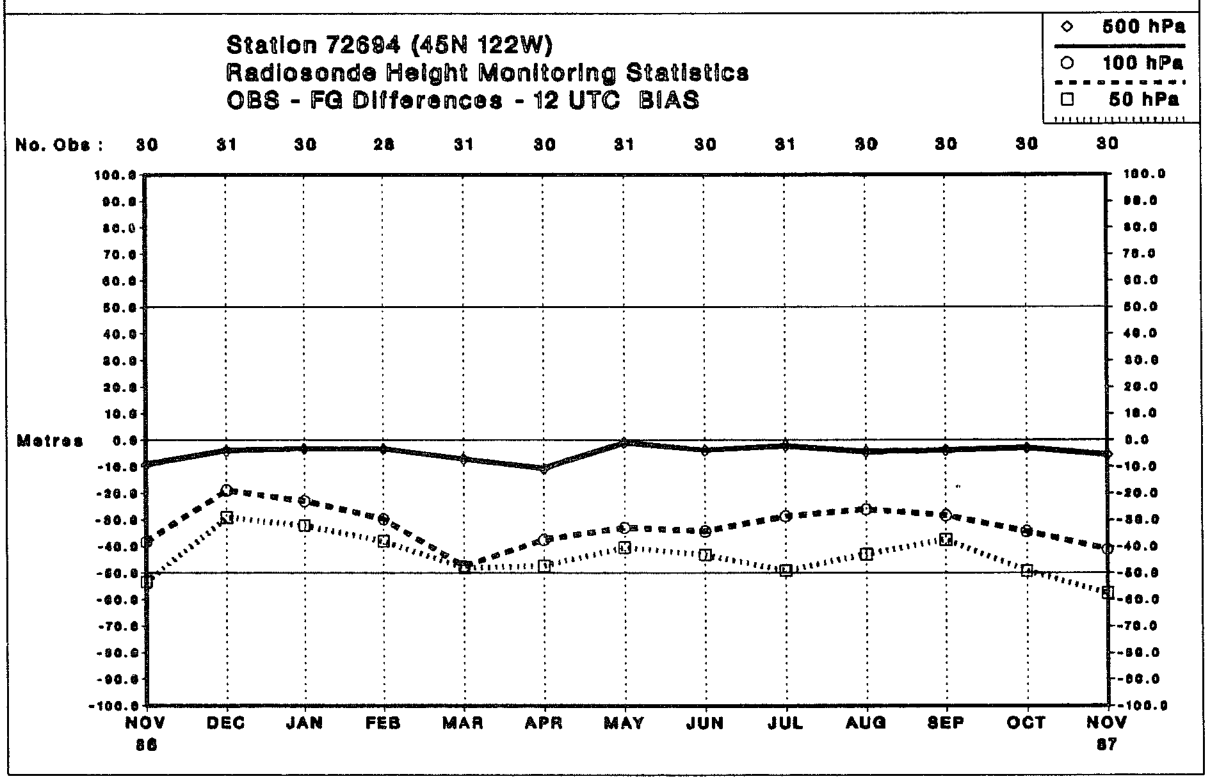


Fig. 7 Time graphs of mean monthly differences between observations and first guess of geopotential height at station 72694 (metres), 00 UTC data (above) and 12 UTC (below)

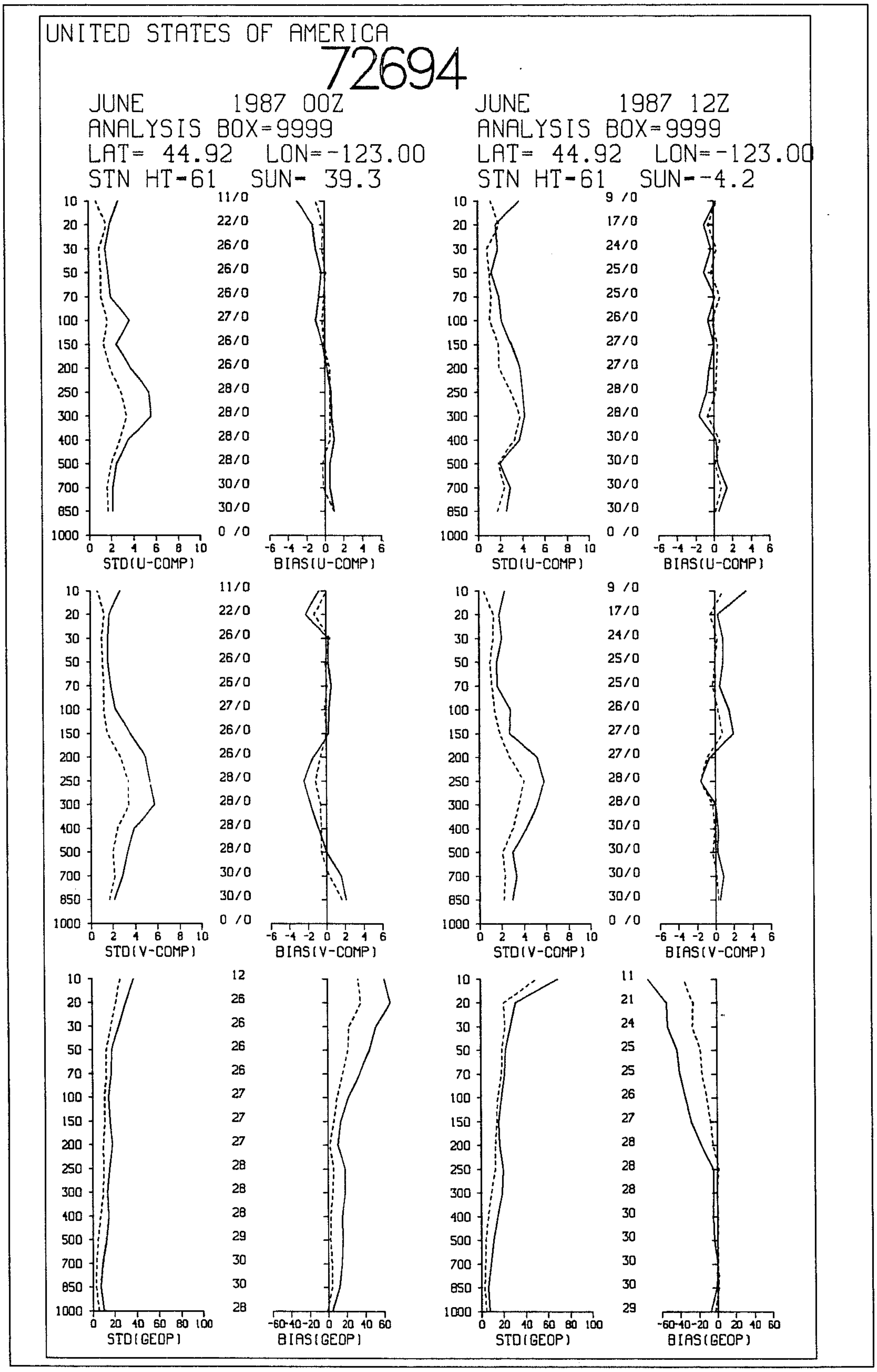
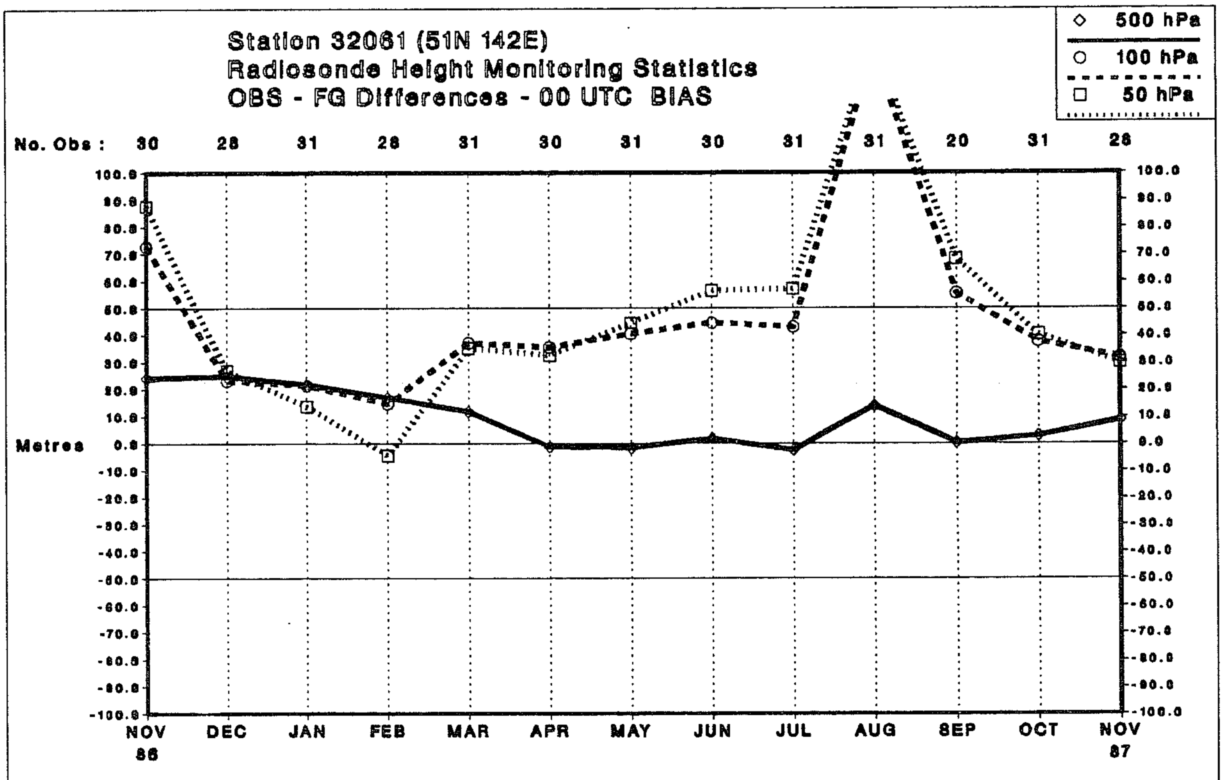


Fig. 8 Vertical profiles of observed minus first-guess (solid lines) and observed minus analysis (dashed lines) differences at station 72694 for June 1987



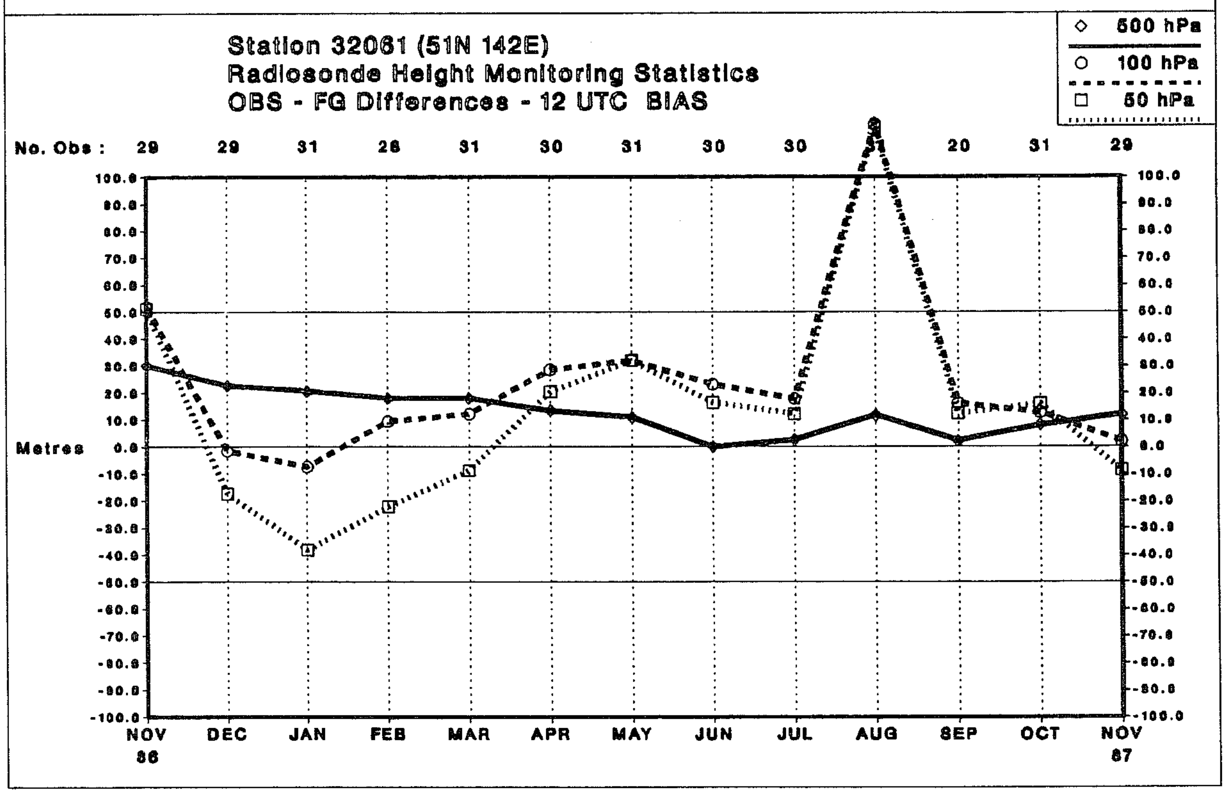
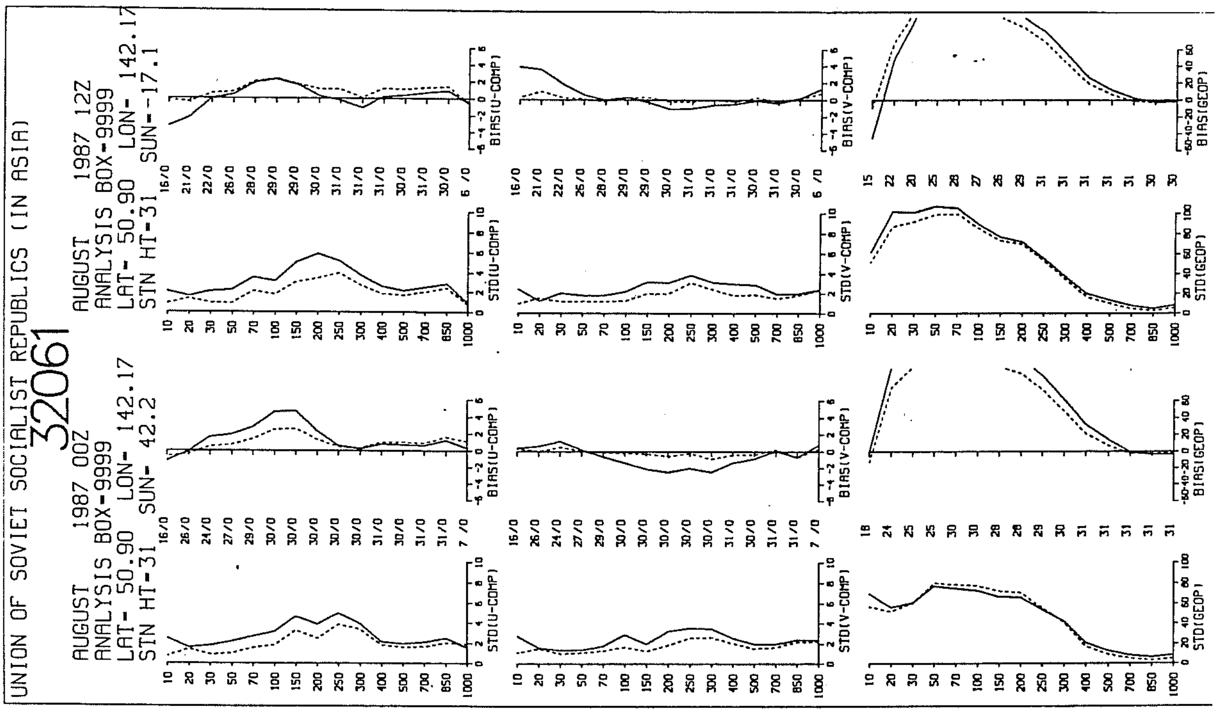


Fig. 9 As Fig. 7 but for 32061



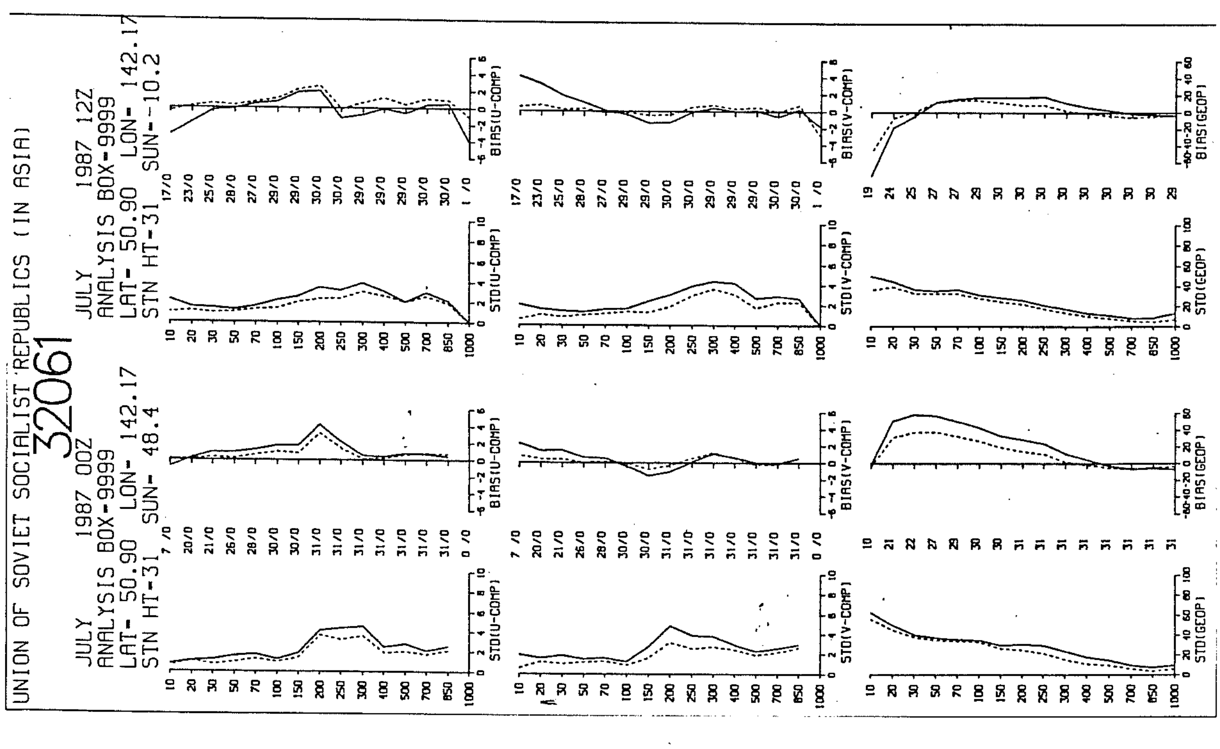


Fig. 10 As Fig. 8 but for 32061 for July 1987 (left) and August 1987 (right)

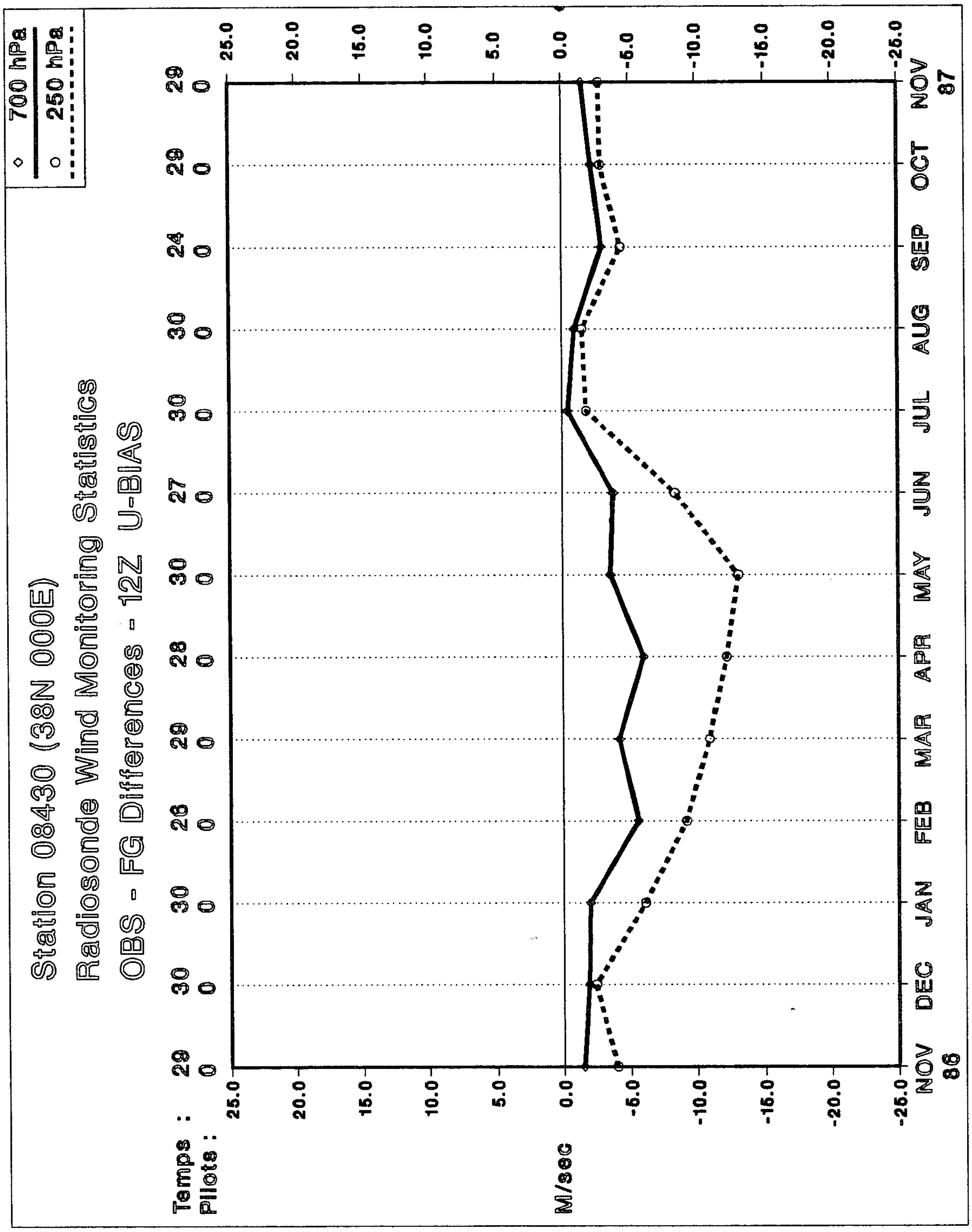


Fig. 11 Time graph of mean monthly differences between observations and first-guess of the zonal wind component at station 08430 (metres per second) for 12 UTC data