THE GLOBAL OBSERVING SYSTEM

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1. INTRODUCTION

Every day, an operational global numerical weather prediction system like the one run at ECMWF is presented with more than 200,000 items of information about the atmosphere. They come on one hand from several thousands of meteorological observations collected by all weather services in the world and disseminated onto the Global Telecommunication System (GTS), and on the other hand from data generated by satellite based observing systems. The observations received at ECMWF in July 1996 were coming from:

- upper-air stations	50,000 per 24 hours (on average)
aircraft	35,000
land or marine surface stations	35,000
oceanic buoys	3,000
- motion vectors from geostationary satellites	16,000
- TOVS (NOAA satellites)	110,000
- scatterometer	21,000,

in the order of 270,000 in total. This count includes only the types of data which are used in data assimilation, excluding in particular observations of weather elements.

Different techniques are used to assimilate these observations, depending on their type. It should also be noted that the present data assimilation systems cannot assimilate all data types, nor any data density. Therefore, data selection algorithms have to be used for optimizing the data utilisation. In addition, some observations, although they are of good quality, are affected by local effects which cannot be handled in global models and therefore should not be passed to the assimilation. For example, SYNOP data are much under-used in global assimilation, mainly because of this representativeness problem.

This article describes typical characteristics of the global set of observations in 1996, as far as non-satellite observations are concerned (recent results on wind data from geostationary satellites can be found in Strauss and Garcia-Mendèz, 1996). Problems with the geographical coverage and with the quality of the data are illustrated. The monitoring of the quality of upper-air observations is described in more details, and some examples are shown to illustrate the value of the provision of feed-back information to data producers.

2. SURFACE OBSERVATIONS

Surface observations include data from land stations (SYNOP), ship, drifting and moored buoys. Figure 1 shows a typical coverage of SYNOP and SHIP data for a 24 hour period. Probably the most significant feature for NWP is the inhomogeneity of the spatial coverage, both over sea and over land. There are about

5300 active land stations around the world, which is roughly equivalent to one station for every 170 x 170 km^2 over land, but several large areas are covered very little or not at all.

Like for all other observations, the quality of the SYNOP observations is monitored regularly by comparing the observed values with the values predicted by very short range forecasts. Systematic discrepancies usually reflect problems with the quality of the observations (Hollingsworth et al., 1986). For pressure observations, lead centres have been designated by WMO/CBS, one for each WMO region, to provide station operators with feed-back on detected problems. This system has recently been set up and should be extended to wind observations later on.

The number of ship reporting meteorological data at one time or another over one month is about 2,000. Wind and pressure observations are monitored regularly, the designated lead centre being the UK Meteorological Office. Currently the proportion of platforms reporting poor quality data is about 1% for pressure and 1.5% for wind observations. It should be noted that there has been a significant reduction of these percentages over the recent years, thanks in particular to the effort put by the lead centre into providing regular feed-back to the ship operators.

Figure 2 shows a 24 hour coverage of buoy data. It has been significantly improved over the years, both for the drifters and for the moorings with the TOGA/TAO array in the Tropical Pacific. The number of active buoys at a given time is typically around 300 drifters and 50 moorings. Generally the quality of the observations is very reliable. The percentage of suspect quality platforms s very small, less than 0.1% (this count does not include buoys from which the data do not get onto the GTS). This is largely due to the implementation of a procedure for near real-time transmission of monitoring information and quick response by the buoy operators, which was implemented a few years ago within the framework of the Drifting Buoy Cooperation Panel (DBCP). An example is shown in figure 3, where a bias of about -5 hPa was very quickly corrected after the problem was detected. However, data transmission can still be a problem. Figure 2 actually has two examples of erroneous position over Greenland, most probably due to telecom errors.

3. AIRCRAFT OBSERVATIONS

Figure 4 shows a typical coverage of aircraft observations (wind and temperature). The introduction of on-board automatic reporting systems has considerably improved the situation compared to a few years ago. Good quality observations are received in areas where practically no data at all were available before, thanks to the new ASDAR and ACARS systems. Figure 5 shows that on average, for areas like Africa and the south Indian Ocean, now a limited but far from negligible number of observations are received.

The decoding and quality control of manually transmitted AIREP observations continues to be a very difficult exercise, due to the variety of practices and of errors which can be encountered. Such is not the case with the ASDAR and ACARS data, whose reliability and accuracy are generally very good. Obviously a quality control at the pre-processing level is still required even for these data, as processing errors do occur from time to time, either on-board or during the transmission chain. Many errors can be detected, and sometimes corrected, by automatic quality control systems. However, some errors are still very difficult to detect automatically, like on the example shown in figure 6.

Another highly significant amelioration over the recent period is that many automatic reports now contain observations taken during the ascent and descent phases of the flights. Here again the data quality is normally very good, comparing well with radiosonde data.

4. RADIOSONDE OBSERVATIONS

4.1 Monitoring

In-situ upper-air observations of wind, temperature and humidity continue to be the prime source of information for NWP. In July 1996, there were 711 stations reporting temperature and 763 stations reporting wind observations at 500 hPa or above (this is not including stations whose data were not properly circulated on the GTS). Most stations operate twice a day, at 00 and 12 UTC, although a few data for 06 and 18 UTC are also available. Typical coverages at 00 and 12 UTC are shown in figure 7 for TEMP data and figure 8 for PILOT and profiler data.

The average station density over land areas is about one station for every 460 x 460 km^2, but, like for surface stations, the data coverage is highly inhomogeneous: the density ranges from 330 x 330 km^2 over China to 810 x 810 km^2 over Africa and 995 x 995 km^2 over South America, critically below the WMO requirement.

The highest level reached by TEMP reports on average is shown in figure 9. Typically around 90% of the profiles reach 100 hPa, 50% go to 50 hPa, 25% to 10 hPa. Data for levels higher than 10 hPa are found in 5% of the reports.

Although the majority of the stations report good quality observations, there are still a number of problems which require careful quality control and monitoring. In July 1996, about 8% of the wind reporting stations and 18% of the temperature reporting stations were listed as "suspect" according to the WMO agreed terminology, i.e., they were producing questionable observations.

Like for other data types, problems detected in the quality monitoring of upper-air data are often seen as random errors which cannot easily be explained. However, there are three specific categories of errors which can be traced back to well identified reasons, the first two being actually very simple, but not always that easy to correct:

- station elevation errors: with the current procedures, the processing of a TEMP observation requires the use of the station elevation independently by the observer and by the user. It is not uncommon that the value used by one or even both of them is in error. For the user, the normal source of information for the station elevation is the WMO Volume A, which relies on proper notification of the correct values by the member countries to the WMO Secretariat. Figure 10 shows the pattern generated by an error in Volume A when checking an entire profile of height departures from background.
- antenna alignment errors, for stations using an antenna in their wind measurement system: a misalignment of the antenna will cause a systematic error on the wind data. An azimuth error will simply cause a constant bias of the wind direction, while an elevation error will affect the speed measurement at low antenna elevations, and will therefore be very noticeable at jet level (figure 11).
- radiation correction errors: in the stratosphere the temperature measurements are affected by infra-red radiative cooling, combined to solar heating during the day. If no correction is applied, this results into a cold bias during the night and a warm bias during the day, usually growing with solar elevation (figure 12). Nowadays many sounding systems have an appropriate built-in correction procedure, and the data they transmit on the GTS are practically not affected by the problem. The number of stations operating such systems has considerably increased over the past ten years. Unfortunately, a significant proportion of stations still operate systems with

either no correction applied at all, or not entirely adequate corrections. In such cases, the ECMWF pre-processing includes a simple correction procedure whereby a pre-determined correction is applied to the data, depending on sonde type, level and solar elevation. The correction tables for the various sonde types were established in 1992, based on an empirical compromise between results from WMO/CIMO radiosonde intercomparison experiments and ECMWF monitoring statistics. The types of sondes used at every station are taken from the TEMP bulletin itself when the corresponding information is present (group 31313), or from a separate station directory. The stations which were corrected in early 1996 are shown in figure 13.

Among the various problems of random error which are encountered, the errors which affect the temperature measurements over India are particularly noticeable. Figure 14 shows a typical example for an Indian station, where the large values of standard deviation reflect the erratic fluctuations which are commonly observed. This feature has been there for many years, although a consistent trend towards improvement has been seen over the past two years or so. It should be noted that currently the 35 Indian stations account for 5% out of the 18% of suspect stations for geopotential height observations. Wind observations over India are not affected in the same way, many of them being of normal quality.

4.2 Marine upper-air observations

Highly valuable upper-air observations are those produced in oceanic areas by ship. Stationary Ocean Weather Ship have all disappeared except one, but an increasing number of ship on commercial routes or on research activity carry out a regular observing programme, either as part of the WMO Automated Shipboard Aerological Programme (ASAP) or independently. At the moment, 21 ship report TEMP data, operated by the following countries:

Denmark	2	
France	4	
Germany	4	
Japan	5	
Norway	1	
South Africa	1	
Spain	1	
Sweden - Iceland	1	
UK	1	
USA	1	(+2 planned in the coming years)

There are plans to operate one ship in the Indian Ocean, which is not covered at all currently. This would be quite valuable not only for data assimilation but also for the possibility that it would provide of cross-checking other data types.

TEMPSHIP observations are normally high quality data, although transmission problems occasionally cause the loss or the corruption of bulletins. The frequency of such problems seems to depend much on the telecommunication channel which is utilized.

4.3 Feed-back to data producers

As for surface marine observations, feed-back to system operators about upper-air data quality has proven useful to help achieving quick and efficient correction to problems. Since 1989, ECMWF as the WMO/

CBS designated lead centre has produced 6-monthly consolidated lists of suspect stations, based on monitoring results from all global NWP centres participating in the exercise. These lists are sent to the WMO Secretariat which forwards them to the relevant National Meteorological Services for action. The stations listed for the period January-June 1996 are shown in figure 15.

Two examples of follow-up corrections are shown in figure 16. The first one is a simple correction of a large wind direction bias, dating back from 1989 when the interest of establishing procedures for the regular provision of feed-back was being investigated. The other one shows the correction of a more complex error on height measurements, further to a consolidated list in 1992.

In addition to providing feed-back via the WMO Secretariat by means of the 6-monthly reports, problems are notified directly to the data producers when a contact person is available. The notification is done as soon as possible, provided that the problem is reasonably well identified and that it is likely to be due to an error at the station and not to a deficiency of the background field.

5. WIND PROFILERS

Wind profiler data are circulated on the GTS, as shown in figure 8. At the moment, data from about 30 sites from the NOAA demonstration network, from Capel Dewi in the UK and from Christmas Island are received regularly. The quality of most of these data is good. On average, a well functioning system has a quality similar to that of a good radiosonde station, as illustrated in figure 17. The profiler has the drawback of the limited range, usually not above 100 hPa, but the advantage of the hourly or even higher frequency of observations, which should be beneficial with 4D assimilation systems.

The profiler of Christmas Island, at 157W and 2N, has been for many years a highly valuable source of meteorological information in the equatorial Pacific.

6. CONCLUSION

We have described the Global Observing System from the point of view of the use of the observations in global NWP. Obviously, global NWP is not the only application of meteorological observations, and certain characteristics of the network which are not optimal for NWP may well be beneficial in other applications. It should also be borne in mind that the techniques used for the numerical assimilation of the observations do not develop independently from the evolution of the observing network. With the assimilation systems operational at the moment, it is not possible to use all the observations which are available, so that for example off-time observations, which are more and more numerous, can only have a limited impact with the present analyses which are valid at specific times. Overall, the 3D-Var system operational at ECMWF makes an effective use of about 35% of all the observations received. The 4-dimensional variational systems currently under development at ECMWF and elsewhere should radically change the way the observations are used.

However, regardless of possible improvements in data assimilation, the availability of numerous and good quality meteorological observations is and will continue to be of paramount importance for weather prediction. Some encouraging trends have been seen over the past few years, especially with the quality of the data, but there are also worrying signs of deterioration, the significance of which should not be underestimated.

REFERENCES

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) pp 861-879

Strauss, B. and Garcia-Mendèz, A. (1996): Monitoring of cloud-motion wind data in numerical weather prediction. EUMETSAT/JMA/WMO/NOAA/SMI Third International Wind Workshop, pp 175-184

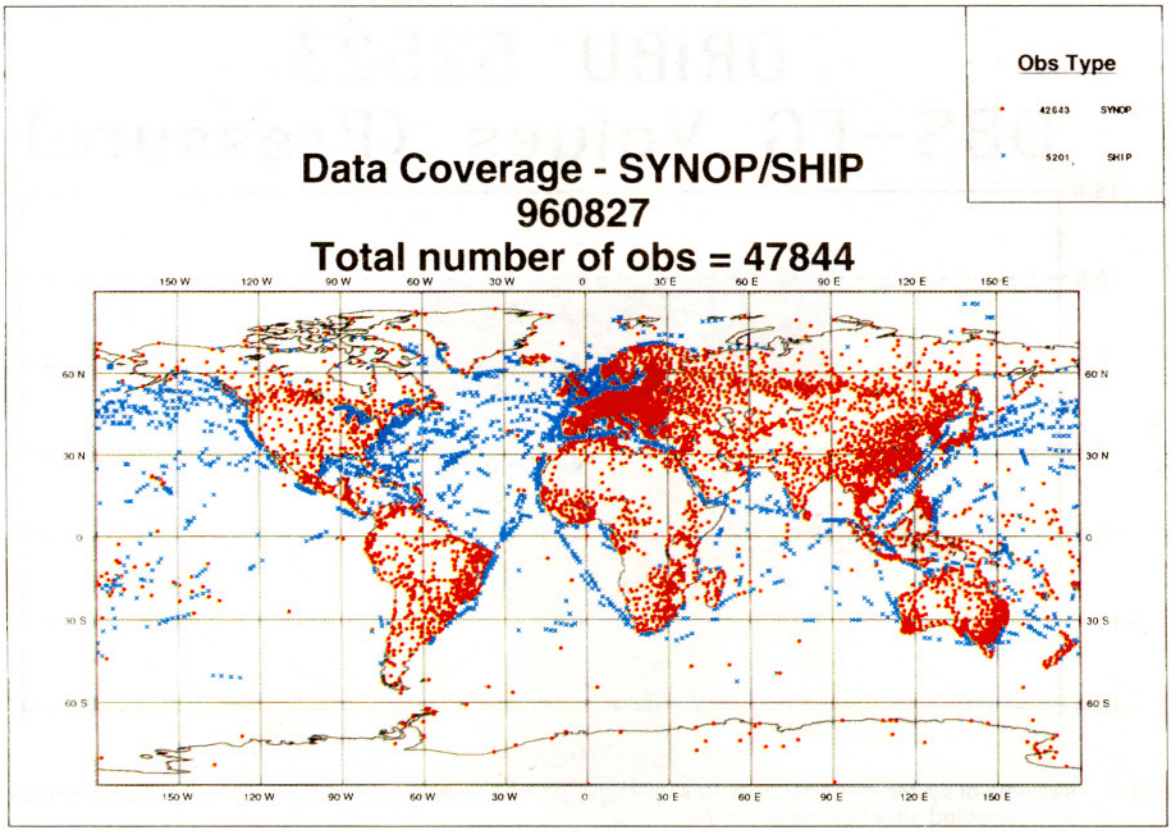


Figure 1 : coverage of SYNOP and SHIP observations.

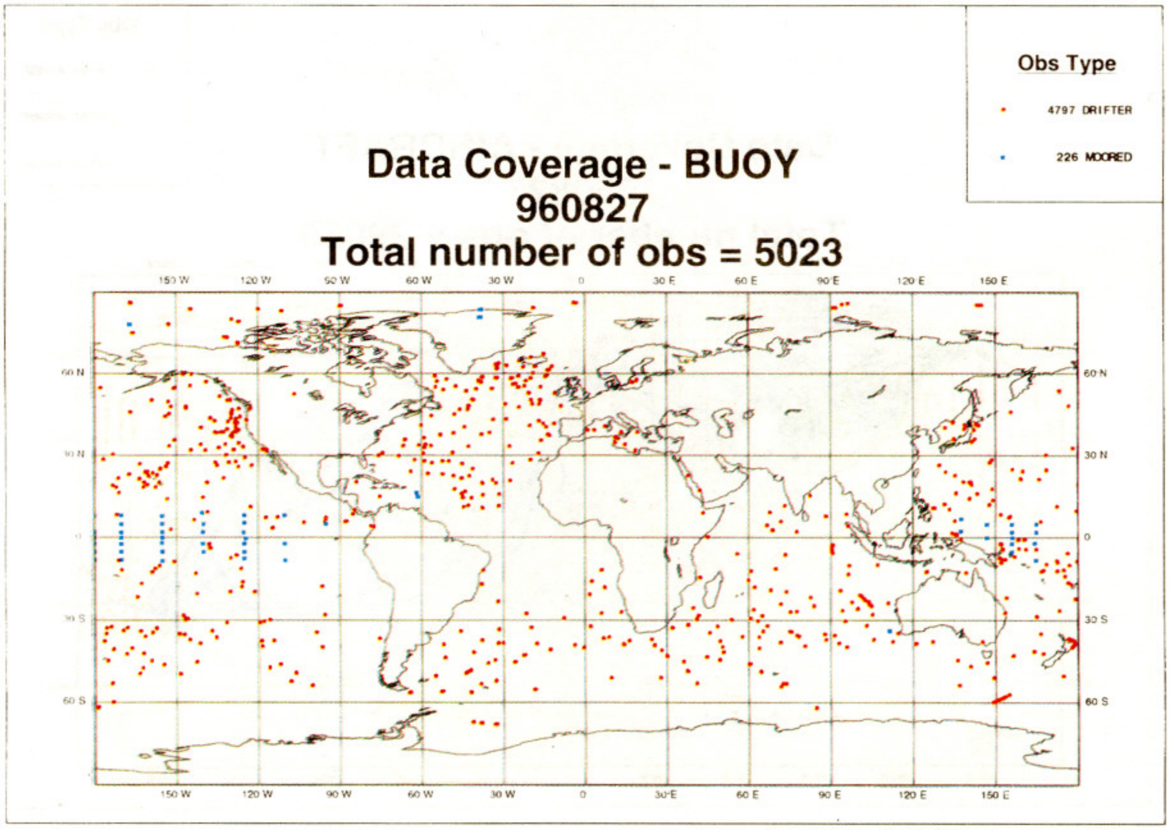


Figure 2 : coverage of drifting and moored buoys observations.

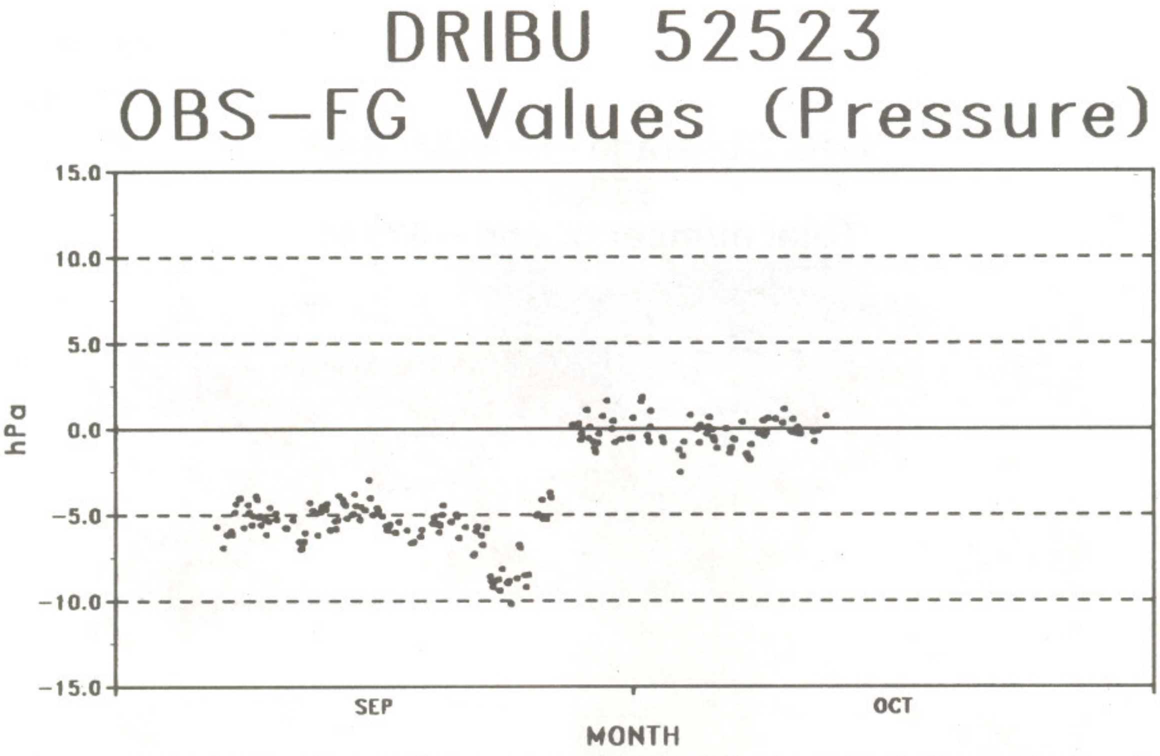


Figure 3 : example of systematic error with pressure reported by a drifting buoy, detected in operational monitoring and corrected after notification to the operator.

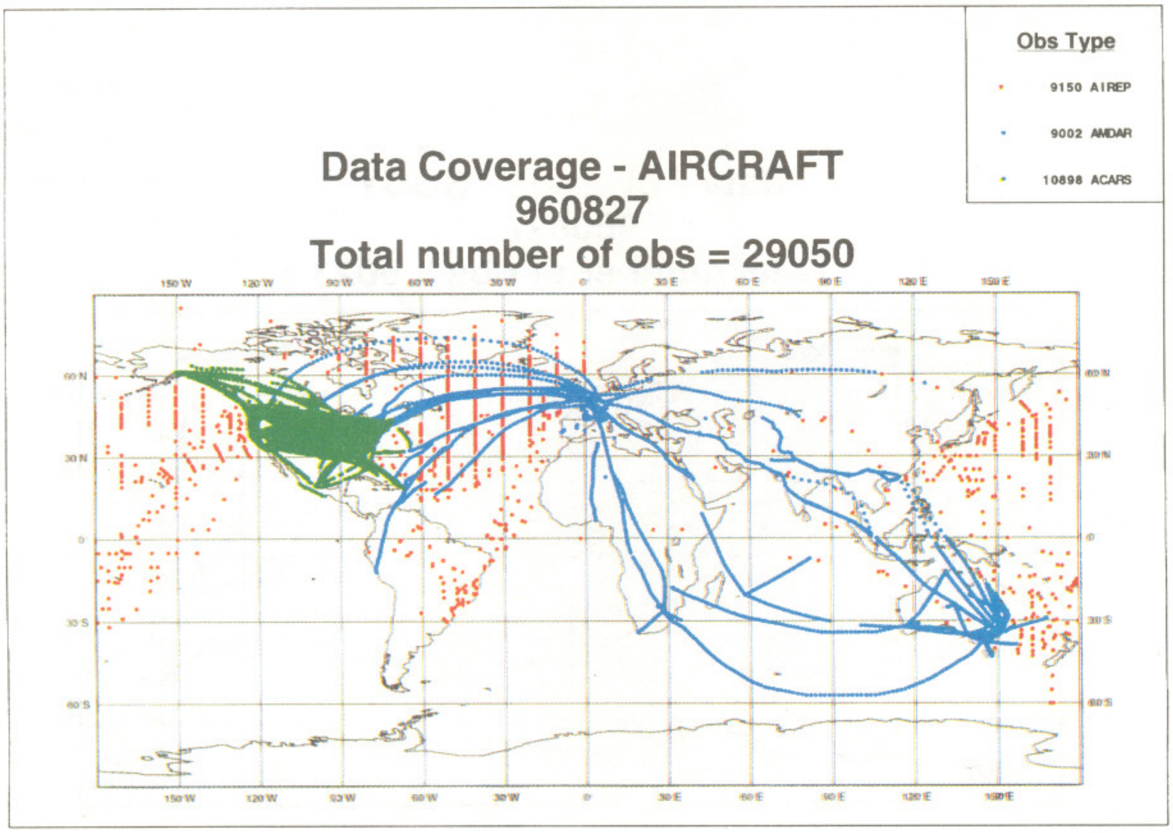


Figure 4 : coverage of aircraft observations

ECMWF Monitoring Statistics - JUL 1996

Availability - AIRCRAFT winds 300-150 hPa

Average number of observations in 24 hours - 13167

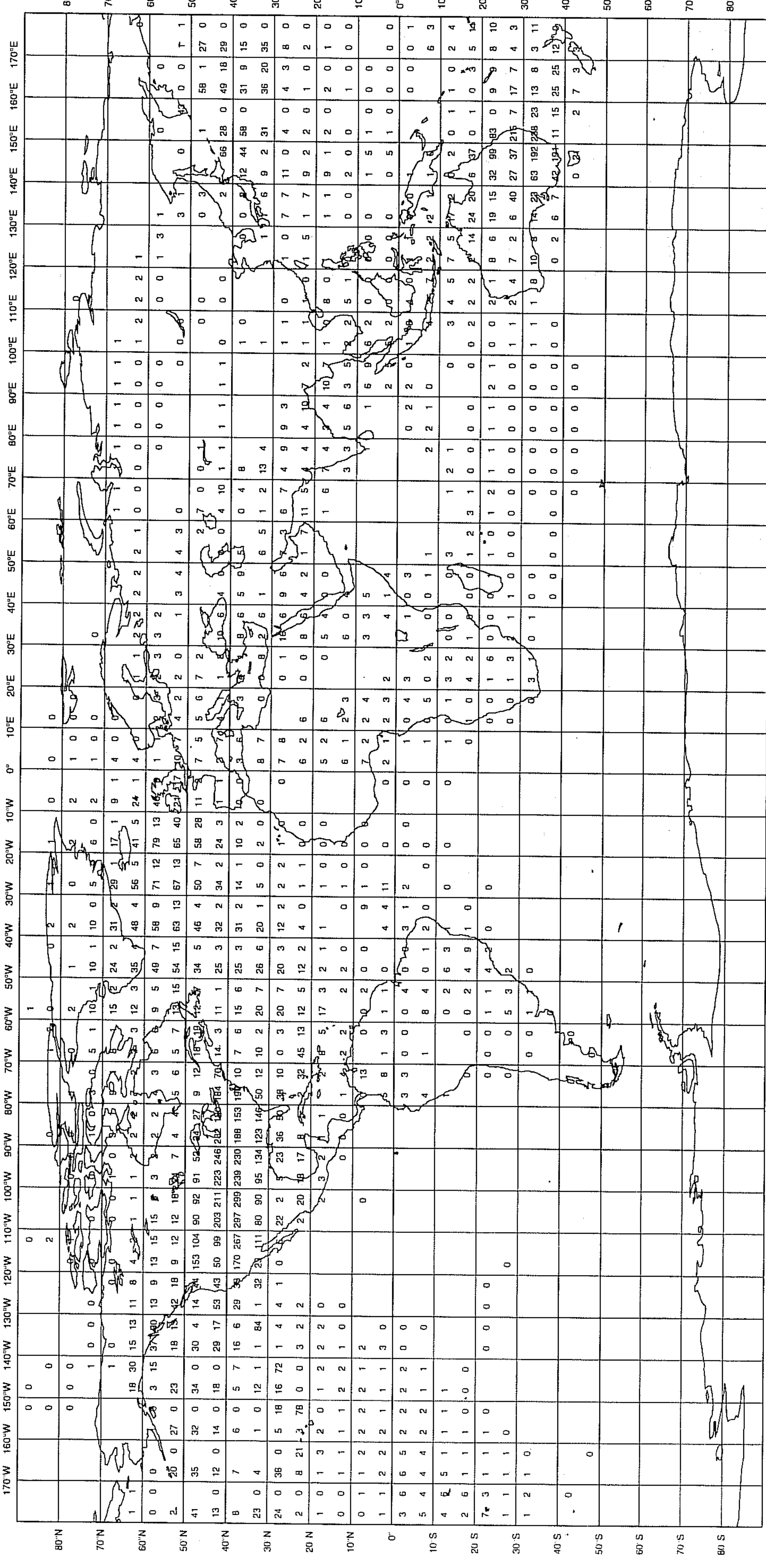


Figure 5 : monthly coverage of aircraft observations, average number of observations in 24 hours per squares of 5°x5°

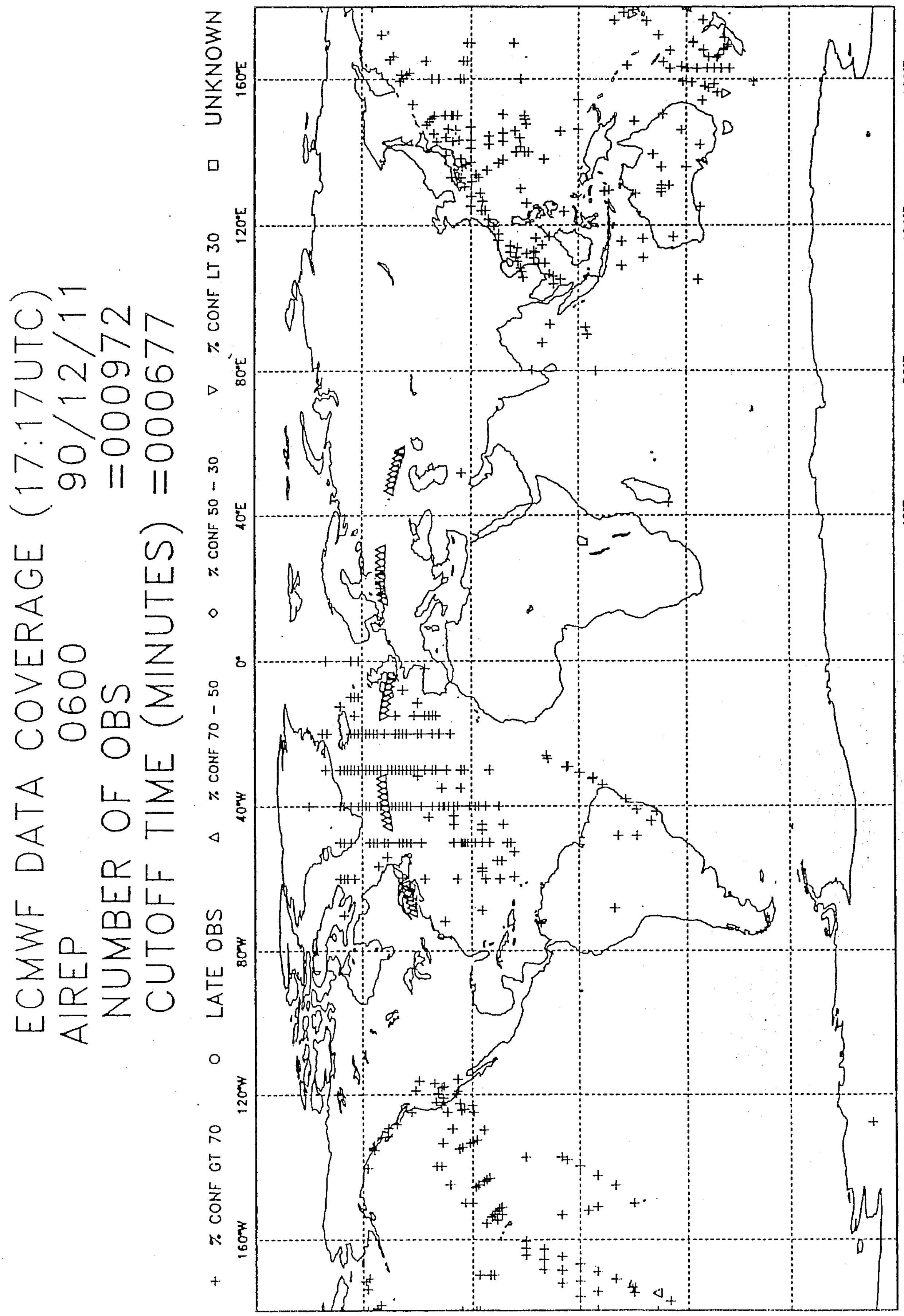
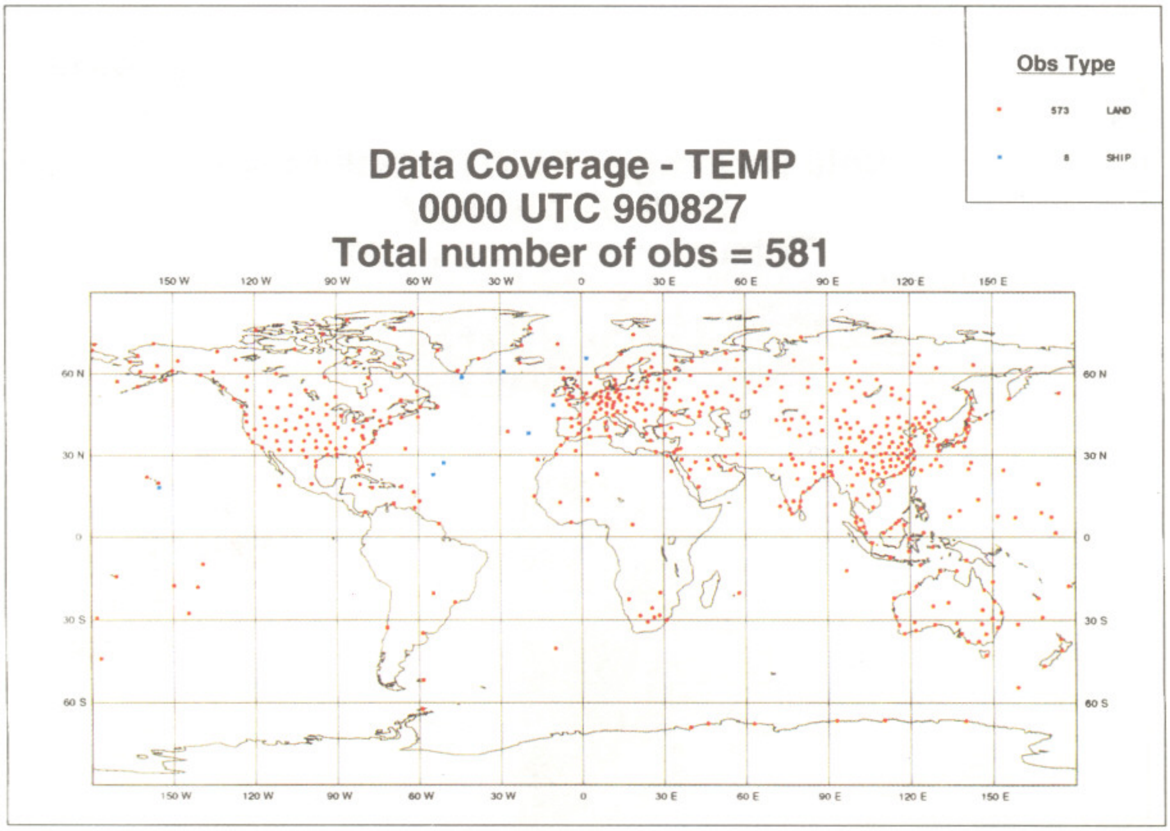


Figure 6: example of error with aircraft observations from an automatic system: the reported logitude switched from West to East or from East to West every hour. The data on the eastern legs were in error, but it would be difficult to flag all of them automatically.



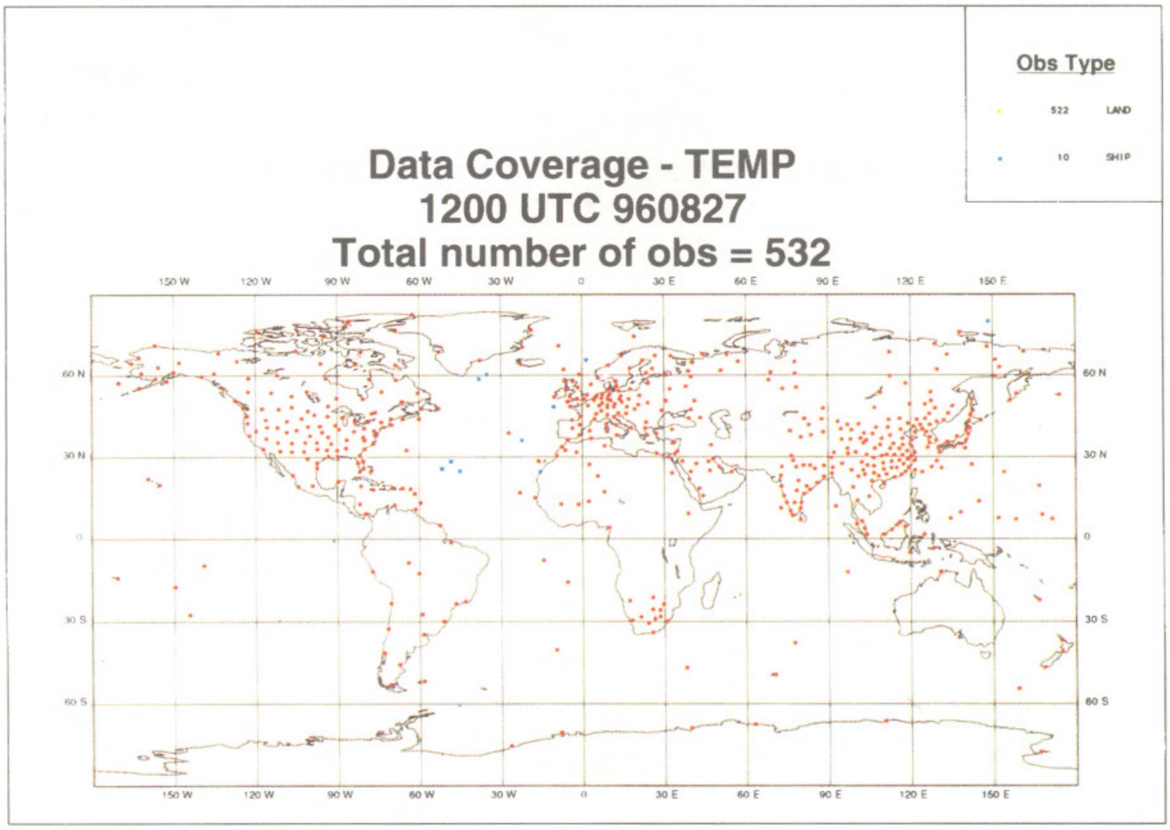


Figure 7 : coverage of TEMP observations at 00 and 12 UTC.

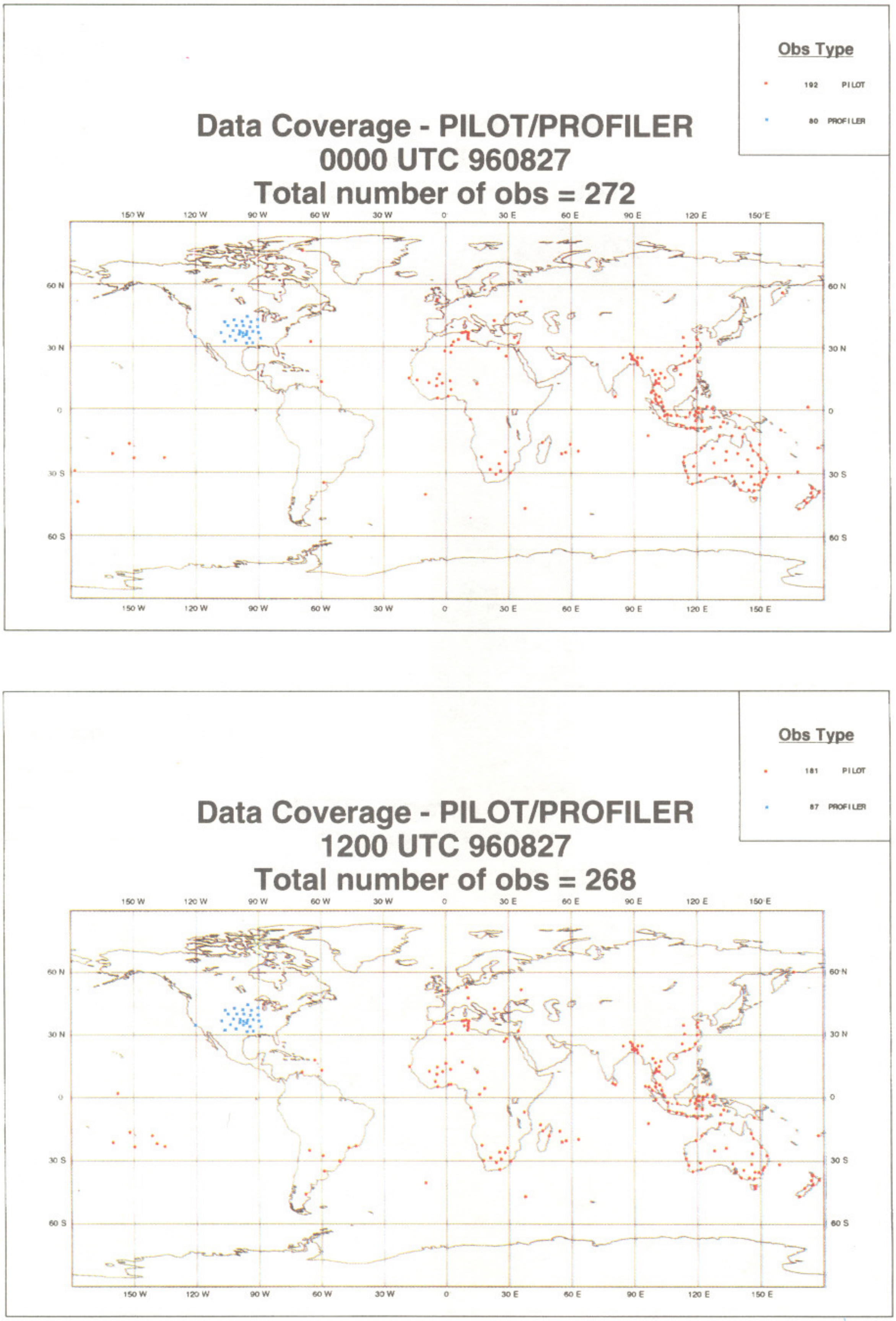


Figure 8 : coverage of PILOT and profilers observations at 00 and 12 UTC.

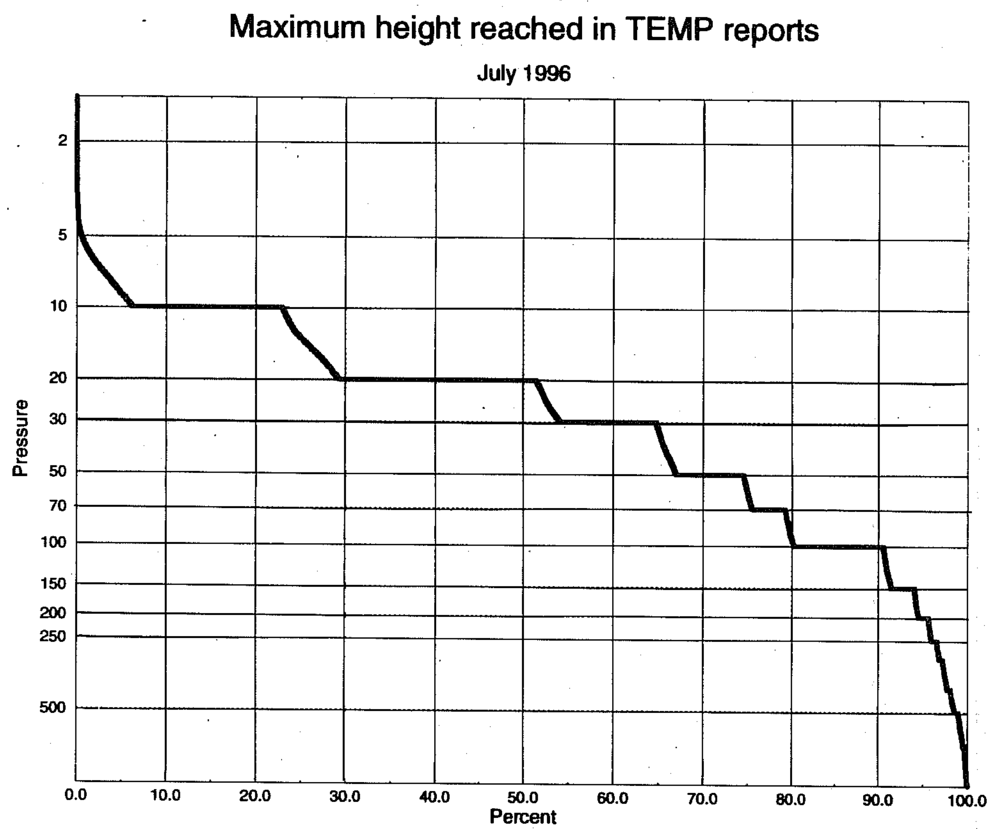


Figure 9 : highest level reached in TEMP reports, July 1996

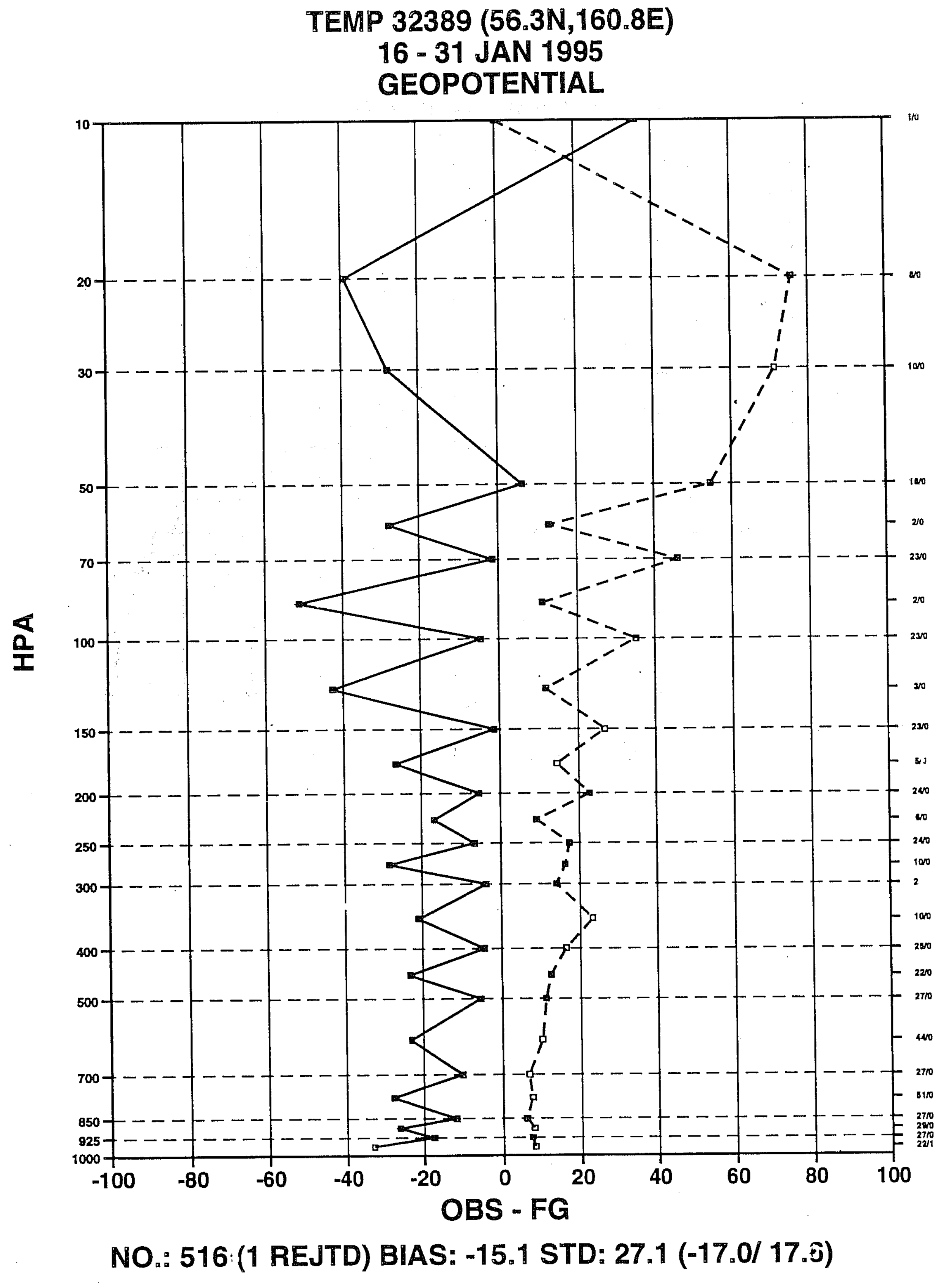


Figure 10 : example of error pattern due to radiosonde station elevation error: mean (solid line) and standard deviation (dashed line) of the geopotential height departures from background at standard levels and at significant levels.

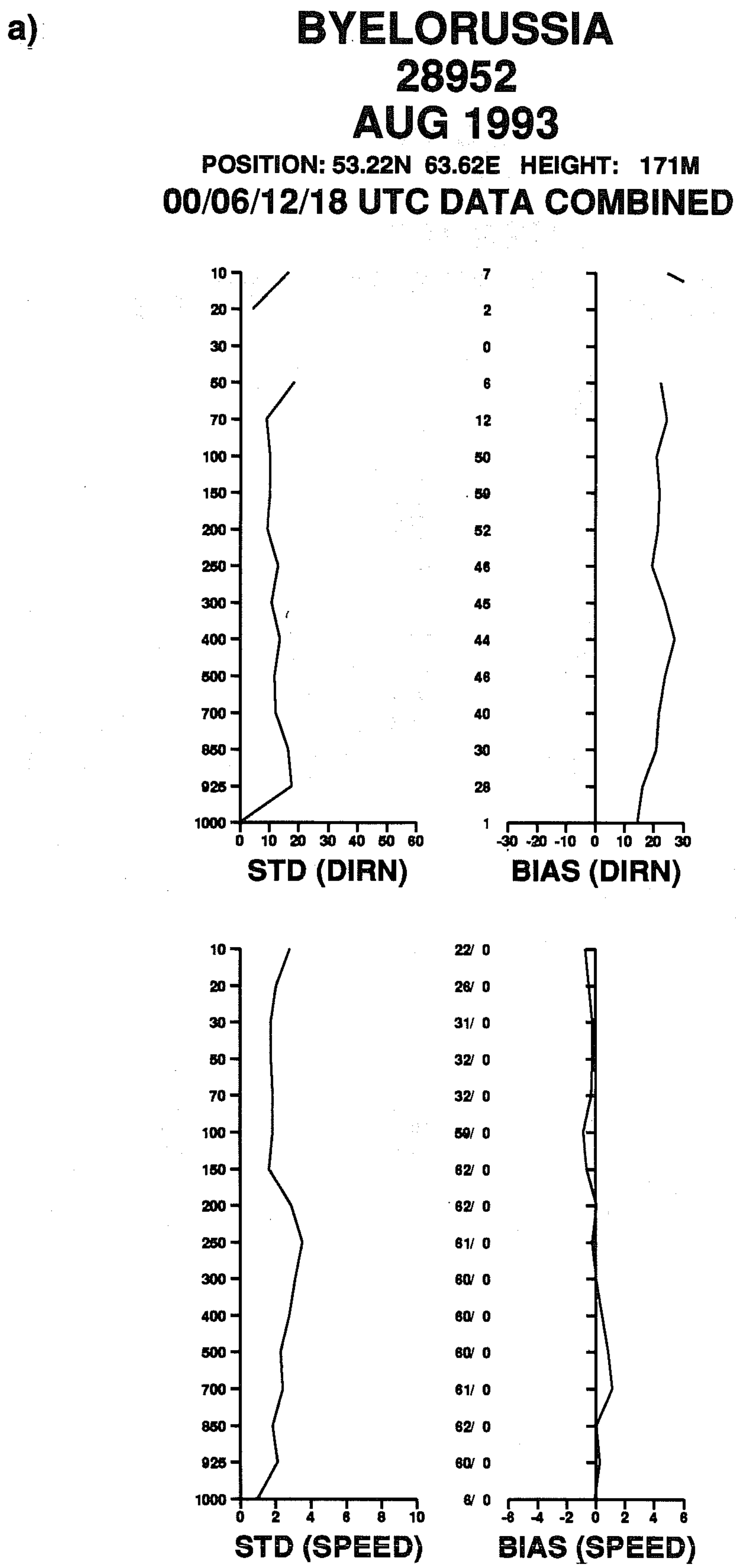


Figure 11 : errors due to misalignment of the wind finding antenna: direction bias due to antenna azimuth error (a), speed bias at low elevation due to antenna elevation error (b).

b) **JAPAN**

47778

FEB 1995

POSITION: 33.45N 135.77E HEIGHT: 67M

00 UTC SUN= 26.5 **12 UTC SUN=-45.6**

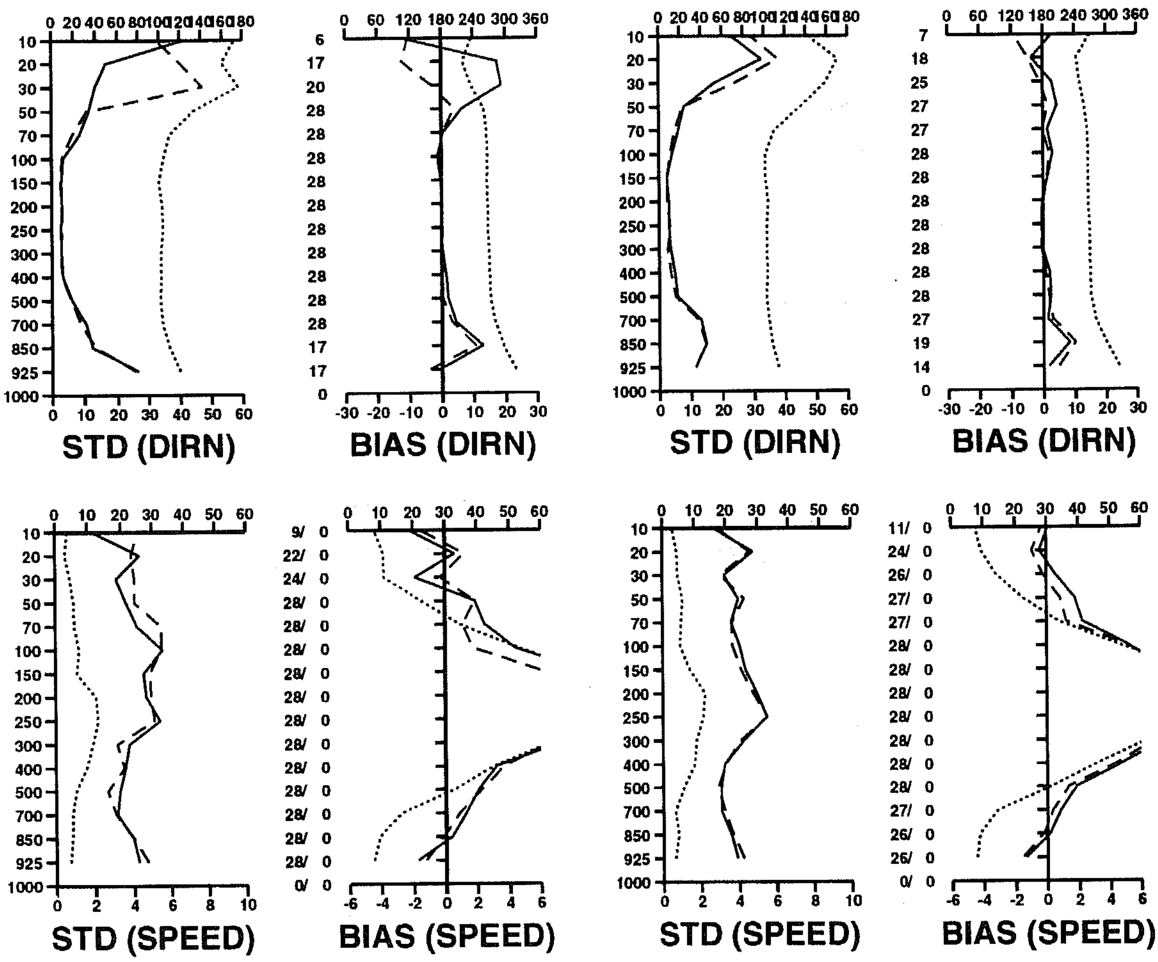


Figure 11b

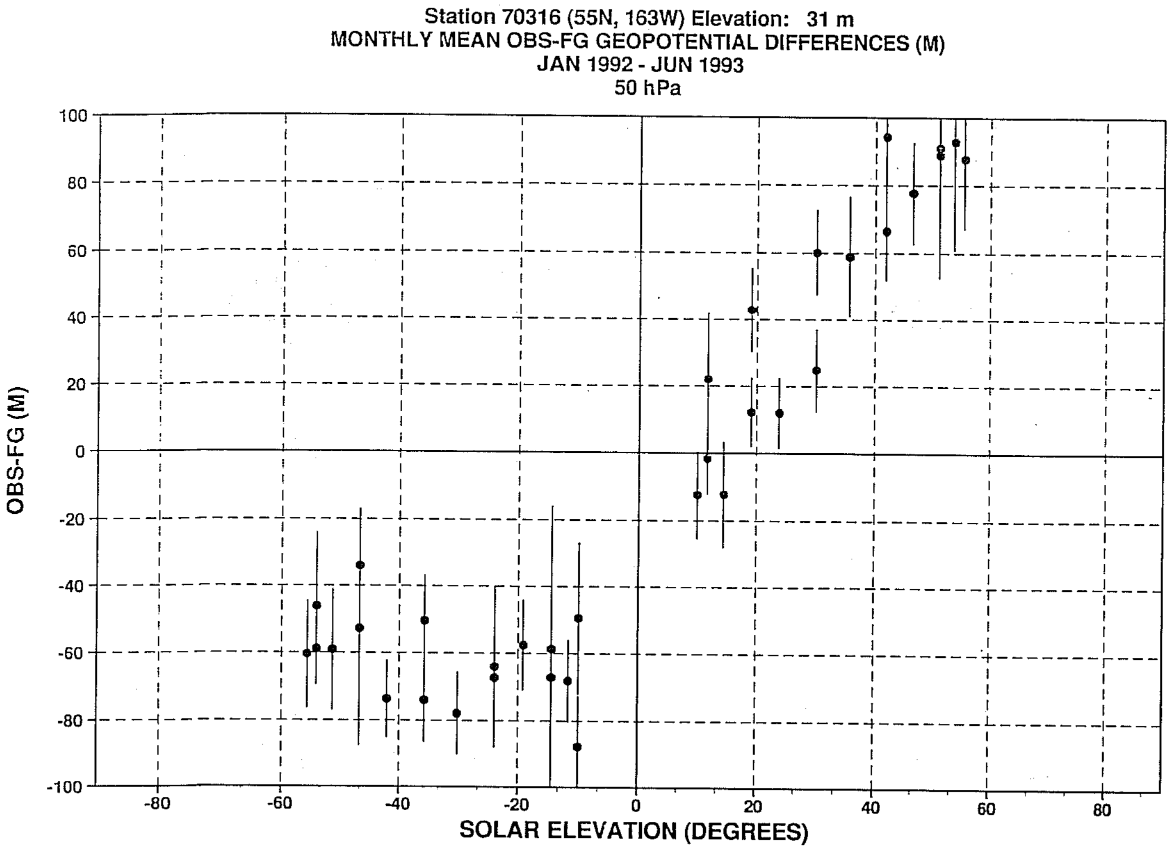


Figure 12 : example of bias at 50 hPa for a radiosonde measurement without radiation correction.

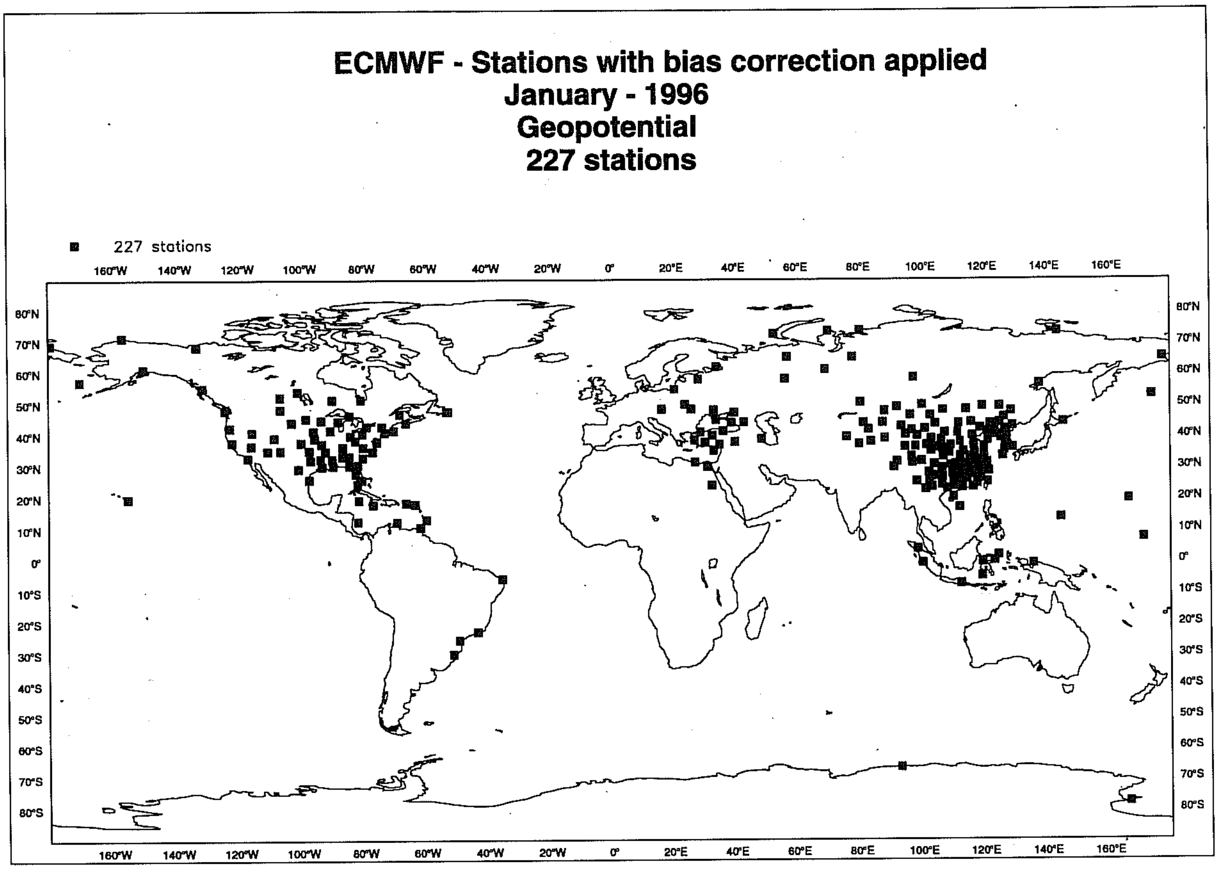


Figure 13 : radiosonde stations for which a radiation correction was applied in the ECMWF pre-processing, January 1996.

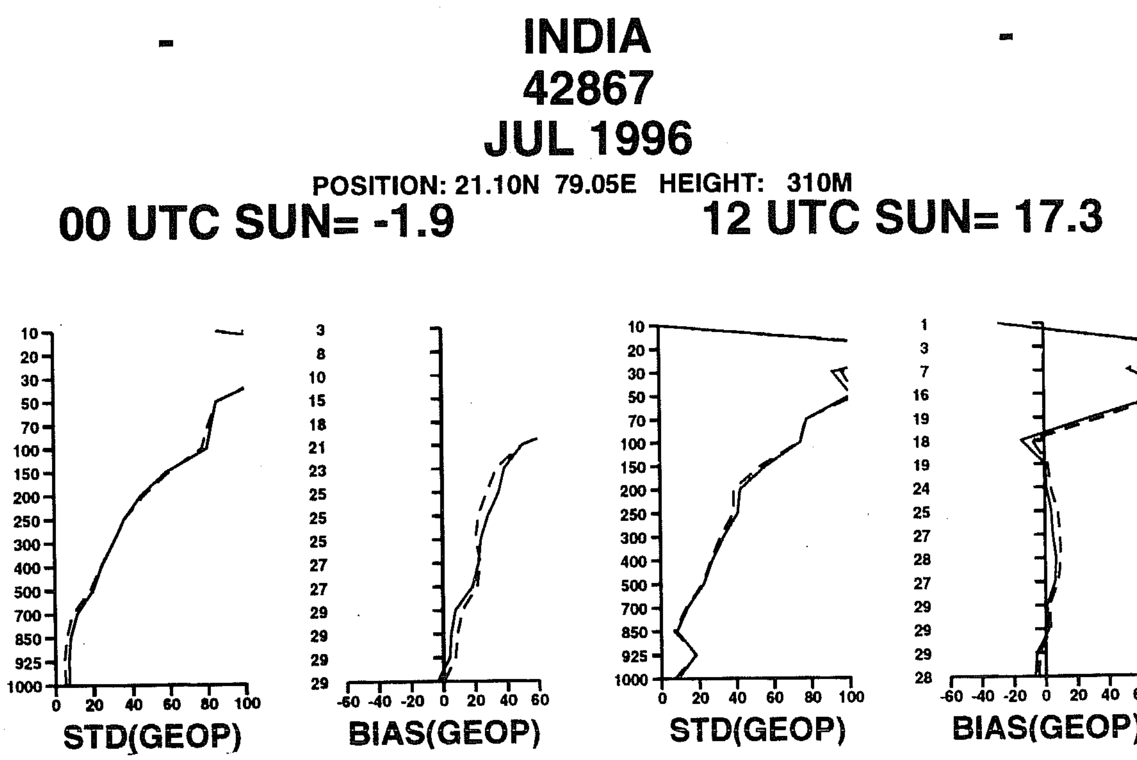
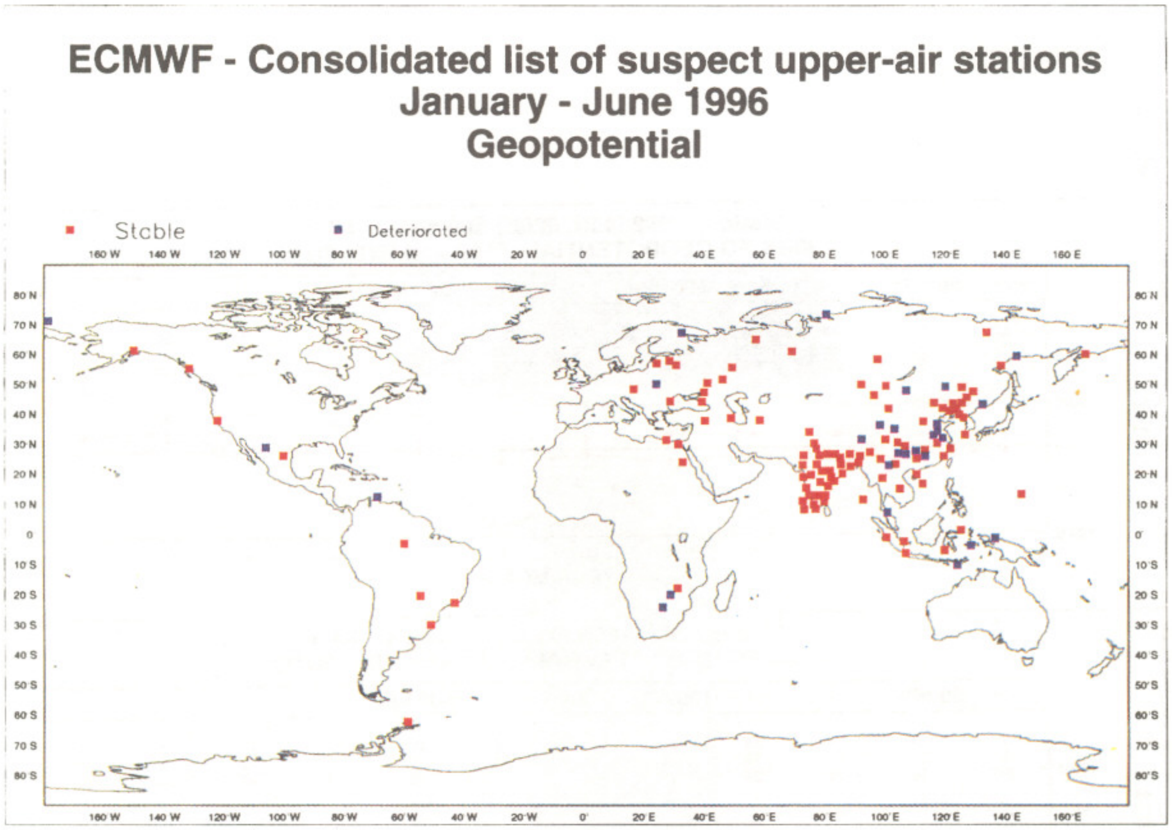


Figure 14 : example of monthly geopotential height departure from background for an Indian station.



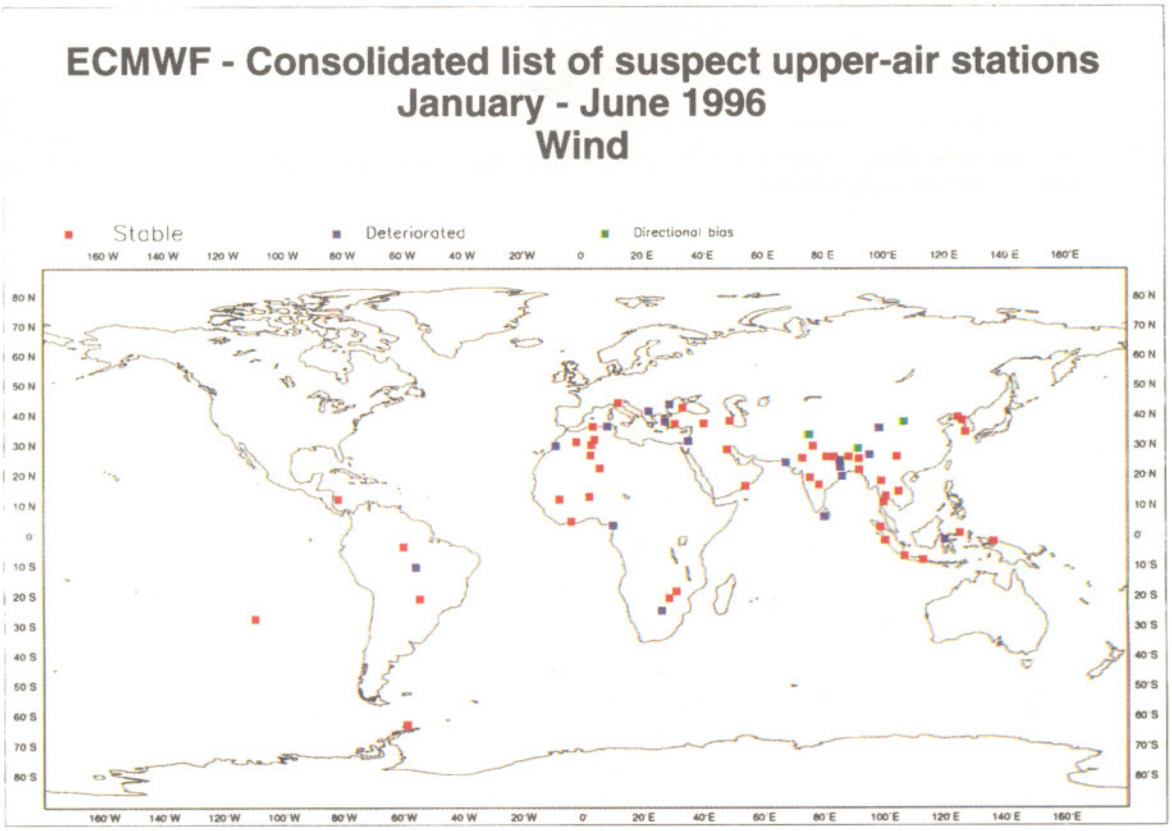


Figure 15 : upper-air stations appearing in the consolidated lists of suspect stations for January-June 1996.

a)

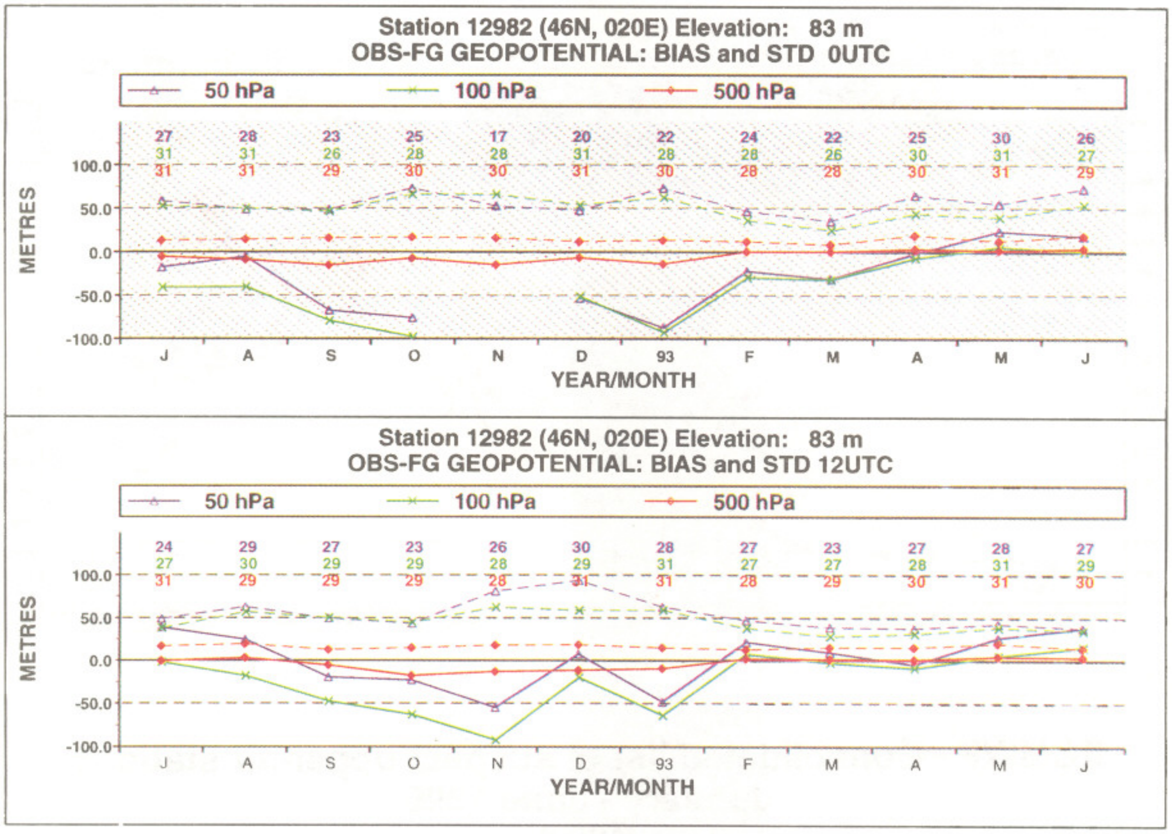
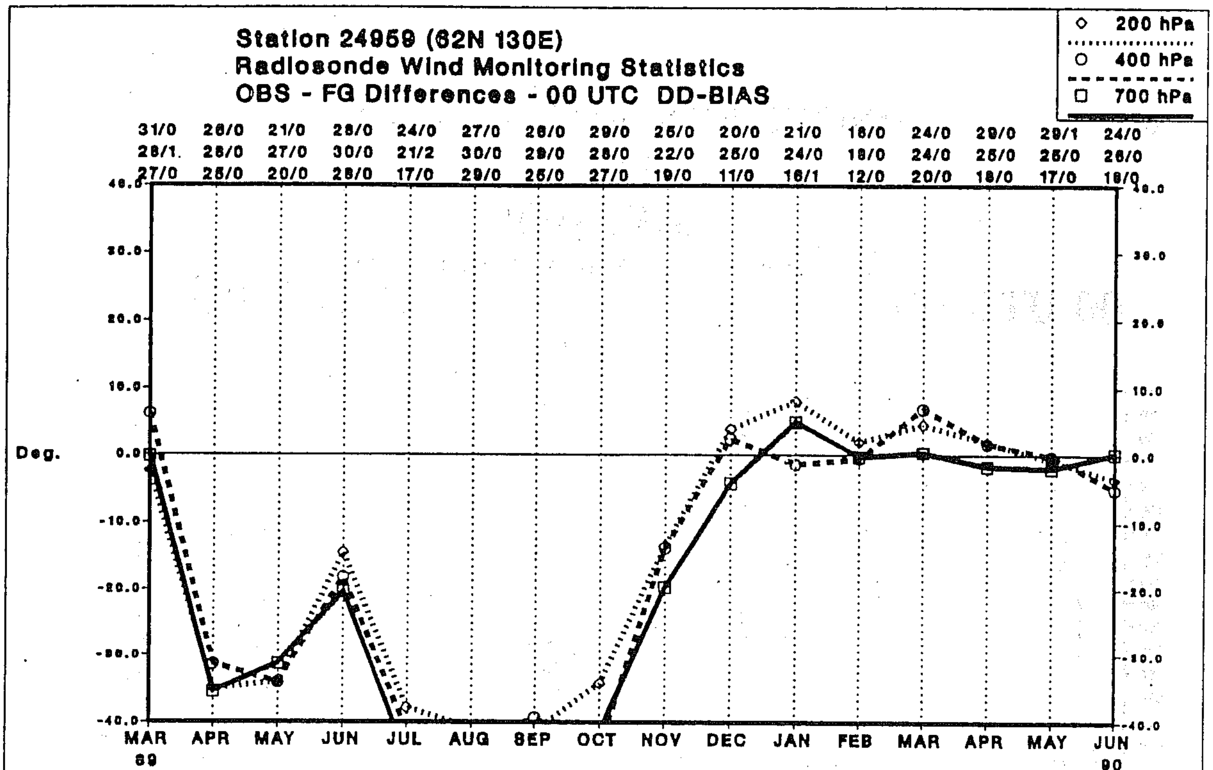


Figure 16 : two examples of corrections further to feed-back to operators: geopotential bias at station 12982, wind direction bias at station 24959.

b)


Station 24959 (62N 130E)
Radiosonde Wind Monitoring Statistics
OBS - FG Differences - 00 UTC DD-BIAS
200 hPa
400 hPa
700 hPa
Deg.
MAR 89
APR
MAY
JUN
JUL
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SEP
OCT
NOV
DEC
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MAR
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MAY
JUN 90

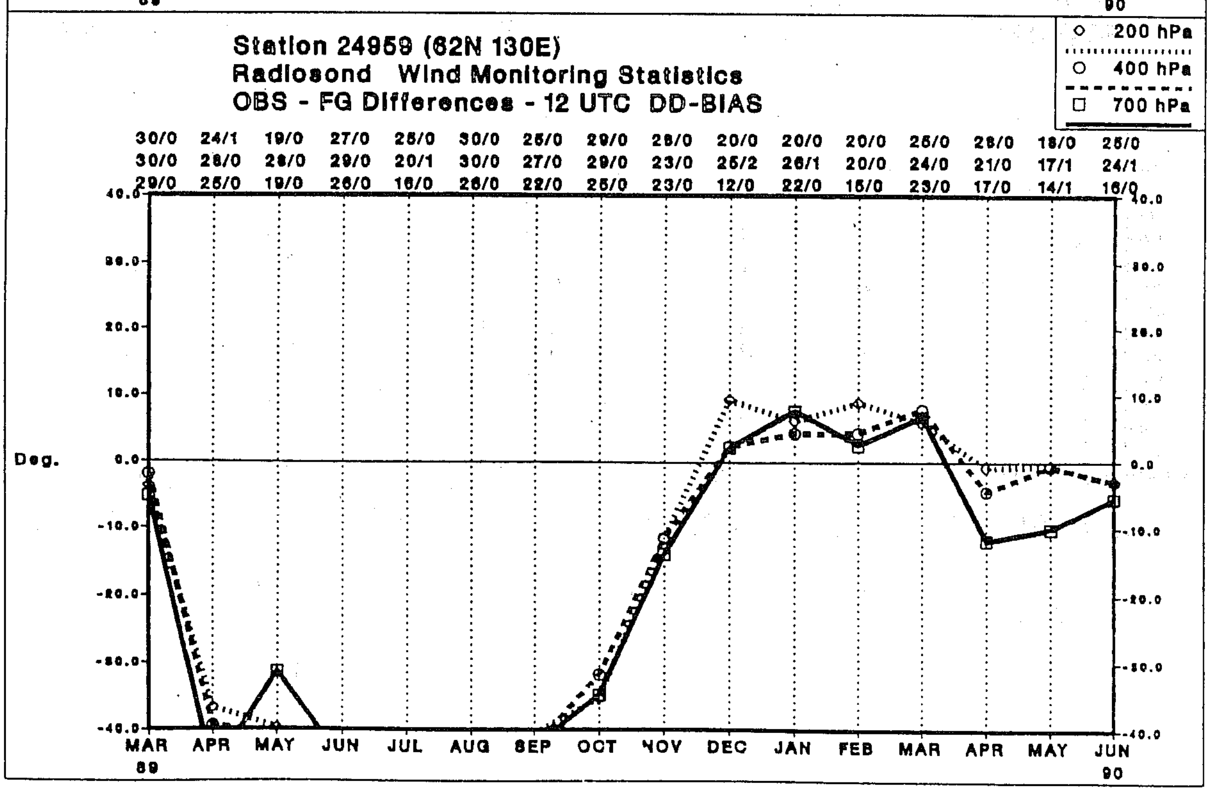
Station 24959 (62N 130E)
Radiosond Wind Monitoring Statistics
OBS - FG Differences - 12 UTC DD-BIAS
200 hPa
400 hPa
700 hPa
Deg.
MAR 89
APR
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Figure 16b

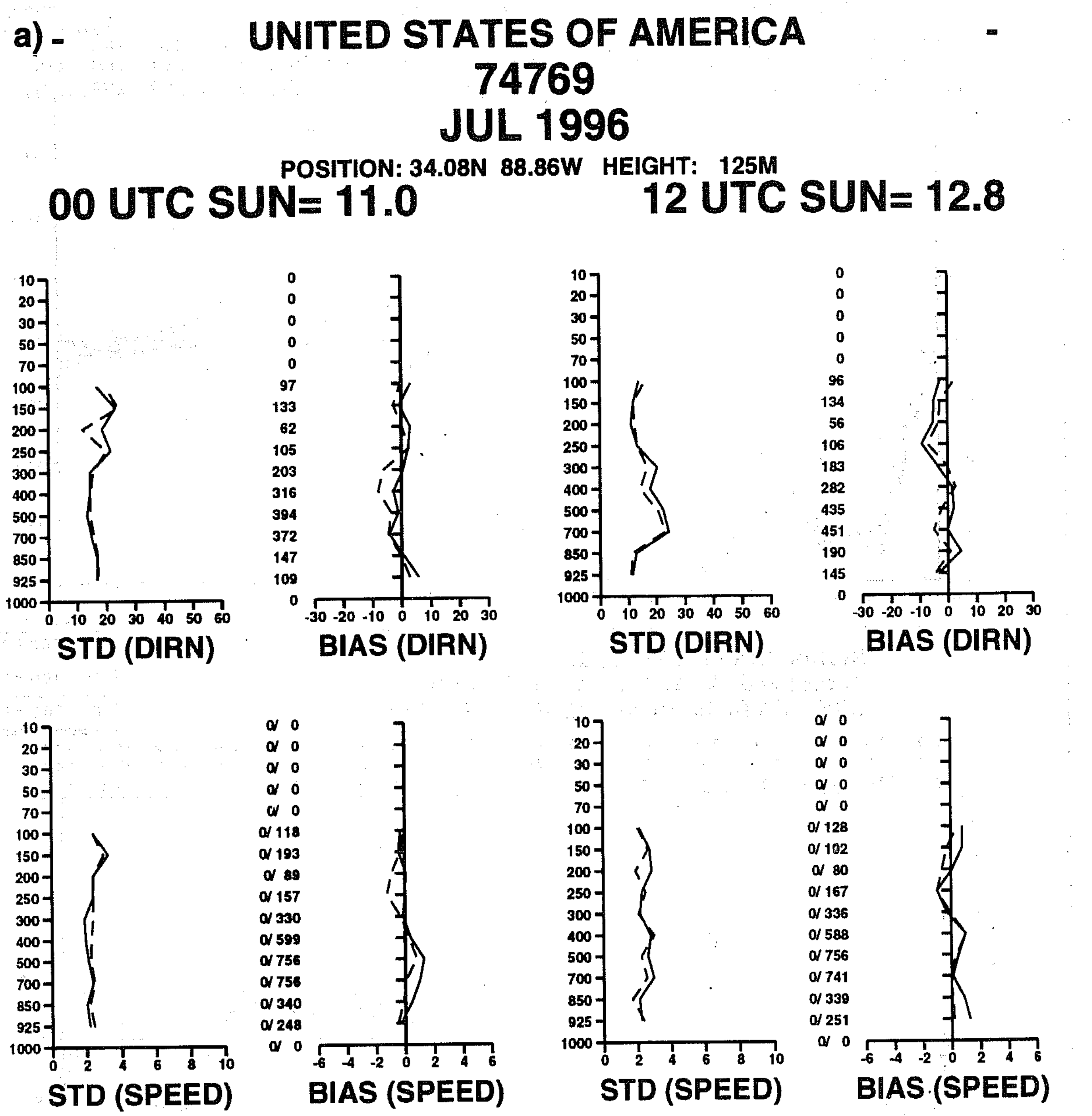

Figure 17 : comparison between a profiler system (74769) and a neighbouring conventional radiosonde station (72230).

b) - **UNITED STATES OF AMERICA** **-**

72230

JUL 1996

POSITION: 33.17N 86.77W HEIGHT: 178M

00 UTC SUN= 9.1 **12 UTC SUN= 14.2**

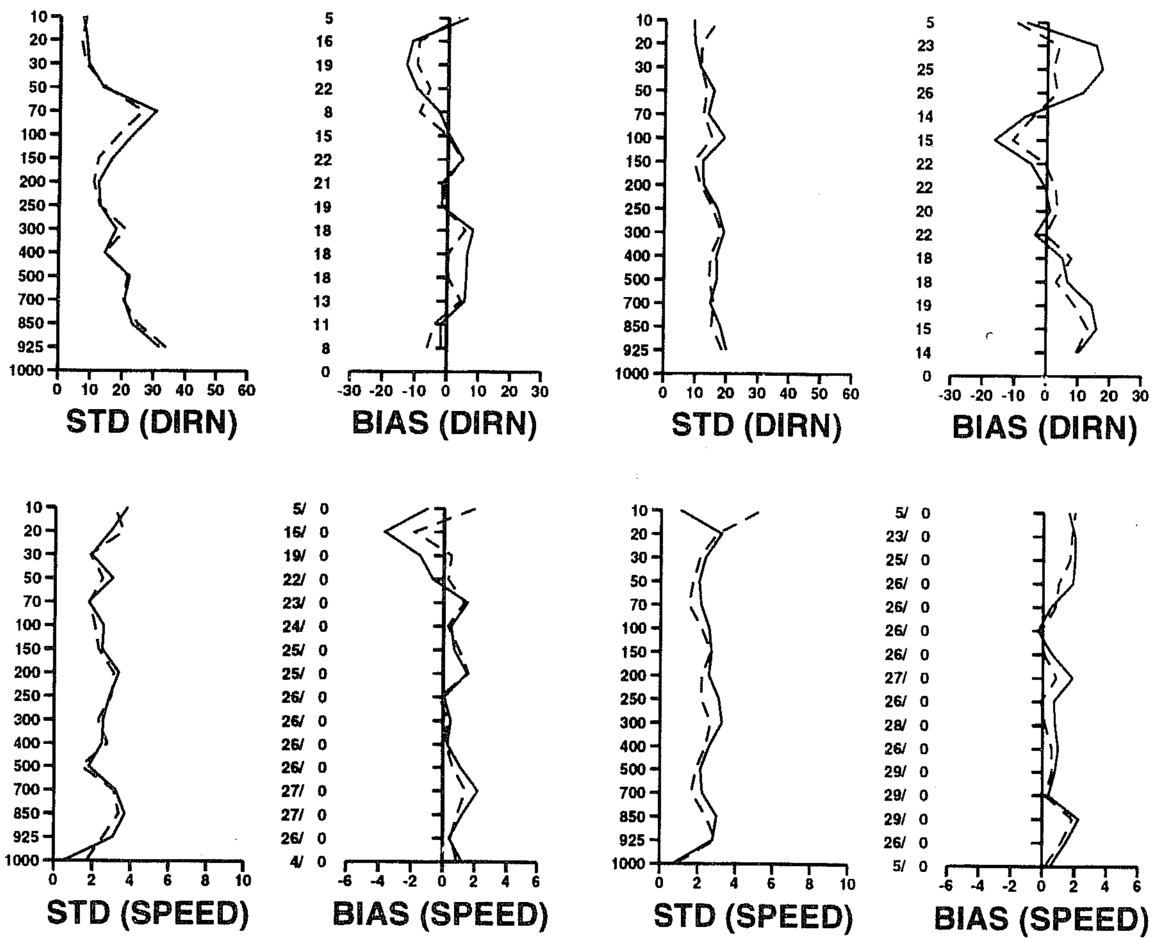

Figure 17b