Operational Monitoring of Satellite Data and its Availability

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Abstract

The availability and quality of satellite data are discussed in the context of usage in Numerical Weather Prediction (NWP). Monitoring techniques based on comparisons with short range forecasts and earth based observational platform data are described.

1 Introduction

In comparison with earth based observational platforms, satellites offer substantial improvements in the temporal and spatial availability of meteorological data. For example, the TOVS (TIROS-N Operational Vertical Sounder) instruments on the NOAA series of polar orbiting satellites provide large volumes of radiance or temperature/humidity data over areas where there are few conventional data available for NWP. Likewise, the geostationary satellites provide cloud motion wind data (CMW) which are particularly important in the tropical regions.

Quality is monitored by comparing observations with either validating short range forecast fields or collocated data from other platforms.

2 Availability

The TOVS units on board the polar orbiting NOAA satellites scan a swathe of the atmosphere on each orbit, covering the complete globe over a period ~12 hours. A typical coverage chart for the 120 km resolution data received at ECMWF and screened for the NWP analysis is shown in figure 1. Similarly, the 4 geostationary satellites (GOES, METEOSAT, INSAT and HIMAWARI) provide CMW data with quasi uniform coverage over large areas centred on the equator (figure 2).

In contrast, the traditional earth based observational network provides a less generous space and time coverage. For example, the upper-air network, which is the main source of high quality data for NWP, is largely concentrated in the northern hemisphere. The density of observations over Europe and N. America is adequate but over the oceans and particularly in the southern hemisphere, it is quite poor (figure 3). Furthermore, TEMP/PILOT data are usually only available at the main synoptic hours (00, 06, 12 and 18 UTC) with many stations committed to just 1 report per day.

Similar deficiencies occur with aircraft wind/temperature data (figure 4): the observations are clustered around established flight tracks with few data available over large areas in the southern hemisphere and over Asia.

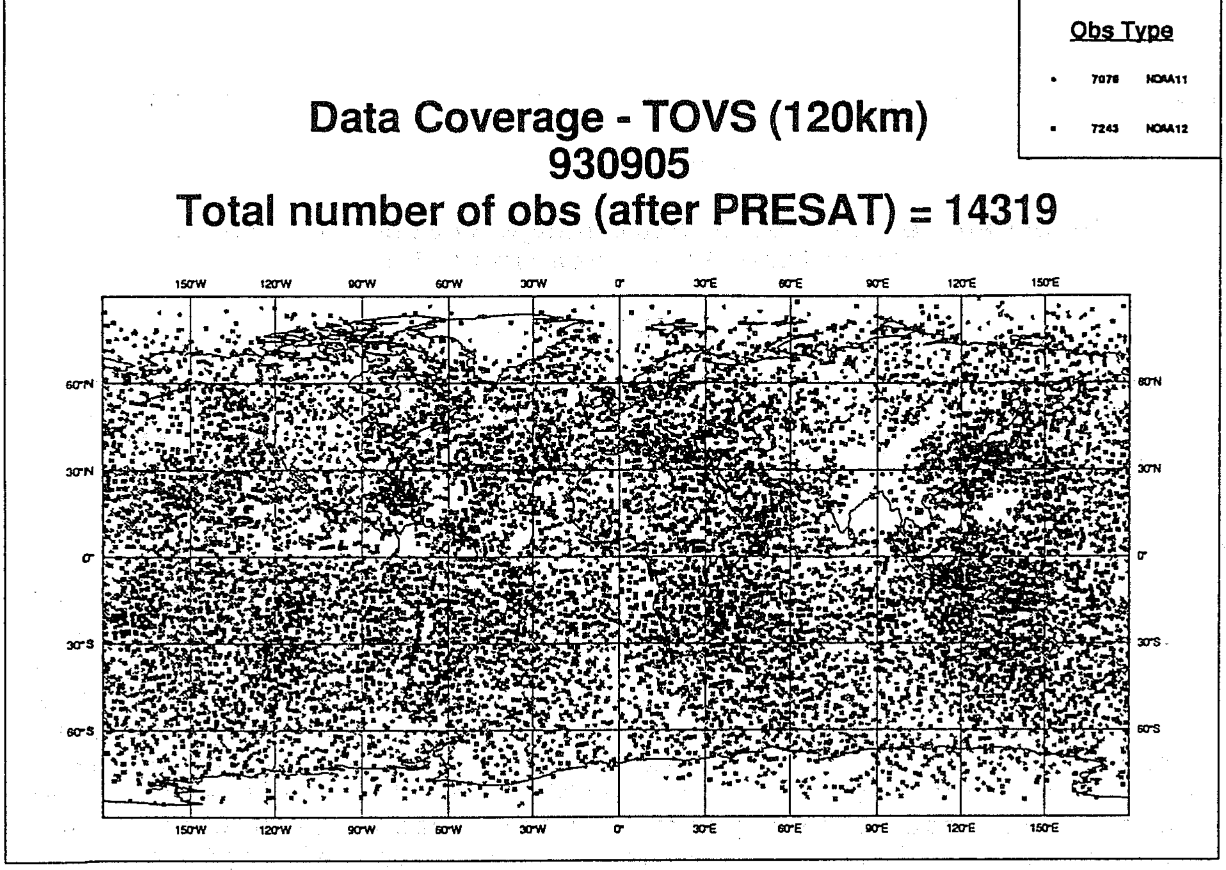


Fig. 1 Typical 24 hour coverage of screened TOVS data received at ECMWF.

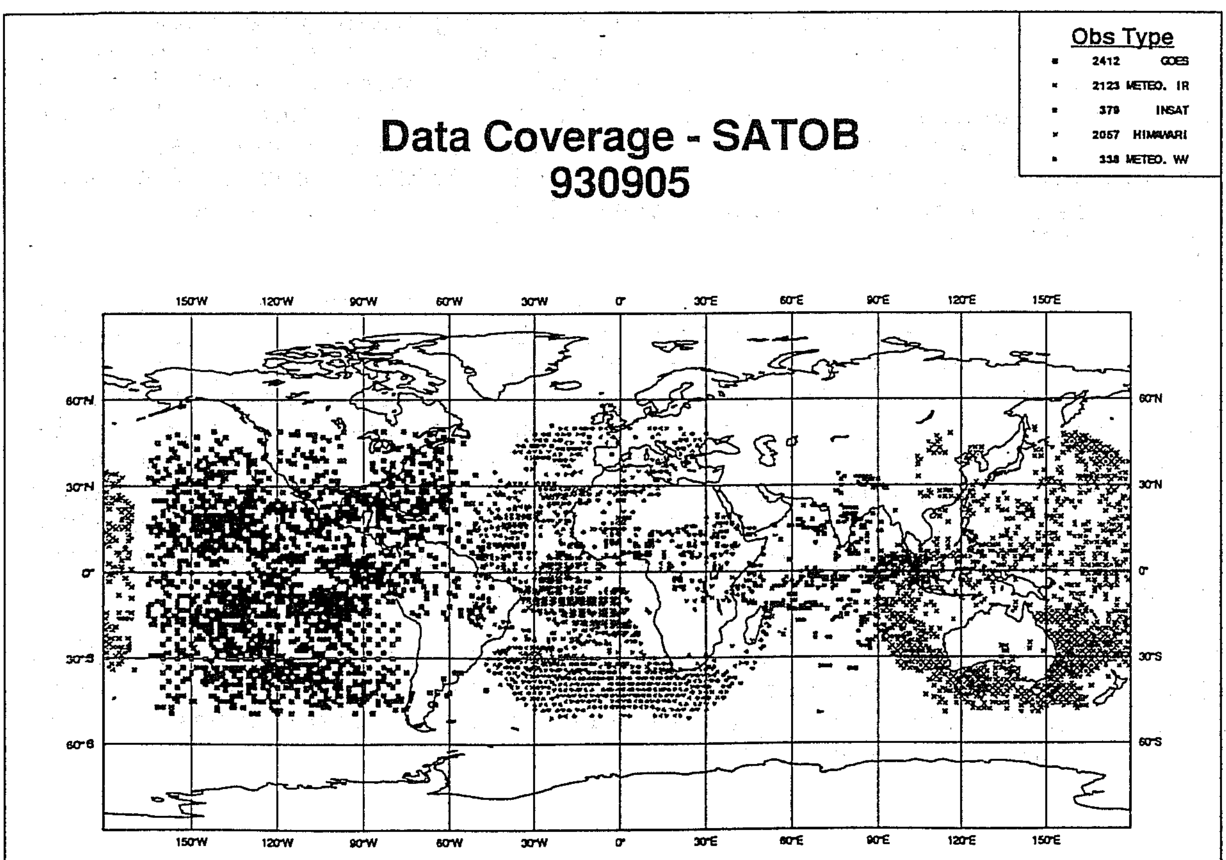


Fig. 2 Typical 24 hour coverage of SATOB received at ECMWF.

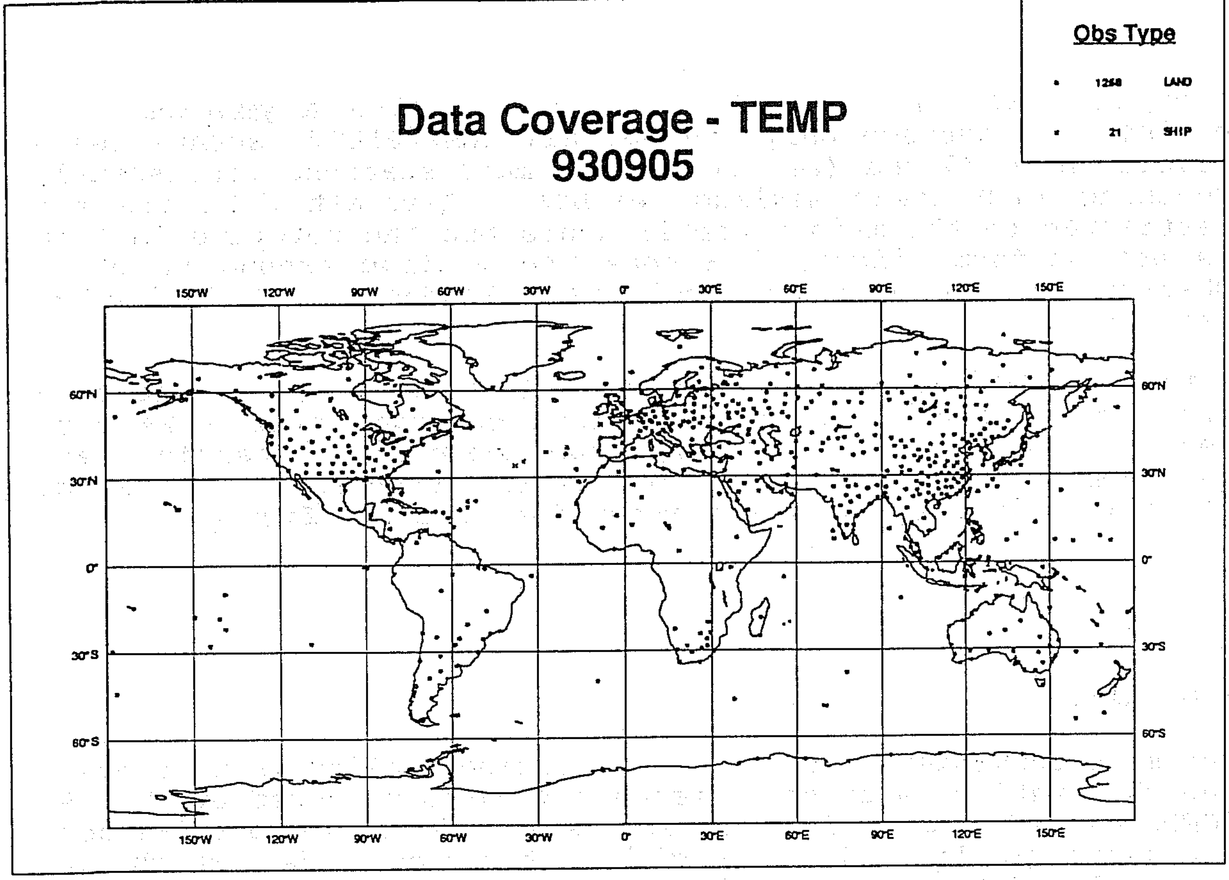


Fig. 3 Typical 24 hour coverage of TEMP data received at ECMWF.

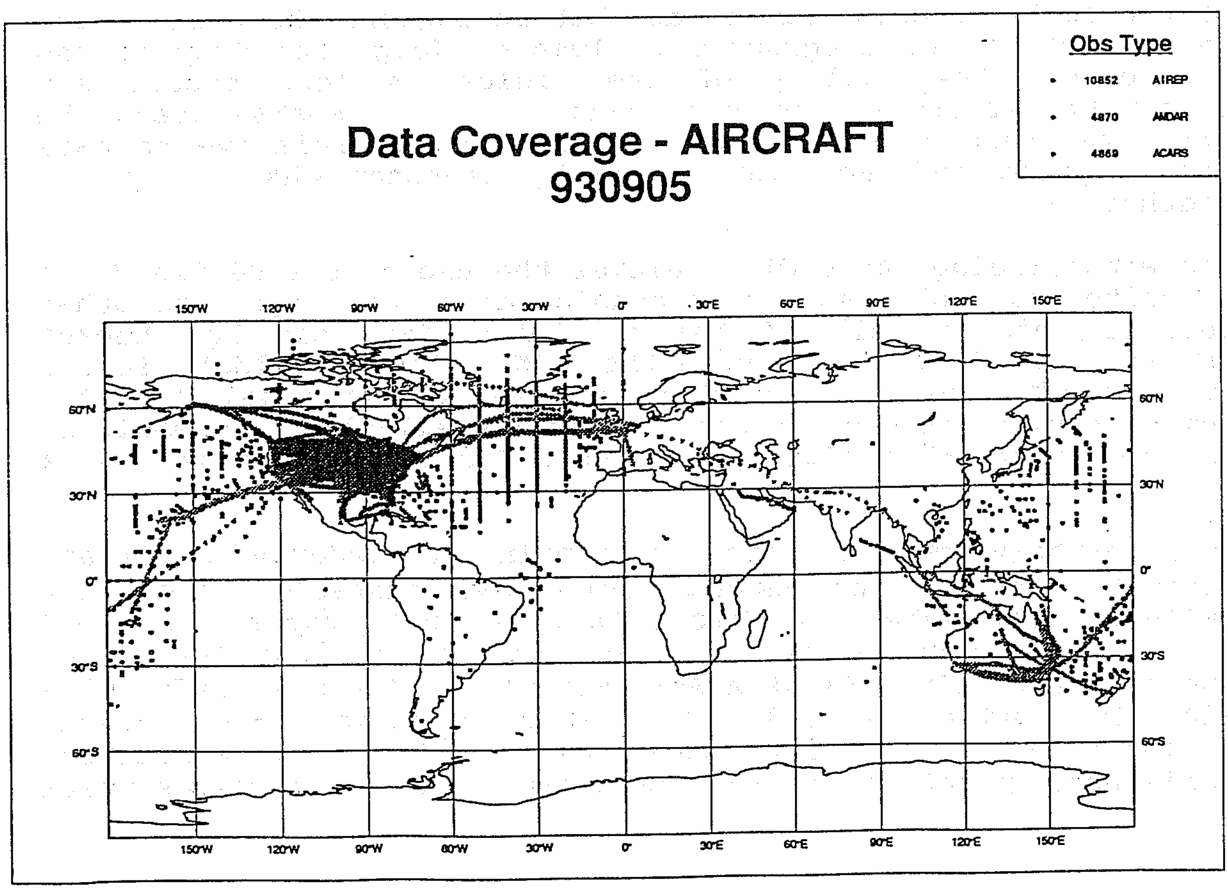


Fig. 4 Typical 24 hour coverage of aircraft data received at ECMWF.

Lack of data in the vertical plane is also a problem. For example, on average only ~50% of all TEMP/PILOT ascents reach levels above 30 hPa (see figure 5), many stations consistently reaching much lower maximum heights. Aircraft data are not restricted to the main synoptic hours but the coverage in time is not uniform (figure 6 - note the maximum around 00 UTC). Observations are mostly at cruising altitudes around 200-300 hPa (figure 7).

Satellite data meet some of these deficiencies, providing good areal and, with TOVS, good vertical coverage over a 24 hour period (figure 8). However, the complex processing and telecommunication overheads are often responsible for large variations in the day to day reception of data (figure 9).

3 Quality

The most convenient method for monitoring quality is to compare the observations with short range forecasts produced by NWP. At ECMWF these background or 'first-guess' (FG) fields are 3-9 hour forecasts produced by the global forecast model which are interpolated in space and time to compare with observations. The differences between the observations and the FG fields, averaged over a suitable time period, are used as a measure of data quality (Hollingsworth *et al*, 1986).

The justification of the method depends on the errors of the FG fields being comparable to those of high quality observations. These conditions are generally true for the ECMWF fields, particularly in data rich areas, but in regions where there are large diabatic or orographic influences (e.g. the Tropics and Antarctica) the quality of the fields is less secure and systematic errors are known to occur. In data sparse areas the error variance of the fields will be greater relative to data rich regions and more influenced by seasonal changes in the weather.

Not withstanding these difficulties the use of the FG fields as a monitoring tool possesses a considerable advantage over other methods: usually all of the available data can be checked (surface level to 10 hPa with the ECMWF global fields). In the upper stratosphere, where there are few conventional data for comparison, it is usually the only tool available. An example of the use of the FG fields applied to CMW data is shown in Figure 10.

An alternative method, which is in principal independent of any forecast model, is to compare, using some suitable collocation 'window', the satellite data with other data types e.g. TOVS against TEMP temperature/moisture data, CMW against TEMP/PILOT and aircraft (AIREP/AMDAR/ACARS) wind data. The main difficulty lies in finding suitable collocation material. For reasons discussed previously, few data will be available in the southern hemisphere, particularly over the oceans, and collocation samples

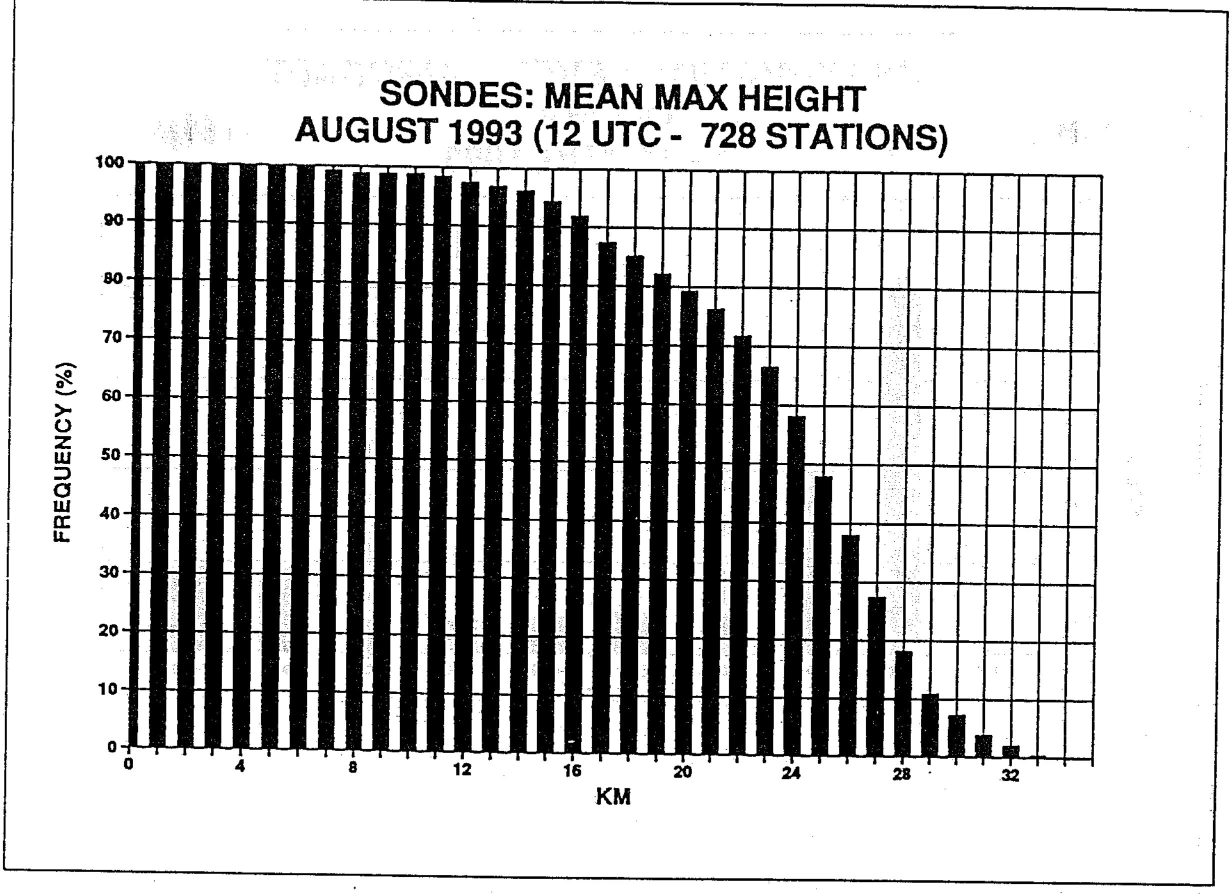


Fig. 5 Cumulative frequency of the mean maximum reported height for all 12 UTC sonde (TEMP) ascents in August 1993.

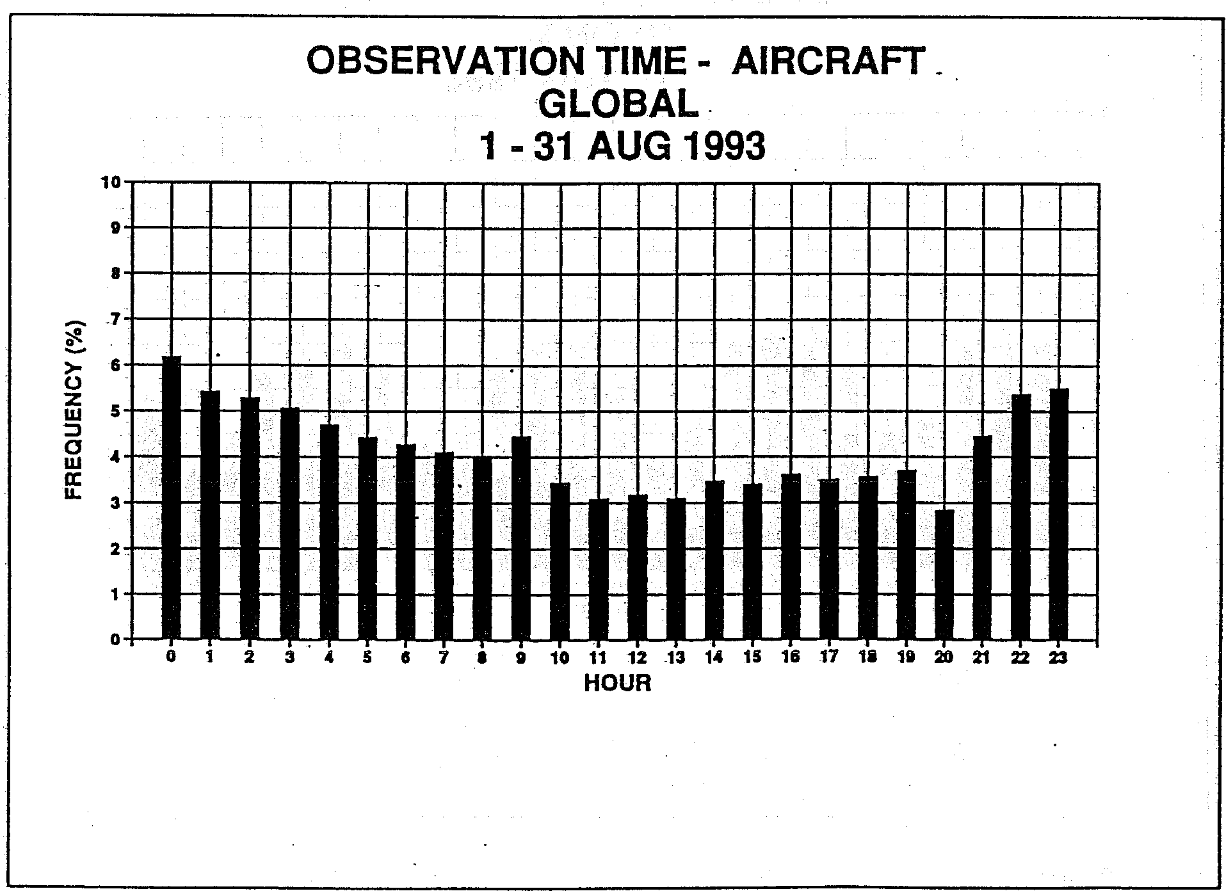


Fig. 6 Availibity of aircraft data as a function of observation time.

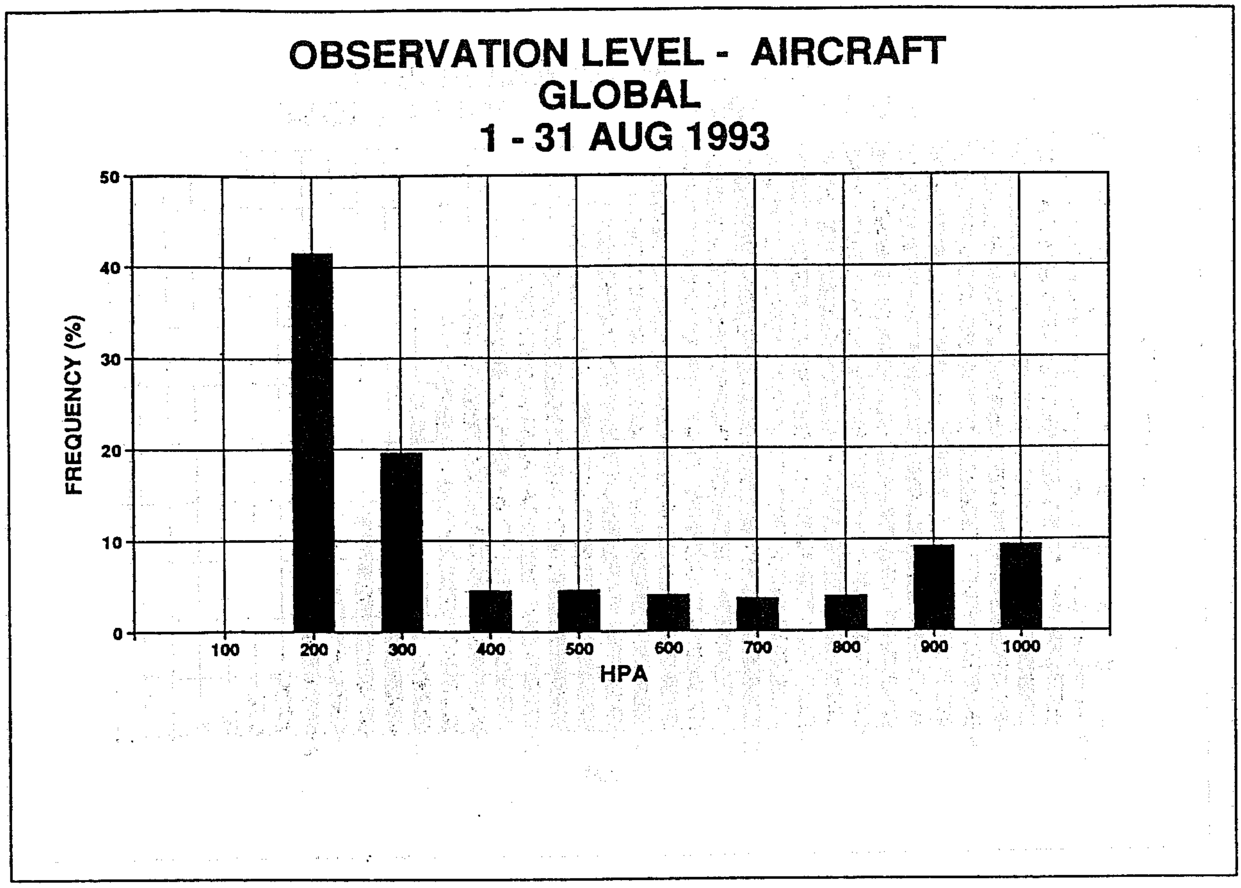


Fig. 7 Availibity of aircraft data as a function of observation level.

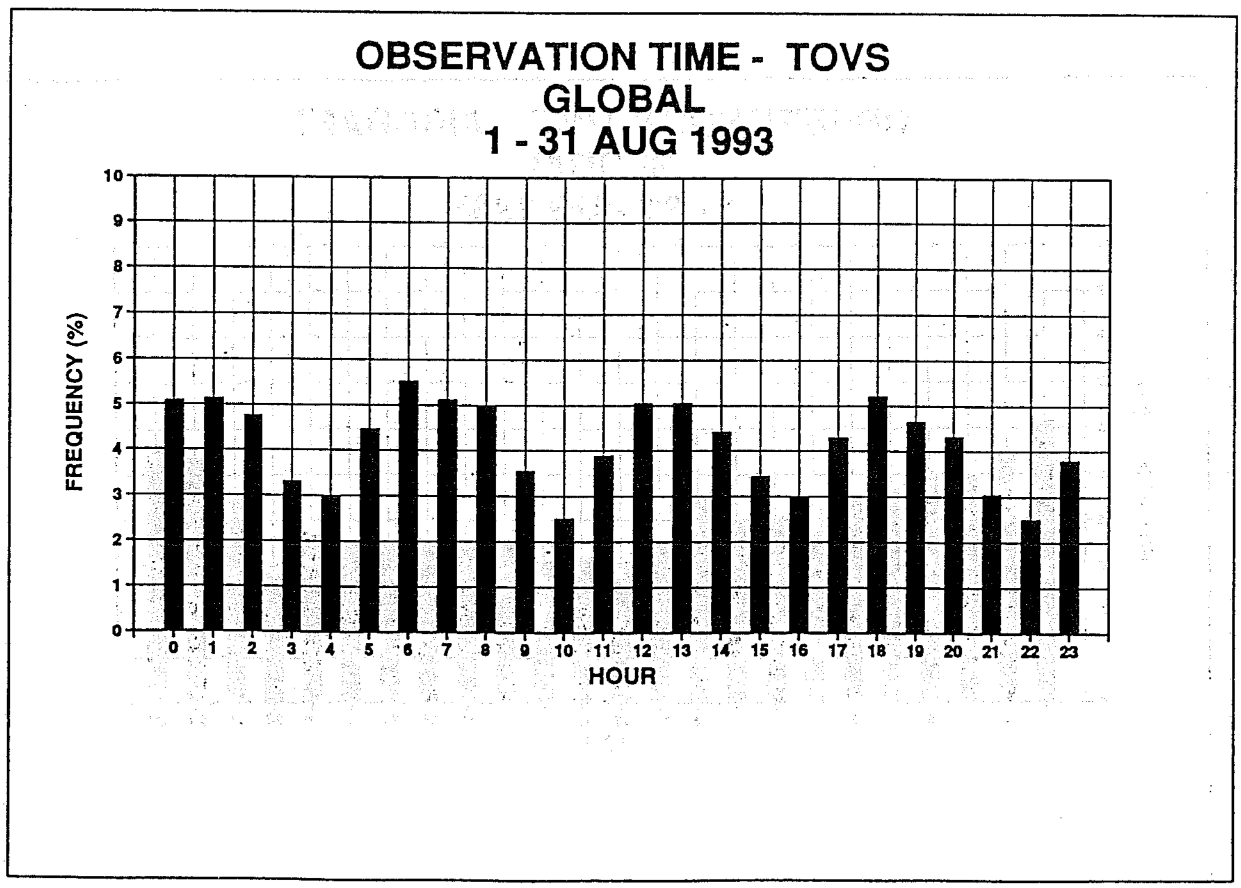
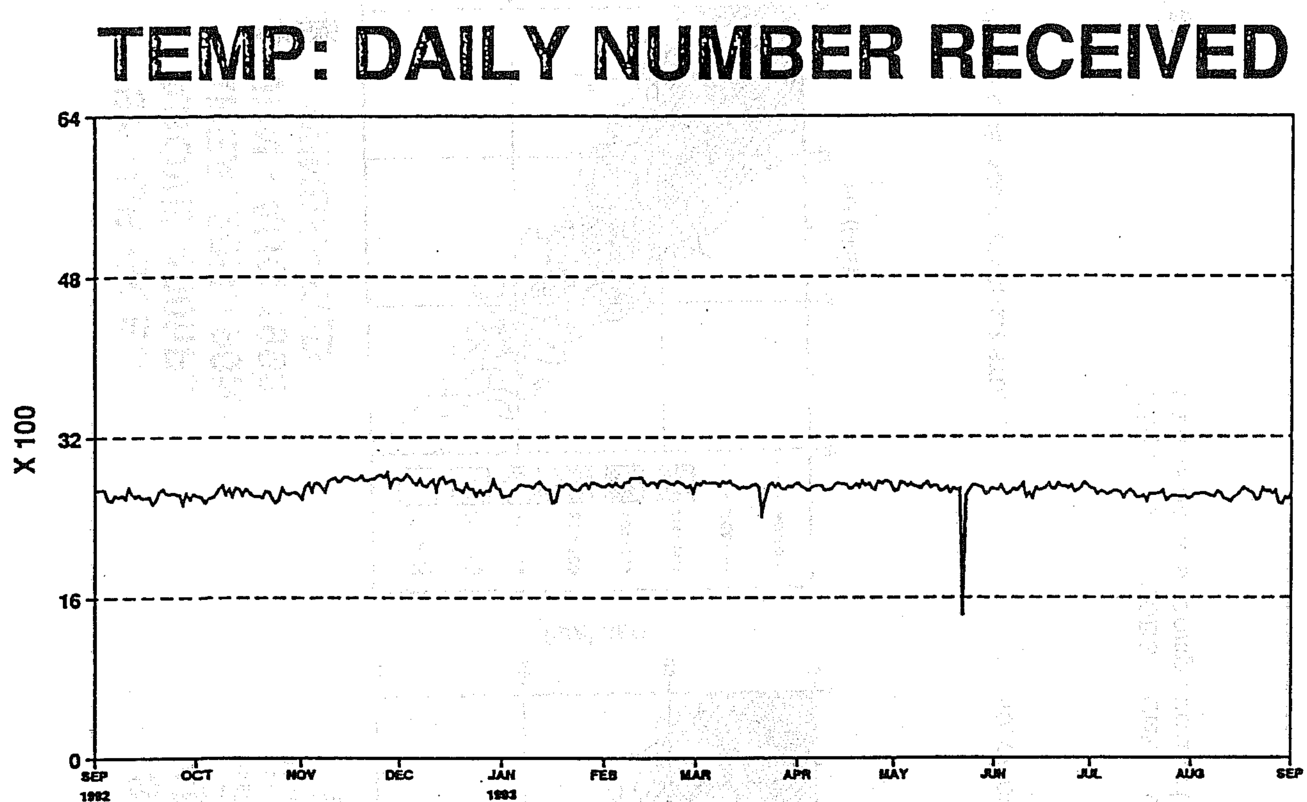


Fig. 8 Availibity of TOVS data as a function of observation time.



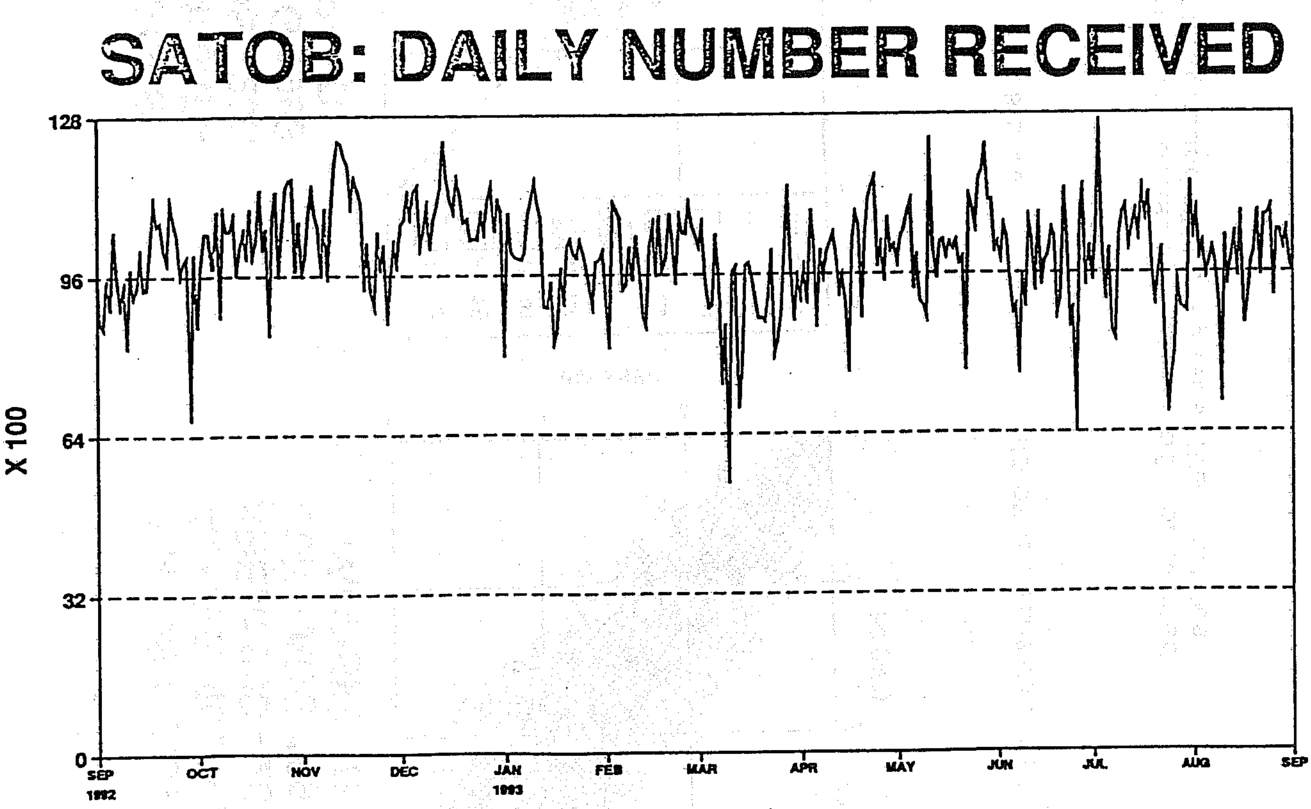


Fig. 9 Reception of TEMP (top) and SATOB (bottom) data at ECMWF over a 1 year period.

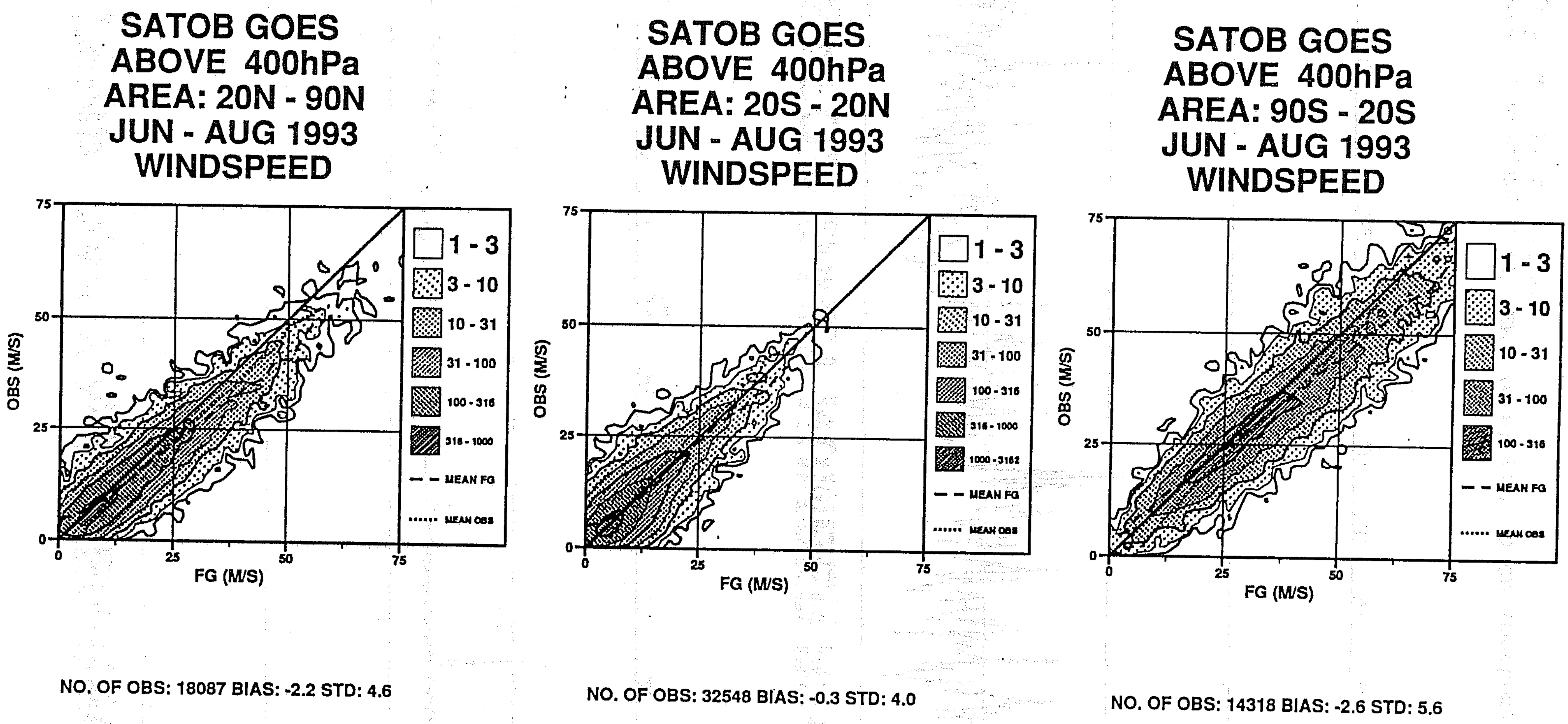


Fig. 10 GOES CMW verification: density plot of observed windspeeds compared with the background/first-guess (FG) values.

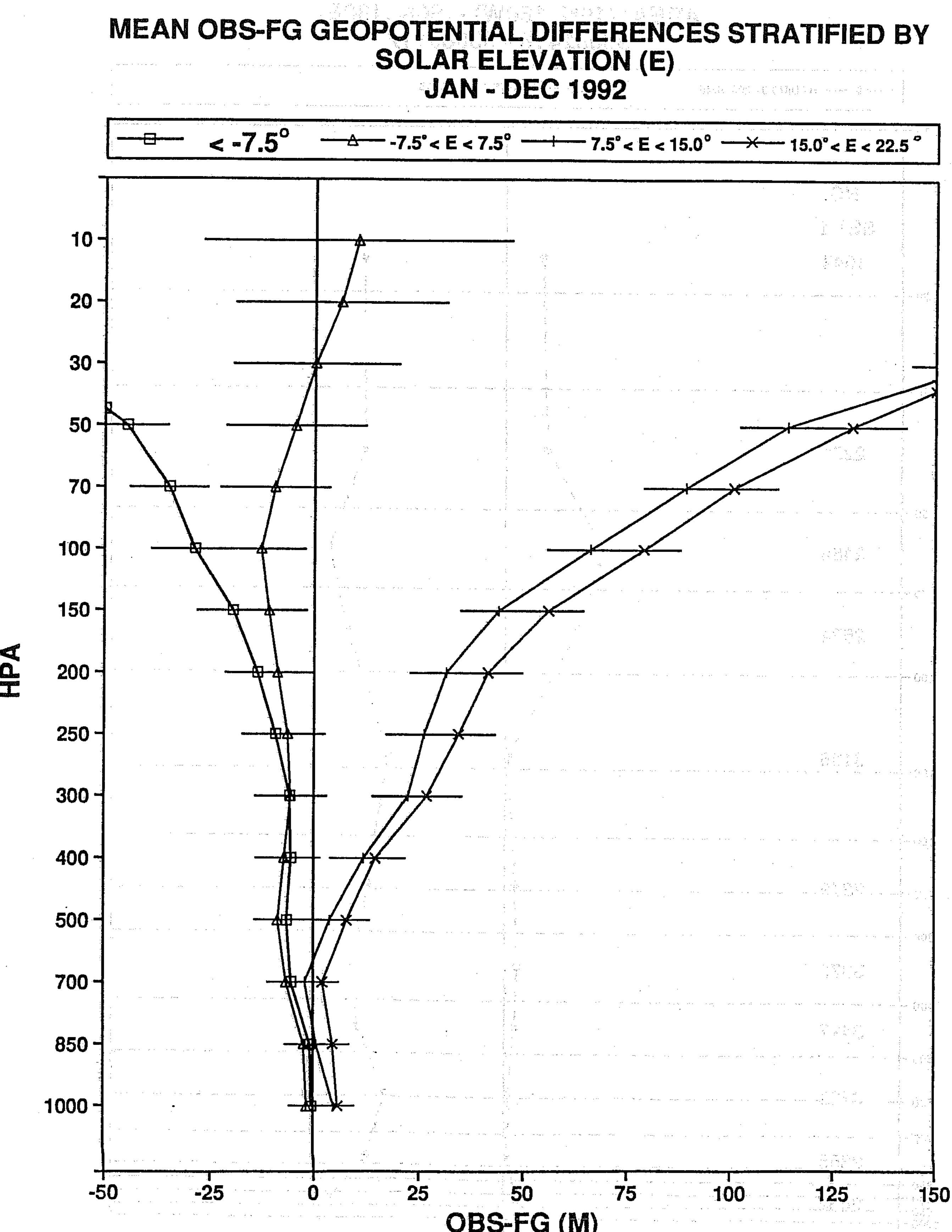


Fig. 11 Example of sonde data heavily influenced by radiative heating/cooling effects. Data are from the 00/12 UTC ascents in 1992 stratified by the solar elevation (degrees - negative values at night) at the station. The bias and standard deviation (horizontal bars) values are based on departures from the background/first-guess (FG) values.

TEMP/TOVS COLLOCATIONS
NOAA-11 120KM RESOLUTION - ALL SOUNDINGS
AREA: (10N ,180W) - (90N ,180E)
93082418 - 93083112

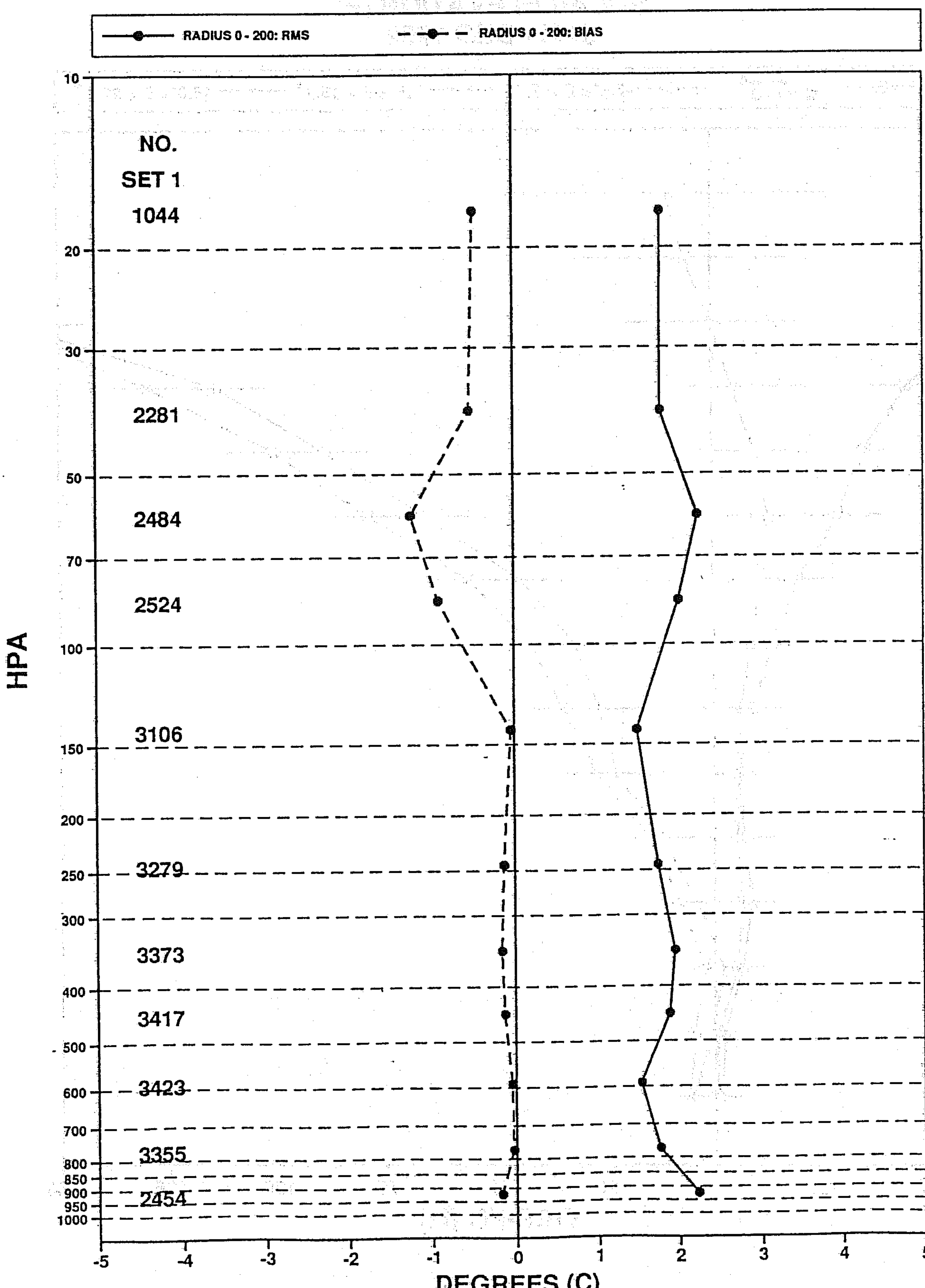


Fig. 12 Verification of NOAA-11 TOVS temperature/thickness data in the northern hemisphere using collocated TEMP data. The collocation 'window' is ±3 hours in time and 200 km horizontal radius. The mean (dashed line) and rms (solid line) difference values are shown.

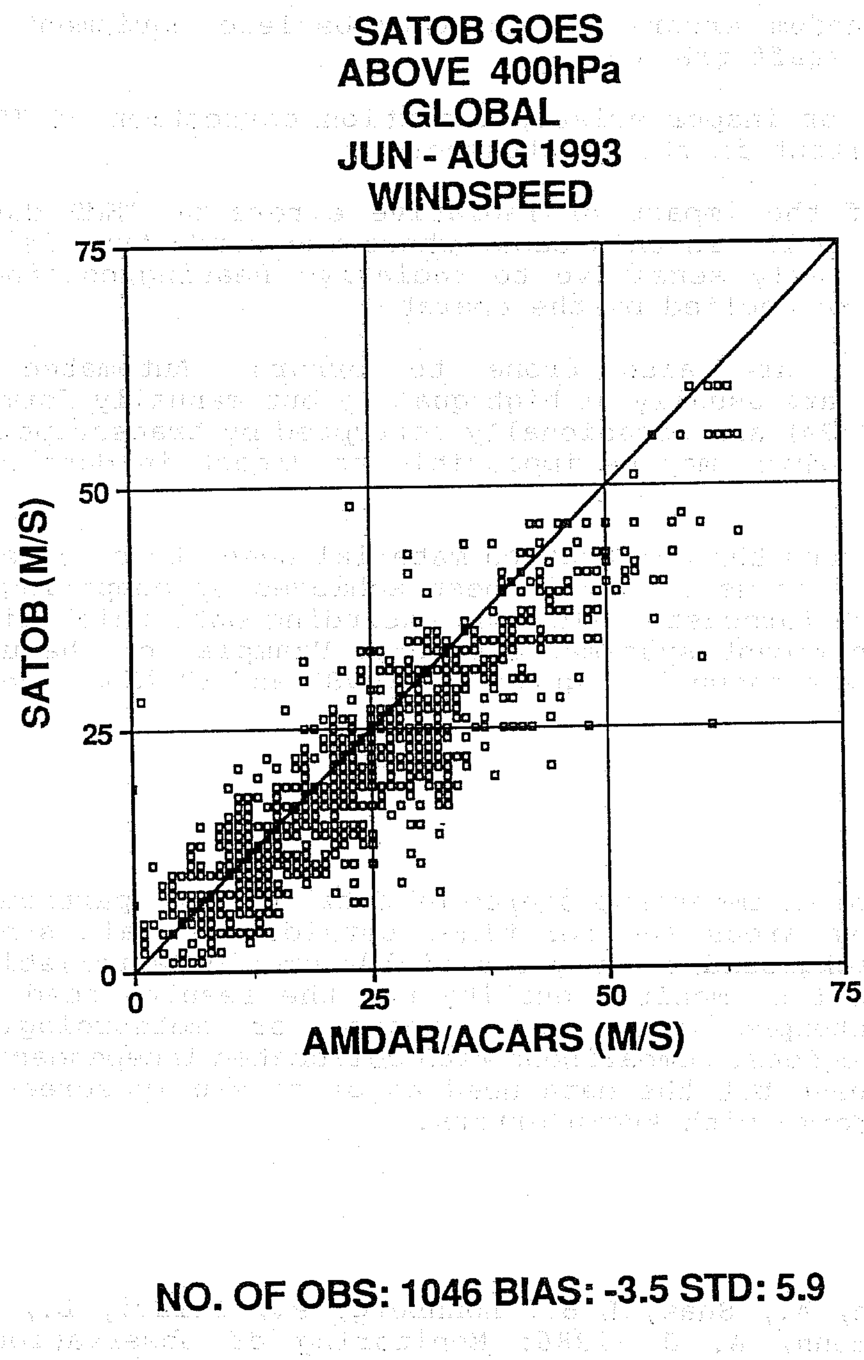


Fig. 13 GOES CMW verification: observed windspeeds compared with collocated automated aircraft wind data (AMDAR and ACARS). The collocation 'window' is ±1.5 hours in time, ±25 hPa in the vertical and 150 km horizontal radius.

will be heavily grouped around the main synoptic hours (TEMP/PILOT) or flight times/tracks (aircraft data).

The quality of the collocation data needs also to be addressed. Some upper-air observations are of very poor quality for the following reasons.

- Large random errors due to old/obsolete equipment or inadequate staff training.

- Lack of, or inappropriate, radiation correction of TEMP data (important in the stratosphere).

An example of the impact of radiative errors on TEMP data is shown in figure 11. In this case, where the sonde type is known to be particularly sensitive to radiative heating/cooling, no corrections are applied by the operator.

Aircraft data are also prone to errors. Automated data (AMDAR/ACARS) are usually of high quality but manually formatted products (AIREPs) are occasionally corrupted by transcription or coding errors which may be impossible to detect in data sparse areas.

For these reasons the collocation material needs to be carefully screened prior to use. This is best achieved by comparing data against the FG forecast fields and excluding data which display gross or significant systematic errors. Examples of the use of collocations are shown in figures 12 (TOVS) and 13 (CMW - compare figure 10).

Conclusion

Satellites are an important source of data for NWP, particularly in data sparse areas and for times outside the main synoptic hours. NWP background/first-guess fields provide a reliable and convenient tool to monitor quality but the results need to be carefully interpreted in data sparse or meteorologically 'difficult' regions. Comparisons with collocated independent data may also be used but the data need to be carefully screened to exclude platforms with known errors.

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. Review. (114) 861-879.