Monitoring of cloud-motion winds at ECMWF

A. Radford

European Centre for Medium-Range Weather Forecasts

Shinfield Park, U.K.

1. INTRODUCTION

The functioning of the global observing system and the quality of the observations are of vital importance for the performance of numerical weather prediction systems. This is particularly true for remotely sensed data where deficiencies tend to affect the performance of the forecasting system over large areas or even globally. It is therefore essential that the availability and quality of satellite data are monitored in both real-time and delayed mode in order to detect immediate problems or long term trend deterioration. ECMWF operates a global data monitoring system by comparing the observations to the first-guess (6-hour forecast) from the model in addition to cross-checking the observations from different data types. The ECMWF monitoring system was described by Delsol (1984) and Radford (1987).

In this paper recent monitoring results of the availability and quality of cloud-motion wind data are presented. Results for sounding data from the polar-orbiting satellites are described by Strauss elsewhere in these proceedings.

2. AVAILABILITY

Single-level cloud-motion winds are obtained from geostationary satellites of which there are currently four in operation - GOES (United States), METEOSAT (Europe), INSAT (India) and HIMAWARI (Japan) - each covering a circular field of view of around 55° radius centred over a point on the equator. Prior to 21 January 1989 there were two GOES satellites (GOES-east and GOES-west) covering an area from 180°W to 20°W, but on that date GOES-west died and GOES-east was subsequently moved further west.

The reporting practice (frequency and distribution of observations) varies between the different operations centres. For instance, reports are available from most satellites every 6 hours but INSAT observations are produced at 0600 UTC only; winds from METEOSAT are always associated with specific points on a pre-defined grid whereas those from GOES are usually on a 2.5° degree grid.

Figure 1 shows the typical 24-hour coverage of satellite wind data as received at ECMWF. Each symbol type represents one of the four satellites and each plotted symbol represents one or more observations received during the 24-hour period. The total number of observations for each satellite is displayed in the top right of the figure.

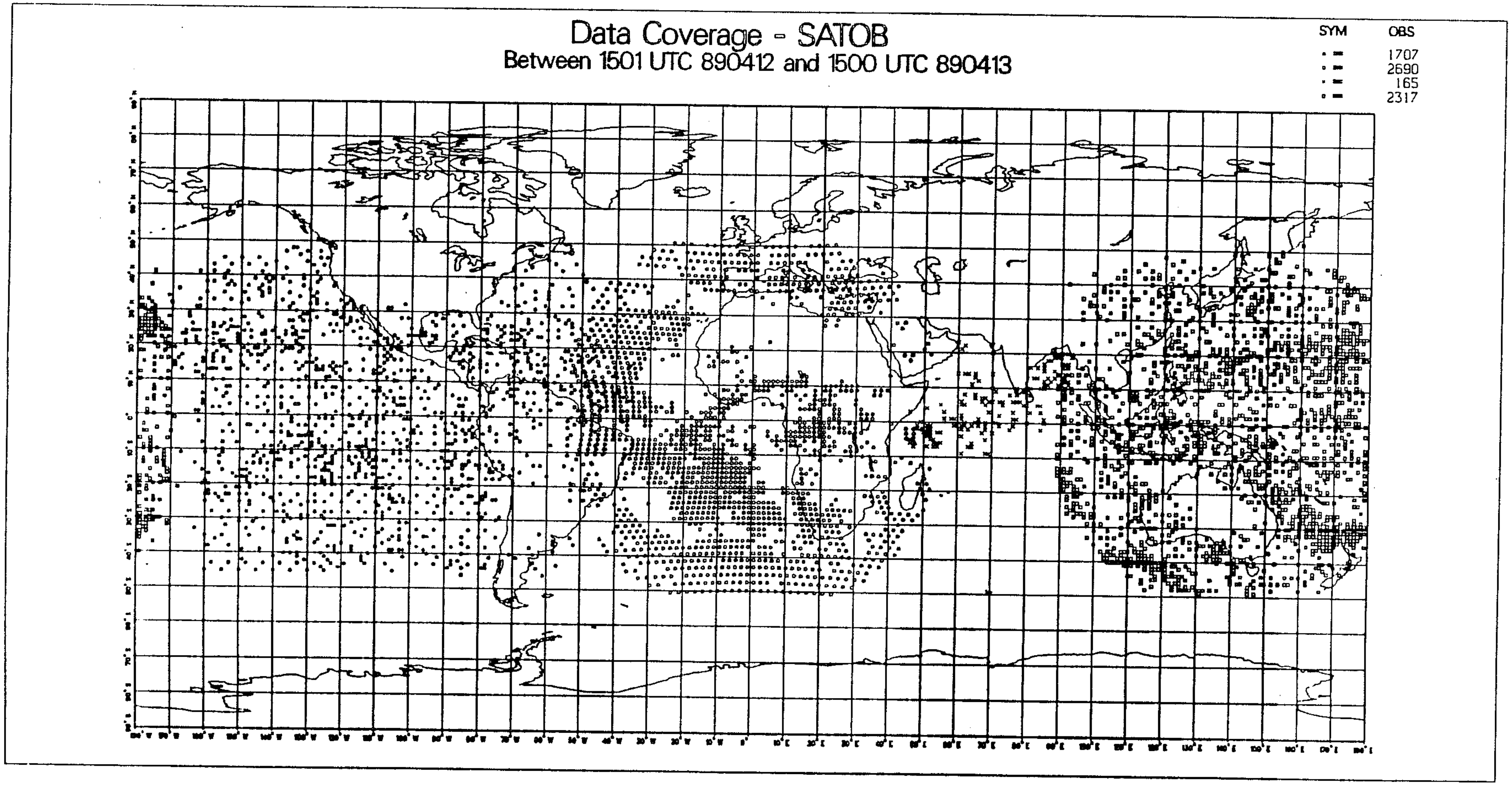

Fig. 1: Global data coverage of satellite wind observations for the 24-hour period from 1501 UTC 12 April 1989 to 1500 UTC 13 April 1989. Each symbol type represents observations from satellites according to the key:

- ● GOES (USA)
- o METEOSAT (Europe)
- x INSAT (India)
- ▫ HIMAWARI (Japan)

3. QUALITY

The quality of cloud-motion wind data is assessed in two ways. The first is with reference to the ECMWF first-guess fields (6-hour forecast), where the statistics will contain both observation and forecast errors. The second method is independent of the forecast model and uses statistics of collocated observations from other observing systems.

3.1 Observed minus first-guess statistics

As with other types of observations the principal method of measuring the quality of cloud-motion winds at ECMWF uses statistics of observed minus first-guess (OB-FG) differences accumulated over monthly periods. A convenient method of looking at the performance of satellite data is to average the statistics over latitude/longitude boxes, typically 5° square, and plot the mean OB-FG wind vectors or 'bias'.

Figure 2 shows the bias of the cloud-motion winds between 400 and 100 hPa obtained from METEOSAT for March 1989. A reference value of wind speed is plotted in the top right corner of the figure. An arrow is only plotted if 10 or more observations are used in that 5 degree square. For comparison the mean observed wind (derived from the cloud-motion wind observations) is shown in figure 3.

In general the bias vectors are small, although certain patterns are discernible. In particular in areas of strong flow - such as near the sub-tropical jet over northern Arabia - the cloud-motion winds exhibit a definite easterly bias, i.e. the observed winds are lighter than those in the first-guess fields. This is a well-known inherent problem with cloud-motion winds in the jet-stream regions, as discussed by Kållberg and Delsol (1986).

Another way of investigating the SATOB speed bias problem is to look at the distribution of the bias according to wind speed. Figure 4 displays the mean speed difference between METEOSAT wind observations and the ECMWF first-guess field in the form of histograms classified according to the wind speed of the first-guess (in bands of 10 ms^{-1}). The data used was from observations of upper level winds (above 400 hPa) for March 1989. The chart shows two histograms - one for all observations received (hatched shading) and the other for those observations actually used by the analysis (solid shading), i.e. those wind data which were not rejected. The numbers of observations for each set of data are given at the top of the graph.

It is clear that the speed bias of the cloud-motion winds increases almost linearly as the speed increases. It is also clear that the quality control procedures within the ECMWF data assimilation are successful in rejecting much of the biased data - 18% of the observations in the classes above 30 ms^{-1} were not passed to the analysis, reducing the effective bias from around 3.6 ms^{-1} to 2.0 ms^{-1}.

We have concentrated on statistics derived from METEOSAT observations. However the same effects are evident in data from the other satellites. Figures 5 and 6 show equivalent histograms for upper level winds from the United States GOES and Japanese HIMAWARI satellites and can be directly compared with figure 4. These charts imply that GOES winds are slightly more biased than METEOSAT winds while the Japanese HIMAWARI winds are significantly worse. The proportion of observations rejected (in the three highest speed classes) is 26% for GOES and 40% for HIMAWARI. The relatively poor quality of the HIMAWARI

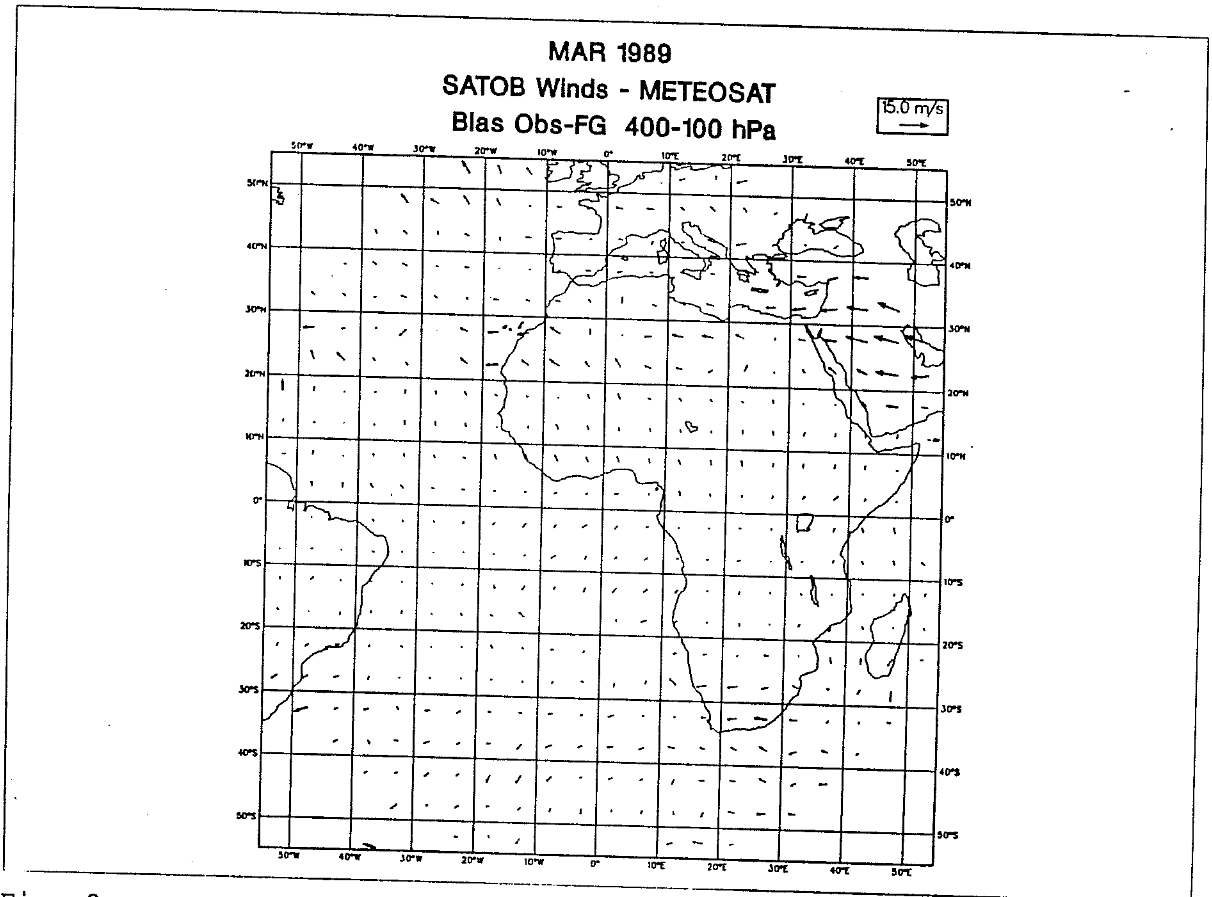

Fig. 2: Mean observed minus first-guess differences of vector wind from METEOSAT for March 1989 in the layer 400-100 hPa. Statistics are averaged over latitude/longitude boxes of 5° x 5°.

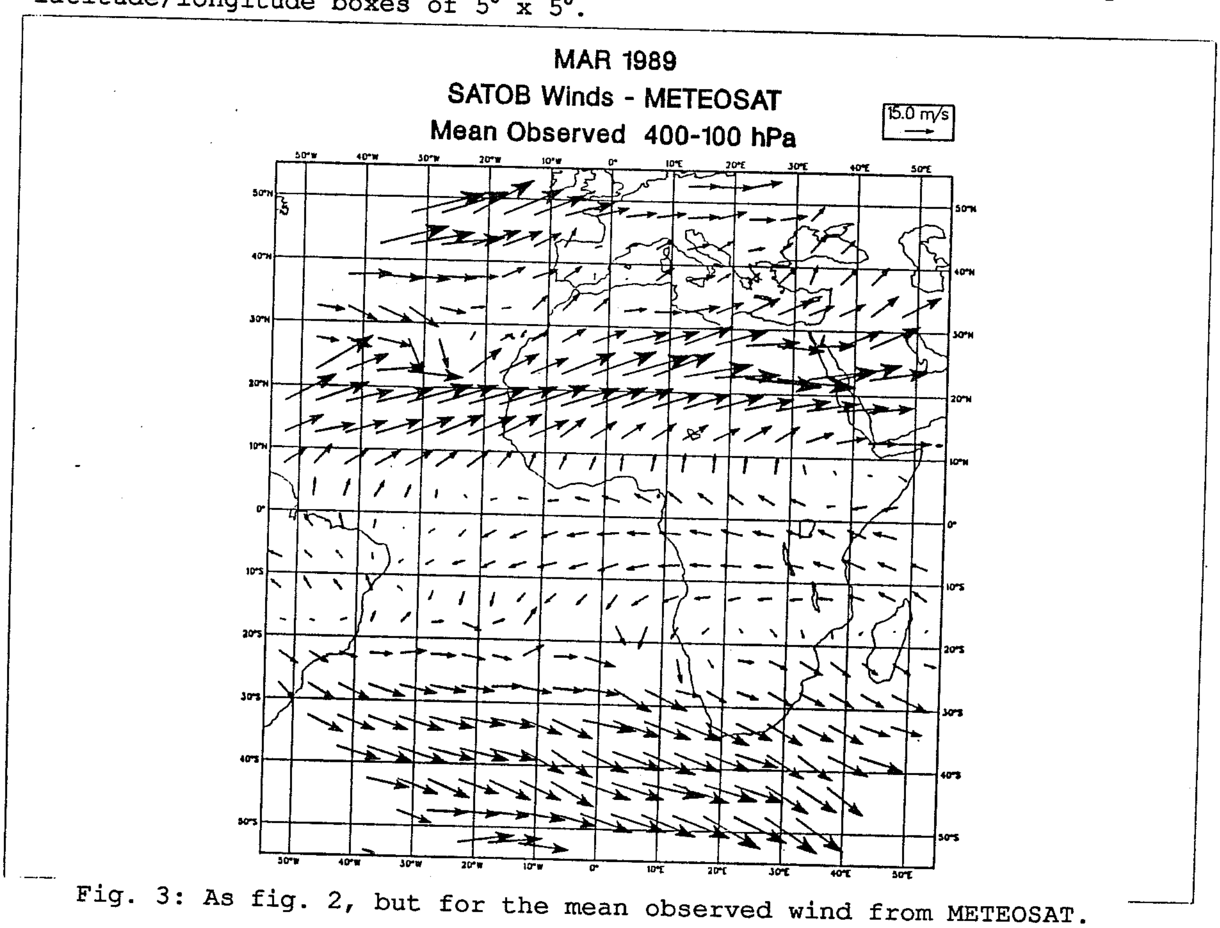

Fig. 3: As fig. 2, but for the mean observed wind from METEOSAT.

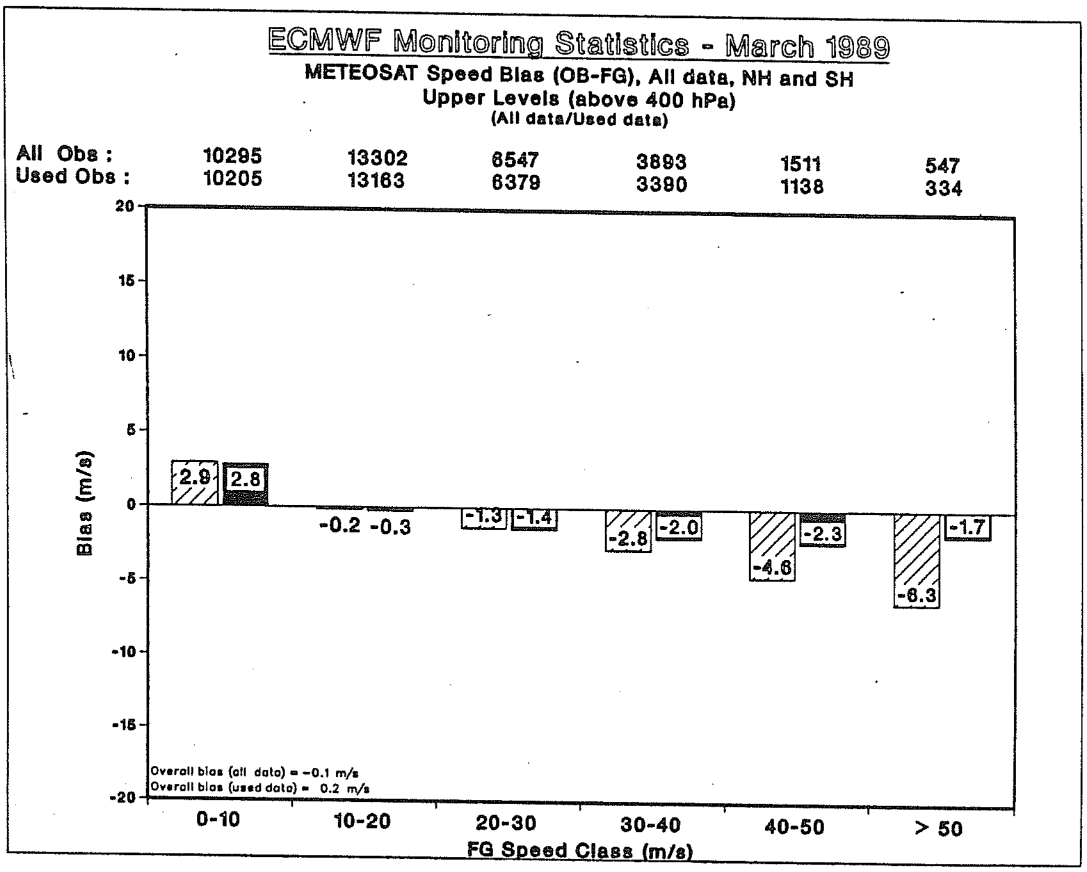

Fig. 4: Mean observed minus first-guess differences of wind speed from METEOSAT for March 1989 for upper levels. The statistics are presented in the form of histograms classified according to the first-guess wind speed. The hatched histogram refers to all data presented to the analysis, whereas the solid histogram refers only to those data used by the analysis. Units are ms^{-1}.

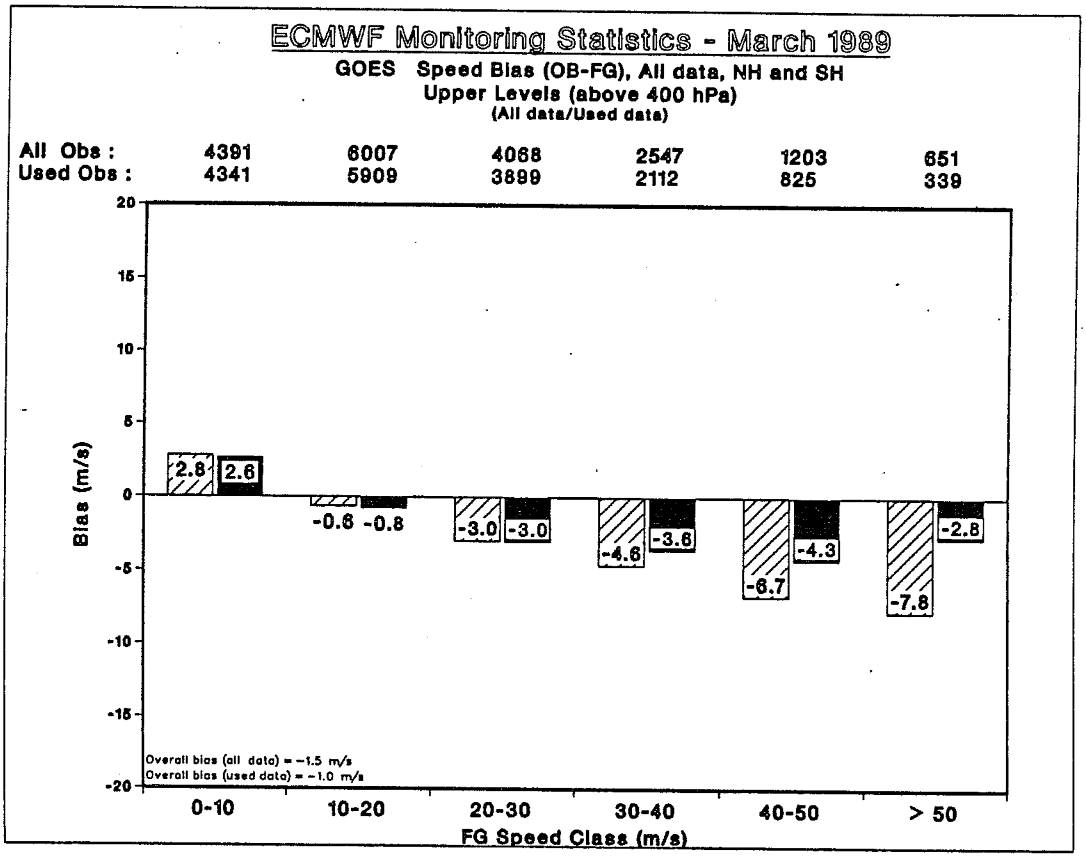

Fig. 5: As fig. 4, but for GOES.

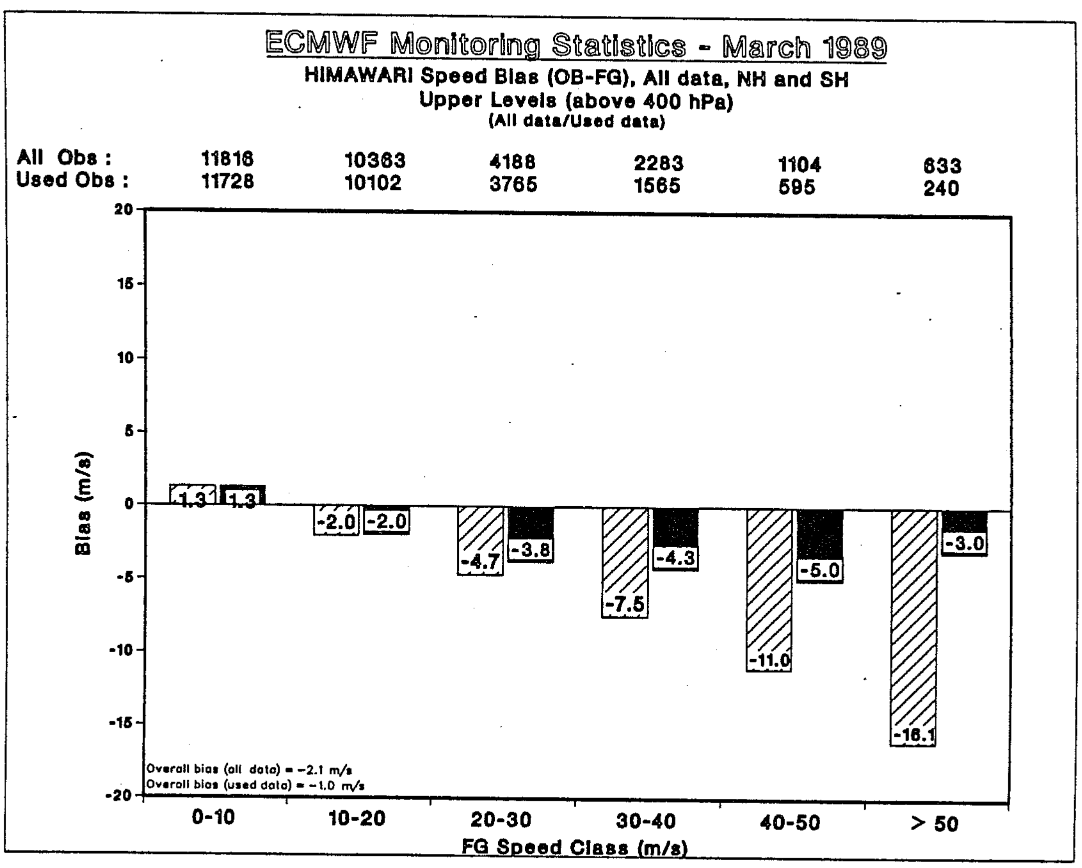

Fig. 6: As fig. 4, but for HIMAWARI.

data is almost certainly due to the climatological method of cloud height assignment (see paper by Fukui elsewhere in these proceedings).

A third tool used to monitor OB-FG differences is the scatter plot, of which figure 7 is an example. Wind speeds from HIMAWARI are compared with the first-guess speeds for all upper-level observations received during March 1989. The diagram clearly shows that the cloud-motion winds are heavily biased in areas of strong winds. The same signal may be seen in observations from medium levels although the general wind speed is naturally lower in this part of the atmosphere.

3.2 Collocation Statistics

An independent method of assessing the quality of cloud-motion winds is to compare them with neighbouring winds obtained from other observing systems, such as the global radiosonde network or aircraft reports. Once again a convenient method of comparing the performance of two observing systems is to average the statistics over latitude/longitude boxes and plot the mean vector difference for each box. Figure 8 is an example of such a map comparing global cloud-motion winds (SATOBs) between 300 and 200 hPa with observations from aircraft (AIREPs) for March 1989. The collocation 'window' used was 50 hPa vertically and 200 km horizontally, and the statistics have been averaged over boxes of 10^{o} square. A reference value of wind speed is plotted in the top right corner of the figure and an arrow is only plotted if there were ten or more collocations in that square.

The speed bias detected by the OB-FG statistics is confirmed when comparing the observations with aircraft reports, in particular for HIMAWARI between 30^{o}N and 40^{o}N. There is also evidence for a bias in the direction of METEOSAT observations near the northern boundary of its field of view, which can also be seen to a lesser extent in figure 2.

Scatter plots may also be produced to compare winds from two observing systems. Figure 9 shows a comparison between global cloud-motion wind speeds with observations from radiosondes and pilot balloons for March 1989. The collocation 'window' used was 50 hPa vertically and 200 km horizontally. The negative bias in the cloud-motion winds is once again clearly evident.

4. Observations from the Indian Geostationary Satellite (INSAT)

Cloud-motion winds from the Indian satellite are not currently used in the ECMWF analysis. Past studies at ECMWF (Akyildiz, 1984, and Radford, 1986) have shown the data to be internally inconsistent and generally of poor quality. There have been suggestions recently that the quality of the observations has been improved due to the use of manual editing on all disseminated winds.

Daily maps of INSAT observations produced at ECMWF confirm that there has been some improvement but there are still a significant number of occasions when the internal consistency is poor. A scatter plot of observed against first-guess wind speed for low-levels (1000 to 700 hPa) for March 1989 shown in figure 10 indicates that the winds have large random errors.

The quality of cloud-motion winds from INSAT will continue to be closely monitored at ECMWF with a view to using them in the data assimilation system when they are considered to be of a sufficiently high quality.

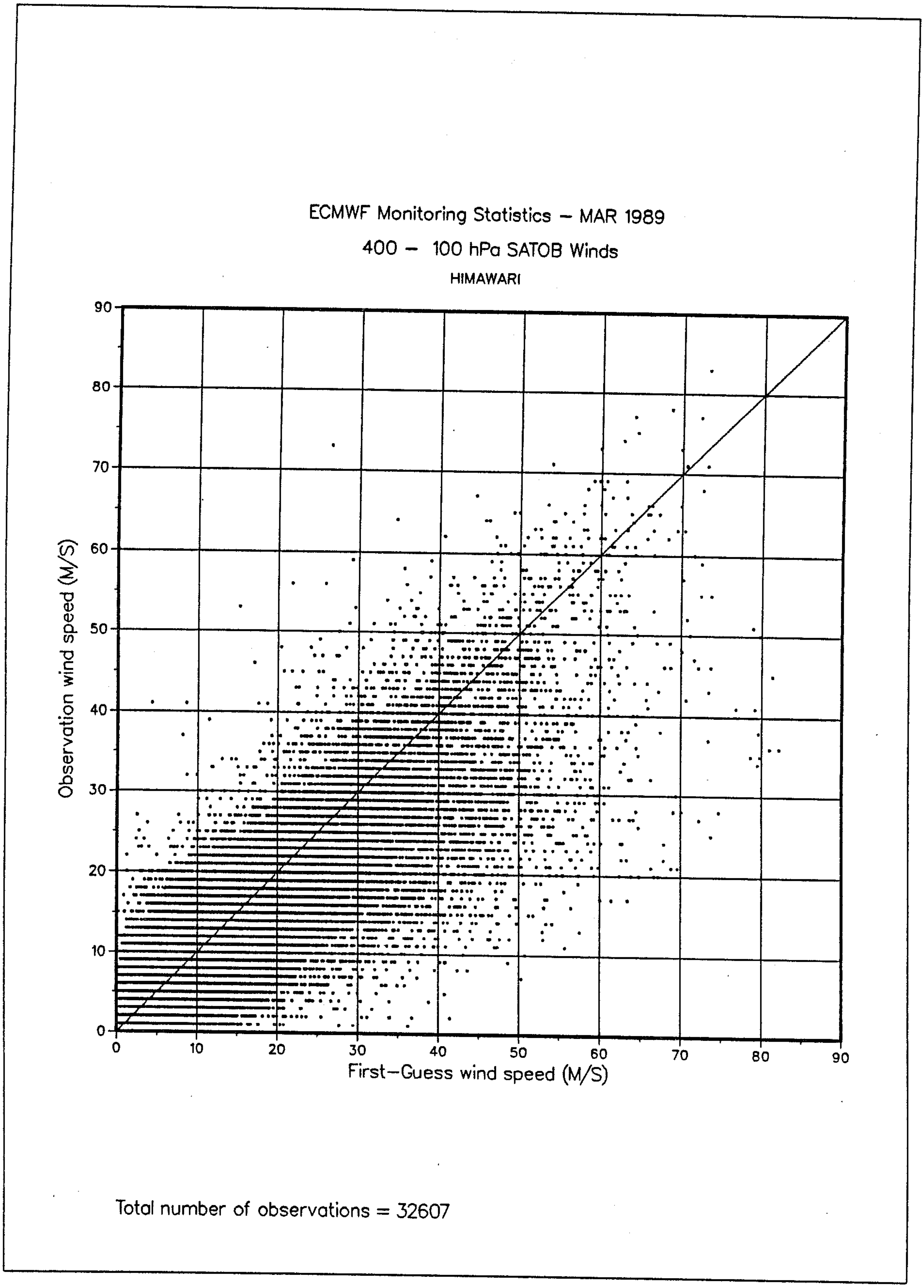

Fig. 7: Scatter plot of observed upper-level wind speeds from HIMAWARI during March 1989 against the first-guess wind speeds. Units are ms^{-1}.

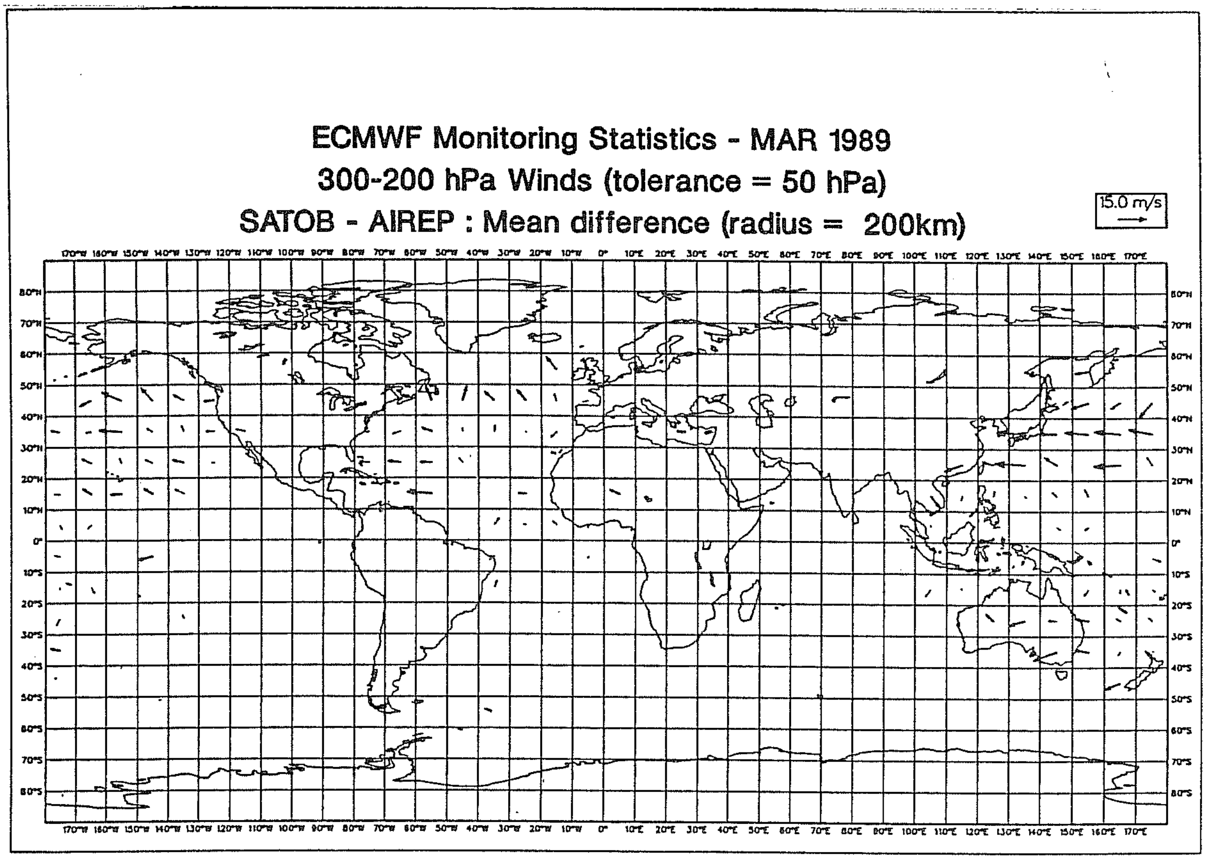

Fig. 8: Mean vectors of cloud-motion wind observations minus aircraft wind observations for March 1989 in the layer 300-200 hPa. Statistics are averaged over latitude/longitude boxes of 10° x 10°. The tolerance for collocated observations is 50 hPa vertically and 200 km horizontally.

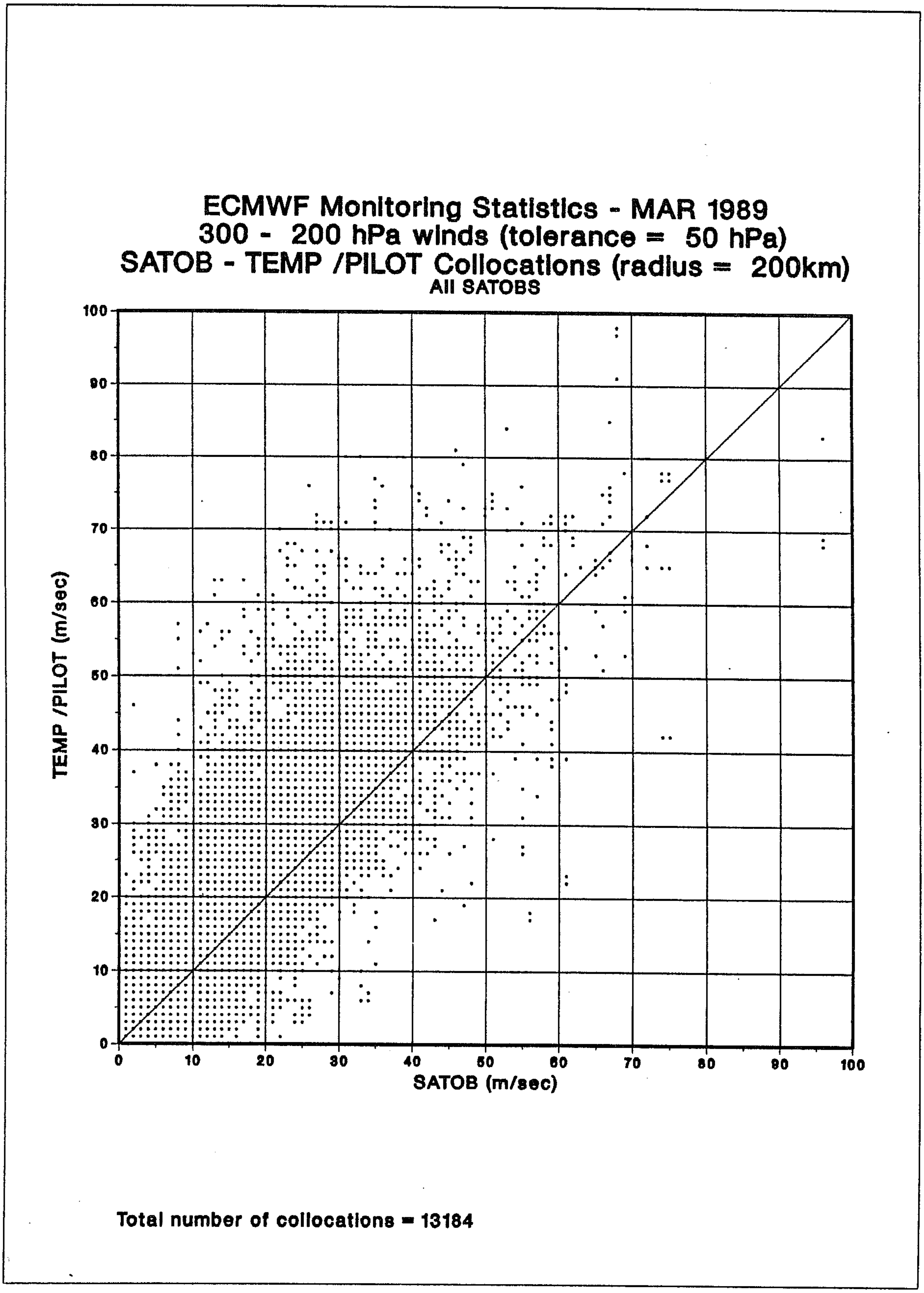

Fig. 9: Scatter plot of cloud-motion wind speed observations (from all satellites) against radiosonde and pilot balloon observations for March 1989 in the layer 300-200 hPa. The tolerance for collocated observations is 50 hPa vertically and 200 km horizontally.

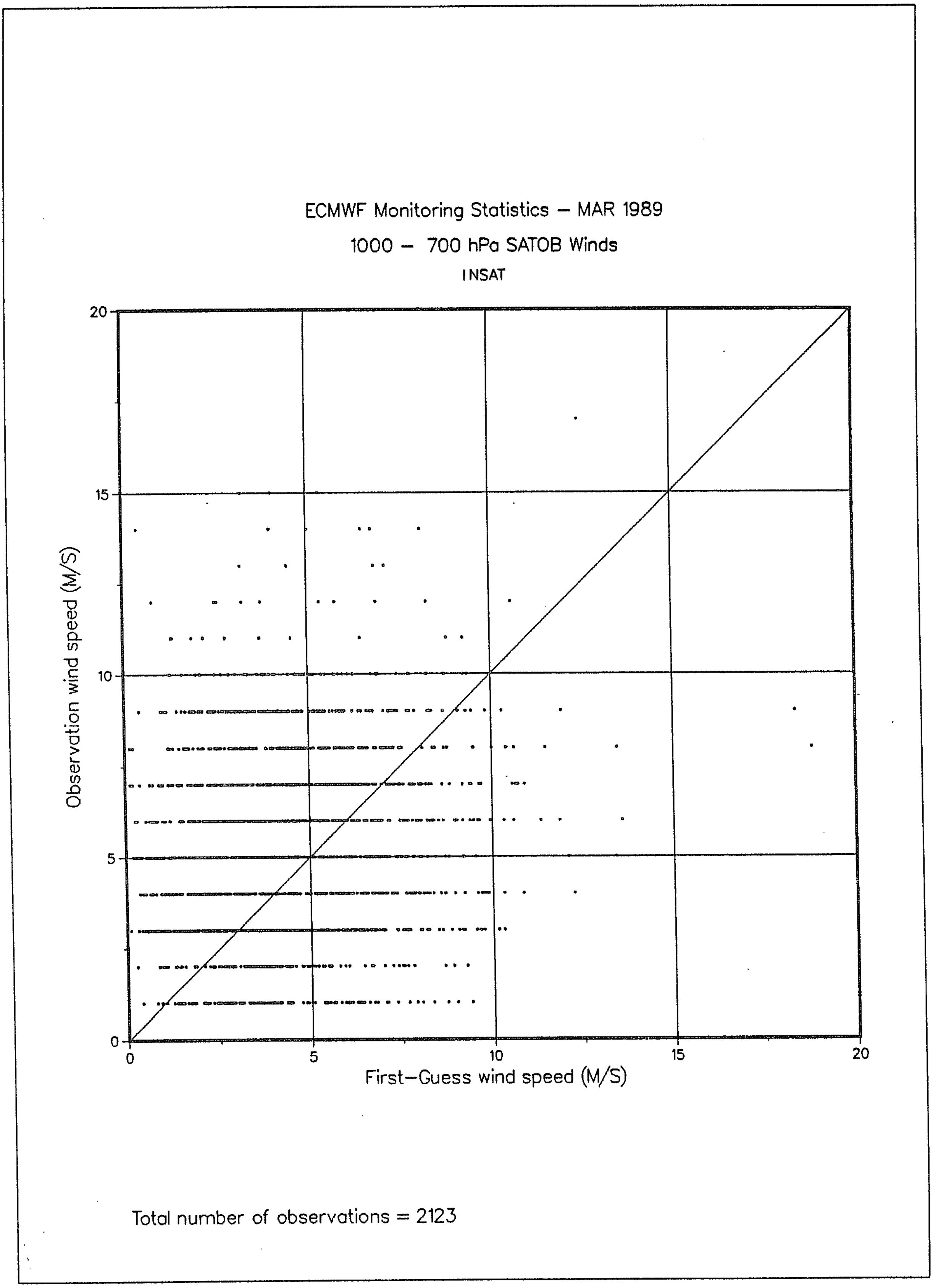

Fig. 10: Scatter plot of observed lower-level wind speeds from INSAT during March 1989 against the first-guess wind speeds. Units are ms^{-1}.

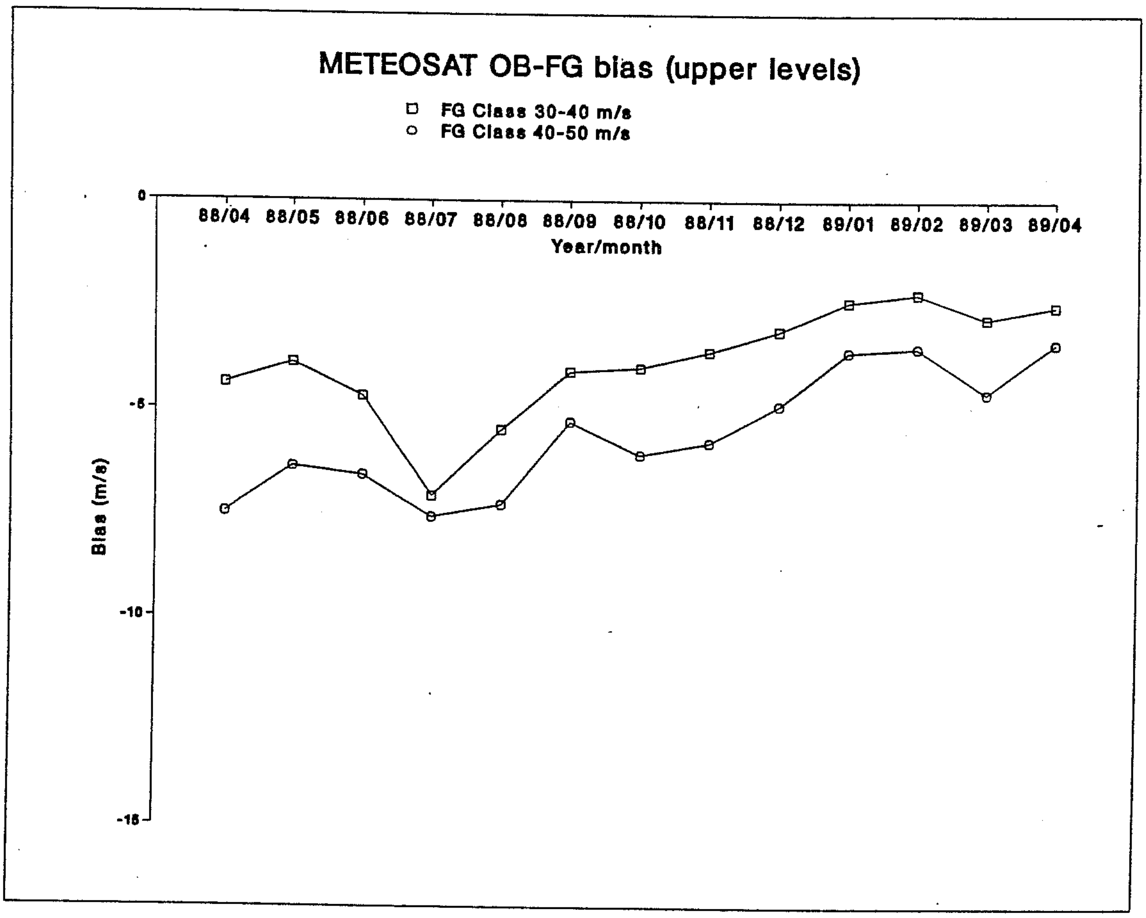

Fig. 11: Graph of the evolution between April 1988 and April 1989 of the upper-level wind speed bias (mean observed minus first-guess difference) of METEOSAT observations. Graphs are shown for two classes of first-guess wind speed - 30 to 40 ms^{-1} and 40 to 50 ms^{-1}.

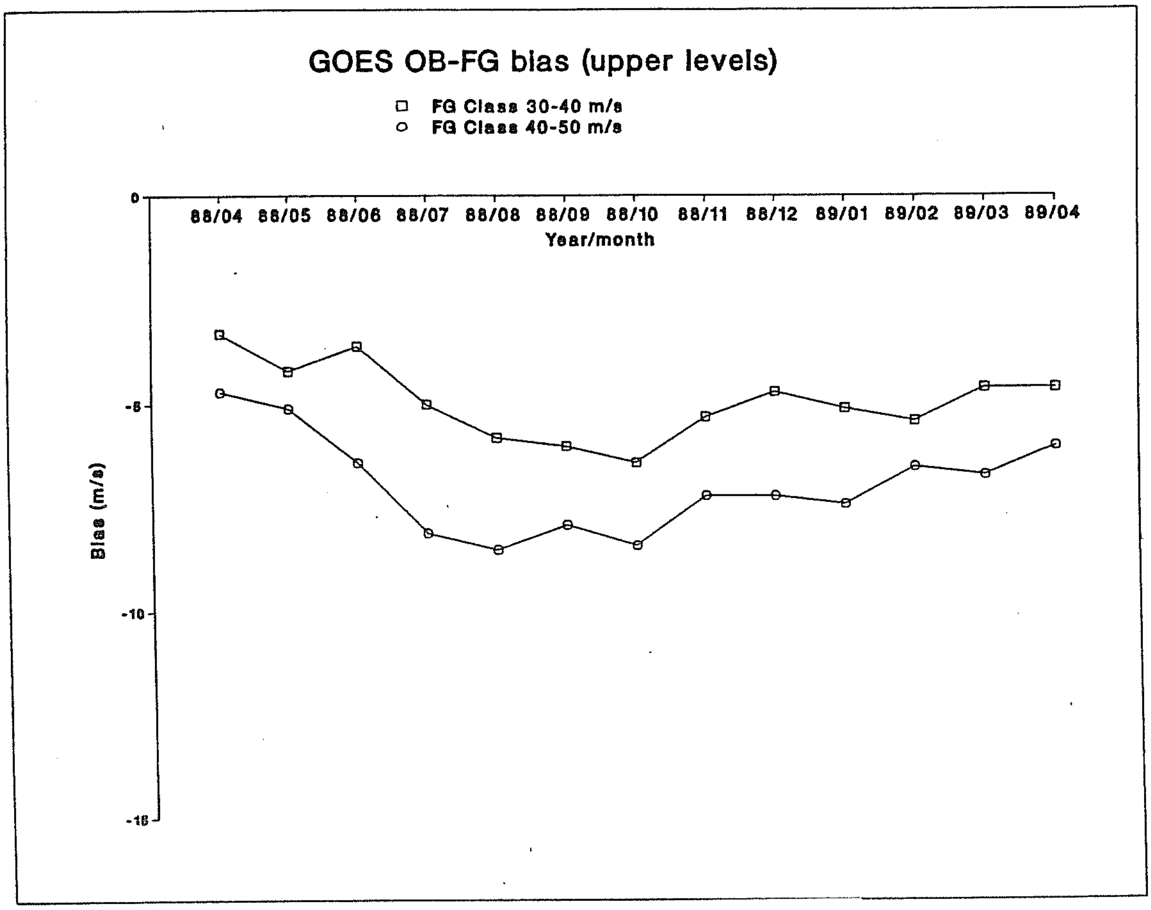

Fig. 12: As figure 11, but for GOES.

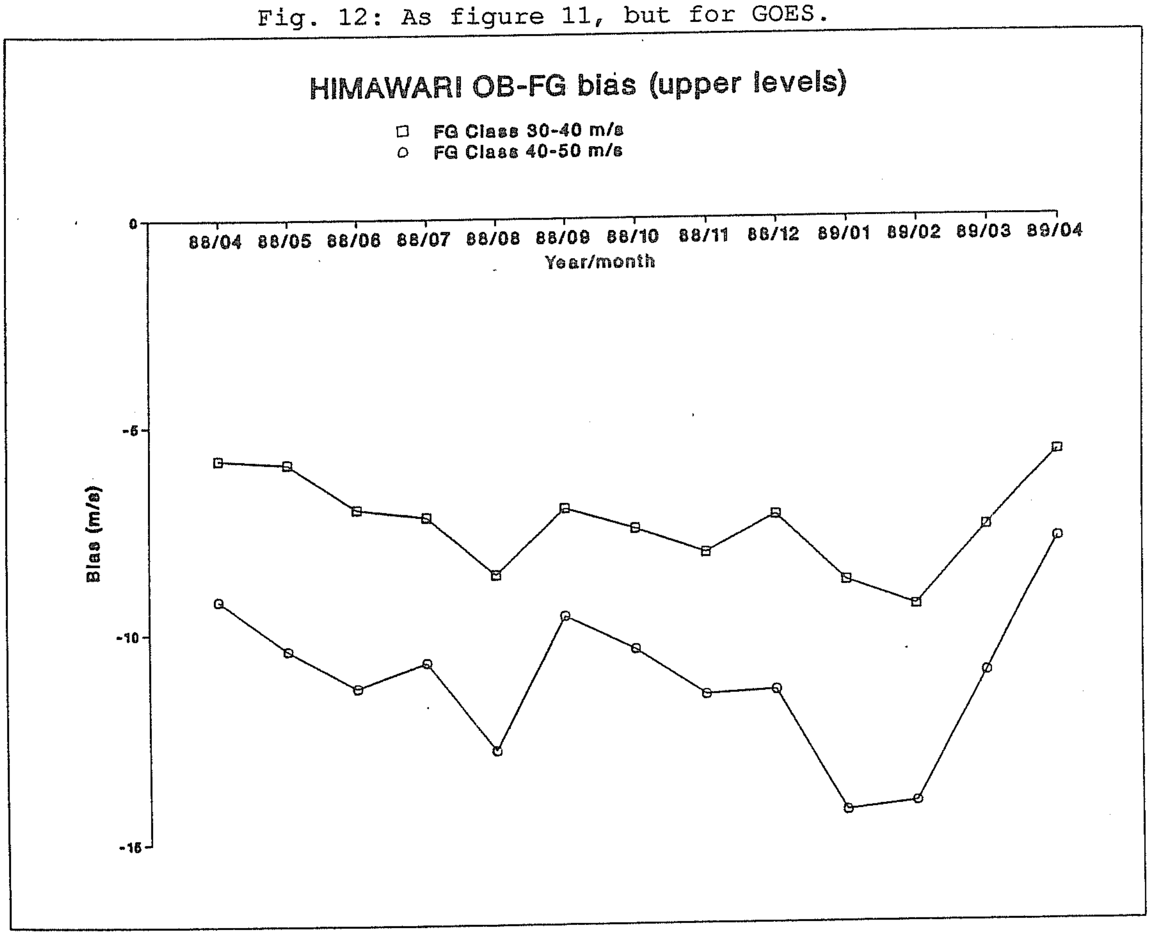

Fig. 13: As figure 11, but for HIMAWARI.

5. Recent trends in the quality of cloud-motion winds

A measure of the changing performance of cloud-motion wind observations may be seen by plotting a graph of monthly values of mean OB-FG wind speed difference. Figure 11 shows the evolution of the OB-FG speed bias for two speed classes (30 to 40 ms^{-1} and 40 to 50 ms^{-1}) between April 1988 and April 1989 for observations from METEOSAT. Monthly fluctuations can be expected due to changing synoptic situations but there appears to be a clear trend of improvement since July 1988. No such trend can be seen in similar graphs derived from observations from GOES (figure 12) and HIMAWARI (figure 13). It may also be seen that the magnitude of the bias in METEOSAT observations is generally smaller than that for GOES, which is in turn smaller than that for HIMAWARI, confirming the pattern already seen when looking at the statistics for March 1989 alone.

6. Summary

Monitoring the quality of cloud-motion wind data using the ECMWF first-guess field as a reference enables the well-known problem of underestimation of the wind speed in jet streams to be clearly visualised. The results obtained from this method are confirmed using the independent reference of other observing systems.

There appear to be general differences in the overall quality of the observations from the three major producers of satellite winds. It is possible that some of the difference could be due to spatial variations in the quality of the ECMWF first-guess field although graphs of performance over the last year indicate an improvement in the quality of METEOSAT winds only. The relatively poor quality of the HIMAWARI data is almost certainly due to the climatological method of cloud height assignment.

REFERENCES

Akyildiz, V., 1984 - ECMWF Internal Memorandum.

Delsol, F., 1984 - Monitoring the availability and quality of incoming GTS observations at ECMWF. ECMWF workshop on the use and quality control of meteorological observations, 1984.

Kållberg, P., Delsol, F., 1986 - Systematic biases in cloud-track wind data from jet stream regions. Proc. WMO/IUGG symposium on short and medium-range numerical weather prediction, Special issue of J. Met. Soc. Jap. Tokyo, ed T. Matsuno.

Radford, A., 1986 - ECMWF Internal Memorandum.

Radford, A., 1987 - Data monitoring at ECMWF. ECMWF workshop on meteorological operational systems, 1987.