A STUDY ASSESSING THE QUALITY AND IMPACT OF CLOUD TRACK WINDS USING THE ECMWF ANALYSIS AND FORECAST SYSTEM

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1. INTRODUCTION

Few improvements were added to the operational production of Cloud Motion Winds (CMW) from FGGE, 1979, until 1985. During this period the accuracy of the ECMWF six hour forecast had steadily improved and it was found to be a useful data quality monitoring tool, particularly for CMW's. Källberg and Delsol (1986) describe the use of the ECMWF six hour forecast to inter-compare various observing systems, including CMWs, in both data dense and data sparse regions. The six hour forecast can now be used as a transfer standard to inter-compare various observing systems.

Recently a series of discussions were held between ECMWF, ESOC/ESA and CIMSS/NESDIS, two of the operational CMWs producers, with the aim of improving the quality, quantity and user feedback for problems with CMWs. Some joint experiments were planned and have been conducted to test some new methods as well as the use of the water vapour channels for wind deviation.

These winds are important because far too often there are large gaps in the operational CMWs due the lack of suitable upper-level cloud traces. CMWs have always been included in the operational ECMWF assimilation system, but it was becoming clear from routine monitoring that a large number of the high speed CMWs were slow (Delsol, 1985 and Radford, 1987). Various research projects were conducted to study this problem. Soon after FGGE a series of CMW Observing System Experiments (OSEs) were carried out with the 1981 version of the ECMWF data assimilation system and a number of CMW problems were identified. In spite of these problems there was an overall positive impact of CMWs (Källberg et al., 1982). Prior to the FGGE rerun of SOP 1 and 2 (1985), an additional small CMW OSE was run to examine the effect of applying a speed dependent adjustment to the upper winds to compensate for the slow bias (Källberg, 1986). The impact of the speed correction appeared to be neutral, however. This speed correction was used in the FGGE rerun but was not implemented operationally. A further analysis of the FGGE reruns is reported by Hollingsworth et al. (1988) and will be discussed later. The current operational solution to this problem is to apply tough Quality Control (QC) using the six hour forecast (Lönnberg, 1988).

Wednesday 8 February 1989 06z ECMWF Forecast t+ 6 VT: Wednesday 8 February 1989 12z
250 hPa winds
PILOT/SATOB reports (300 – 100 hPa) – 8 February 1989 12z

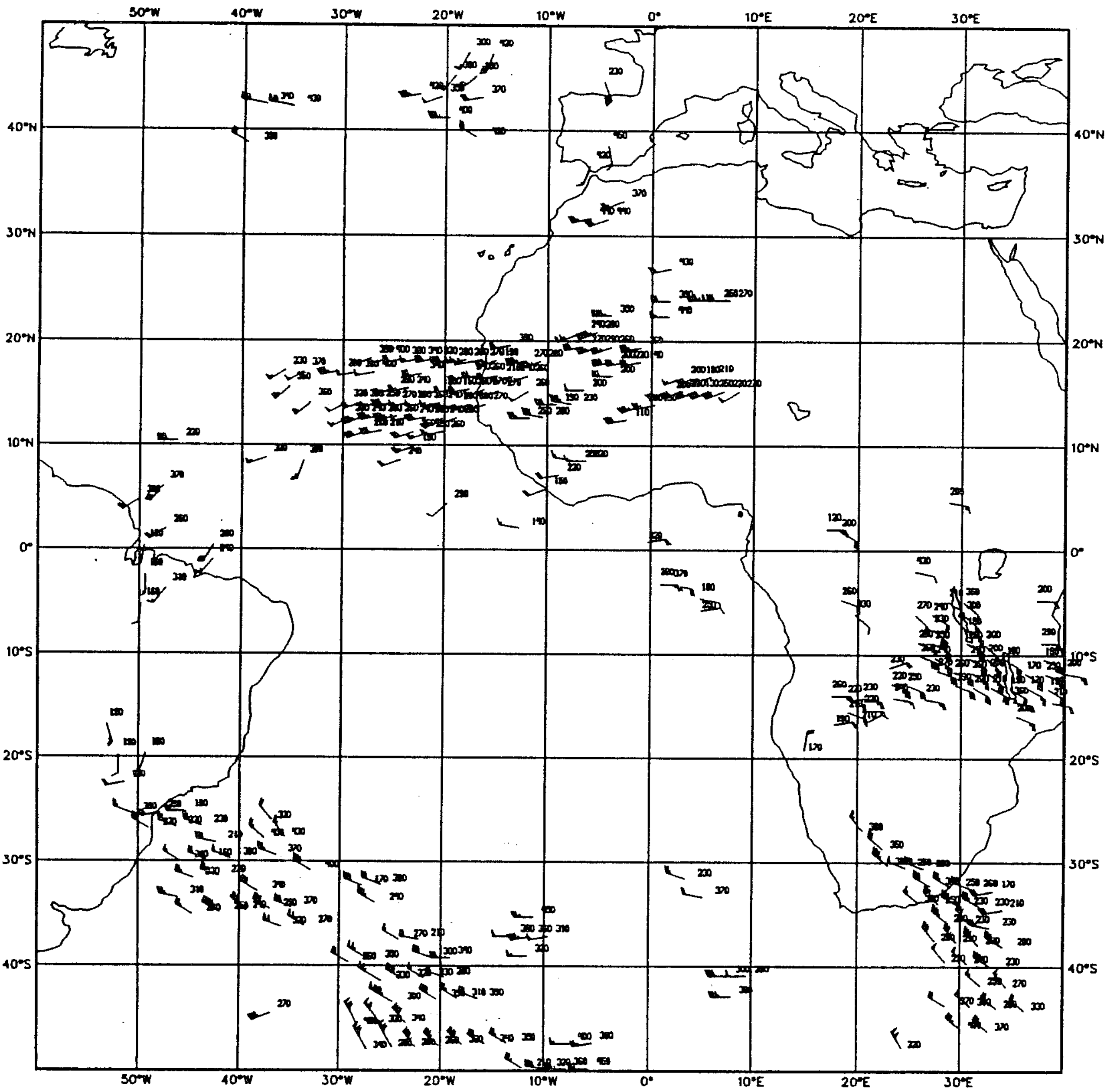

Fig. 1(a) Meteosat upper level winds for 12 UTC 8 February 1989.

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850 hPa winds
PILOT/SATOB reports (500 - 100 hPa) - 8 February 1989 12z

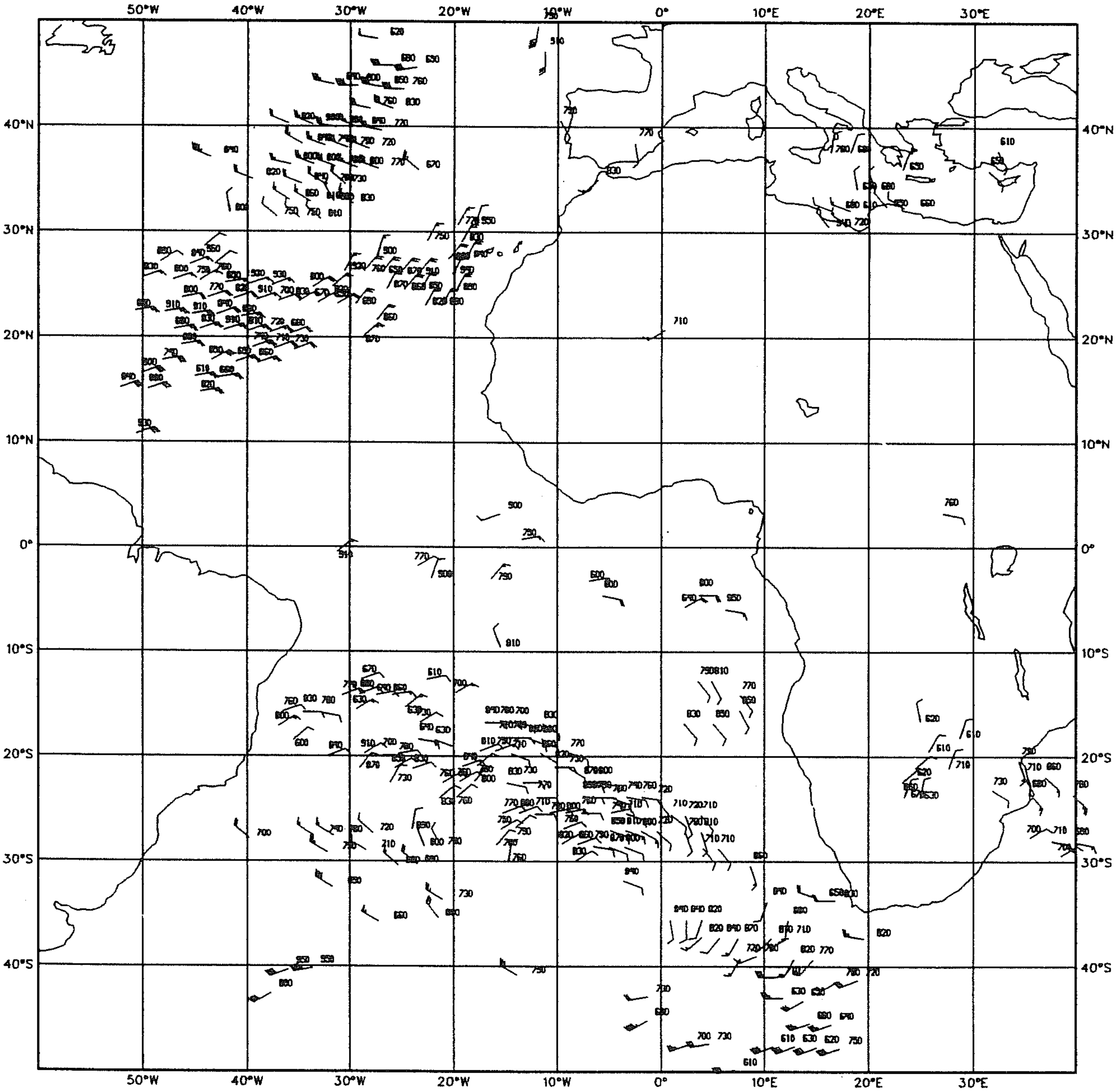

Fig. 1(b) Same as fig 1(a) for lower level winds.

This paper will firstly compare current CMWs produced by the three major satellite operators, NOAA/NESDIS, ESA/ENOC and GMS, with the ECMWF six hour forecast. Winds produced by the Indian satellite are not included. The INSAT winds cover a limited area and are produced once per day and the current data monitoring at ECMWF indicates their quality to be poor (Radford, 1989). They are therefore not used by the operational data assimilation system. An experimental CMW data set (Merrill,1989; Hayden and Merrill,1988) has recently been provided on tape by CIMSS at the University of Wisconsin and comparisons have been made using the six hour forecast. A case study using Meteosat winds in the tropics will be examined highlighting problems in using a forecast for quality control. Finally some results from a short OSE will be described suggesting that changes to the current ECMWF operational assimilation system.

2. OPERATIONAL COMPARISON OF CMWs AND SIX HOUR FORECAST

Since 1987 the data monitoring at ECMWF has indicated a steady improvement in the quality of Meteosat CMWs. This improvement appears to follow changes in both the cloud height assignment and tracking algorithm, summarized by Schmetz (1989). A recent paper on CMW quality by Radford (1989) has also confirmed this improvement with the Meteosat product but has not found any similar improvement in the other operational CMWs.

A first major limitation of CMWs, produced from infrared and visible imagery, is the non-uniform data coverage. There are often large regions without observations and current operational numerical analyses often have problems with this type of data distribution. For example clusters of CMW's are often obtained from jet stream cirrus on the poleward side of the Sub-Tropical Jet. In this region there often exists a large horizontal wind shear and even if the CMW's are correct it is difficult to preform the correct numerical analysis. Figure 1(a) shows the operational data coverage for Meteosat for upper level winds and Figure 1(b) for lower level CMWs. Note the lack of upper level data between the equator and 30 degrees in the Atlantic.

The second problem with CMW's is to determine its accuracy. Some scatter plots are shown in Figure 2 for the month of February 1989. These plots are the six hour forecast wind speed versus CMW speed for each satellite producer. The squares represent data rejected by the analysis and the smaller circles depict data used during the assimilation cycle. CMWs from Meteosat show a smaller number of rejected data together with a much tighter fit to the first guess than GOES CMWs on Himawari. It must be remembered that Meteosat CMW processing makes some use of the ECMWF forecast. However its effect on the derived CMWs is considered small (Schmetz, 1989). The scatter plots for the lower level winds, up to 500 hPa, are shown in Figure 2(b). GOES and Meteosat show a similar scatter with a small number of winds being too slow. Most of these winds are above 700 hPa. The plots for

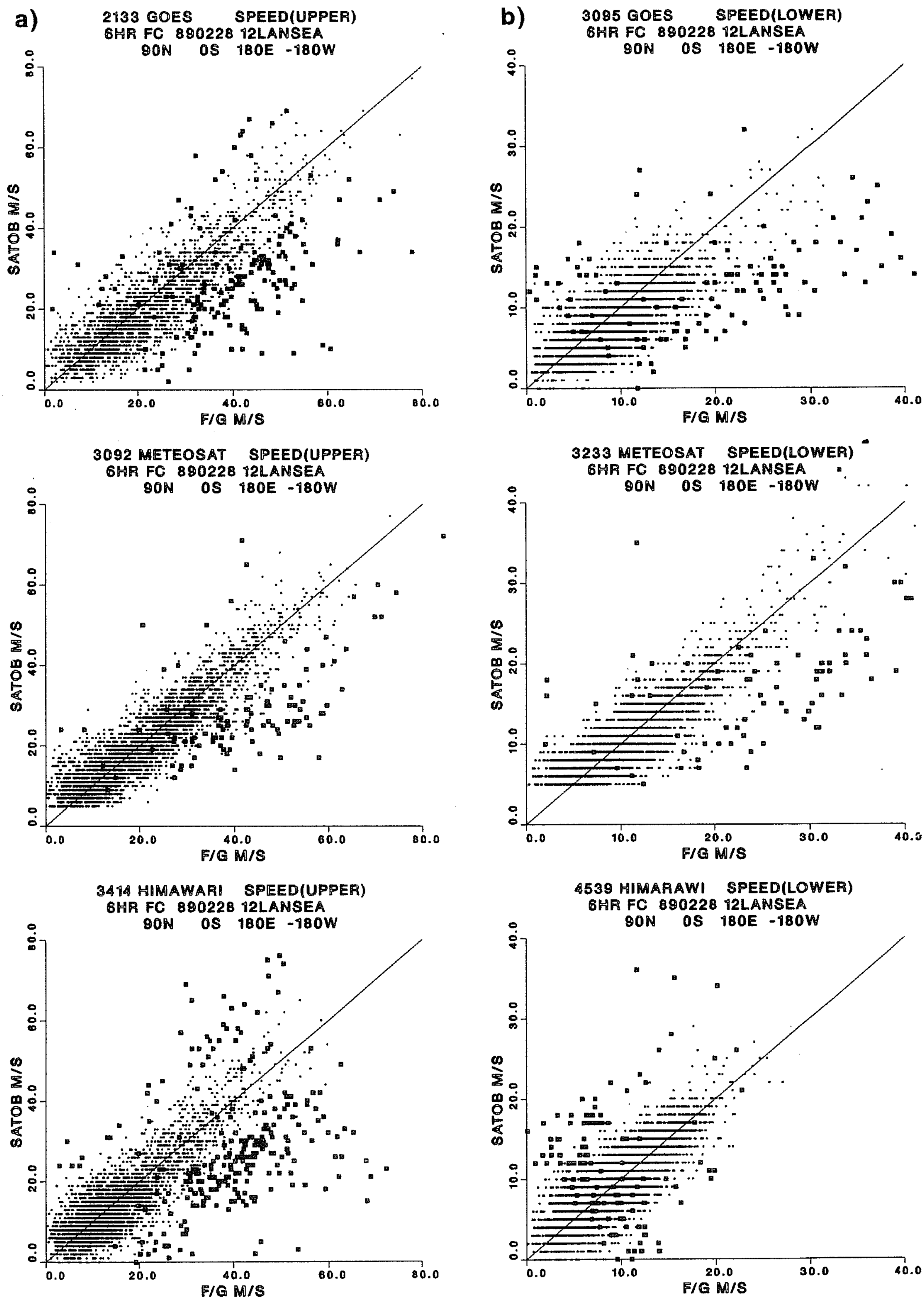

Fig. 2(a) Scatter plots of upper level CMWs versus the six hour ECMWF forecast for February 1989. The solid squares represent CMWs rejected by the analysis quality control. Top figure is GOES (NESDIS), middle Meteosat (ESA) and bottom Himawari (Japan).

(b) Same as (a) for lower level winds.

Himawari are a little different, there is less rejected data, as shown by the squares, and fewer winds at the higher speeds. A possible explanation is that most of the winds are below 700 hPa whereas the other producers tend to track more mid-level clouds.

3. WISCONSIN EXPERIMENTAL WINDS

Meteosat cloud height assignment is done using only two infrared channels. The VAS instrument, on the other hand, has 12 channels and it is possible to use a more accurate carbon dioxide splitting technique to determine cloud heights. In the cloud free regions the two VAS vapour channels at 6.7 and 7.2 micron are used to produce CMWs. This work is described in articles by Merrill (1989) and Hayden et al. (1989).

A limited regional CMW data set (7°N to 44°N and 40°W to 110°W) was produced at Wisconsin and has been compared with the ECMWF first guess and other current operational products during 8 to 22 february 1989 at 12 UTC. Figure 3(a) shows a scatter plot of upper level winds (above 500 hPa) and includes both cloud and water vapour winds. Figure 3(b) show a similar example of low level CMWs.

The results in Figure 4 can be directly compared with the operational results shown in Figure 2. The quality appears better, and there are fewer data rejected (squares on the plots). This may partly be due to the manual quality control which was used in their production but the main improvement is due to the use of extra VAS channels (Hayden, 1989).

4. METEOSAT CASE STUDY

The recent improvement in the Meteosat CMWs quality is mostly due to two refinements. Firstly, the cloud heights have been improved by a better calibration of the water vapour channel and also by making use of the ECMWF temperature forecasts. Secondly, the wind tracking algorithm has been modified to make use of the ECMWF forecast as a starting point for the initial correlation surface search. Further details on these changes can be found in Schmetz (1989).

It is important to understand some of the characteristics of the forecast errors if the forecast is to be used for CMW calculations and quality control. Unfortunately the operational forecast at ECMWF is only run once per day for periods longer than six hours and the CMWs production time constraints are such that they have to use forecasts in the time range of 24 to 36 hours. Recent work of Hollingsworth et al. (1988) have investigated the systematic tropical errors for the six hour forecast and these errors tend to grow quickly as the forecast progresses. On the other hand, forecast errors outside the tropics

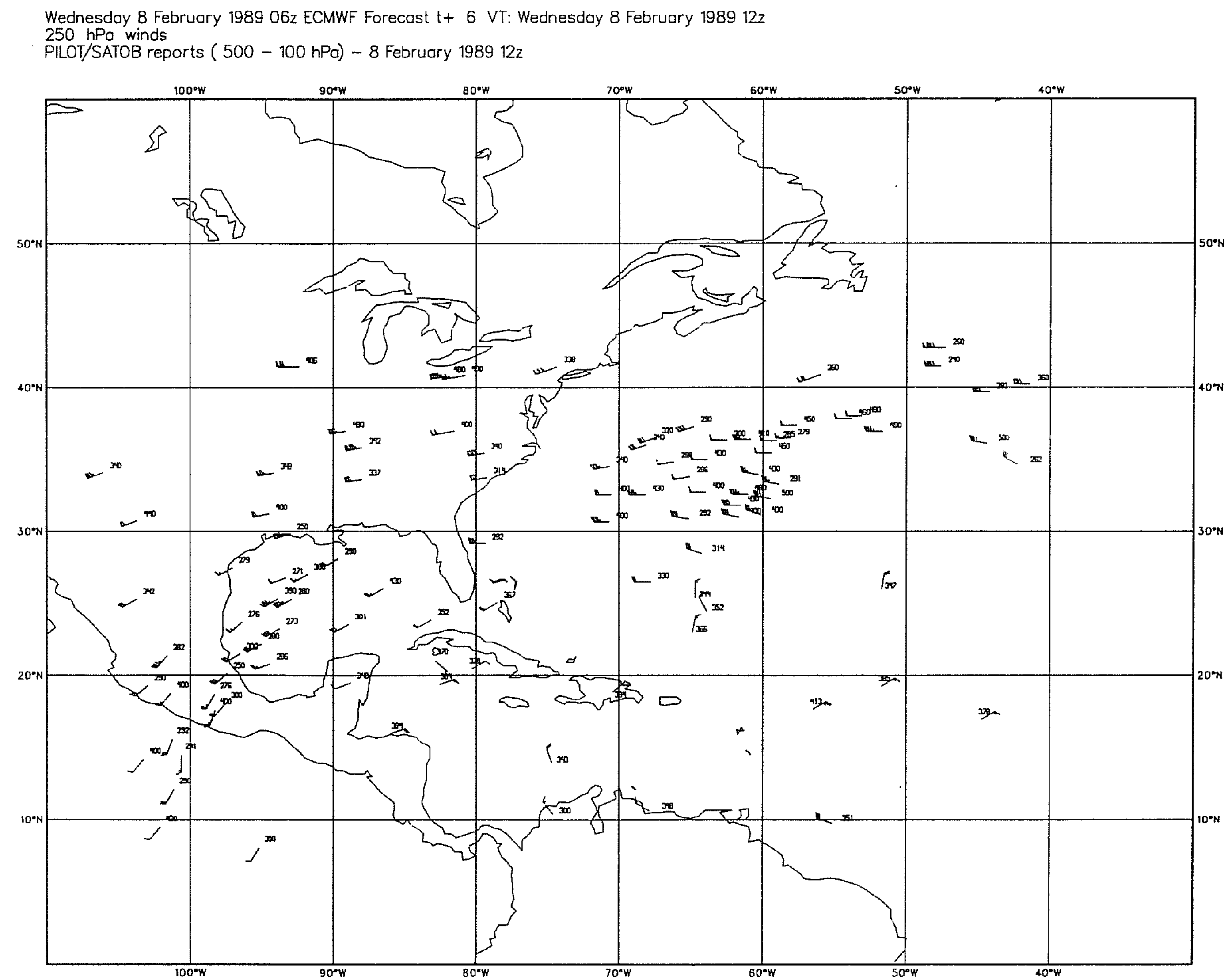

Fig. 3(a) VAS limited area upper level winds for 12 UTC 8 February 1989.

Wednesday 8 February 1989 06z ECMWF Forecast t+ 6 VT: Wednesday 8 February 1989 12z
850 hPa winds
PILOT/SATOB reports (1000 – 700 hPa) – 8 February 1989 12z

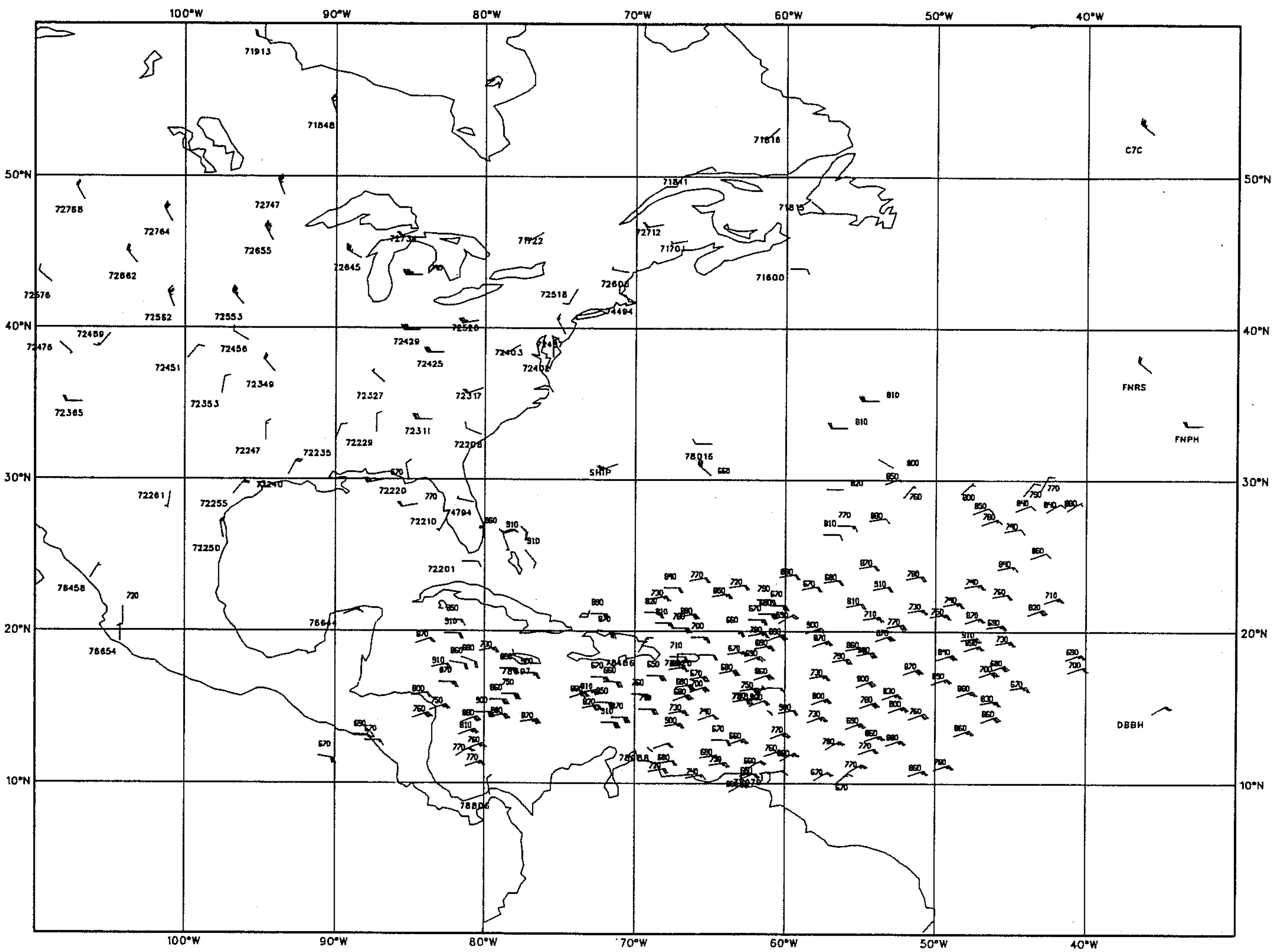

Fig. 3(b) Same as fig. 3(a) for lower level winds.

are less of a problem. At ESOC the ECMWF forecast is currently also used for automatic quality control. However it is followed by a manual quality control in which a skilled meteorologist can reinstate rejected CMWs.

A recent example of their intervention will be demonstrated. In Fig. 5 CMWs from Meteosat are plotted on the ECMWF twenty four hour forecast, the six hour forecast, and the analysis. There is a large discrepancy in wind direction in the region of the equator and 10 degrees west. Initially the automatic quality control based on the twenty four forecast, Figure 5a, rejects many of these winds based on the deviations in wind direction. This is then followed by the monitoring meteorologist who reinstates some of these CMWs. The same CMWs are plotted on the six hour forecast, Figure 5b, and now there is better agreement although there are still some small discrepancies. In the previous twelve hours there were CMWs in this area and their influence on the analysis has been maintained by the data assimilation. Figure 5(c) shows these same CMWs plotted on the analysis and these winds are generally drawn for. This example demonstrates that if wind observations are not received in particular tropical regions then the data assimilation will also become unrealistic in these regions.

5. OSE EXPERIMENT

It is now clear from various studies (Källberg et al., 1986; Hollingsworth et al., 1988) and the case study discussed above that the CMWs have a positive influence on the tropical wind field. However, in the subtropical jets CMWs still appear to be slow. To investigate the CMW impact on numerical weather prediction two parallel data assimilation experiments were run for a period of four and a half days with CMWs excluded in one experiment. Both experiments started from the same initial conditions and four 10 day forecasts were run for each experiment with identical forecast model settings.

An impact of upper level CMWs on the assimilation system can be investigated by averaging for each experiment all the six hour forecasts which are used as background for the analysis. Firstly we will examine 200 hPa wind fields. The normal assimilation (OPS) including CMWs is shown in figure 6b, and the NOSATOB assimilation, is shown in figure 6a. Outside of the tropics the differences are small with a tendency for the jets to a little stronger in the NOSATOB experiment. In the tropical regions, particularly north of Australia and over Africa, there are marked differences in both wind direction and speed. The NOSATOB experiment appears to be too zonal suggesting that without CMWs the assimilation produces a Hadley cell which is too weak. Figure 7 shows the difference between figures 6a and 6b in the Himawari region. This, further highlights that the NOSATOB experiment is too zonal in the tropics. The OPS experiment in the Southern

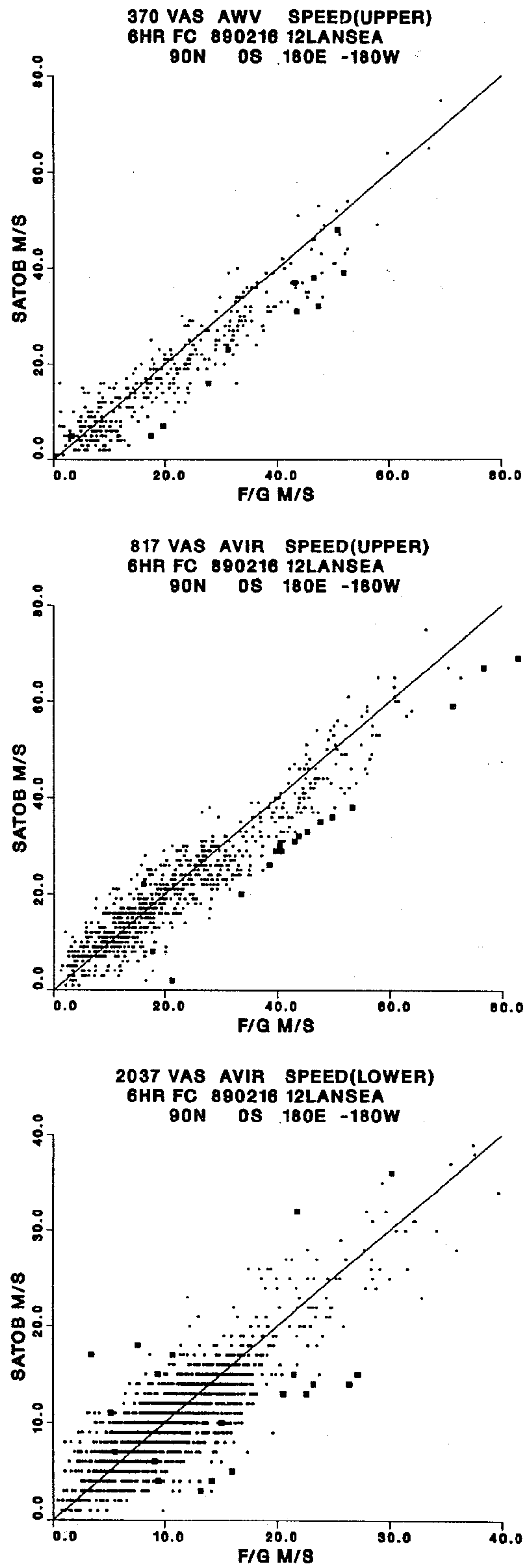

Fig. 4 Scatter plots of CMWs versus six hour ECMWF forecast for 12 UTC 8 to 16 February 1989. The solid squares represent CMWs rejected by the analysis quality control. Top figure is the upper level CMWs derived for water channels, middle upper level CMWs derived from infrared channels and bottom low level CMWs using infrared channels.

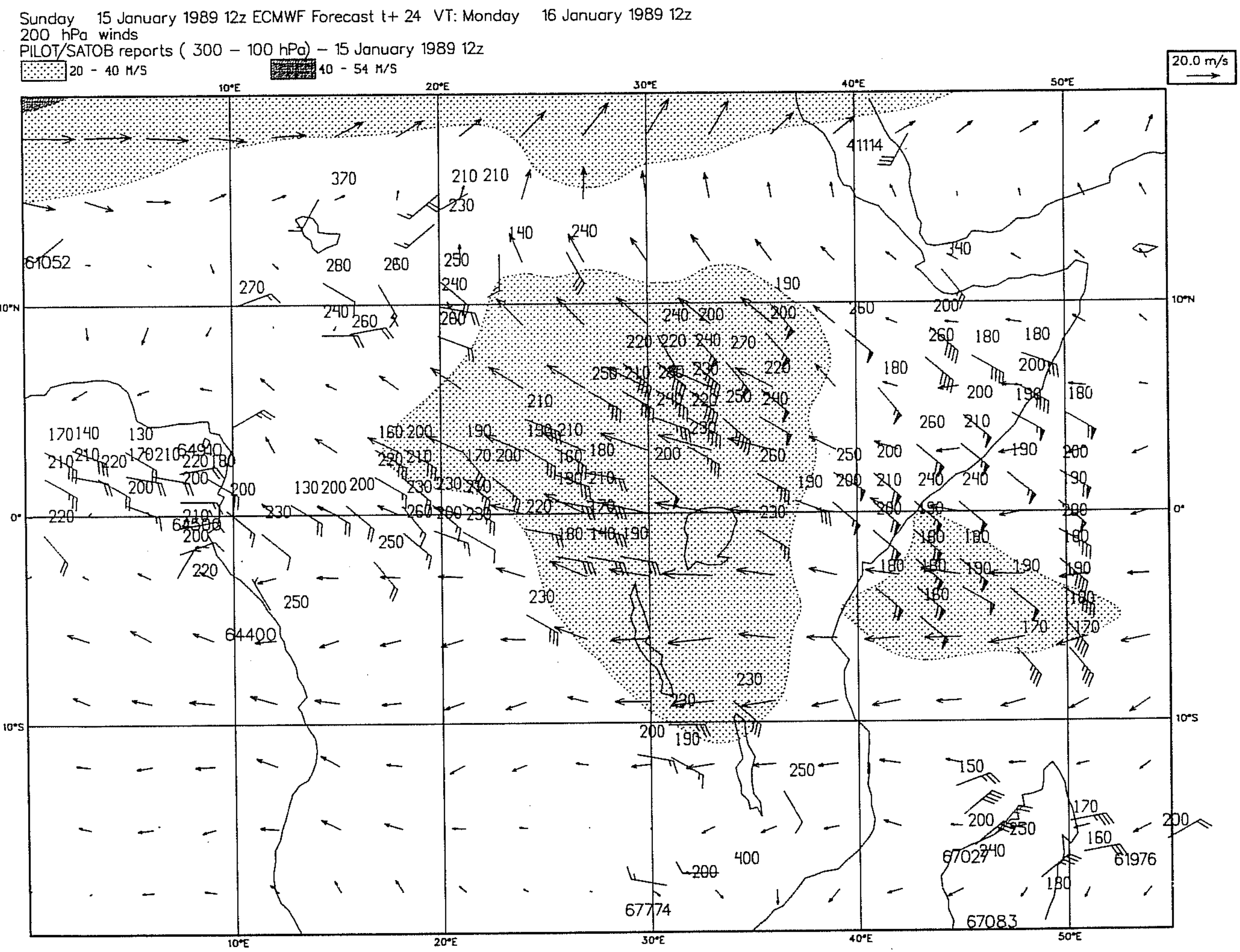

Fig. 5(a) Operational ECMWF 24 hour forecast verifying on 12 UTC 16 January 1989 (the grid of arrows represent the speed and direction, the speed isotachs are always shown in 20 m/s contours). Also plotted (wind barbs) are the operational upper level CMWs from Meteosat for the same time.

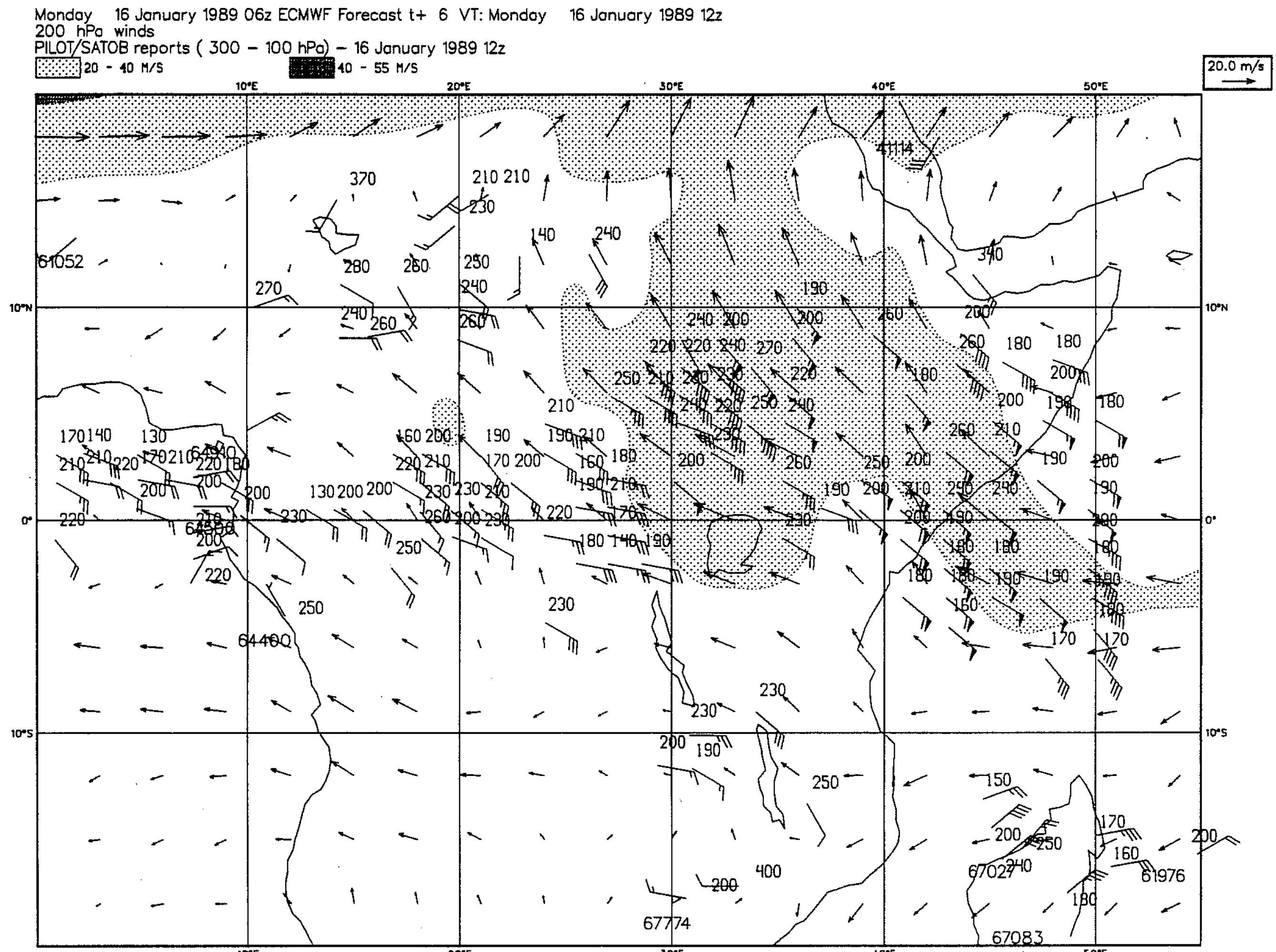

Fig. 5(b) Same as fig. 5(a) except the forecast period is only six hours.

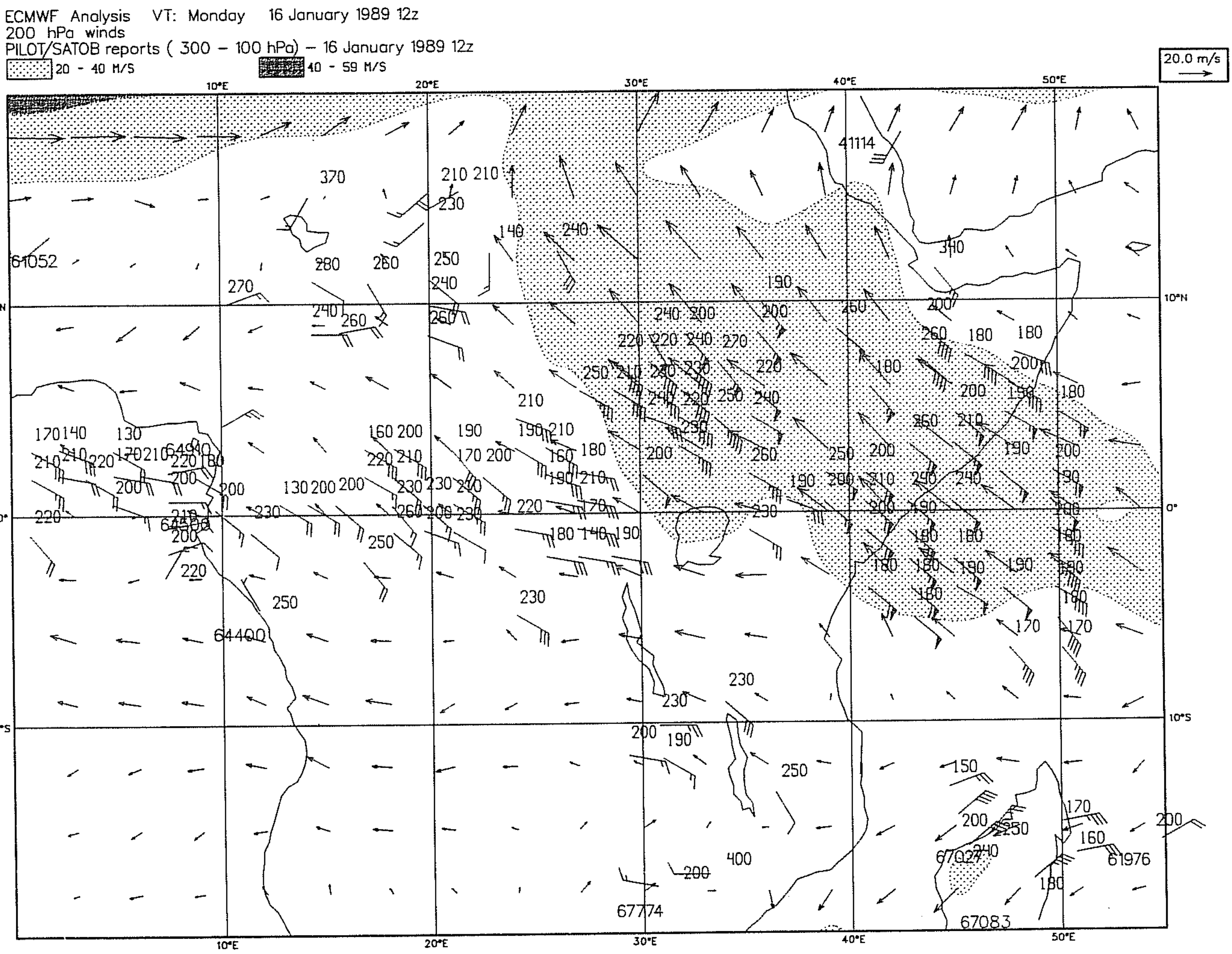

Fig. 5(c) Same as fig 5(a) except the ECMWF operational analysis is plotted.

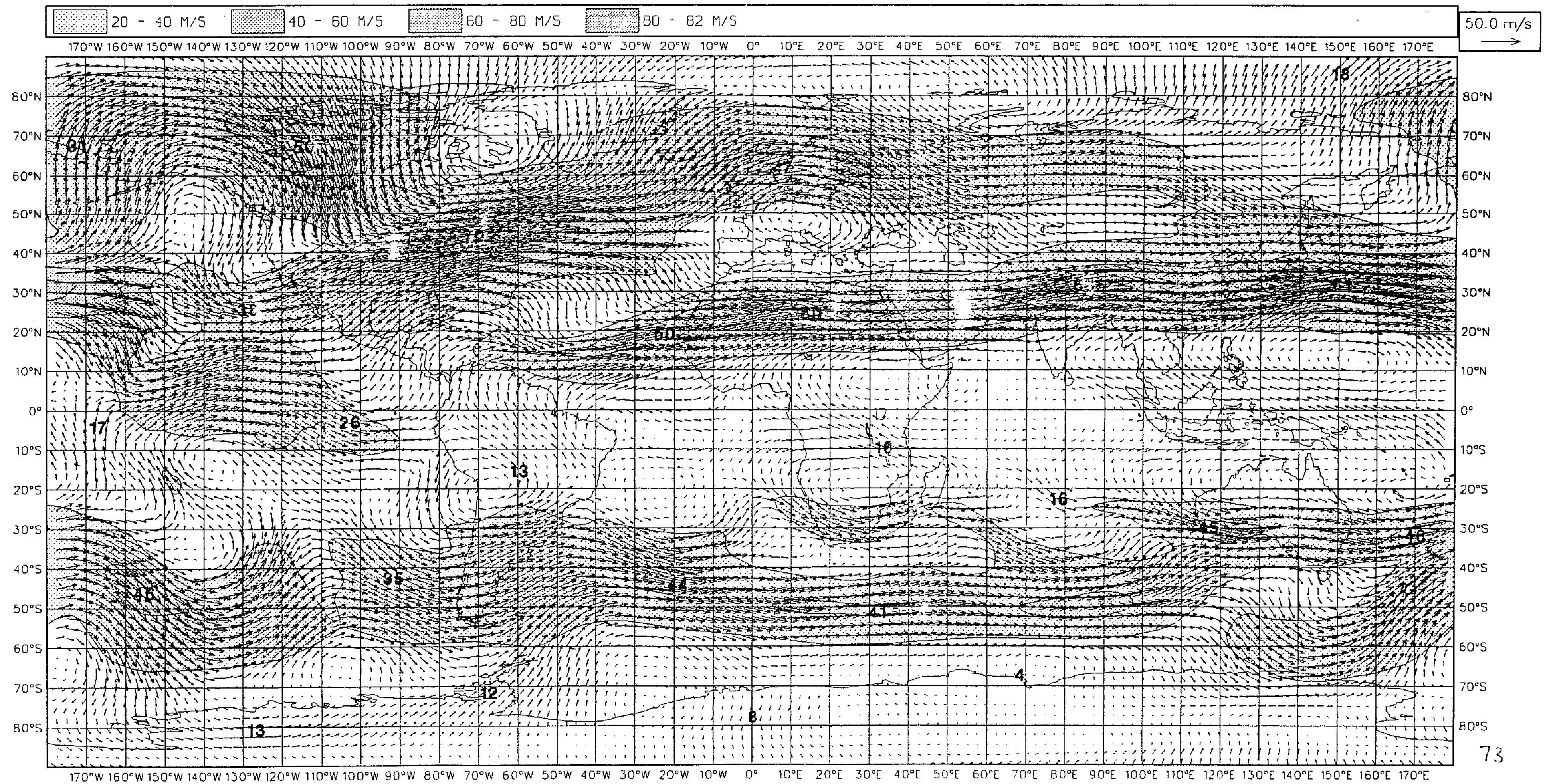

Fig. 6(a) The time averaged 200 hPa wind field from 00 UTC on the 6 February and 12 UTC 9 February 1989 for the NOSATOB experiment.

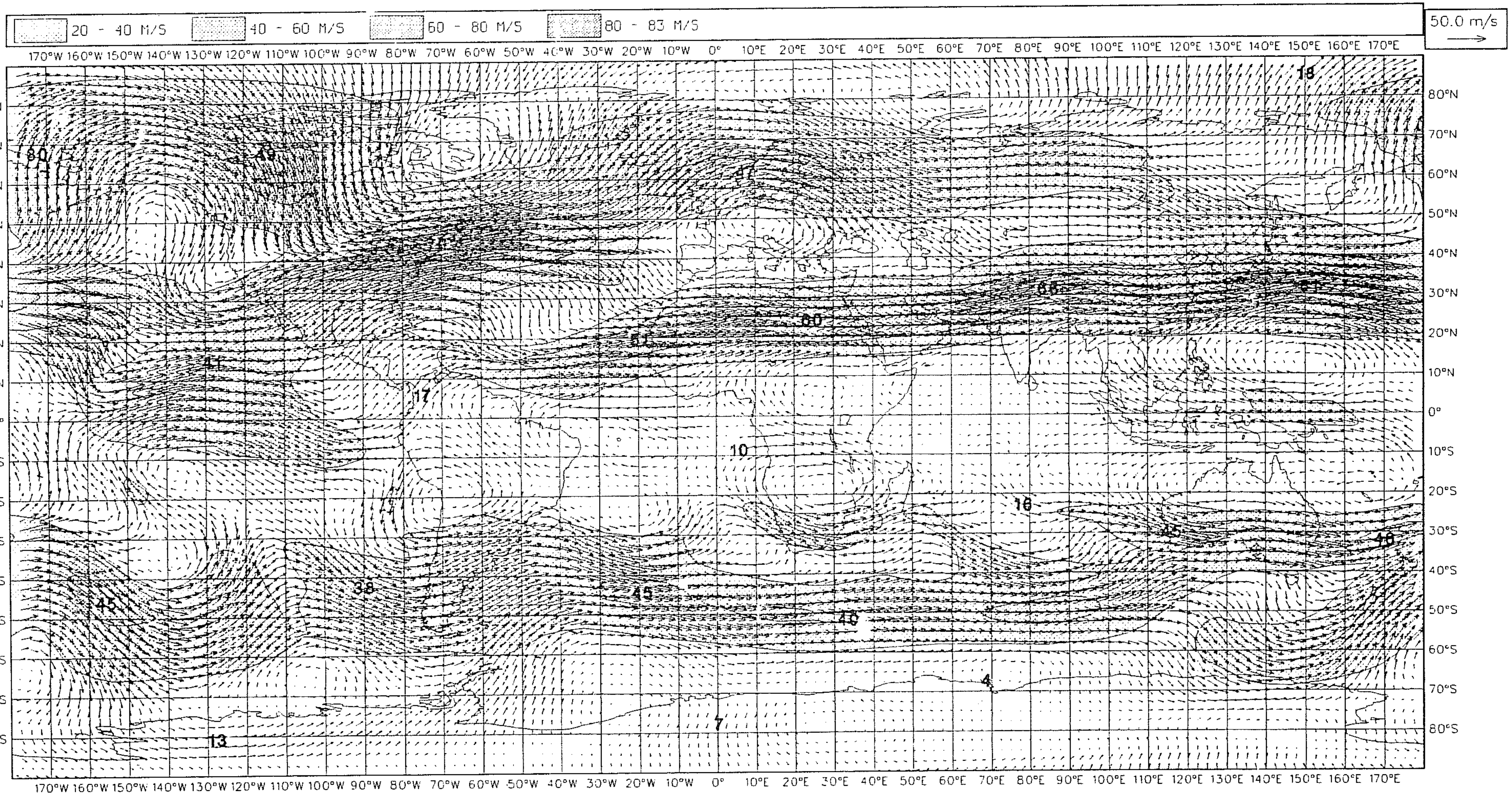

Fig. 6(b) Same as 6(a) for the OPS experiment.

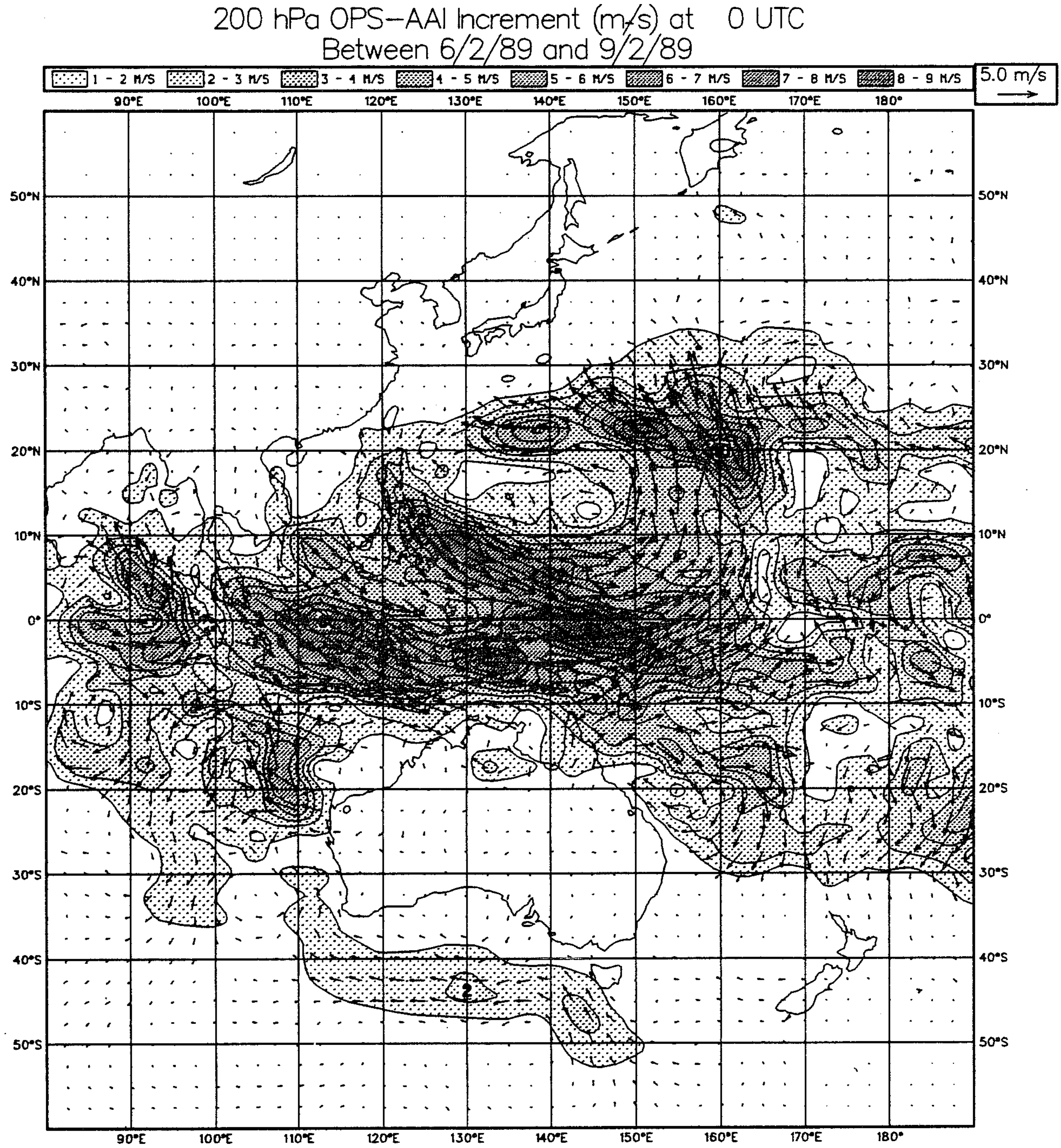

Fig. 7 The time average increment (Operations minus NOSATOB) for the same time period as Fig. 6 in the Himawari region.

Hemisphere mid-latitudes shows a reduction in the sub-tropical jet of up to 5 m/s and the easterlies north of Australia appear to be too strong.

The main question one tries to answer is: what is the impact on the forecast? Four 10 day forecasts were run from both experiments and verified using the OPS analysis. The Northern Hemispheric 500 hPa height anomaly correlation is shown (Figures 8a,b,c and d) for each forecast. It was expected that the impact in the Northern Hemisphere, given the tight quality control (Lönnberg, 1988,1989), would to be small and this was true for forecasts run from the 6th, 7th and 9th. However, there was a large negative impact on the 8th. One must remember to the scatter of the forecasts obtained in the OSE experiments involving satellite temperature profiles (Andersson et al., 1989) in which 15 forecasts were run. This sample of four forecasts which includes only one with any sensitivity, may be too few to draw definite conclusions at this stage in the experiment.

Similar verifications for the Southern Hemisphere are a little more encouraging (Figures 9a,b,c, and d). Three of the forecasts show positive impact of CMWs and the fourth is positive until day three. Generally the forecast accuracy in the Southern Hemisphere is less, due to the lack of data and it is relative easy to show impact of satellite data.

In the tropics the more important variable to verify is wind rather than geopotential height and Figures 10 a,b,c and d show the absolute correlation of the 200 hPa wind field for the four forecasts. At the initial time there is a clear difference between the wind fields of each experiment and this is a disadvantage for the NOSATEM forecast. In any event in the tropics a major data source are CMWs and the OPS analysis should be closer to the truth. The impact of the OPS experiment was positive in all four forecasts up to day five.

6. CONCLUSION AND RECOMMENDATIONS

It is encouraging to see some improvements in the quality of CMWs. This has been possible with the use of extra infrared channels to improve cloud heights and emissivities. Also the use of a forecast improves the tracking algorithm and quality control.

The best results were obtained using all the infrared channels from the VAS instrument using the algorithms developed by CIMSS group at the University of Wisconsin. Every effort should be made to encourage NESDIS to adopt these methods for operations as soon as possible.

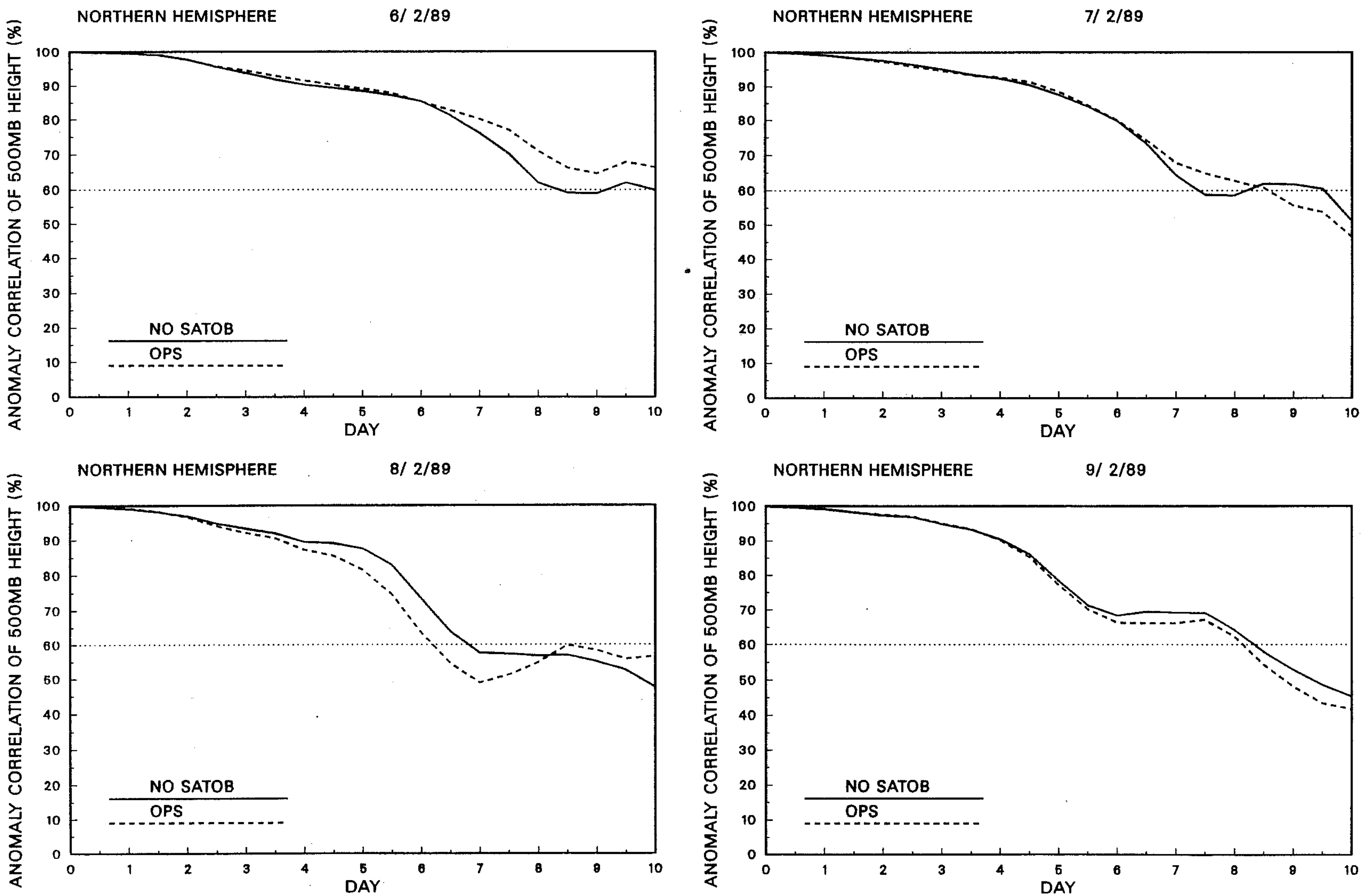

Fig. 8 Northern Hemispheric 500 hPa anomaly correlation for four ten day forecasts. The solid line is the NO SATOB forecast and the dashed the operational forecast.

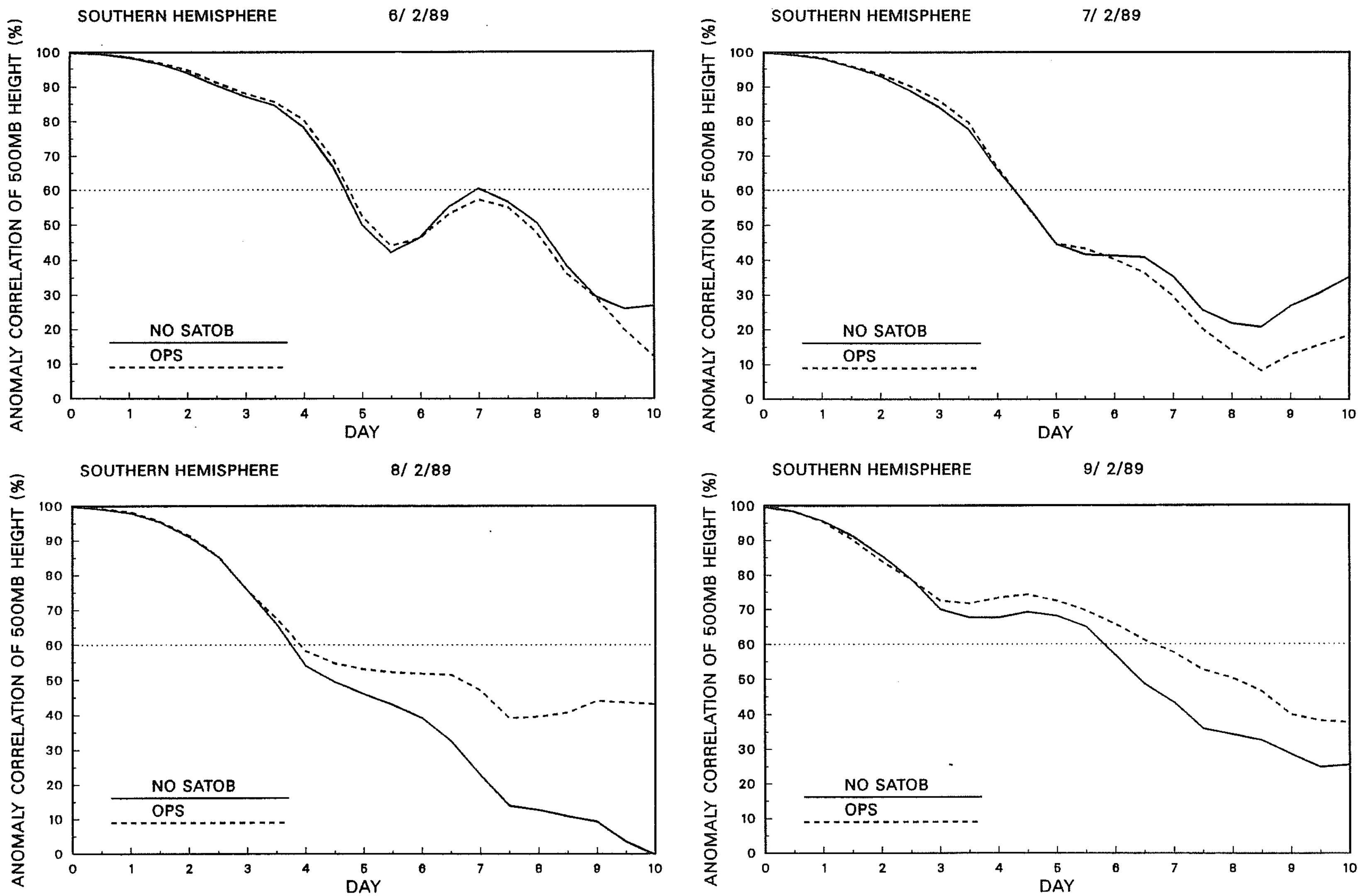

Fig. 9 Same as Fig. 8 for the Southern Hemisphere.

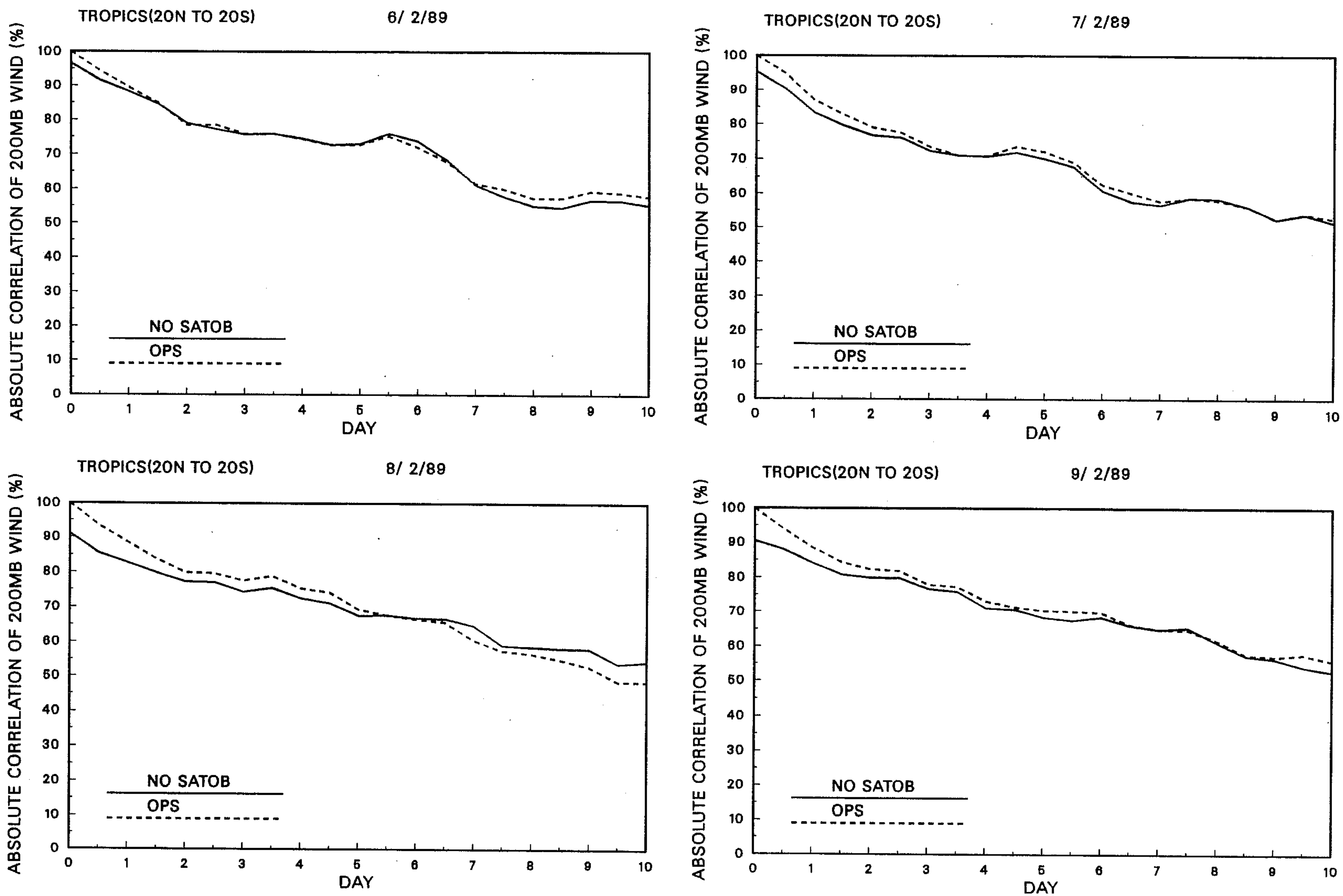

Fig. 10 Same as Fig. 8 for the Tropics.

In future meteorological geostationary satellite designs it will be important to include a full set of temperature sounding channels or even an interferometer for CMWs. This is because the accuracy of cloud height and emissivity is crucial for good CMWs.

The results obtained from the four forecasts in the short OSE suggest that more work is required. It must be remembered that the results from previous OSE satellite temperature sounding experiments, using the same version of the assimilation system, showed a large sensitive and the one negative score obtained in the Northern Hemisphere on the 8th may not be significant when a larger sample of forecasts are evaluated.

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