NUMERICAL EXPERIMENTS USING CLOUD MOTION WINDS AT ECMWF

Graeme Kelly
ECMWF
Reading, UK

Abstract

Recent monitoring of cloud motion winds (SATOBs) at ECMWF has shown an improvement in quality. Currently, in operations, cloud motion winds are excluded from certain geographical regions and recent numerical experimental results have indicated that the current "blacklist" for cloud motion can be revised. Results for these experiments will be discussed.

1. INTRODUCTION

There has been a steady improvement in the quality of Cloud Motion Winds in the past year. The results presented in the Winds Workshop, (*Thoss*, 1991 and *Strass*, 1991), showed improvements only in METEOSAT, but now both HIMAWARI and GOES SATOBs are much better.

The METEOSAT improvements are in part due to the close cooperation between ECMWF and the ESOC/ESA group. Also similar collaboration occurred between the NESDIS group in Wisconsin and ECMWF (*Kelly*, 1989) to help with the validation of the new use of CO_2 height assigned winds. This system finally became operational in 1993. Routine monitoring of satellite winds at ECMWF began to show a clear improvement in both NESDIS and GMS winds from 1992 to late 1993.

In addition, some NWP impact tests have been run at ECMWF removing some of the operational black listing (see Table 1), and results indicated that some removal of satellite wind blacklisting over ocean regions should be made. Currently, in operations, upper level winds from both NOAA and GMS are not used outside tropical regions.

The Indians (INSAT) and the Australians using GMS also produce SATOBs operationally. INSAT winds are currently on the GTS and are monitored by ECMWF but not used. Recently there appears to be some improvement in quality which will be discussed. The Australian winds are not received at ECMWF.

2. RELATIONSHIP BETWEEN SATELLITE PIXEL SIZE, MODEL RESOLUTION AND SEGMENT PROCESSING

Fig 1(a) is a schematic representation of the METEOSAT infrared and water vapour pixel resolution and T213/L31 operational ECMWF model grid resolution. There are clearly many cloud and water vapour features which could never be resolved by the forecast model due to be sub-grid scale. On the other hand, the operational wind processing at ESOC subdivides the earth images into segments of 32x32 pixel from which correlation surfaces are produced using pairs of images 30 minutes apart. Fig 2(b) schematically shows this area in relation to the forecast model computational grid. The question now arises as to which horizonal and vertical scale a particular SATOB really represents? This is a difficult question and the scale varies in the horizontal for different correlation surfaces depending on which areas in the segment pairs are most highly correlated. It would be very useful to NWP if this could be determined in the processing as it should be a measure of the horizontal averaging of the SATOB. Likewise some measure of the vertical depth of the SATOB would be important to NWP. If the feature tracked is just water vapour then the vertical depth is determined solely by the 6.3 micron water vapour weighting function as shown in Fig 1(b).

TABLE 1

SATOB data are used between 50°N and 50°S.
For each satellite data is only used within certain longitude limits:

METEOSAT:	50°W - 50°E
GOES:	160°W - 60°W
HIMAWARI:	90°E - 170°W

In addition to that, the following restrictions apply:

METEOSAT:	Not used over land between 50°N and 35°N Not used over land between 20°S and 50°S when p>500hpa
METEOSAT WV:	Not used
GOES:	Between 50°N and 20°N only used when over sea and p≥700hPa Not used over land between 20°S and 50°S when p>500hpa
HIMAWARI:	Between 50°N and 20°N only used when over sea and p≥700hPa Between 20°S and 50°S only used when over sea and p≥700hPa
INSAT:	Not used

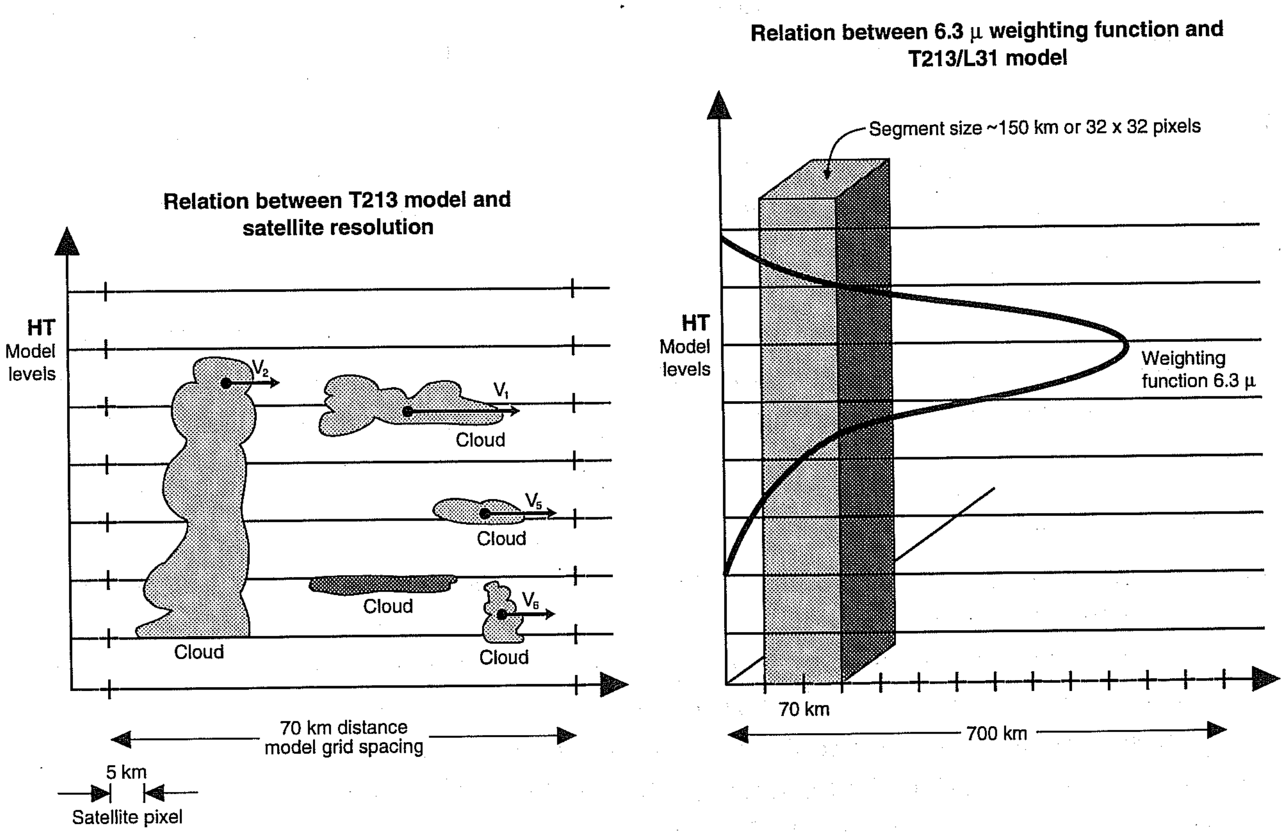


Fig. 1 Sematic representation of atmospheric scales as seen by the model and meteosat imagery.
(a) sub-model scales.
(b) Wind segment and water vapour weighting function.

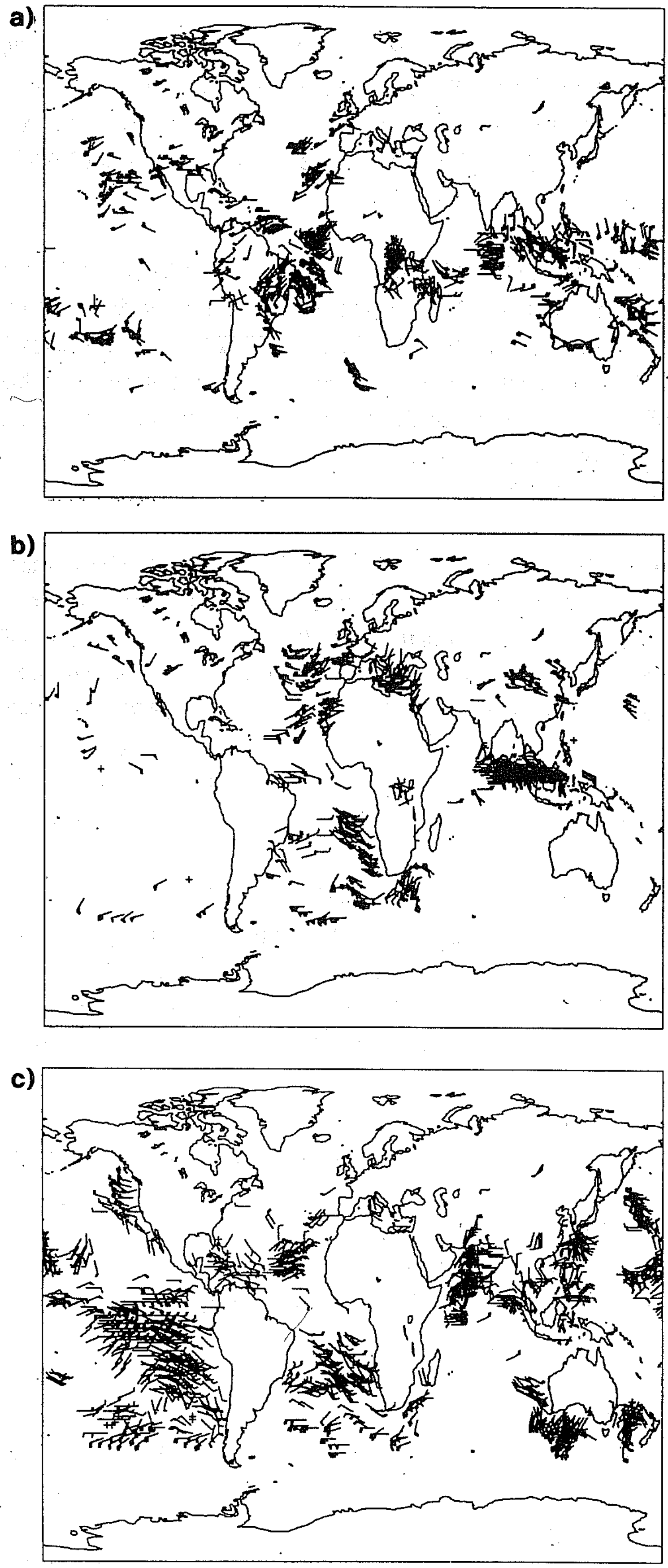


Fig. 2 Data coverage of satobs received operational at ECMWF on the 18 January 94.
(a) Upper level satobs from 350 to 100 hPa.
(b) Mid level satobs from 811 to 349 hPa.
(c) Lower level satobs from 1000 to 800 hPa.

3. OPERATIONAL COVERAGE AND COMPARISON OF SATOBS AND ECMWF GUESS

Since 1987, ECMWF have been monitoring the quality of SATOBs. A major limitation of these data has been the data coverage. Fig 2 shows the current situation. There has been some improvement in coverage recently and, in particular, since the introduction of new water vapour winds from METEOSAT and the new GOES wind processing.

One measure of the overall accuracy of SATOBs is a comparison with the ECMWF first guess which, for SATOBs, is generally the six hour forecast. Fig 3(a) shows a recent scatter plot of two months of SATOBs versus ECMWF first guess for the HIMAWARI, GOES and METEOSAT. The overall quality is similar for each satellite with GOES having a lower RMS error but a more pronounced slow bias. There is a little more scatter in HIMAWARI which is expected due to the satellite having only one infrared channel and hence lower skill with height assignment. These results are also confirmed with Fig 3(b) which is a comparison of aircraft winds and SATOBs.

The operational comparison of INSAT winds with the ECMWF first guess shows many more differences than the other operational SATOBs, although lately there has been some improvement. The quality of the INSAT winds is best demonstrated by overlaying the INSAT SATOBs over the ECMWF analysis as shown in Fig 4. An initial observation is that the 1000 hPa analysis fits the ship data well with a few exceptions. With regard to the INSAT winds, some agree with either the 1000 hPa or 850 hPa ECMWF flow indicating that some winds must be close to or in the boundary layer and some are clearly above. Unfortunately all low level INSAT winds are at the same level. Also there are clearly a number of INSAT winds that are from the east and clearly in strong disagreement with one ECMWF analysis or the other.

4. EXPERIMENTS TO REVISE THE ECMWF OPERATIONAL BLACKLIST

A series of data assimilation experiments has been run to examine the influence of modifying the use of SATOBs, shown in Table 1. The changes are to use both HIMAWARI and GOES in the same way as METEOSAT. This includes the use of all SATOBs over the ocean regions for these three satellites. In addition, the use of water vapour winds from METEOSAT which are included from the GTS.

4.1 Comparisons with first guess

Firstly we will examine the first guess statistics averaged over a two week experiment, run during March 1993, as shown in Fig 5. The observation numbers are not shown but the average is around 600 and the range is from 200 to 10 000. The northern hemispheric results are shown in Fig 5. The solid lines and crosses represent the SATOBs and the dashed lines are radiosonde winds which is common for all plots. It is clear that the fit to the model first guess in an rms sense is very similar to radiosondes.

Similar plots for comparing SATOBs and radiosonde winds in the tropics are shown in Fig 6. In this region there are much fewer radiosondes, a factor of ten less than the Northern Hemisphere. Hence the analysis is very dependent on SATOBs. A problem has been noticed with the lower METEOSAT water vapour winds at about 350 hPa. They appear to have a poorer fit than at other levels and this will be discussed later in the paper.

4.2 Forecast scores for 1989 satellite impact experiments

A series of four Observing System Experiments (OSEs) have been carried out using a T106/L19 version of the forecasting system. The aim was to get a detailed evaluation of the impact of satellite data (SATEMs and SATOBs). The data assimilation experiment was run between 6 and 22 February 1989 and used all the

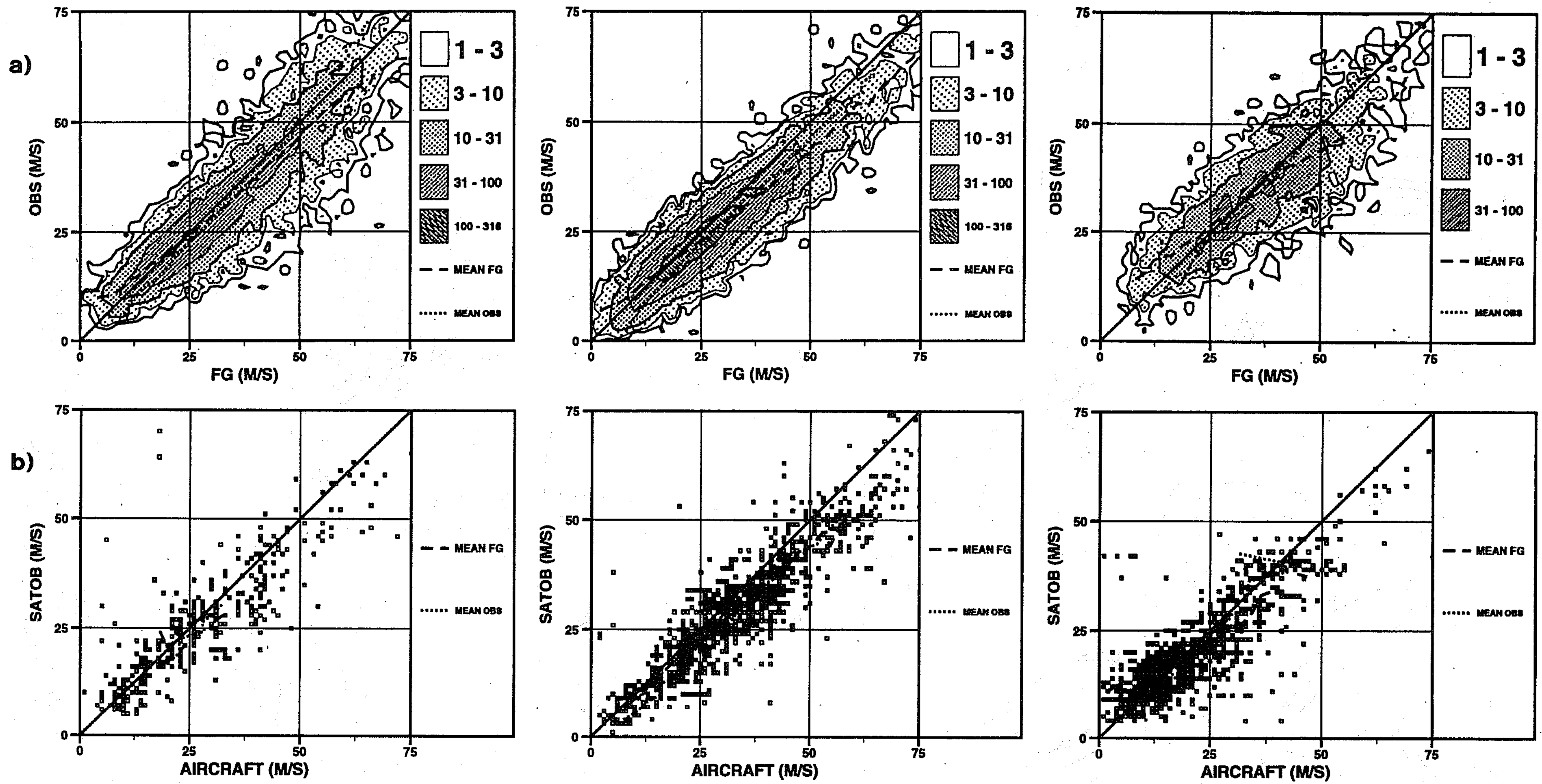


Fig. 3 SATOB statistics.
(a) First Guess differences for operational SATOBs in the northern hemisphere for january and february 1994.
(b) Differences between collocated aircraft winds.

a)

b)

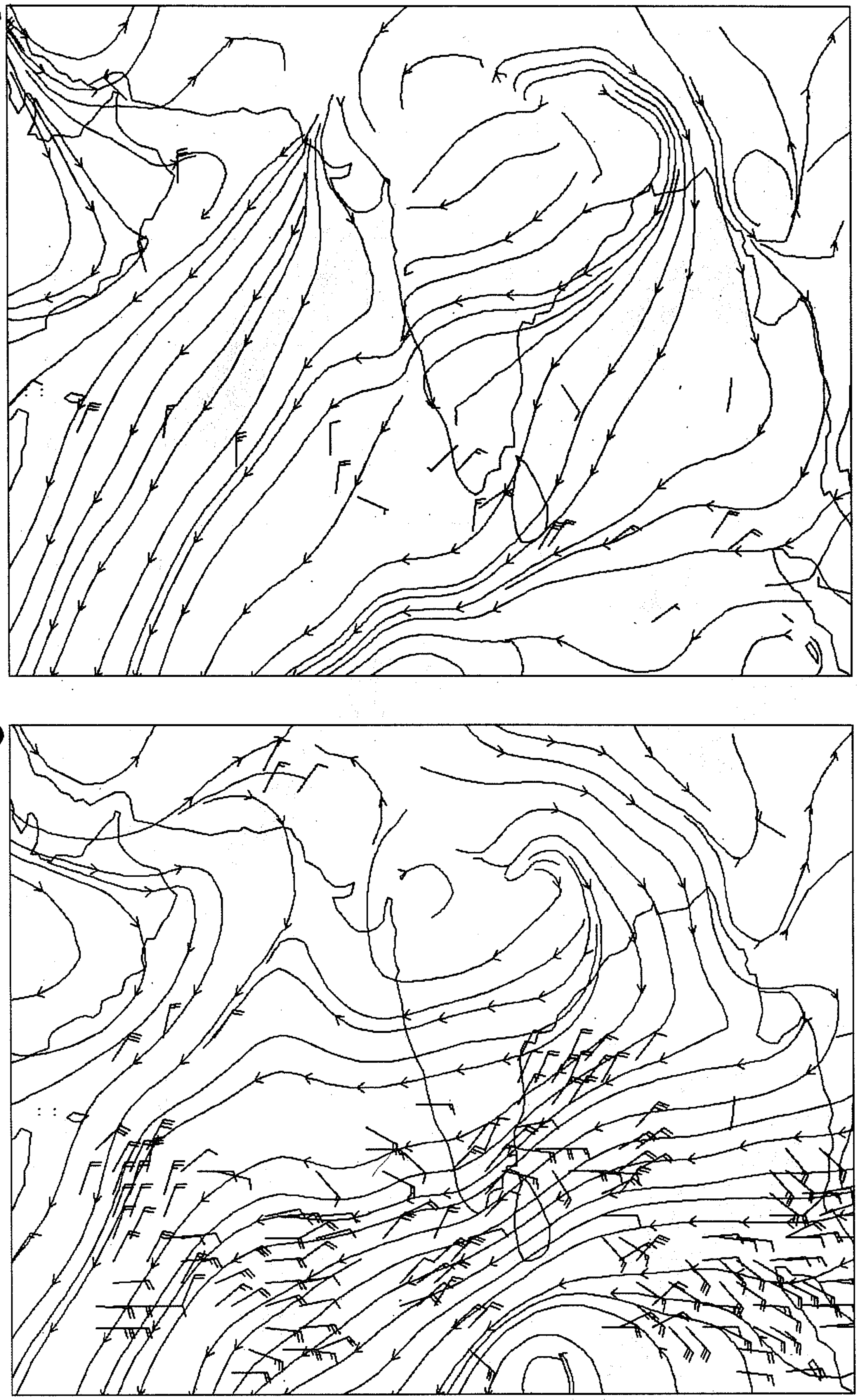


Fig. 4 A comparison between INSAT SATOBs, ship winds and ECMWF analysis.
(a) Ship observations plotted with 1000 hPa streamlines.
(b) INSAT SATOBs observations plotted with 850 hPa streamlines.

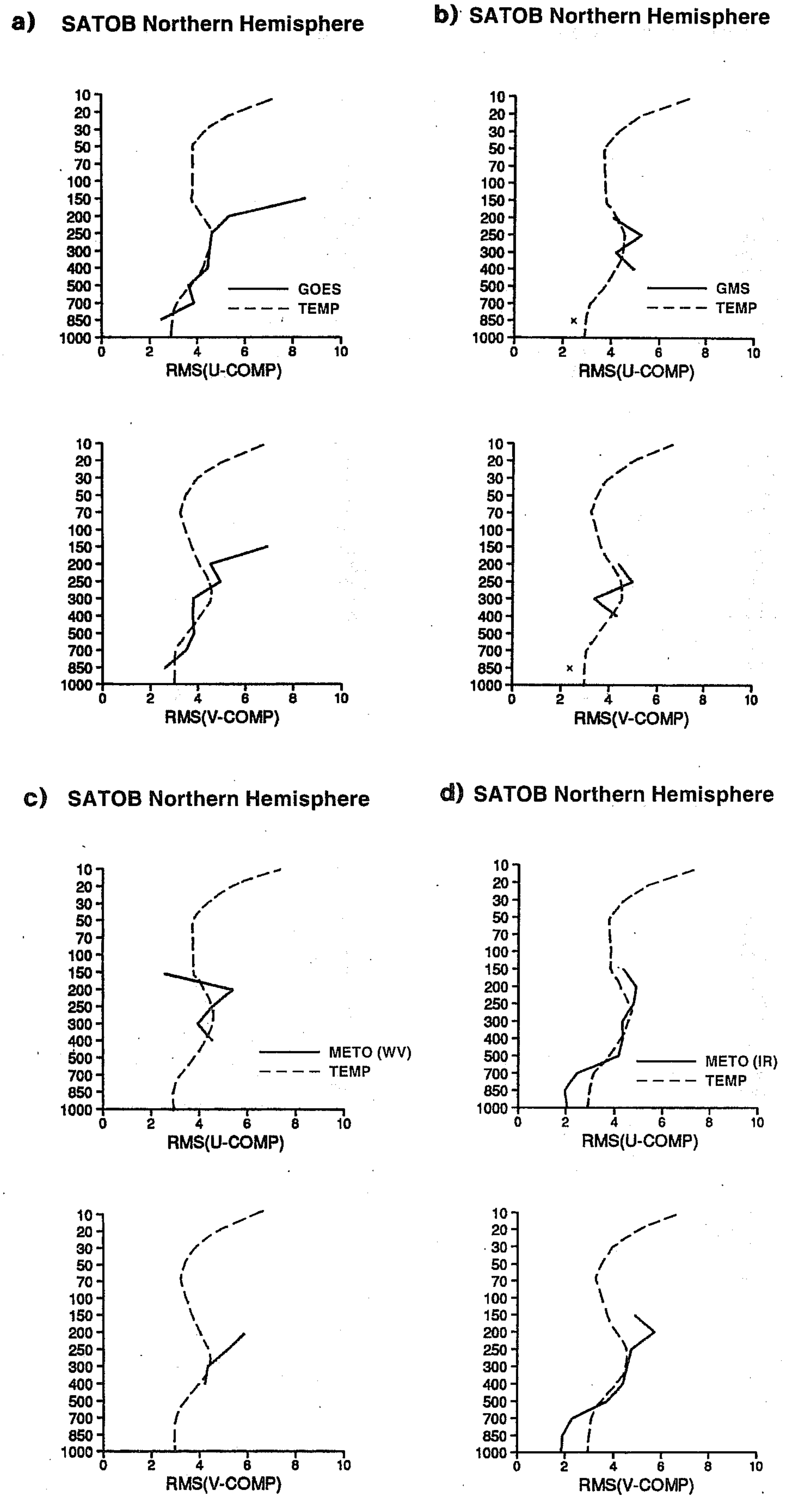


Fig. 5 First Guess differences for radiosondes (dashed) and satobs (solid) but for the Northern Hemisphere (20°N to 50°N).
(a) GOES (b) GMS (c) METEOSAT (IR) (d) METEOSAT (WV)

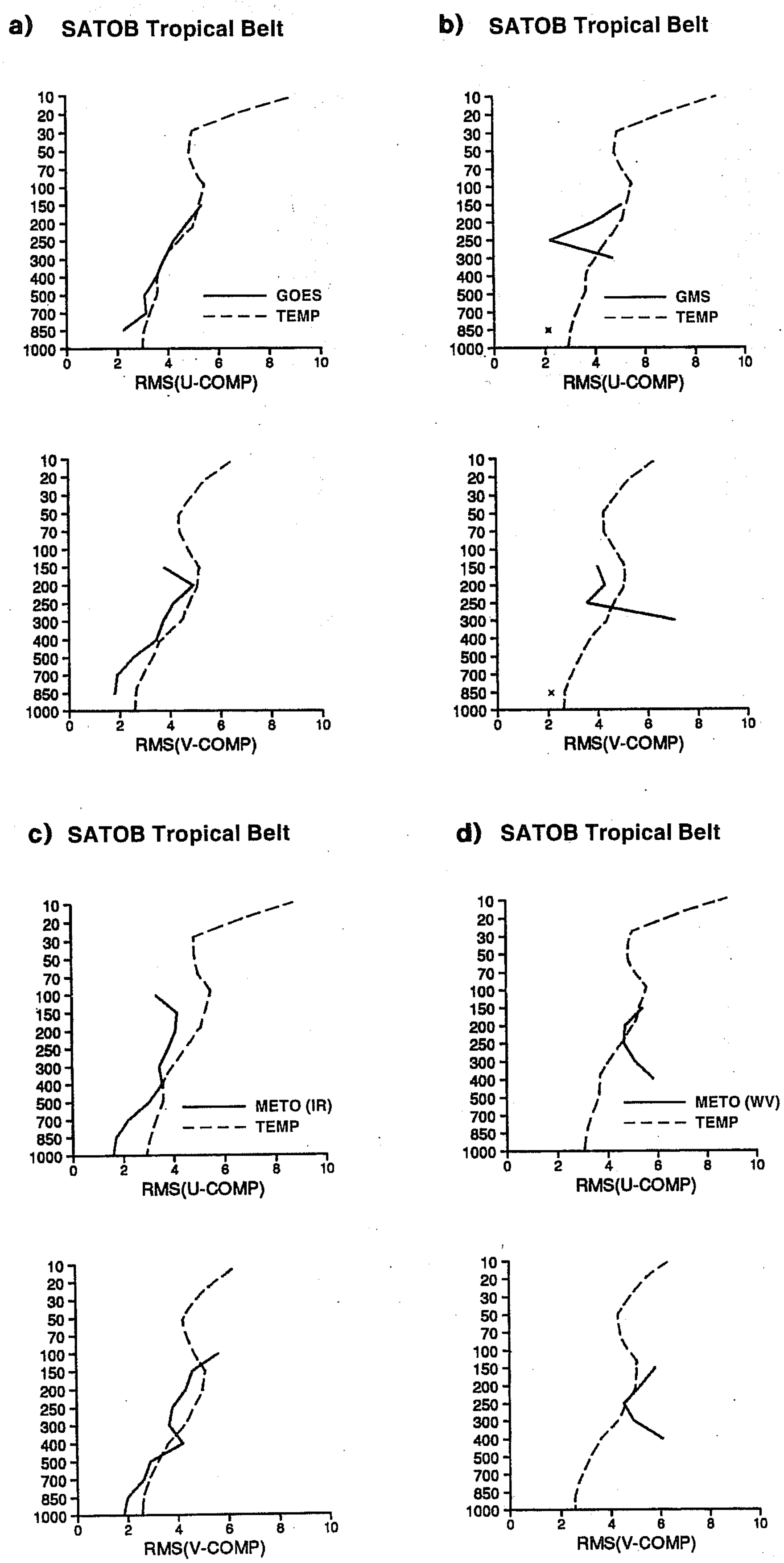


Fig. 6. Same as Fig. 4 for the tropical belt (20°N to 20°S).

conventional observation types, and different combinations of SATEMs and SATOBs as they were used at ECMWF at that time.

By adding SATOBs and SATEMs to "NOSPACE" and the combination, it is possible to evaluate their individual impact with respect to conventional observations. The comparison between the different parallel forecasts has been made and generally the forecast scores show a gradual increase of the forecast quality when one adds more observing systems. This is true for just adding SATOBs or SATEMs but not true with the combination as shown in Fig 7. The experiment which contains all the satellite data performs worse in the medium range than "NOSPACE + SATOB" and "NOSPACE + SATEM"; it indicates that the combination "SATEM + SATOB" is not used properly by the ECMWF assimilation system. Accordingly the combination which produces the best anomaly correlation on the Northern Hemisphere is "NOSPACE + SATOB" (i.e. an assimilation not using any SATEMs)!

The surprising and puzzling aspect of this last result was the original reason for investigating in more detail the series of parallel data assimilation experiments, especially by looking at the individual impacts of SATOBs, SATEMs. The outcome of these OSE experiments was to remove SATEMs from the operational analysis in the tropics and Northern Hemispheric troposphere until the introduction of 1D-VAR which used the satellite radiances and produced an analysis in the Northern Hemisphere which improved the forecast.

4.3 Revised SATOB blacklist impact experiments

The impact experiment described above was run using the SATOB data coverage as described in table 1. Two additional experiments, each of 15 days, have been run on later periods allowing the inclusion of extra winds from GOES and HIMAWARI. The low and upper level wind from these two satellites are extended from the equatorial region to be similar to METEOSAT. Fig 8 shows a two week experiment which parallels operations except for the extra winds. In this period 1D-VAR was operational. The forecast scores are neutral in the northern and Southern Hemisphere but there is a small improvement over Europe.

The other experiment was run on a later period but was at T106/L19 and, in addition to the previous experiments, included an additional no-SATOB experiment. The results from these experiments are not as clear as the previous experiments although there was no separation of the scores up to day four. In the hemispheric scores there was a small loss after day six for all the SATOB experiments and a small gain in the Southern Hemisphere. In the European region there is a loss with the SATOB experiments.

4.4 METEOSAT tropical case study

Some disagreement was noticed between the lower level (approx. 400-300 hPa) tropical water vapour winds and the first guess as shown in Fig 6(b). Fig 10 shows the ECMWF analysis wind stream lines at 250 hPa and 150 hPa. In the region near Lake Chad (14 N 14 E) there is almost a reversal in wind direction with height. Fig 11 shows the METEOSAT SATOBs and the reported radiosonde winds. The analysis generally draws closely to radiosondes.

The assigned SATOB heights are plotted on Fig 11(a) and in the Lake Chad region they vary from 280 hPa to 100 hPa, but the wind direction is always from a southerly direction. It appears that all these winds should be above 150 hPa and are cirrus winds and not purely water vapour. If we further examine a time sequence of four water vapour images, Fig 12, one can see in the first image (21 UTC on 5/3/93) a very large convective cluster developing in central Africa. At 09 UTC on 6/3/93 the convective cluster has decayed but the cold cirrus is being blown towards the north. By 15 UTC on 6/3/93 this cirrus is now being

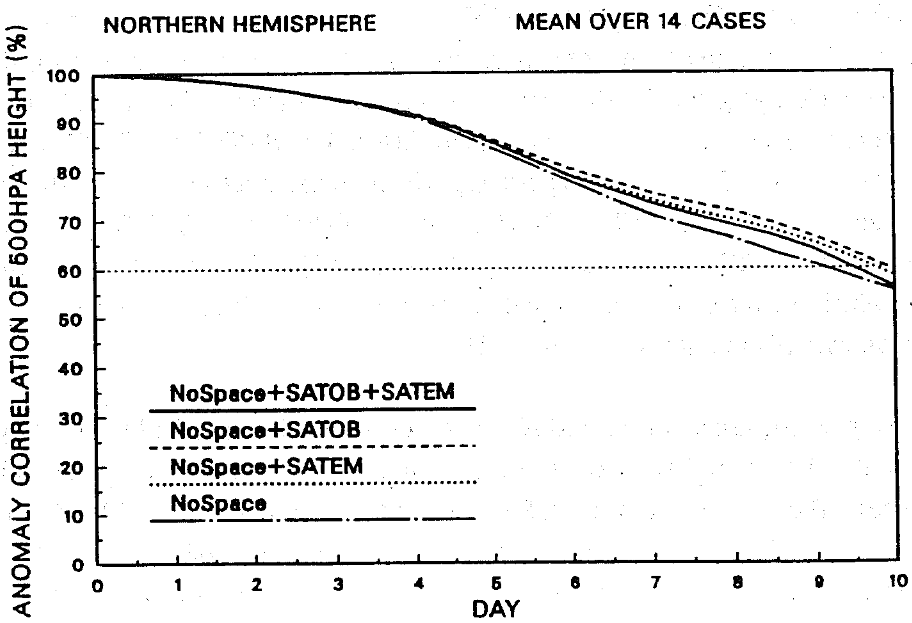


Fig. 7. Northern Hemisphere extra-tropics anomaly correlations of 500hPa for a two week period in February 1989. Impact of space observing systems (SATEMS, SATOBS and the combination).

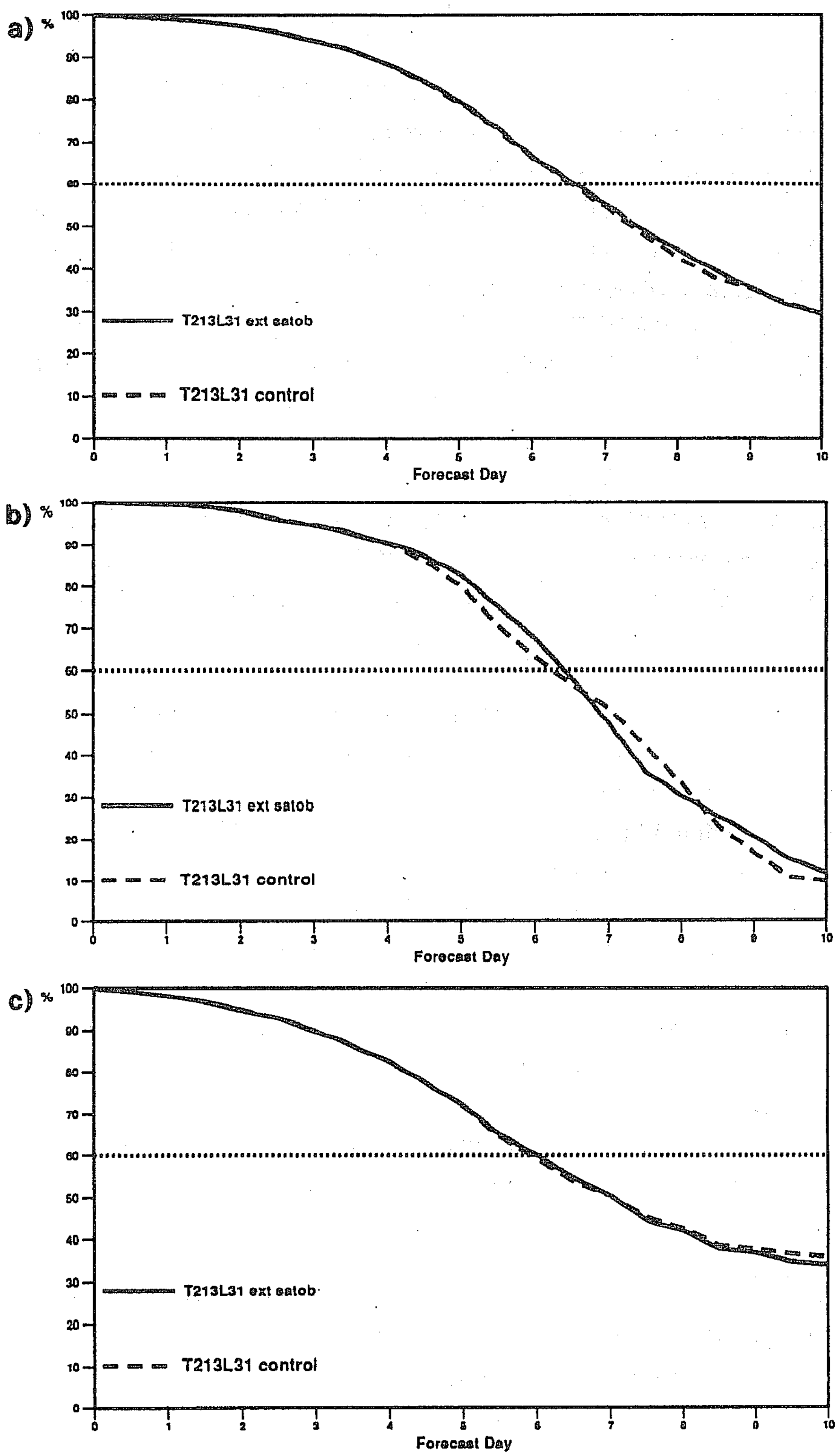


Fig. 8. Anomaly correlation for examining the impact of modifying the current operation blacking in order that GMS and GOES are treated the same as METEOSAT. The solid line is the modified blacklist experiment and the dashed the than current operations.
(a) Northern hemisphere, (b) Results for the european area, (c) Southern hemisphere.

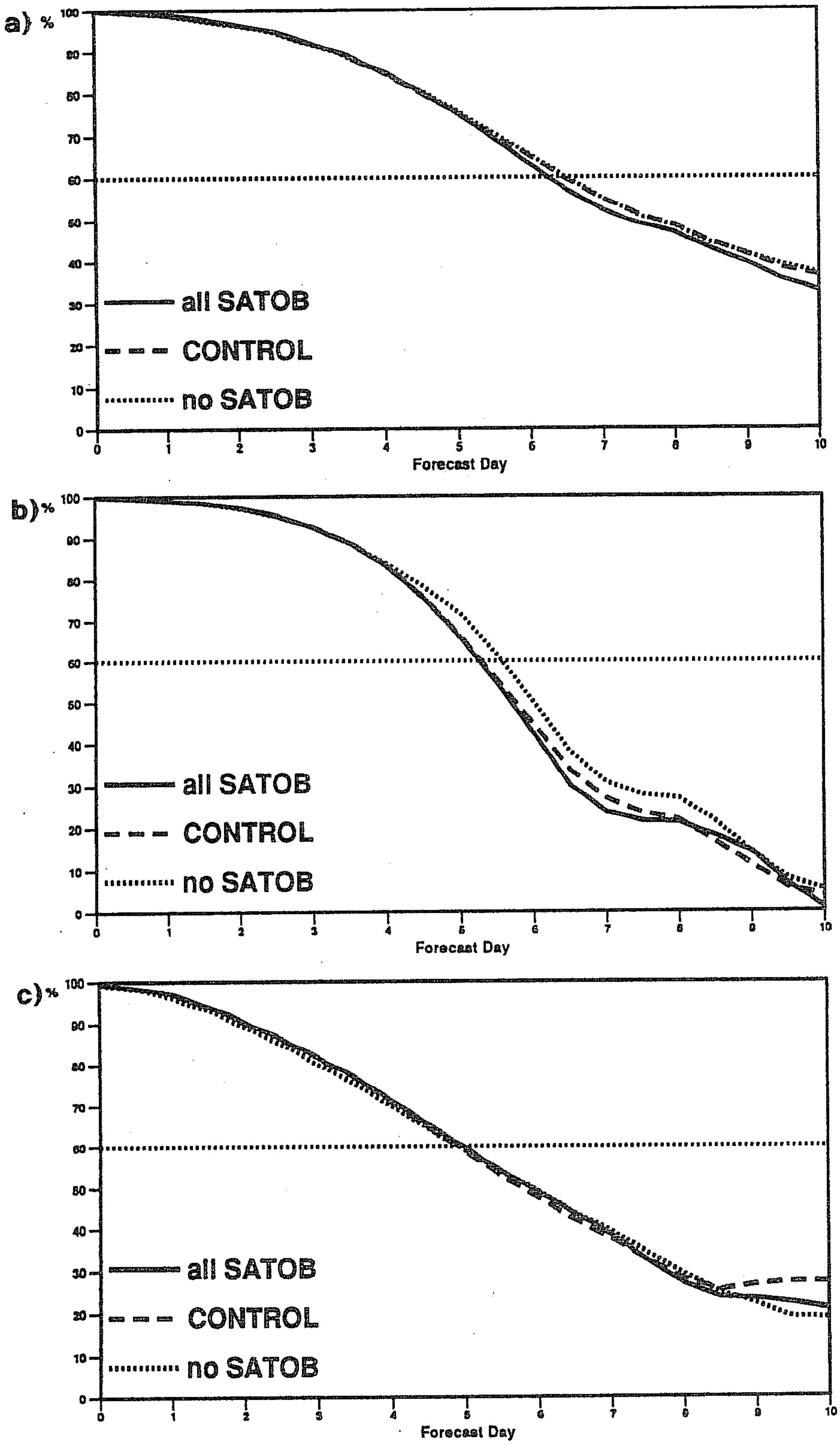


Fig.9. Anomaly correlation for examining :
(i) the impact of modifying the current operation blacking in order that GMS and GOES are treated the same as METEOSAT. The solid line is the modified blacklist experiment and the dashed the than current operations,
(ii) the impact of removing all satobs from the assimilation (dotted).
(a) Northern hemisphere, (b) Results for the european area, (c) Southern hemisphere.

a)

b)

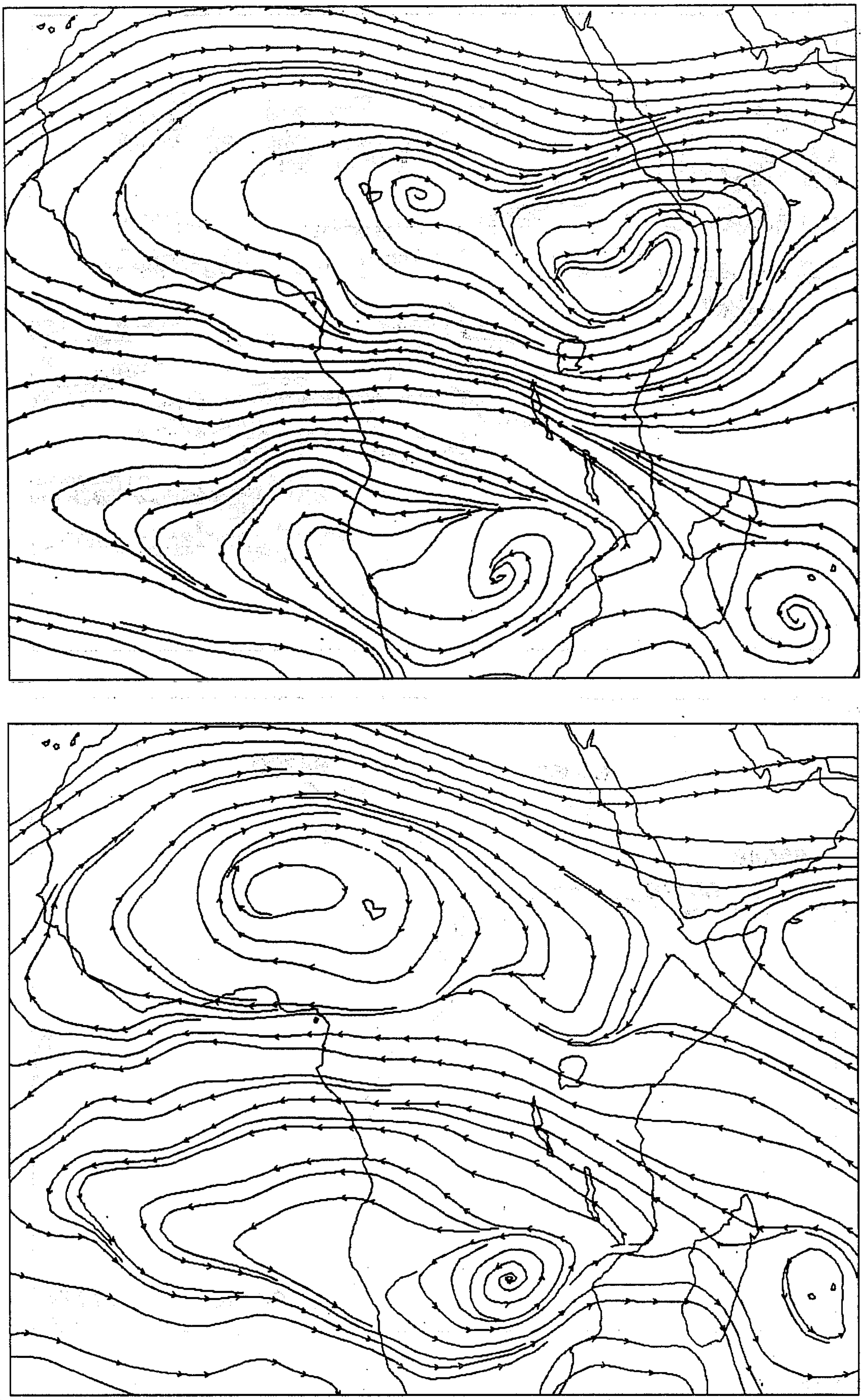


Fig. 10. Wind stream lines for the 12 UTC 6/3/1993 ECMWF analysis.
(a) 150 hPa, (b) 250 hPa.

a)

b)

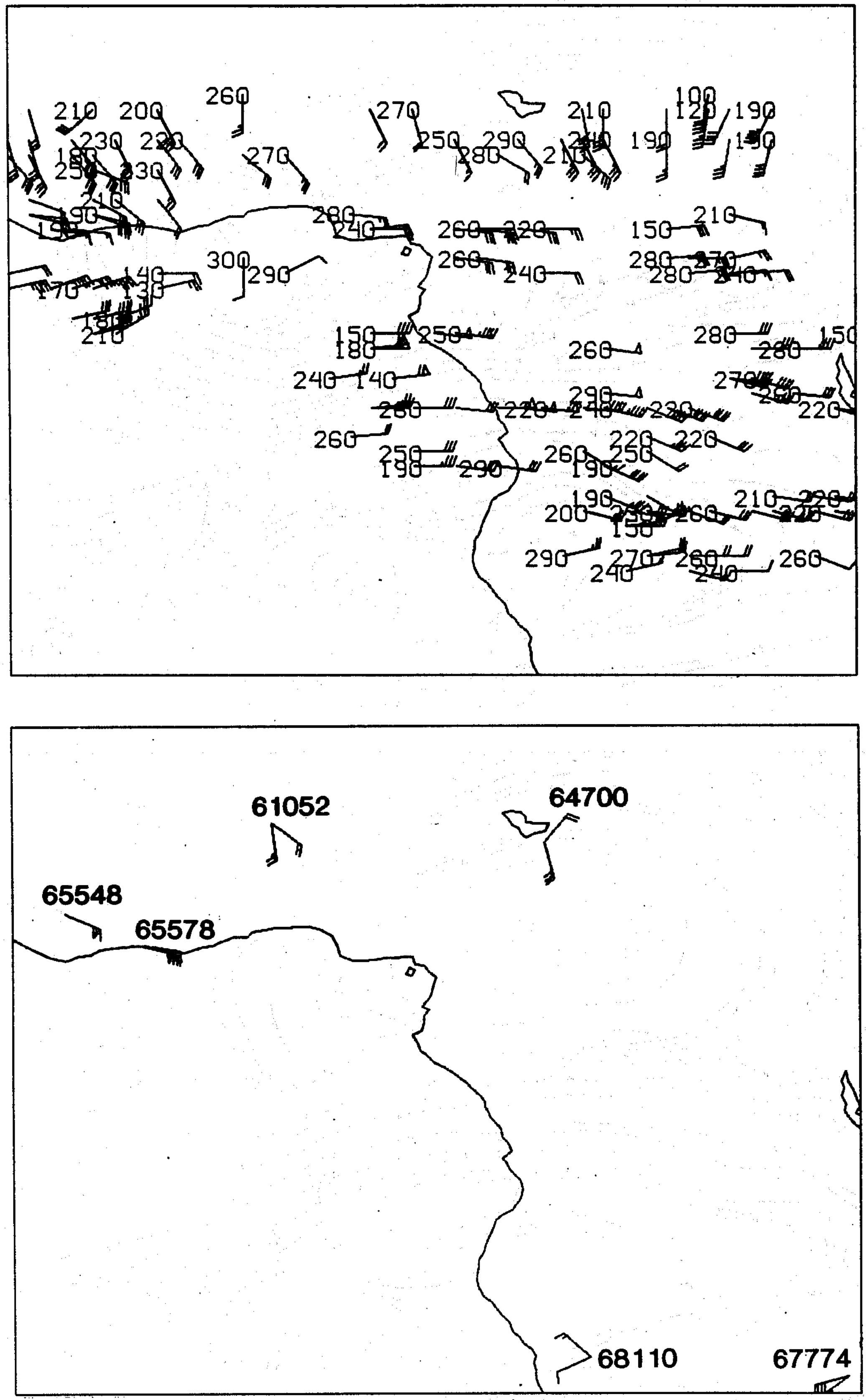
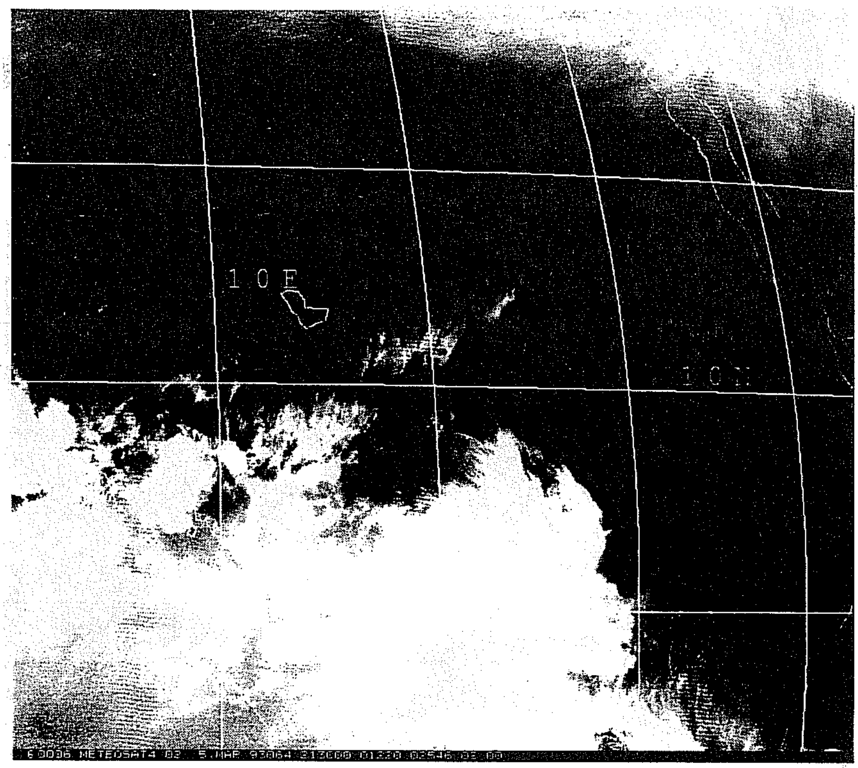


Fig. 11. Observations.
(a) SATOBs from METEOSAT between 300 hPa and 100 hPa for the same time as Fig. 10. The heights are plotted in hPa. (b) Radiosonde winds at 250hPa and 150 for the same time as Fig. 10.

5 March 1993
2130 UTC



6 March 1993
0930 UTC

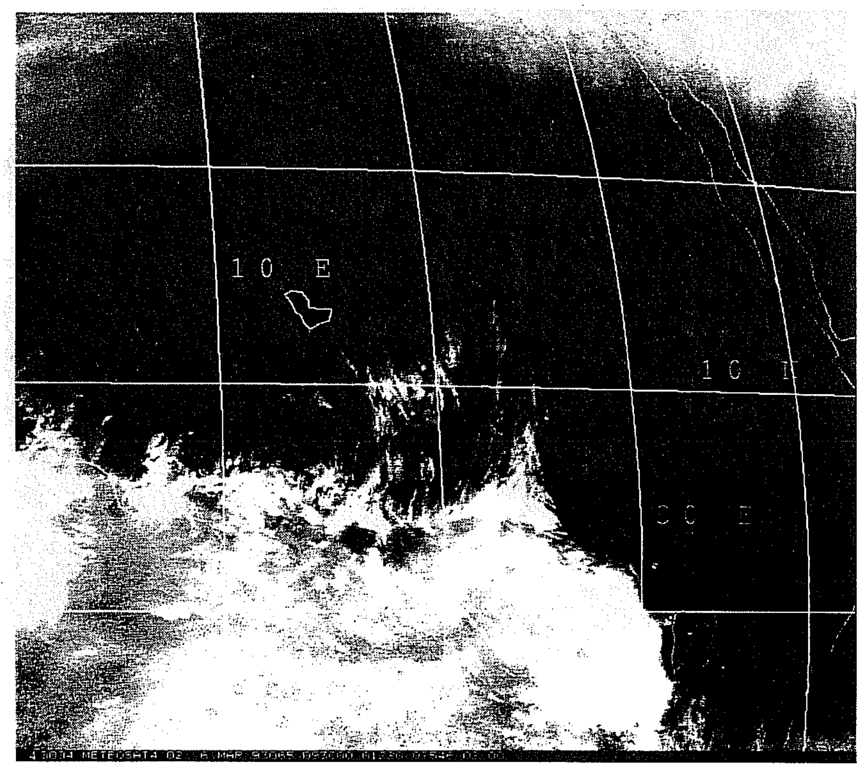
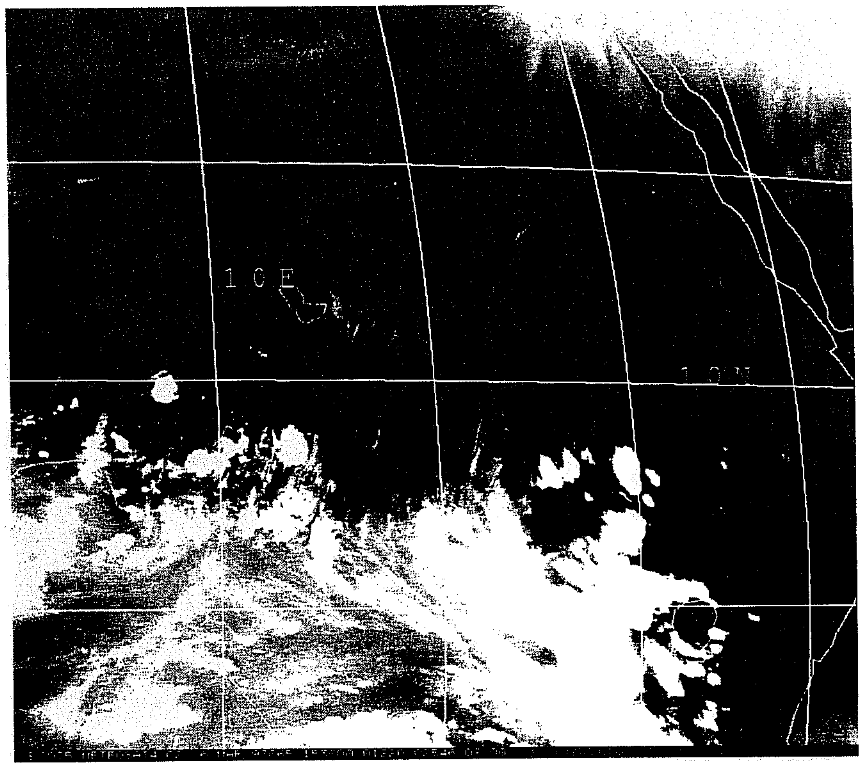


Fig. 12. Meteosat 6.3 micron water vapour channel.

6 March 1993
1630 UTC



6 March 1993
2130 UTC

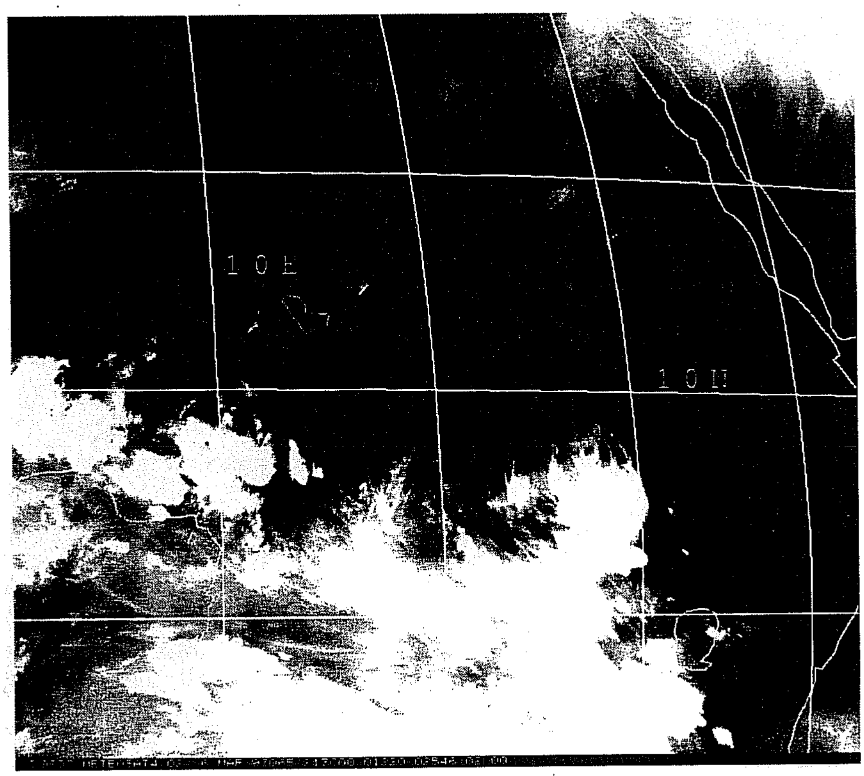


Fig. 12 cont

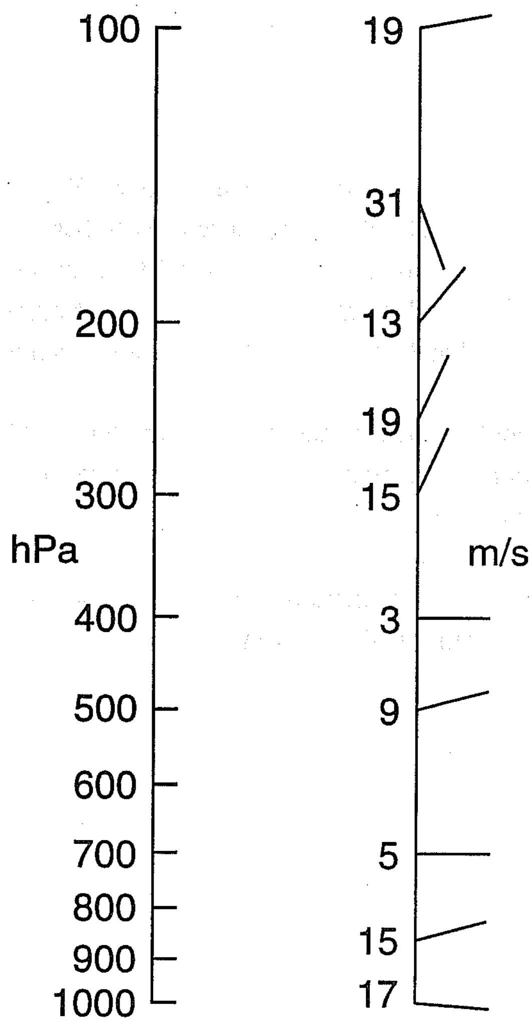


Fig. 13 Radiosonde wind profile for NDJAMENA, CHAD (WMO 64700) at 12 UTC 6/3/93 lat 12:08N long 15:02E .

transported westerly by the southern edge of the Northern Hemispheric sub-tropic jet. The upper wind sounding at WMO station 67700, shown in Fig 13 also supports that the SATOBs should be above 150 hPa.

It appears that, because the cirrus is very thin, it has a lower brightness temperature and the height assignment puts some of these SATOBs too low.

CONCLUSIONS

There have been improvements in both the quality and quantity of SATOBs recently, but there are still many regions, in particular in the tropics and sub-tropics, where SATOBs are the only source of upper air observations for NWP. One problem is that the satellite wind producers may become too sensitive to the NWP monitoring in order to improve the "errors" and hence reduce the number of SATOBs produced. With the development of new four dimensional analysis systems, better use can be made of more frequent winds.

More information is required about the quality and nature of the target. The variational analysis methods can make good use of information concerning the nature of the measurement, for example if it is a deep layer water vapour wind or a shallow layer cloud wind.

Clear 6.3 micron radiances would be an important output of the segment processing and would help get the NWP product in closer agreement with wind processing.

There are some signs of improvement in the INSAT winds but more monitoring is required before they could be used in the ECMWF analysis.

The Australian winds should be put on the GTS.

REFERENCES

Kelly, G and J Pailleux, 1989: A study assessing the quality and impact of cloud track winds using the ECMWF analysis and forecast system. Proc ECMWF/EUMETSAT workshop on 'Satellite data in operational numerical weather prediction 1989-1993' Vol 2, p 317-338, Reading, UK, publ ECMWF.

Thoss, A, 1991: Cloud motion winds, validation and impact on numerical weather forecasts. Proc. EUMETSAT, NOAA and WMO on 'Workshop on wind extraction from operational meteorological satellite data.' p 105-112 Washington, DC USA, publ EUMETSAT.

Strauss, B, 1991: Monitoring of cloud-motion winds at ECMWF. Proc. EUMETSAT, NOAA and WMO on 'Workshop on wind extraction from operational meteorological satellite data.' p 151-157 Washington, DC USA, publ EUMETSAT.