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Experiments Using NSCAT Data in the NCEP Global Data Assimilation and Forecast System[1]

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1. Introduction/motivation

The NASA scatterometer (NSCAT) aboard the Japanese satellite ADEOS provided unprecedented coverage of marine surface winds during it's short-lived mission. Unfortunately, the satellite mission failed (June 1997) before the data were ever used in any of NCEP's operational numerical weather prediction model. One of the goals[1] of the NSCAT mission was to "develop improved methods of assimilating wind data into numerical weather and wave prediction models." Despite the fact that the NSCAT data never made it into an operational model, the question of what kind of impact it would have had on today's numerical weather prediction models remains valid. Several future scatterometer missions are planned, including the QSCAT launch in the spring of 1999. Thus a retrospective test of NSCAT data in the NCEP global data assimilation and forecast model system may help to answer questions about data assimilation and assist in planning and developing improved methods of data assimilation of satellite surface winds. This paper describes the assimilation and forecast experiments used to test the NSCAT data in the NCEP global model system and the results obtained from the experiments.

2. The NSCAT sensor

The NSCAT was a microwave radar scatterometer which measured the roughness of the ocean surface, which was then converted into wind vectors over the world's oceans. The NSCAT was a double-sided radar, with three fixed antenna beams on each side of the satellite orbit, scanning two 600 km wide bands of ocean. The coverage was such that every two days, at least 90% of the Earth's ice-free oceans were sampled. NSCAT transmitted quick pulses of microwave energy which were then reflected or backscattered and measured at a receiving antenna. The basic design of a three-stick scatterometer was similar to that of ERS-1 and ERS-2.

The data were processed by NASA-JPL and provided to NCEP by NESDIS. Typical six-hour coverage of NSCAT data is shown in figure 1. The data were ingested on a workstation and some preliminary validation against buoys was done (Gemmill and Chang, 1997). Statistics showed that the NSCAT speeds were comparable to ERS-1 and ERS-2 in terms of RMS error, and directions were also generally good. Some quality control problems were noted with the NESDIS "fast-delivery" winds, such as unusually high wind speeds along the inside edge of the satellite track, and areas of poor ambiguity removal (figure 2). In general, NSCAT wind speeds were observed to be greater in areas of high winds than ERS-1, ERS-2 or SSM/I.

3. Experimental Design

To test the impact of NSCAT data on the current NCEP global model system, a 16 day period during May and June of 1997 was chosen. At this time, ERS-2 data were not yet being

[1] NASA-JPL NSCAT home page:
http://winds.jpl.nasa.gov/missions/nscat/nscatindex.html

assimilated into the NCEP global data assimilation system (GDAS). This was due to the fact that during a conversion between two computer systems, the ERS-1 satellite was replaced by the ERS-2 satellite and validation of the wind data was not yet completed . SSM/I wind speed data were included in the NCEP GDAS at this time. The experiments documented here used a T62 version of the NCEP global model, roughly equivalent to 100 km resolution at the equator. The data assimilation system and model codes used were those that ran operationally at NCEP in June of 1997, including the direct assimilation of satellite radiances.

During the period May 31 - June 15, NSCAT wind vectors were packed into BUFR and then merged into the prepdata file, which is then read by the analysis code. This approach was similar to what was initially done with ERS-1 data in order to assimilate the winds into the GDAS (Yu, 1995). A control run was initiated starting May 31, 0000 GMT. The control run included all conventional data sources, such as rawinsondes, ships, SSM/I and satellite radiances, except no scatterometer data. Every six hours, a new analysis was produced. A 120 hour (five day) MRF forecast was generated once daily, at 0000 GMT, from the analysis. The parallel run was identical to the control, with the important exception that NSCAT wind vectors were now included along with the other conventional data types.

A series of one control and three parallel experiments were performed. The control experiment used all available conventional data, including satellite radiances and SSM/I wind speeds. The first parallel experiment used the NSCAT "fast-delivery" vectors, which NCEP was receiving operationally in 1997. A second parallel used the NSCAT "science" data, obtained from NASA-JPL, which were not available in near real-time but were of a higher quality generally. A third parallel experiment involved using the same science dataset, but reduced the observational error assigned to the data, in order to increase the weight of the data. This will be described in more detail in the following section.

Table 1

Model Experiments

1. CONTROL	Conventional Data, SSM/I wind speeds, satellite radiances
2. NSCAT-FD	CONTROL + NSCAT "fast-delivery" data
3. NSCAT-SC	CONTROL + NSCAT "science" data
4. NSCAT-SE	CONTROL + NSCAT "science" data, reduced observation error

4. Results: Anomaly Correlation Scores

The results of the experiments 1-3 are presented in figure 3a-d, in terms of anomaly correlation scores for day 1 - 5 forecasts. The anomaly correlation is a measure of the forecast skill that correlates the forecast anomaly, defined as the difference between the forecast and climatology, and the verifying analysis anomaly. The verifying analysis is provided by the model, in this case the GDAS analysis. The sample size for these results is 11 cases, from the period May 31 - June 10. The 1000 hPa (near-surface) anomaly correlation scores for the Northern and Southern Hemisphere are shown in figure 3a and 3b, respectively.

In the Northern Hemisphere, the impact of the NSCAT-FD and NSCAT-SC data appears to be very small, as the scores for day 1 - day 5 are nearly identical to that of the CONTROL run. There appears, however, to be a very small but noticeable improvement in the anomaly correlation score of the NSCAT-SC data compared with the control and the NSCAT-FD at day 5. In the Southern Hemisphere, both the NSCAT-FD and the NSCAT-SC show a clear positive improvement in anomaly correlation scores over the CONTROL. The "fast-delivery" data (NSCAT-FD) actually shows the highest score at day 5. The improvement in forecast accuracy

(NSCAT-FD) appears to represent an extension of about five hours in forecast skill at day 5. Thus it appears that the NSCAT data had a positive and significant impact in the Southern Hemisphere, in terms of 1000 hPa anomaly correlations.

Anomaly correlation scores at 500 hPa are shown in figure 3c-d. In the Northern Hemisphere (3c), there appears to be almost no difference between the three experiments. The CONTROL, NSCAT-FD and NSCAT-SC runs all produced nearly the same scores. This suggests that there was no real impact at 500 hPa from the assimilation of either the NSCAT-FD or the NSCAT-SC data. In the Southern Hemisphere (3d), there is a very different result. The impact of both the NSCAT-FD and the NSCAT-SC data is clearly positive by day 5. The NSCAT-FD data has the largest positive impact, equivalent to about a 7-8 hour extension of useful forecast skill at day 5. The increase in forecast skill also appears to be larger for the NSCAT-FD data, suggesting that the data may retain their positive impact at extended ranges past day 5. The NSCAT-SC data has less of a positive impact, but still represents quite a significant improvement over the CONTROL.

A fourth experiment (third parallel) was performed, where the observational error used by the analysis to assign a weight to the data was modified. The observational error controls the weighting given to the fit of the data, and encompasses two components: instrument errors and errors of representativeness. The smaller the observational error, the more heavily weighted the data will be in the analysis. For the original NSCAT-SC experiment, the observational error for scatterometer data was set to 2.5 m/s (the same as ship wind data in the operational analysis). As an additional experiment, this observational error was reduced to 2.0 m/s, to test the sensitivity of the analysis and forecasts by forcing the analysis to fit more closely to the scatterometer data. Additional positive impact might suggest that the value of the observational error should be set to be lower for this type of scatterometer data. The value of 2.0 m/s is very near the NASA specified accuracy of the NSCAT sensor.

The results of the fourth experiment are shown in Figure 4a-b. Only the Southern Hemisphere results are shown, because the Northern Hemisphere results were very similar. The NSCAT-SC data and NSCAT-SE (reduced observational error) 1000 hPa anomaly correlation scores are shown in Figure 4a. There appears to be very little if any additional forecast skill gained by reducing the observational error, based on the closeness of the two curves. A very slight increase in anomaly correlation score is seen at day 5 in the NSCAT-SE experiment. Similarly, at 500 hPa (figure 4b), the NSCAT-SC and NSCAT-SE anomaly correlation scores are nearly identical. There is some slight improvement at day 5 obtained from the reduced observational error, but such a small difference is probably not significant. Thus it appears that there is not much to gain by reducing the observational error beyond 2.5 m/s within the current operational NCEP data assimilation and forecast system for this type of scatterometer data.

5. Results: Case Study

Although anomaly correlation scores are useful for assessing the overall picture of model performance, cases of large impacts are often obscured by globally and temporally averaged statistics. It is useful to look at these individual cases as well, in order to fully understand the results of a forecast experiment. The positive impact of scatterometer data on numerical weather prediction models is predominantly seen in the Southern Hemisphere, where a greater percentage of the earth is ocean-covered and fewer conventional data sources exist. However, from time to time positive impacts can occur in the Northern Hemisphere as well. One such case is briefly described here.

Two MRF day five forecasts of mean sea level pressure are shown in Figure 5a-b. The first is from the CONTROL forecast (5a), while the second is from the NSCAT-FD forecast.

The primary feature of interest is a cyclone in the Gulf of Alaska, near 50°N and 150°W. This case occurred during the period of the parallel experiments, with the forecast valid time being 0000 GMT June 10, 1997. The verification map shown in figure 6 is a hand drawn surface analysis produced by marine forecasters of NCEP's Marine Prediction Center. This chart will be assumed to be "ground-truth" for purposes of model forecast evaluation. The cyclone appears to be located near 49°N, 144°W, with a central pressure of 1002 hPa. The CONTROL forecast (figure 5a) has this cyclone too far west and south, near 47°N, 152°W. It also appears to be a little too deep, below 1000 hPa. The NSCAT-FD forecast (figure 5b), while still not progressive enough, has the storm near 48°N, 148°W, a great deal closer to the verification position. The central pressure appears to be very close to the CONTROL, i.e. a little too deep. Overall, the forecast from the NSCAT-FD experiment seems to be a good deal more accurate with respect to this particular cyclone in the Gulf of Alaska. Further differences in the mean sea level pressure forecast can be seen downstream over Canada, however the verification chart doesn't extend far enough east to evaluate which forecast (CONTROL or NSCAT-FD) is superior in this region. At least with regard to the Gulf of Alaska cyclone, this case is an example of the type of positive impact that can be seen in the Northern Hemisphere from the assimilation of scatterometer data into the model.

6. Conclusions

The impact of NSCAT data on a T62 version of the NCEP global data assimilation and forecast system was tested through a series of data assimilation experiments. The version of the global model was very similar to what is currently operational at NCEP today, including the direct assimilation of satellite radiances. The results indicate that the data had an appreciable positive impact in the Southern Hemisphere, in terms of 500 hPa and 1000 hPa anomaly correlation scores. In the Northern Hemisphere, the impact was more or less neutral. The NSCAT "science" data showed surprisingly little advantage over the "fast-delivery" data, in terms of it's impact on the model forecasts, except for a very slight advantage in the day five near-surface anomaly correlation scores in the Northern Hemisphere. An experiment that reduced the observational error for scatterometer data (used by the analysis to control the weighting of the fit to the data) resulted in only extremely small differences from the experiment with a higher value of the observational error. This suggests that the value currently being used in the NCEP data assimilation system for scatterometer data may be adequate, and further reduction may be unnecessary.

Overall, the results suggest that the NSCAT data would have had a beneficial impact on the operational NCEP global model system, mainly in the Southern Hemisphere. Occasional improvements on a case-by-case basis were noted in the Northern Hemisphere. These results are consistent with the experience of other operational numerical weather prediction centers, in terms of the data having more impact in the Southern Hemisphere. Future scatterometer missions which provide similar high quality marine surface wind data should benefit both the global numerical weather prediction models and the forecasting community.

References:

Atlas, Robert, 1998: Observing System Experiments to Assess the Impact of NSCAT Data on Weather Analysis and Forecasting. Available from the Data Assimilation Office, code 910.4, NASA Goddard Space Flight Center, Greenbelt, MD 20771.

Gemmill, W. and P. Chang, 1997: Comparisons of NSCAT and ERS-2 "real-time" wind data sets. American Geophysical Union, Spring Meeting, Baltimore, MD, May 27-30, 1997.

Yu, T.W., 1995: Assimilation Experiments with ERS-1 Winds: Part II - Use of Vector Winds in NCEP Spectral Statistical Analysis System. Ocean Modeling Branch Technical Note Number **117**.

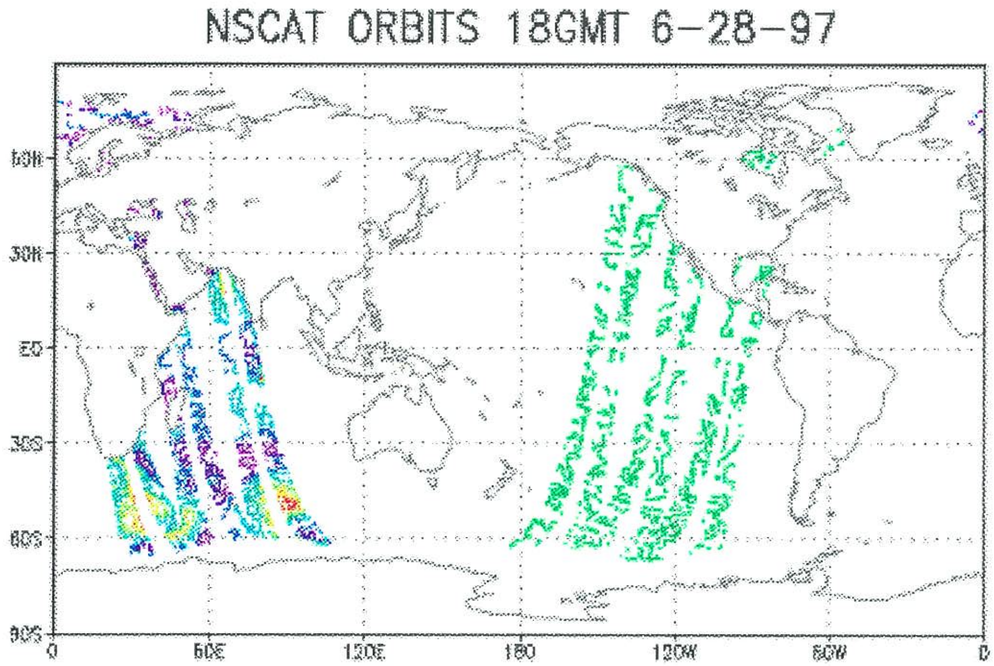


Figure 1: Typical coverage of NSCAT data in a six-hour period.

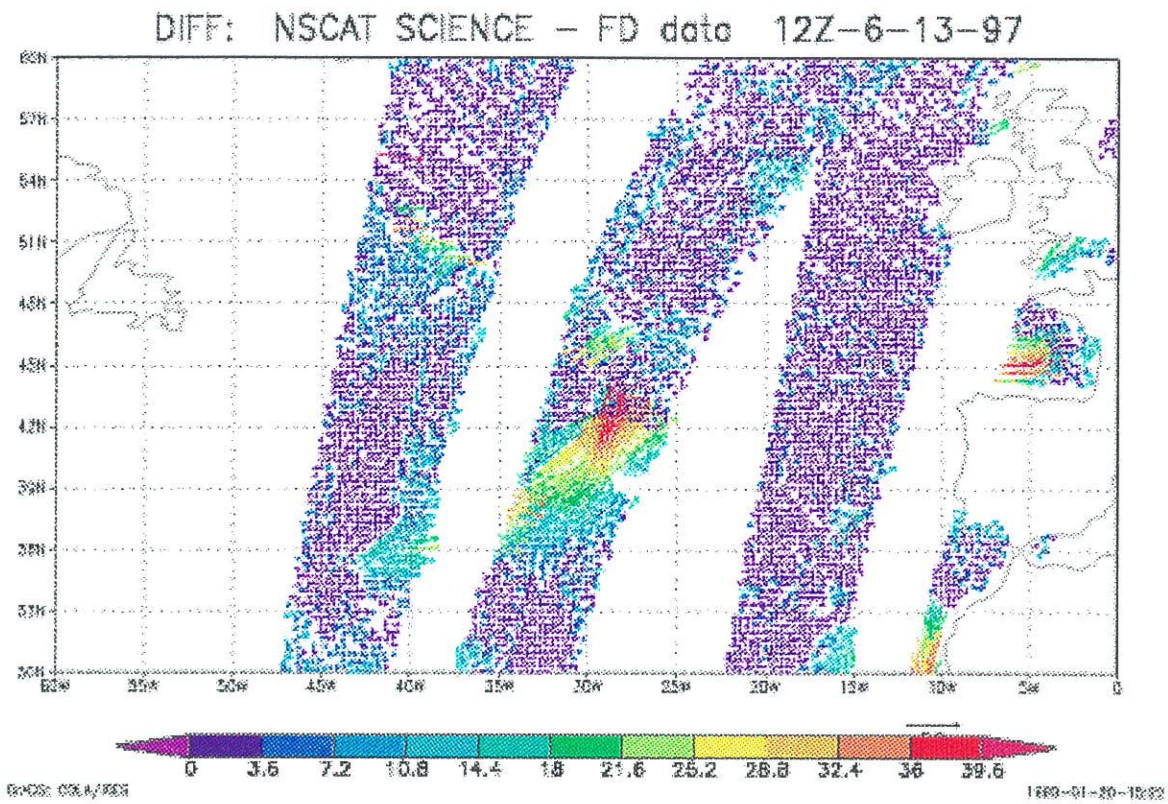


Figure 2: Differences between NSCAT SCIENCE, Fast-Delivery data (m/s).

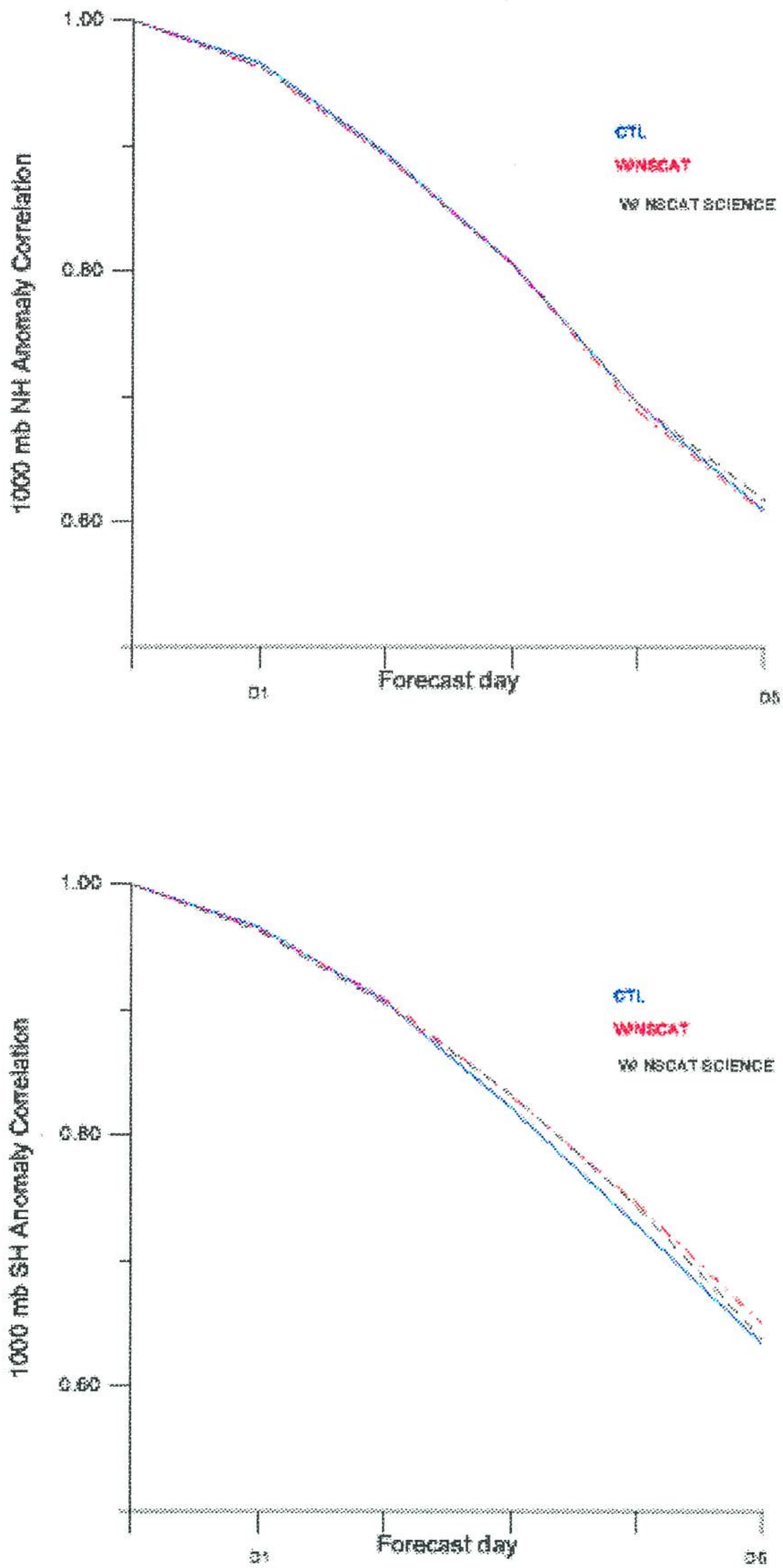
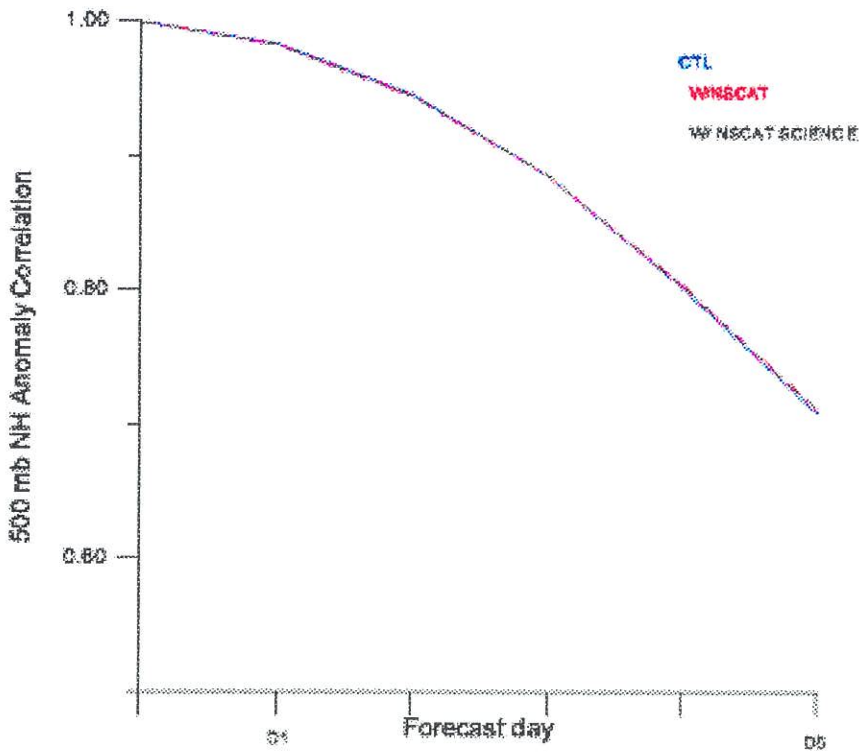


Figure 3a-b: 1000 hPa Anomaly Correlations for Northern, Southern Hemisphere - CONTROL, NSCAT-SC and NSCAT-FD



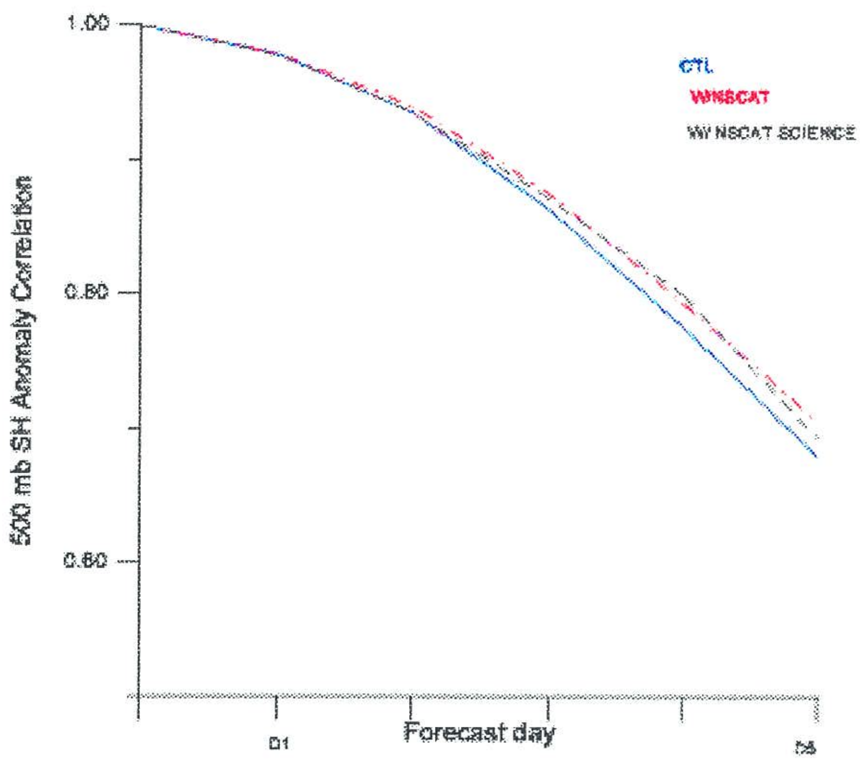


Figure 3c-d: 500 hPa Anomaly Correlations for Northern, Southern Hemisphere - CONTROL, NSCAT-SC and NSCAT-FD

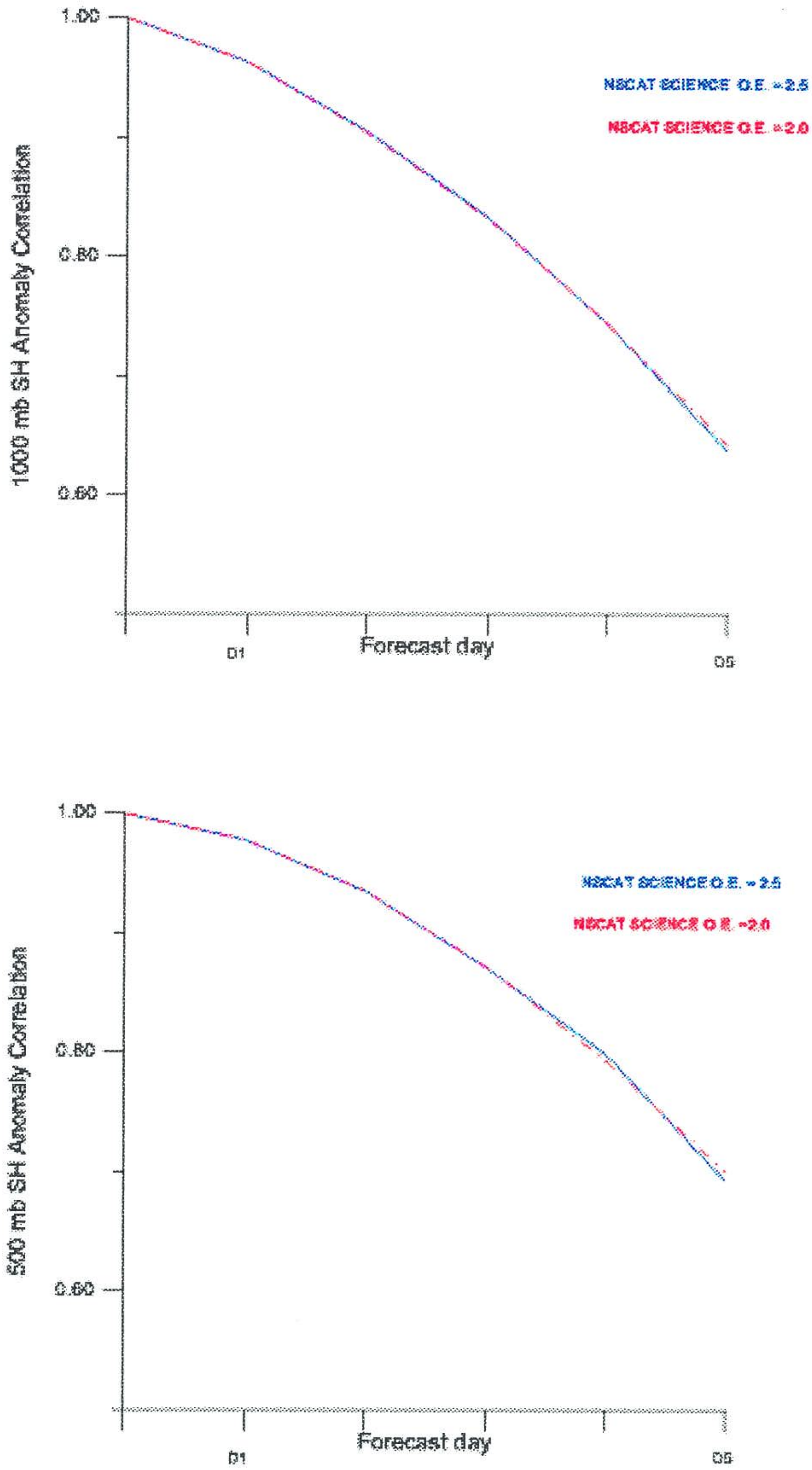


Figure 4a-b: 1000, 500 hPa Anomaly Correlations for Southern Hemisphere, NSCAT Science data with OE = 2.5 (blue), OE = 2 (red)

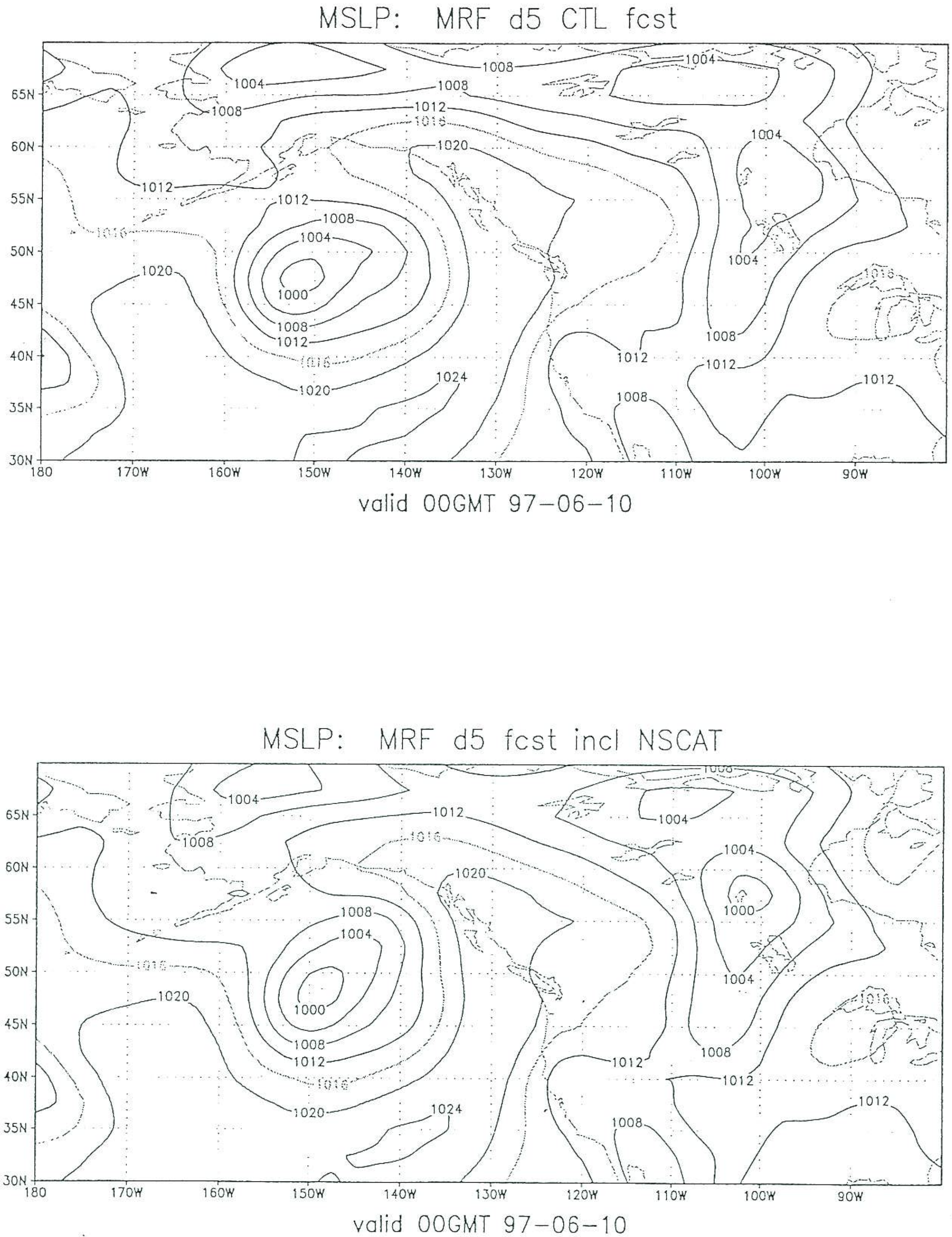


Figure 5a-b: Day 5 MRF forecasts of Mean Sea Level Pressure from CONTROL(top), NSCAT-FD (bottom).

Figure 6: Pacific Surface Analysis from NCEP Marine Prediction Center, valid 0000 GMT June 10 1997.