

IMPACT EXPERIMENTS ON GMAO DATA ASSIMILATION AND FORECAST SYSTEMS WITH MODIS WINDS DURING MOWSAP

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A series of data impact experiments using MODIS winds has been carried out using the most recent version of the GMAO Data Assimilation and Forecast System during MOWSAP (MODIS Winds Special Acquisition Period). With respect to earlier versions of this system, the wind-mass balance was substantially revised, and changes of the skin temperature analysis and of the interactive DAOTOVS retrievals for satellite radiances were implemented as well. Two separate sets of MODIS winds, produced by NESDIS and by CIMSS respectively, were tested for impact, and wind vectors based on imagery from MODIS-Terra and MODIS-Aqua were assimilated both together and separately. These experiments show that the MODIS winds have a small but consistent positive impact on the medium-range forecast skill in the northern hemisphere and a large positive impact on the southern hemisphere skill. Results from the experiments will be shown and the implications of the results for operational numerical weather prediction will be discussed.

Introduction

High-latitude winds derived from imagery obtained with the two MODIS sensors flying on NASA's Terra satellite have been successfully applied in a number of different numerical weather prediction systems (Key et al., 2003). With the launch of a second MODIS sensor on NASA's Aqua satellite in October 2002, the temporal coverage of the MODIS winds product was substantially improved. Still, initial test with the Aqua MODIS winds – alone, or in conjunction with the MODIS winds from Terra – were found to be less encouraging than what had been expected based on the positive experience with the Terra winds (Arctic NWP Workshop, Fairbanks, 2004). A working group consisting of the primary data providers and users of the MODIS winds therefore decided to set up a special experimental period, MOWSAP (MODIS Winds Special Acquisition Period) in order to resolve some of the perceived issues with the MODIS winds. The experimental period ended up running from November 8, 2003 through January 31, 2004, and the among the primary objectives was the testing of test winds generated based on MODIS imagery obtained from Terra and Aqua respectively, separately as well as together.

In preparation for the switch from experimental winds processing carried out by CIMSS since July 2002 to routine operational processing by NESDIS, the latter organization began generating winds in pre-operational mode in November 2002. Conceptually, the wind retrieval algorithms used by the two centers are identical even though the code bases are different. A secondary objective was therefore to test and compare the quality and impact of the two sets of wind observations generated at the two centers. A number of different forecast centers agreed to participate in the MOWSAP experiment, using largely comparable experimental setups and commonly agreed diagnostics and definitions of verification regions. This paper describes the setup and the results from the MOWSAP experiments carried out by NASA's Global Modeling and Assimilation Office (GMAO).

Experimental setup

The experiments were carried out with version 4.02 of the finite volume data assimilation system GEOS-4 developed and operated by the GMAO. This system is based on the flux-form semi-Lagrangian global forecast model (Lin and Rood, 1998) in conjunction with the Physical-space Statistical Analysis System (PSAS, Cohn et al, 1998), a global 3D-VAR like solver for the Kalman filter analysis equation.

The MOWSAP assimilation runs were carried out for the period of November 8, 2003, 0Z, through January 31, 2004, 18Z, and several different experiments were carried out. In the control experiment, the full set of observations used for routine operation analysis were assimilated, i.e. rawinsonde heights and winds, aircraft winds, conventional observations of sea surface pressure, surface winds from Quikscat, AMSU and HIRS data from the NOAA polar orbiting satellites, and satellite winds from the geostationary satellites. In the perturbation experiments, various subsets of the MODIS winds were assimilated in addition to the standard observations. For all experiments, a 120-hour forecast was launched every other day at 0 Z. The forecast verification statistics shown in this paper thus incorporate results from 42 quasi-independent forecast runs.

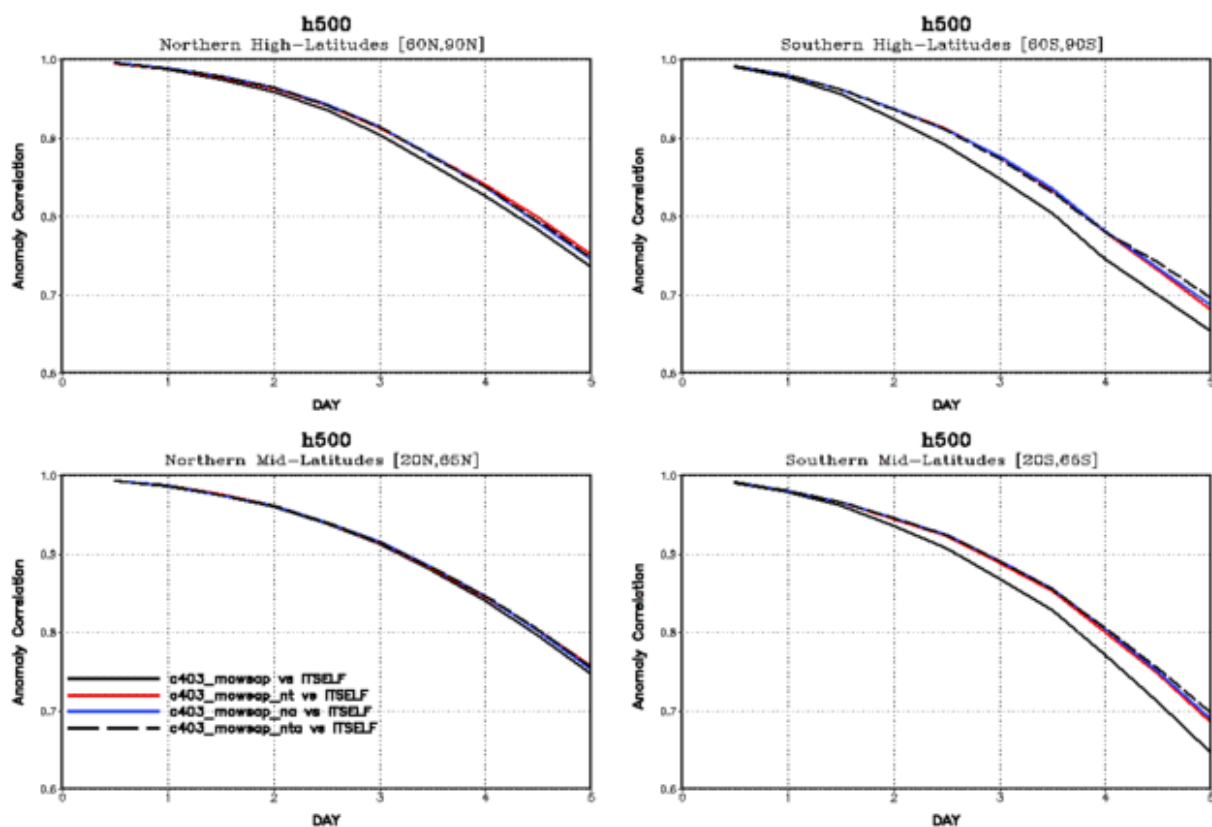


Figure 1. Average forecast skill for MODIS experiments versus control run using self verification

All perturbation assimilations were scored against the control assimilation by calculating the anomaly correlation coefficients between the perturbation and control analyses. Furthermore, the forecasts launched from the experiments were scored against three separate verifying analyses, namely the control analysis, the analysis from the perturbation experiment itself, and the NCEP operational analysis. Generally, the assumption behind conducting OSE's (Observing System Experiments) is that the choice of verification has minimal impact on the results and their interpretation. In the case of the MODIS winds, this is not necessarily true, since the observation locations are almost exclusively beyond 65° latitude. Few conventional observations are taken here, and the utilization of satellite sounding data is hampered by the prevalence of clouds, which limits the usefulness of the infrared observations, and of snow and ice on the surface, posing problems for the microwave emissivity models. For these reasons, both the quality and the level of robustness of the operational analyses are lower in the high-latitude regions than what is generally seen elsewhere on the globe, and objective measures such as forecast skill scores accordingly tend to fluctuate with the choice of verification more than what is normally expected.

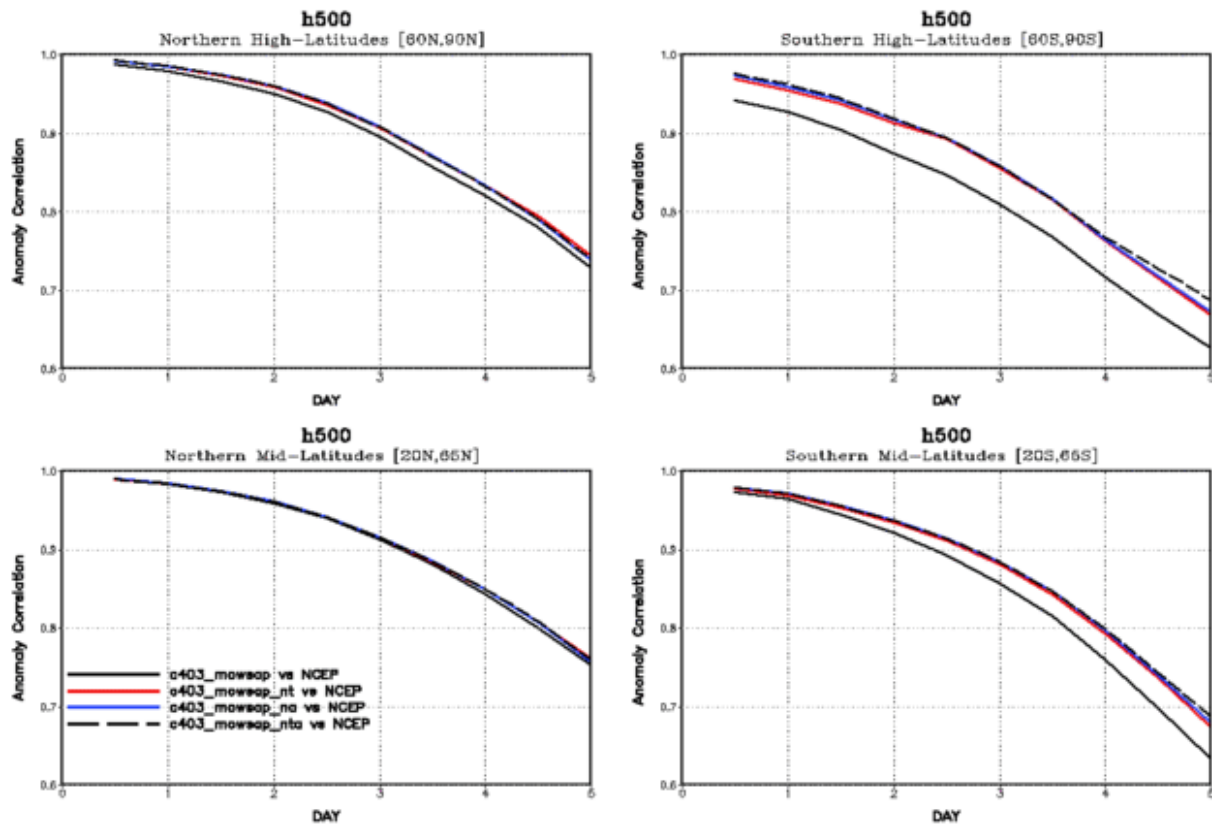


Figure 2. As figure 1, but using NCEP verification

As mentioned earlier, one of the purposes of MOWSAP was to test the consistency of the MODIS winds across the transition from CIMSS processing to NESDIS pre-operational

processing. During the experiments, it was found that the difference in forecast impact of the two sets of winds was somewhat larger than could be easily explained in terms of the known differences between the two processing packages, namely different code versions and the use of different background forecast fields for height assignment and quality control purposes (NOGAPS for CIMMS, NCEP GFS for NESDIS). Since the differences remain partly unexplained, and since the future plans for the MODIS winds involve a complete transition to NESDIS processing in any case, only results using the NESDIS processed winds are shown here.

Results

Figure 1 shows the average forecast skill (500 hPa anomaly correlation coefficients) as a function of the forecast range for three different MODIS winds experiments as well as for the control run, which had no MODIS observations. For each experiment, the forecasts were verified against analyses from the experiment itself. The average skill of the control run is the solid black line, and experiments with MODIS winds from Terra, MODIS winds from Aqua, and MODIS winds from both Terra and Aqua are represented by the red, blue, and black dashed lines, respectively. The two left panels show the skill from the Northern hemisphere high latitudes (top) and mid-latitudes (bottom). The corresponding plots for the southern hemisphere are shown in the two panels on the right.

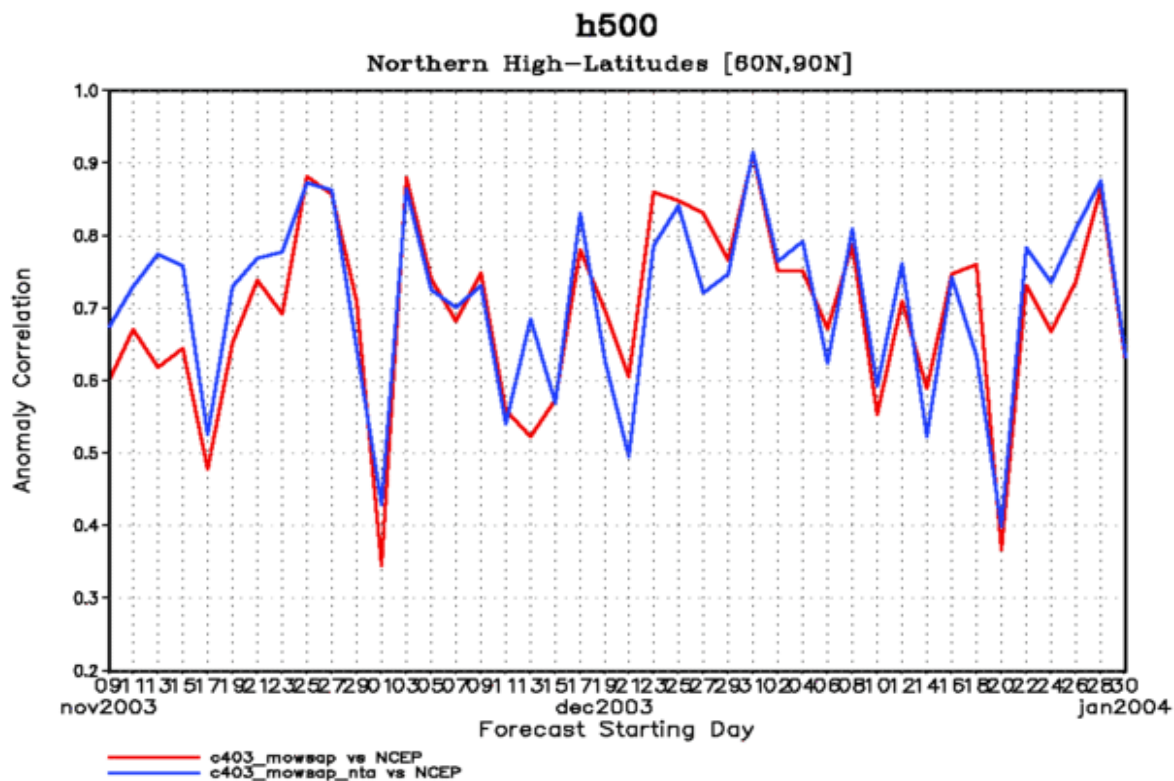


Figure 3. 500 hPa anomaly correlation coefficients on day 5, northern high latitudes

The northern hemisphere impact is significant in the high latitudes, and marginal but positive for the mid-latitudes. The southern hemisphere impact is very substantial in both the high and middle latitudes. There is no apparent difference between the respective impacts of the winds retrieved from the Terra vs. Aqua images, however, there does appear to be a modestly increased impact in the southern hemisphere from having winds from both platforms. It is not clear whether this is also true in the northern hemisphere.

Figure 2 shows skill curves similar to those of Figure 1, but using the NCEP operational analysis for verification. There is no significant difference in the overall conclusion with respect to Figure 1, but the magnitude of the impact is generally larger when the forecasts are verified against the NCEP analysis. It is worth noting that there is some evidence of separation between the control and the MODIS curves even for the northern hemisphere mid-latitudes. This indicates that the positive impact of the MODIS winds is felt even at the low latitudes that are not covered by these data. Again, the impact seems to be largest when data from both satellites are used.

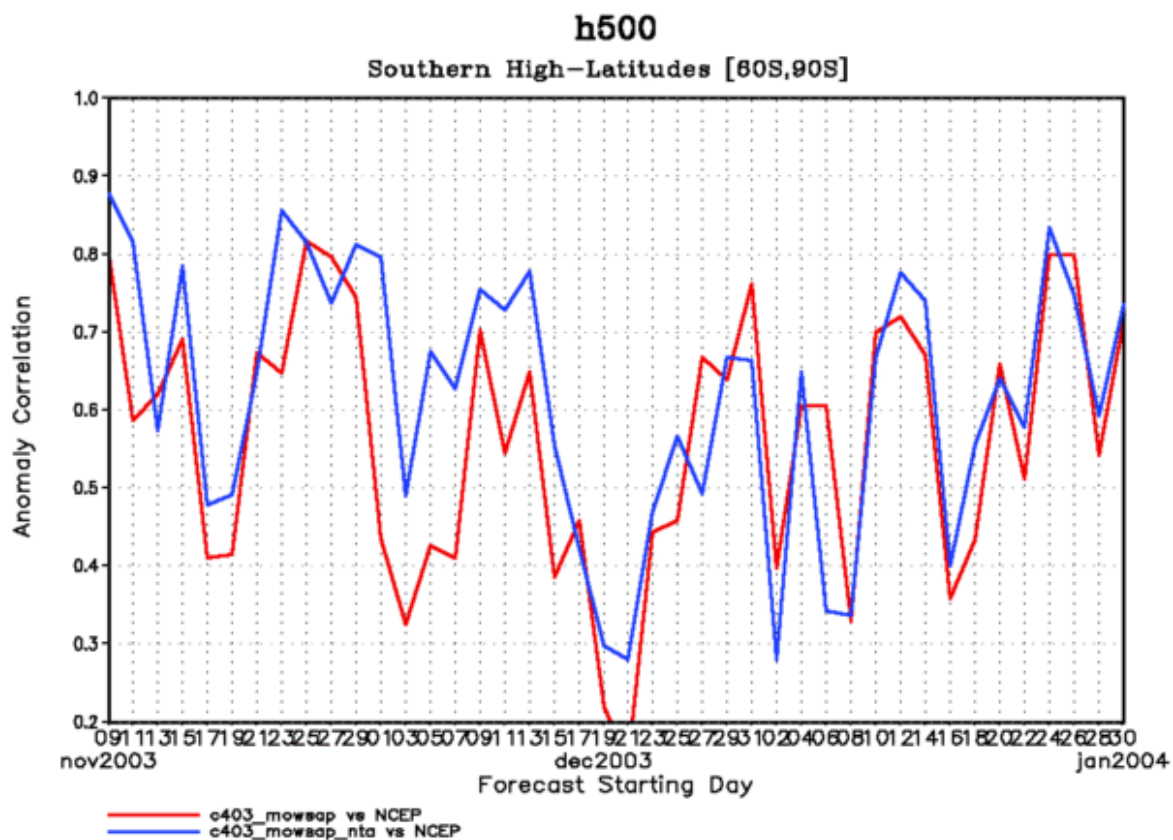


Figure 4. As Figure 3, but for the southern hemisphere high latitudes.

Figure 3 shows the time series of the day-5 forecast skill of the control run (red) and the MODIS winds experiments including winds from both Terra and Aqua (blue) for the high northern latitudes. The forecasts were verified against the NCEP operational analysis. In Figure 4, a similar plot is shown for the southern hemisphere.

Just as one would expect from the average skill curves shown in Figures 1 and 2, the red and blue curves are close on average in Figure 3, whereas the blue curve on average is clearly above the red curve in Figure 4, corresponding to a markedly better forecast skill of the experiment that included the MODIS winds. Another noteworthy feature of figures 3 and 4 is the slightly more limited amplitude of the curve representing the MODIS winds experiment. In other words, one of the main effects of including the MODIS observations in the assimilation is that of reducing the extremes in the day-to-day variation in forecast skill. In particular, the local minima in forecast skill tend to be somewhat less pronounced in the northern hemisphere, and substantially less pronounced in the southern hemisphere. Since decreasing both the frequency and the severity of the forecast busts remains high on the list of priorities for the operational weather services, the true impact of the MODIS winds may be even more significant than suggested by the average skill curves shown in Figures 1 and 2.

Discussion and conclusions

Impact experiments have been conducted in the Global Modeling and Assimilation Office using MODIS wind observations from both Terra and Aqua, using both CIMSS and NESDIS processed data. Due to the only partly understood differences between the two datasets, only results using the NESDIS processed winds are presented here.

The experiments revealed no significant differences between the impacts of the MODIS winds from Aqua and Terra when assimilated separately. It is worth pointing out that this is contrary to what was reported initially by several groups immediately following the launch of Aqua. It is not known whether this result would depend on the particular experimental period studied.

There is a small but positive increment in the impact when winds from both satellites are assimilated. The impact is larger in the southern hemisphere than in the northern hemisphere and larger in the high latitudes than in mid-latitudes. However, the impact is positive at all forecast ranges and over all verification regions.

The overall conclusion from the experiments shown is that there seems to be a definite benefit to be had from introducing high-latitude satellite wind observations into NWP systems used to support operational weather forecasting. However, the current acquisition, processing and dissemination schedule means that the MODIS winds tend to arrive too late in order to be used in the initial condition for the main forecast runs in many weather services. Currently, the bulk of the MODIS winds are delivered to the end users in the interval from 4 to 6 hours after the nominal observation time (defined to be the time of the central image in the triplet). Most operational weather services have data cut-offs for their forecast systems between 1 and 3 hours, depending on the range of the forecast and the extent of the domain. These systems will not be able to obtain the full benefit of the MODIS winds, since they arrive too late to be included in

the forecast run. However, several weather services rely on so-called update runs for improving the first guess prior to generating the initial conditions for their main forecasts. These update runs generally have a later cut-off, and experiments are currently underway to test whether some of the impact of the MODIS winds can be retained by using them in the update runs only.

Finally, it should be mentioned that work is also being undertaken to investigate whether the dissemination of the MODIS winds can be accelerated by making use of the direct broadcast capability of the spacecraft, as opposed to relying on orbital dumps.

Results from both of these efforts will be report at the next International Winds Workshop.

References

Cohn, S. E., A. da Silva, J. Guo, M. Sienkiewicz, and D. Lamich, 1998: Assessing the effects of data selection with the DAO physical-space statistical analysis system. *Mon. Wea. Rev.*, 126, 2913-2926.

Key, J. R., D. Santek, C. S. Velden, N. Borman, J.-N. Thepaut, L. P. Riishojgaard, Y. Zhu, and W. P. Menzel, 2003. Cloud-drift and water vapor winds in the polar regions from MODIS. *IEEE Trans. Geosci. Remote Sensing*, 41, 482-492.

Lin, S.-J., and R. B. Rood, 1998: A flux-form semi-Lagrangian general circulation model with a Lagrangian control-volume vertical coordinate. *The Rossby-100 symposium*, Stockholm, Sweden.