P1.4

RECENT MODIS DATA ASSIMILATION EXPERIMENTS IN THE NCEP GFS

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1. INTRODUCTION

The primary role of geostationary and polar orbiting satellites in the atmospheric sciences is to provide frequent observations over a large geographical extent. In otherwise data sparse maritime regions, satellite observations have become the primary source of information. Currently, the National Environmental Satellite, Data, and Information Service (NESDIS) process a wealth of nearly continuous remotely sensed data, which generously supplements in-situ data.

Through collaboration with the Joint Center for Satellite Data Assimilation (JCSDA) and National Centers for Environmental Prediction (NCEP) personnel, the Cooperative Institute for Meteorological Satellite Studies (CIMSS) has obtained the capability to run impact studies of all data types used in the NCEP Global Data Assimilation System (GDAS). This work originally began in 1997 by running denial experiments in the regional Eta Data Assimilation/Forecast System (EDAS). The regional impact studies were for the most part completed locally at CIMSS using a workstation version of the EDAS.

From project onset, a primary goal of the CIMSS EDAS effort was to maintain a system consistent with the operational EDAS, both in terms of the assimilation methodology and forecast model. If consistent with the NCEP operational algorithms, the EDAS running at CIMSS was a viable source for parallel runs to investigate the impact of current and planned satellite data sources on operational NWP models. Such studies have allowed a better understanding of how to utilize current and future in-situ and remotely sensed data types in present-day three-dimensional assimilation systems. An overview of the regional EDAS denial impact study results is presented in Lord et al. (2004) and Zapotocny et al. (2000, 2002 and 2005 a and b).

More recently, CIMSS has been granted permission to undertake global data denial/addition studies in the NCEP GDAS. Several advantages of the global studies over the previously completed regional studies are that the global experiments remove contamination from the lateral boundary conditions of the model. The global studies also allow investigation of data types not available within a regional model domain. The global studies have already identified results of interest about existing data types. These studies also have the ability to provide information about new data types coming online before they are accepted into the operational data stream. Finally, perhaps the greatest advantage of these global studies is that EMC provided adequate computer resources to complete the simulations at the operational resolution of the model (at the time of this study that was T254L64 to 84 hours, T170L42 to 180 hours and T128L28 to completion). Until now both computer and human resources prevented detailed studies of this nature from running at the operational resolution.

This poster shows forecast results from incorporating Moderate Resolution Imaging Spectroradiometer (MODIS) data in the global data assimilation and forecast model. A companion poster at this conference (poster 1.5), with James A. Jung as the lead (Le Marshall et al. 2005), presents results for assimilating NOAA polar orbiting data in the GDAS, while poster P1.8, with Li Bi as the lead, shows preliminary results from including WindSAT data in the NCEP global system.

The primary objectives are three-fold. First, is to advance the understanding of data impacts in the NCEP operational models. Second, is to identify potential problems with the assimilation impacts vertically, horizontally and temporally for the current suite of available data. Finally, these studies provide an early examination of data sets coming online in the future.

2. EXPERIMENTAL DESIGN

The in-situ and remotely sensed data types studied to date are listed in Table 1. The dates of the denial experiments are also listed. The “No Satellite” and “No Conventional” denials represent cumulative denials to investigate the overall impact of an observing platform while the remaining “single” denials/additions examine a specific instrument. Note that a control run was always completed for comparison to the denials. This removes uncertainty in the model version used, computer/compiler inconsistencies and the like.

Since the MODIS data are a relatively new data type which only recently became operational at NCEP, JCSDA personnel with guidance from NCEP had the

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opportunity to outline the basic assimilation conditions used for rejection from quality control. The high latitude MODIS winds were rejected from the assimilation if an observation was higher (height) than the model defined tropopause, lower (height) than 200 hPa above the earth's surface, or not within 7 m s^{-1} of the model background (u- or v-component). The 7 m s^{-1} value decreases with slower winds.

Figure 1 shows the distribution of data counts by pressure level for MODIS IR winds over the open ocean of northern latitudes during the middle two weeks of September 2004. Notice that the highest concentration of MODIS IR winds for this time period are between 450 and 550 hPa, with significantly few observations in the lower troposphere.

Once the 45 day MODIS experiments were completed, several diagnostics were performed on the archived data. In addition to the anomaly correlation and hurricane track statistics traditionally performed by NCEP, geographical distributions of forecast impact were evaluated. Both the anomaly correlation statistics and hurricane track statistics were performed using the NCEP algorithms, while the geographical forecast impacts were evaluated using:

$$FI = 100 \times \left\{ \left(\sqrt{\frac{\sum_{i=1}^{N}(D_i - A_i)^2}{N}} - \sqrt{\frac{\sum_{i=1}^{N}(C_i - A_i)^2}{N}} \right) \Big/ \sqrt{\frac{\sum_{i=1}^{N}(C_i - A_i)^2}{N}} \right\} . \quad (1)$$

In (1) **N** is the total number of grid points in the diagnostic evaluation. The variables **C** and **D** are the 24-hr (or other) control and denied forecasts, respectively, and **A** is the 00-hr GDAS control analysis containing all data types valid 24-hrs (or other) after the forecast began. In (1) the first term on the right hand side enclosed by parentheses can be considered the error in the denied forecast. The second term enclosed by parentheses can be considered the error in the control forecast. Dividing by the error in the control forecast in (1) and multiplying by 100 normalizes the results and provides a percent improvement with respect to the RMS error of the control forecast. A positive forecast impact means the forecast compares more favorably to the corresponding analysis with the data type included than with it denied. The time-averaged 24-hr FI diagnostics exclude the first 15 days of each 45-day period, removing more impact of the denied data type from the first guess. Finally, for comparative purposes, NCEP maintains a daily record of GFS anomaly correlations at http://wwwt.emc.ncep.noaa.gov/gmb/STATS/html/monarch.html.

3. RESULTS

Using (1), the geographical distributions of the 12- and 24-hr forecast impact to vertically integrated precipitable water (PW) from MODIS data are shown in Fig. 2. It is interesting to note that the largest FI to PW is in tropical regions and the southern oceans. This is diagnosed even though MODIS data are only wind data poleward of 60 degrees in each hemisphere. Another interesting feature is that there is a marked decrease in forecast impact from 12-hrs to 24-hrs in each hemisphere. (Note that the same legend is used in each panel of Fig. 2. Also, FIs larger than 100% are possible when there is small error in the control simulation and the denominator becomes small.)

Figure 3 presents a 500 hPa geopotential height geographical distribution of FIs using (1) at day 5 from the addition of MODIS data during late August and early September 2004. Largest FI are in the southern oceans close to where the data are added. However, the region displaying the second largest impact is in the western Atlantic and Caribbean, which is far removed from the input location from MODIS data. These results are important for adequately resolving the tropical cyclone steering currents discussed below.

Figure 4 displays the traditional 500 hPa geopotential height anomaly correlation die-off curves for days 0 to 7 in the region 60-90°N. Evaluation reveals that the anomaly correlation when MODIS data is included is slightly higher than the control simulation anomaly correlation after 4 days of integration. Largest MODIS benefits are at and after day 5, when a gain of nearly a quarter day in forecast skill is realized in this diagnostic region.

Table 2 summarizes the impact MODIS winds had on tropical cyclone tracks in the Atlantic Basin for the 2004 season. Of the time periods shown, the average track error is smaller with the addition of MODIS data (red values) for all time periods. In fact, the average error is approximately 22 nm smaller at 72-hrs for the 46 cases that occurred that season for this forecast length.

4. SUMMARY

This paper summarized the forecast impacts of assimilating MODIS data in the NCEP GFS. Unique to this study are that the 45 day denials were completed at the operational resolution of the time and that it evaluated a relatively new (operational in October 2005) data type where with the help of NCEP personnel the conditions of the assimilation were outline by the authors with the help of NCEP personnel.

Key findings of the denials completed thus-far, some of which extend beyond the results presented in this paper, are that:

- Cumulatively, satellite data proves more important to forecast quality than conventional data. This is especially in the Southern Hemisphere (see Table 2, results not shown here but available in Zapotocny et al. 2006).
- MODIS high latitude winds provide improved hurricane track forecasts during the 2003 and 2004 Atlantic hurricane season. This data also provides a modest improvement in middle and high latitude anomaly correlation.
- Many more data denials/additions are planned, including improving the quality control for MODIS data. MODIS data became operational

in the GDAS the 25 October 2005.

Studies of this nature provide a more complete understanding of how to utilize existing and future data types and are essential if modeling improvements related to the available data are to be realized.

5. ACKOWLEDGEMENTS

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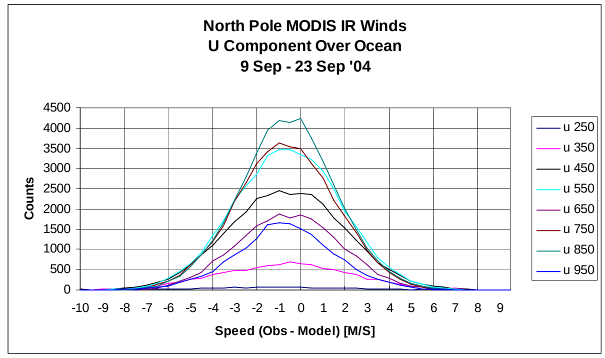

Fig. 1. Data counts of the distribution of MODIS observed wind speed minus model first guess (m s^{-1}) by pressure level for IR winds over open ocean poleward of 60°N during the middle two weeks of September 2004.

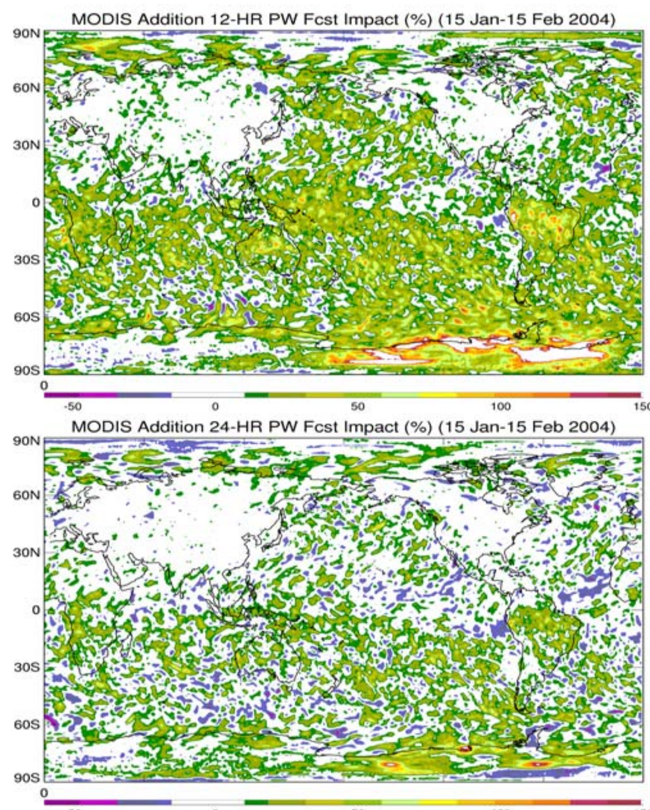

Fig. 2. Geographic distribution of impact to precipitable water at 12 and 24 hours (%) during Jan/Feb 2004. These results were obtained by adding MODIS high latitude winds to the control GDAS assimilation. White values in the plots have a forecast impact greater than positive 150%.

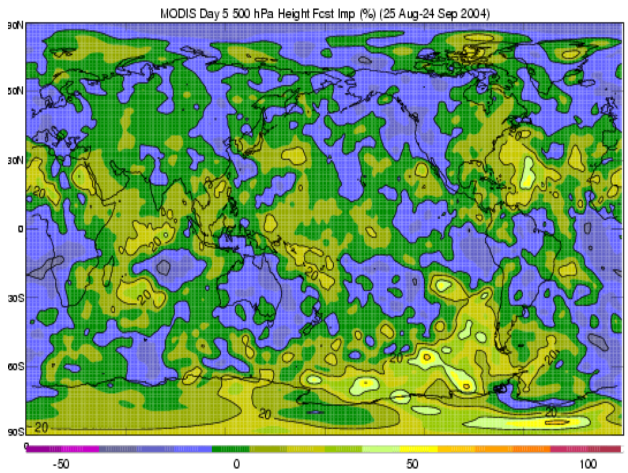

Fig. 3. Geographical distribution of forecast impact from assimilating MODIS data during late August and early September 2004 after 5 days of integration.

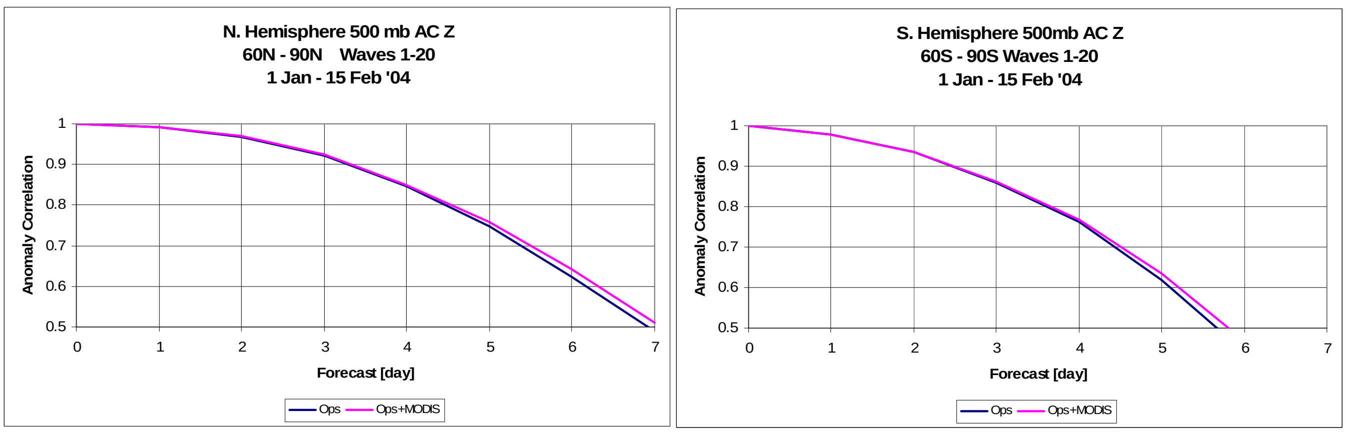

Fig. 4. Anomaly correlation for days 0 to 7 in the region 60-90°N and S during late January and early February 2004. The MODIS results are the magenta line while the control experiment is depicted by the black line. Only wave numbers 1-20 are included.

Table 1. Recent denial/addition experiments completed with the NCEP GDAS/GFS.

Jan-Feb 2003	**Aug-Sep 2003**	**Jan-Feb 2004**	**Aug-Sep 2004**
Control	Control	Control	Control
No HIRS	No HIRS	Add MODIS Winds	Add MODIS Winds
No AMSU	No AMSU	Add AIRS Radiances	Add AIRS Radiances
No AMSU 15	No AMSU 15		Add WindSAT Winds
No Quickscat	No Quickscat		
No Conventional	No Conventional		**Summer 2006**
No RAOB	No RAOB		Real time WindSAT testing
No Geostationary	No Geostationary		(poster P1.8 of this conference)
No Satellite	No Satellite		
No NOAA	No NOAA (poster P1.5 of this conference)		

Table 2: 2004 Atlantic Basin average hurricane track errors (nm) with and without MODIS. The highlighted values indicate the improved performance of using MODIS data to simulate tropical cyclones for this particular season.

13.2	43.6	66.5	94.9	102.8	157.1	227.9	301.1	Cntrl
11.4	**34.8**	**60.4**	**82.6**	**89.0**	**135.3**	**183.0**	**252.0**	Cntrl **+** MODIS
74	68	64	61	52	46	39	34	Number Cases
00-h	12-h	24-h	36-h	48-h	72-h	96-h	120-h	Time