The Impact of Satellite Data in the Joint Center for Satellite Data Assimilation

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1. Introduction

The Joint Center for Satellite Data Assimilation (JCSDA) was established by the National Aeronautics and Space Administration (NASA) and the National Oceanographic and Atmospheric Administration (NOAA) in 2001, with Department of Defense (DoD) agencies becoming partners in 2002. The goal of the JCSDA is to accelerate the use of observations from Earth-orbiting satellites in operational environmental analysis and prediction models for the purpose of improving weather forecasts, ocean forecasts, improving seasonal-to-interannual climate forecasts, and increasing the accuracy of climate datasets.

The cooperative agreement allows the Center partners to take advantage of the science and technology resources of NOAA, NASA and DoD to accelerate the use of existing and new satellite data.

2. The Challenge

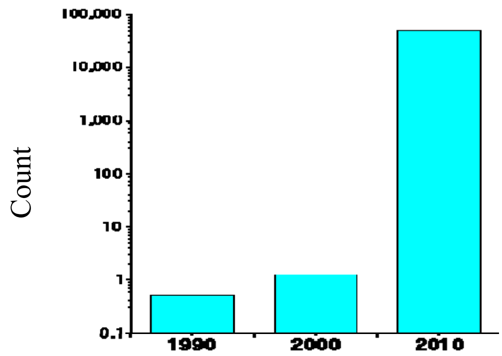


Figure 1: Daily upper-air observation count as a function of time. (1990 – 2010)

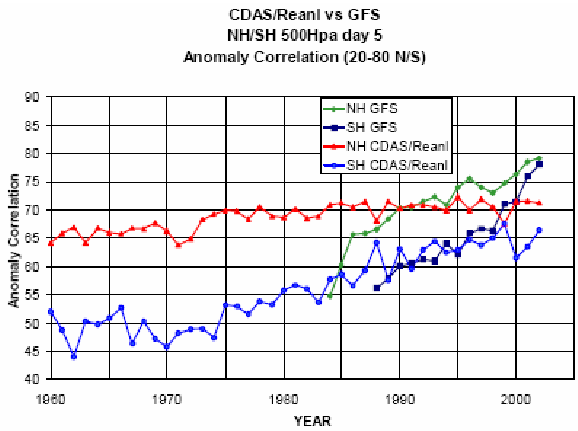


Figure 2: Anomaly correlation coefficient (AC) for 500 hPa height for NCEP 5-day forecast as a function of time. Red and blue (green, black) lines refer to fixed (evolving model and assimilation system. Red and green (blue, black) lines refer to the Northern (Southern) Hemisphere.

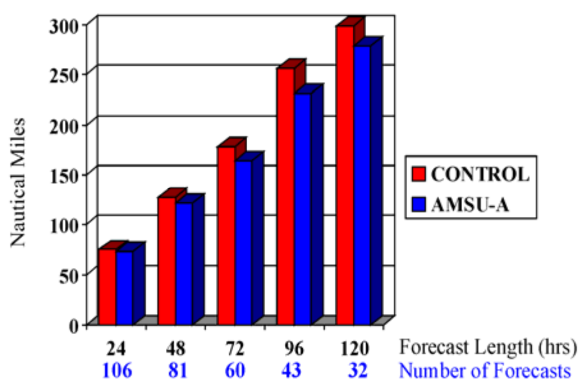
During this decade, planned satellite missions will result in a five order of magnitude increase in the volume of data available for use by the operational and research weather, ocean and climate communities (see Fig.1). These data will exhibit accuracies and spatial, spectral and temporal resolutions never before achieved. To ensure that the maximum benefit from investment in the space based global observing system is realized, the advancement of satellite data assimilation science by the JCSDA has involved the establishment of the JCSDA Community Radiative Transfer Model (CRTM). The CRTM is continually upgraded to allow the use of both current and many future satellite instruments, including, for example, the Advanced Baseline Imager (ABI) to be flown on GOES-R, the Atmospheric Infrared Sounder (AIRS), and snow, ice and land emissivity models/statistical databases for improving the use of microwave sounding instruments over high latitudes.

It has also involved preparation for use of data from the Meteorological Operational Polar Satellite's (METOPs) Infrared Atmospheric Sounding Interferometer (IASI), the Advanced Microwave Sounding Unit (AMSU), the Microwave Humidity Sounder (MHS), the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager/Sounder (SSMIS) and the Challenging Mini Payload (CHAMP) and The Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) Global Positioning System (GPS) based radio-occultation systems. Observing System Experiments (OSEs), Data Impact Studies and Observing System Simulation Experiments (OSSEs), have also been key parts of the work undertaken by JCSDA. In addition, improved physically based Sea Surface Temperature (SST) analyses have also been provided.

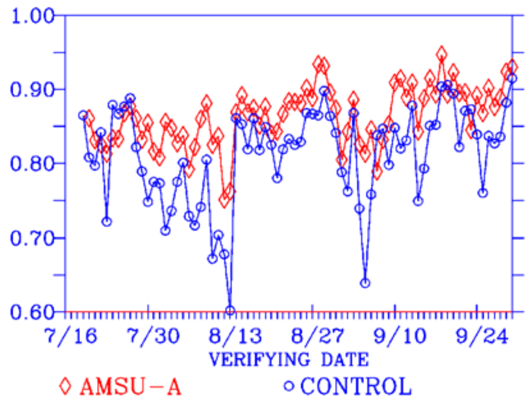
Recent advances at the JCSDA, in answer to this challenge, include the demonstration of the significant benefits to Northern and Southern Hemisphere forecasts from AIRS radiance assimilation using the National Centers for Environmental Prediction (NCEP) global forecast model, the demonstration of the benefits of Moderate Resolution Imaging Spectroradiometer (MODIS) polar atmospheric motion vector assimilation on global forecasts, the beneficial impact from use of the CRTM in the modeling of sea ice and snow emissivity and the beneficial impact of WindSat observations and COSMIC data on global NWP.

3. Background

An indication of the impact of satellite data on improving operational numerical weather forecasts is given in Fig. 2, which shows the anomaly correlation coefficient (AC) for 500hPa height calculated for the NCEP 5-day forecast as a function of time. The correlation is between observed and predicted deviations from the climatological 500hPa height field. Neglecting interannual variability, a steady improvement in the AC is evident, with a larger rate of improvement for the Southern Hemisphere. The noticeable improvements in the late 1990s are due, to a significant degree, to direct radiance assimilation and instruments such as the Advanced Microwave Sounding Unit (AMSU).



(a)



(b)

Figure 3(a)Tropical cyclone track error forecasts with (AMSU-A) and without AMSU-A (Control) in the NRL NAVDAS forecast model. (b) 500 hPa height anomaly correlation for NAVDAS with (AMSU-A) and without (Control) 16 July to 30 September, 2003.

An example of this impact is seen in the implementation of AMSU-A radiance assimilation in the Navy Operational Global Atmospheric Prediction System (NOGAPS) which provided one of the most important advances to NOGAPS skill in a decade. The assimilation of these radiances in the Naval Research Laboratory's Atmospheric Variational Analysis System (NAVDAS) substantially improved the height, wind, and temperature forecasts for both hemispheres at all forecast times, reduced tropical cyclone track error forecasts by up to 25 Nm (Fig. 3a), and resulted in significantly fewer forecast "busts" (Fig. 3b).

Despite these recent improvements in forecast skill, there still remains room for continued improvement, in particular, toward decreasing the frequency of larger than normal forecast errors, or "busts" related to large errors in the initial model fields in areas where existing observing systems do not provide adequate coverage with accurate measurements of temperature, moisture and wind. It is clear that assimilation of satellite data will make key contributions to that improvement. This is a complex challenge whose solution will provide a considerable return on investment made in the satellite observing network. More detail concerning the JCSDA approach to this challenge can be found in Le Marshall et al., 2007a.

4. Recent Advances – Data Assimilation and Impact

4.1. The Community Radiative Transfer Model (CRTM)

The JCSDA has made significant advances in formulating and developing a Community Radiative Transfer Model (CRTM). For atmospheric transmittance calculations, the gas absorption coefficients are predicted with the atmospheric parameters and the polynomial expansions of the absorber amount (Kleespies et al., 2004). This approach significantly reduces the number of coefficients that reside in computer memory from 1,800 to 70 for each channel. The transmittance is calculated with a correction term to account for the average strengths of gaseous absorption within the instrument bandwidth. In addition, new predictors are added to improve the ozone absorption. Figure 4 displays the performance of a fast transmittance model (OPTRAN-V7) and compares it with the recent operational model for 20 HIRS channels. In recent times, work has also progressed on an Optimum Spectral Sampling approach to transmittance calculation (van Delst et al., 2005) which promises greatly improved speed and the prospect of more effective use of hyperspectral observations.

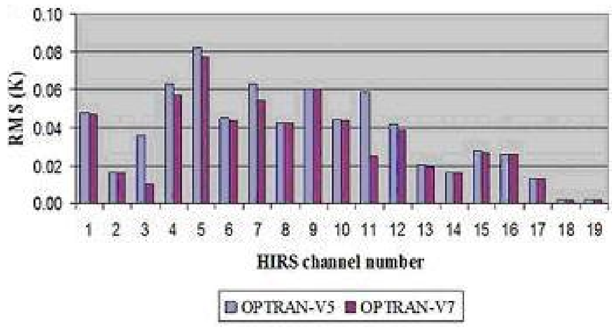


Figure 4: Latest optical path of gaseous transmittance model performed at 19 HIRS channels.

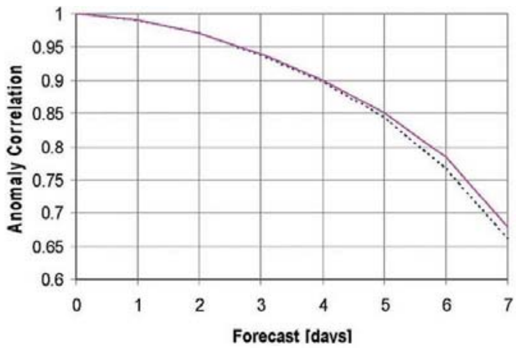


Figure 5: Impact of sea ice and snow emissivity models on the GFS 24-h forecast at 850 hPa (1 Jan–15 Feb 2004, 60°N–90°N); the pink curve shows the AC with new snow and sea ice emissivity models).

Studies have also been completed to develop a fast microwave radiative transfer model which includes scattering and polarization of clouds, precipitation and aerosols (Liu and Weng, 2002) and (Weng and Liu, 2003). Work has also addressed the modelling of ice and snow emissivity, and trials have shown improvement in high latitude forecasts from NCEP's Global Forecast System (GFS). Figure 5 shows the improved anomaly correlation at 850 hPa for the GFS with the new emissivity model, compared to the control (Operations).

4.2. Observing System Experiments

A series of observing system experiments (OSEs) has been undertaken within the Center. The first was to quantify the contributions made to forecast skill by conventional and satellite data. The second was an OSE with four satellite data types and rawinsonde data and the third an OSE using NOAA Polar Orbiting satellite data.

4.2.1. Observing System Experiment with Satellite and Conventional Data

The analysis and forecast model used for these observing system experiments is the NCEP Global Data Assimilation/Forecast System (GDAS/GFS). The OSE consists of 45-day periods during January-February 2003 and August-September 2003. During these periods, a T254 - 64 layer version of NCEP's global spectral model was used. The control run utilized NCEP's operational data base which consisted of all data types routinely assimilated in the GDAS. The two experimental runs had either all the conventional in-situ data denied (NoCon) or all the remotely sensed satellite data denied (NoSat). Differences between the control and experimental runs both based at 00UTC were accumulated over the 45-day periods and analyzed to demonstrate the forecast impact of these data types through 168 hours. The conventional data used in this study is listed in Table 1, while the satellite data used is listed in Table 2.

Table 1: Conventional data denied within the NCEP Global Data Assimilation System for this study. Mass observations (temperature and moisture) are shown in the left hand column while wind observations are shown in the right hand column.

Rawinsonde temperature and humidity	Rawinsonde u and v
AIREP and PIREP aircraft temperatures	AIREP and PIREP aircraft u and v
ASDAR aircraft temperatures	ASDAR aircraft u and v
Flight-level reconnaissance and dropsonde temperature, humidity and station pressure	Flight-level reconnaissance and dropsonde u and v
MDCARS aircraft temperatures	MDCARS aircraft u and v
Surface marine ship, buoy and c-man temperature, humidity and station pressure	Surface marine ship, buoy and c-man u and v
Surface land synoptic and Metar temperature, humidity and station pressure	Surface land synoptic and metar u and v
Ship temperature, humidity and station pressure	Wind Profiler u and v
	NEXRAD Vertical Azimuth Display u and v
	Pibal u and v

Table 2: Satellite data denied within the NCEP Global Data Assimilation System for this study.

HIRS sounder radiances	SBUV ozone radiances
MSU radiances	QuikSCAT surface winds
AMSU-A radiances	GOES atmospheric motion vectors
AMSU-B radiances	GMS atmospheric motion vectors
GOES sounder radiances	METEOSAT atmospheric motion vectors
SSM/I precipitation rate	SSM/I surface wind speed
TRMM precipitation rate	

Anomaly correlations (AC), forecast impacts (FI) and hurricane track forecasts were evaluated for both experiments. The anomaly correlations used the standard NCEP software suite and were partitioned into subsections covering the polar caps, mid-latitudes and the tropical belt. Some results are shown in Fig. 6 and Fig. 7. In the Northern Hemisphere, the impact of satellite data is of similar magnitude to that from the conventional data base (Figs. 6 (a) and (c)) while, in the Southern Hemisphere (Figs. 6 (b) and (d)), satellite data is of paramount importance and almost doubles the length of a useful forecast (one with AC ≥ 0.6)

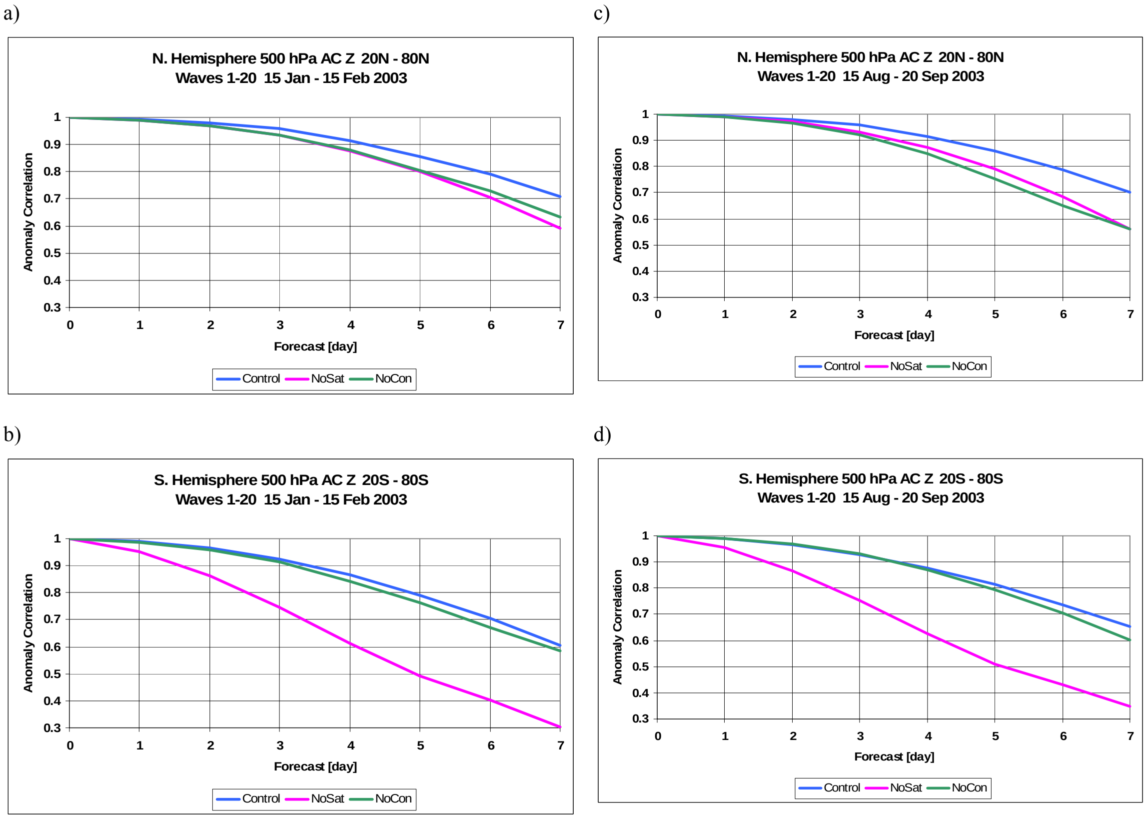


Figure 6: Anomaly correlation for days 0 to 7 for 500 hPa geopotential height in the zonal band 20°-80° for each Hemisphere and season. The control simulation is shown in blue, while the NoSat and NoCon denial experiments are shown in magenta and green, respectively.

Satellite data and conventional data were both found to play a significant role in forecasting for the northern polar regions, while in southern polar regions, satellite data was more important, doubling the length of a forecast of given accuracy. In terms of hurricane track forecasts in the Atlantic and Pacific basins, for the period studied, (Fig. 7 (a) and (b)), both satellite and conventional data provide improvements to track forecasts with the satellite data, in general, providing the greatest benefit to the forecasts. Further detail may be found in Zapotocny et al. (2007a).

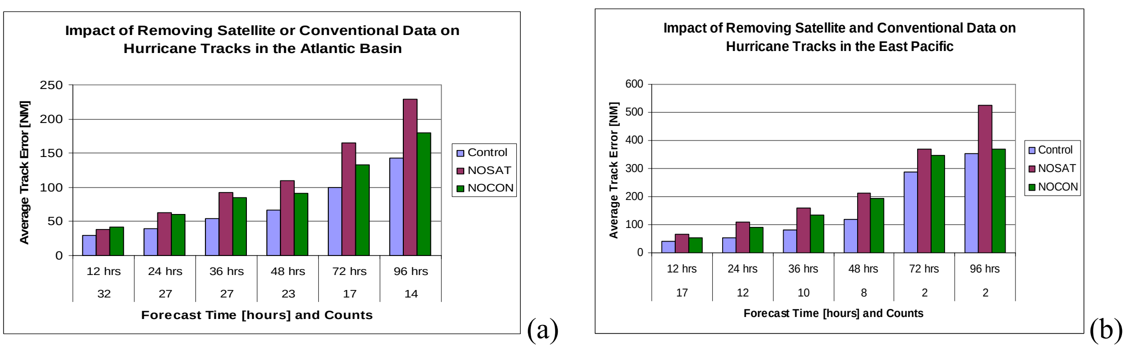


Figure 7: The impact of removing satellite and in-situ data on hurricane track forecasts in the GFS for 15 August to 20 September 2003. Panels (a and b) show the average track error (NM) out to 96 hours for the control experiment and the NoSat and NoCon denials for the Atlantic and Pacific Basins, respectively.

4.2.2. Observing System Experiments with Four Satellite Data Types and Rawinsonde Data.

OSEs covering two seasons have been undertaken to quantify the contributions to forecast quality from rawinsonde data and from four types of remotely sensed satellite data. The impact was measured by comparing the analysis and forecast results from an assimilation/forecast system using all data types in NCEP's operational data base with those from a system excluding a particular data type. The forecast results are compared through 168 hours for periods covering more than a month during two seasons.

The assimilation/forecast system used for these experiments was again the NCEP Global Data Assimilation/Forecast System (GDAS/GFS). The experiment was for 45-day periods during January-February and August-September 2003. As in the previous studies, a T254 - 64 layer version of NCEP's global spectral model was used. The control run utilized all data types routinely assimilated in the GDAS (See Tables 1 and 2). The experimental runs individually denied data from the Advanced Microwave Sounding Unit (No_AMSU), High Resolution Infrared Radiation Sounder (No_HIRS), Geostationary satellites (No_GEO_Wind), in-situ rawinsondes (No_RAOB) and QuikSCAT (No_QSCAT).

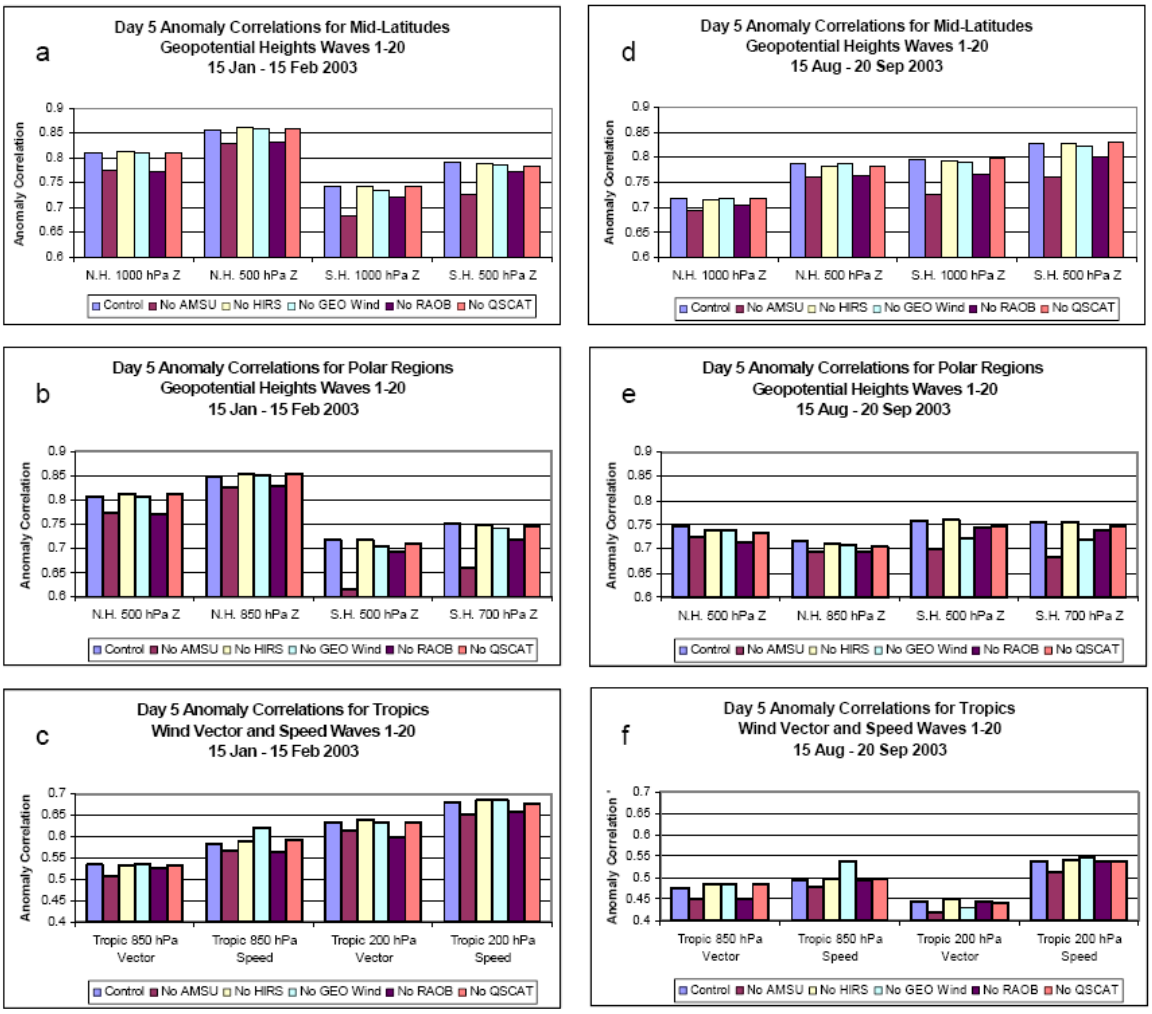


Figure 8: The day 5 anomaly correlations for waves 1-20 for the (a and d) mid-latitudes, (b and e) polar regions and (c and f) tropics. Experiments shown for each term include, from left to right, the control simulation and denials of AMSU, HIRS, GEO winds, Rawinsondes and QuikSCAT. The 15 January to 15 February 2003 results are shown in the left column and the 15 August to 20 September 2003 results are shown in the right column. Note the different vertical scale in (c and f).

Differences between the control and denial experiment forecasts over the two 45-day periods were analyzed to demonstrate the forecast impact of these data types. Anomaly correlations, forecast impacts and hurricane track forecasts were evaluated for all experimental runs during both seasons. A summary of results is seen in Figs. 8 to 10.

Figure 8 presents the anomaly correlation for day 5 from the control assimilation and the five experiments during January-February and August-September 2003. The day 5 anomaly correlations for mid-latitudes, polar and tropical regions are shown. In Fig.8, the AMSU and rawinsonde denials in general show the largest impact for all zonal belts. For the mid latitude ACs ((a) and (d)) the largest impacts are from AMSU and rawinsonde data, with AMSU providing greater impact in the southern hemisphere.

Figure 9 depicts the 20° - 80° Northern and Southern Hemisphere 500 hPa geopotential height day 0 – 7 anomaly correlation die-off for the control simulation and the five denial experiments of this study during January-February 2003. The results demonstrated a positive impact from all data types with AMSU and rawinsonde data providing the largest anomaly correlation improvements in all Northern and Southern Hemispheres. Smaller forecast improvements were noticed from the other data types.

In addition to the anomaly correlation statistics presented, the geographic distributions of forecast impact (Zapotocny et al., 2007) of 500 hPa geopotential heights during the January-February and August-September 2003 time periods from all six denials were investigated. For January-February 2003, the 12-hour results show that the largest forecast impacts are in the polar latitudes of each hemisphere with an equatorward extension of positive forecast impacts over the southern oceans and Northern Pacific Ocean. Examining the 24 to 72 hour forecasts shows a very steady decrease in the magnitude of forecast impacts. In fact, by 72 hours, the largest forecast impacts are along 60° S with large regions of the globe being covered with neutral impacts.

Comparing the 500 hPa geopotential height AMSU denial forecast results for 12 to 72 hours during August-September 2003 with those for January-February 2003 reveals that the forecast impact is much smaller during August-September 2003 than during January-February 2003. In fact, for August-September 2003, by 72 hours, most of the globe is covered by neutral forecast impacts, with only scattered regions of small positive/negative impacts.

The rawinsondes' geographical forecast impact results were, generally, the second largest of the six denials examined here. Similar to the AMSU forecast impact results, the rawinsonde January-February 2003 forecast impacts are largest in polar regions, especially Antarctica, with a large decrease as the forecast proceeds. Also, similar to the AMSU results is that the January-February 2003 rawinsonde forecast impacts are larger than their August-September 2003 counterparts.

The impact of removing four satellite data types on hurricane track forecasts in both the Atlantic and Eastern Pacific Basins for 15 August to 20 September 2003 was also examined. All data used in the GFS were applied except for the specific data type denied in each experiment. Figure 10 displays the average track error in the GFS from the control simulation and where the four satellite data types have been denied.

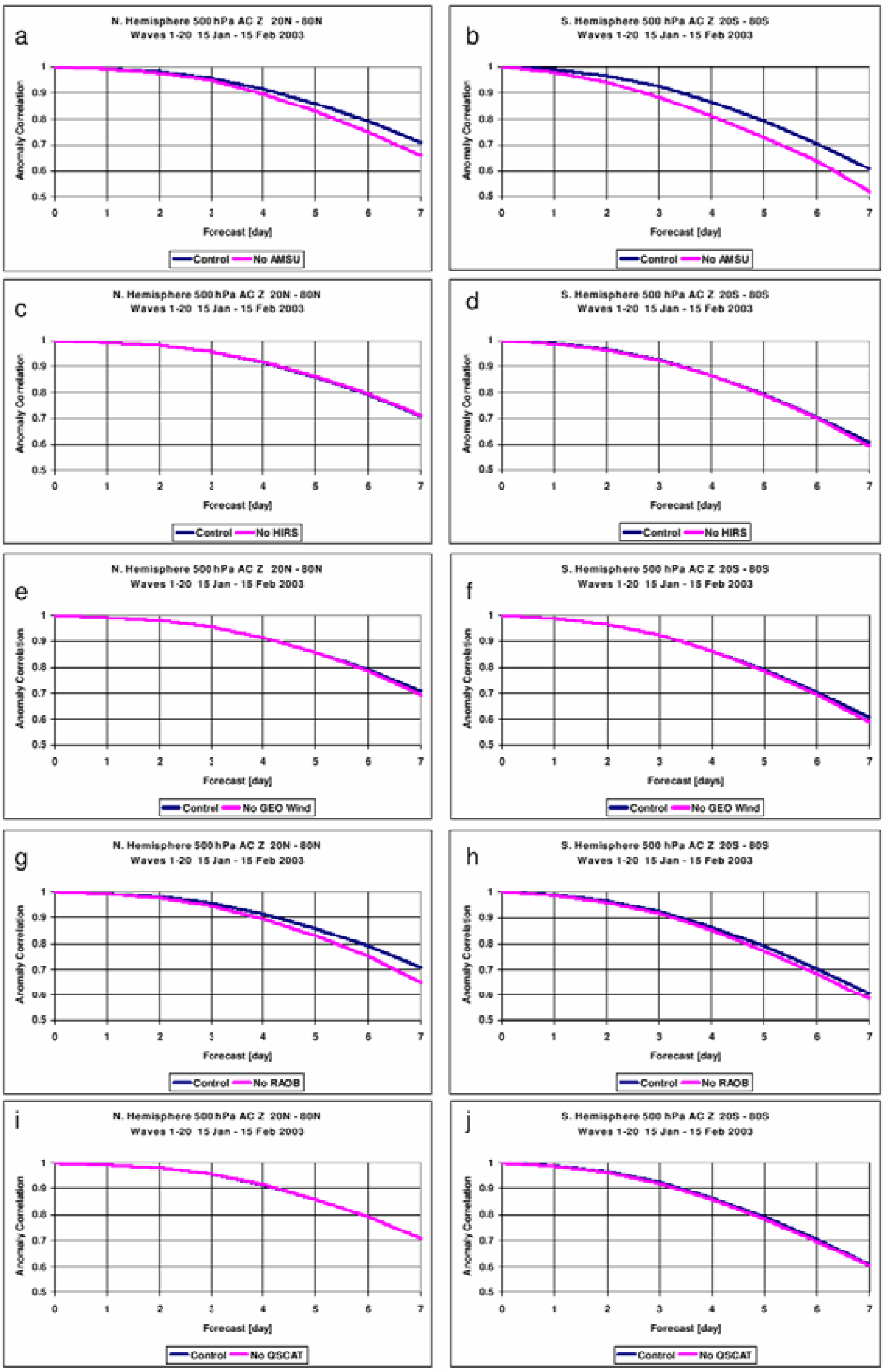


Figure 9: The 15 January to 15 February 2003 day 0-7 500 hPa geopotential height die-off curves for the control and five denial experiments. The Northern Hemisphere results are shown in the left panels and the Southern Hemisphere results are shown in the right panels.

Examination of the figure shows each of the four data types provide similar improvement to the hurricane track forecasts in the Atlantic Basin during this period. However, geostationary satellite AMVs provide the largest improvement to track forecasts in the Pacific Basin. A detailed description of this OSE is found in Zapotocny et al. (2007b).

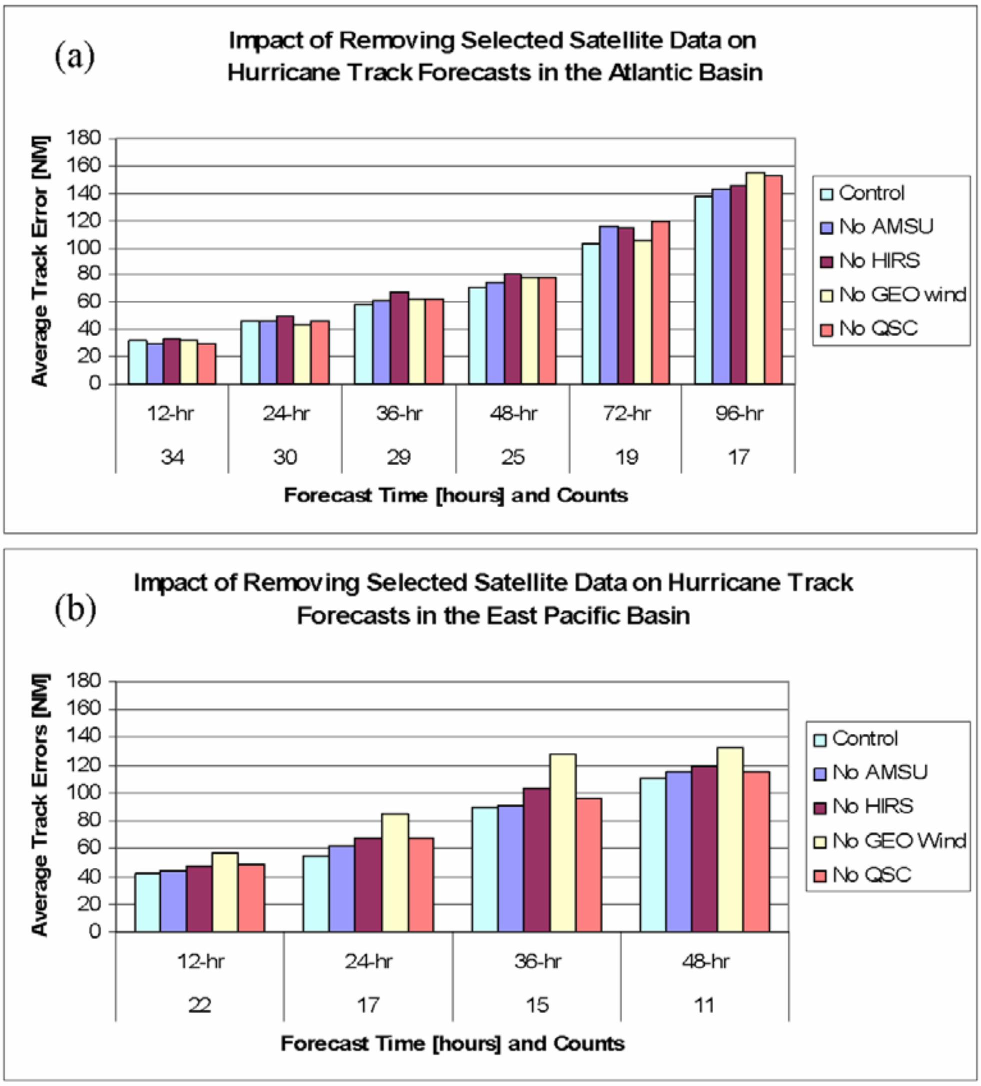


Figure 10: Average track error (NM) by forecast hour for the control simulation and experiments where AMSU, HIRS, GEO winds and QuikSCAT were denied. The Atlantic Basin results are shown in (a), and the Eastern Pacific Basin results are shown in (b). A small sample size in the number of hurricanes precludes presenting the 96 hour results in the Eastern Pacific Ocean.

4.2.3. Observing System Experiments with NOAA Polar Orbiting Satellites in the NCEP GDAS

Observing System Experiments during two seasons have been used to quantify the contributions made to forecast quality from the use of the National Oceanic and Atmospheric Administration's (NOAA) polar orbiting satellites. The impact was measured by comparing the analysis and forecast results from an assimilation/forecast system using observations from one NOAA polar orbiting satellite, NOAA-17 (1_NOAA), with results from systems using observations from two, NOAA-16 and NOAA-17 (2_NOAA), and three, NOAA-15, 16 and 17 (3_NOAA), polar orbiting satellites.

The assimilation/forecast system used for these experiments was again the NCEP Global Data Assimilation/Forecast System (GDAS/GFS). The study periods were January-February 2003 and August-September 2003. During these periods, a T254 - 64 layer version of NCEP's global spectral model was used. These experiments utilized all data types routinely assimilated in the GDAS. The baseline experiment, 1_NOAA, uses the Advanced Microwave

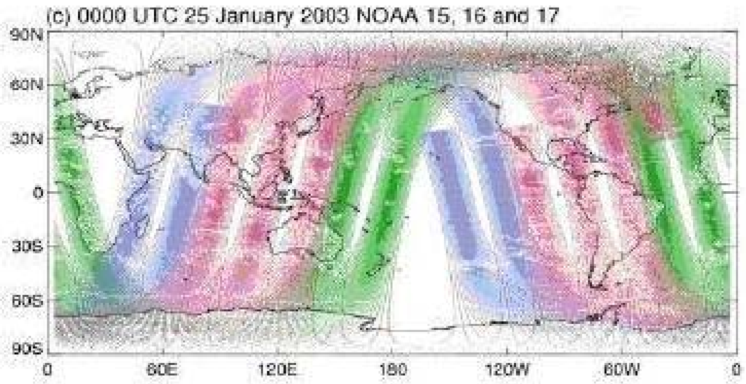


Figure 11: The spatial coverage of 3_NOAA satellites for 25 January 2003 at 0000 UTC. The NOAA-17 orbit is in green, the NOAA-16 orbit is in blue, and the NOAA-15 orbit is in red. This is the coverage of the actual data received by NCEP for the 0000 UTC forecast on that day.

Sounding Unit (AMSU) and High Resolution Infrared Radiometric Sounder (HIRS) from NOAA-17 along with the NCEP operational complement of conventional and satellite data but excludes all data from NOAA-15 and NOAA-16 sensors. The 2_NOAA experiment adds NOAA-16 AMSU and HIRS data to the baseline experiment. The 3_NOAA experiment adds NOAA-15 AMSU and NOAA-16 AMSU and HIRS data to the baseline experiment. Differences between the 1_NOAA, 2_NOAA and 3_NOAA forecasts were accumulated over the two 45-day periods and are analyzed to demonstrate the impact of these data types.

The data coverage for the NOAA satellite available to the 00UTC 25 January 2003 NCEP analysis is seen in Fig. 11.

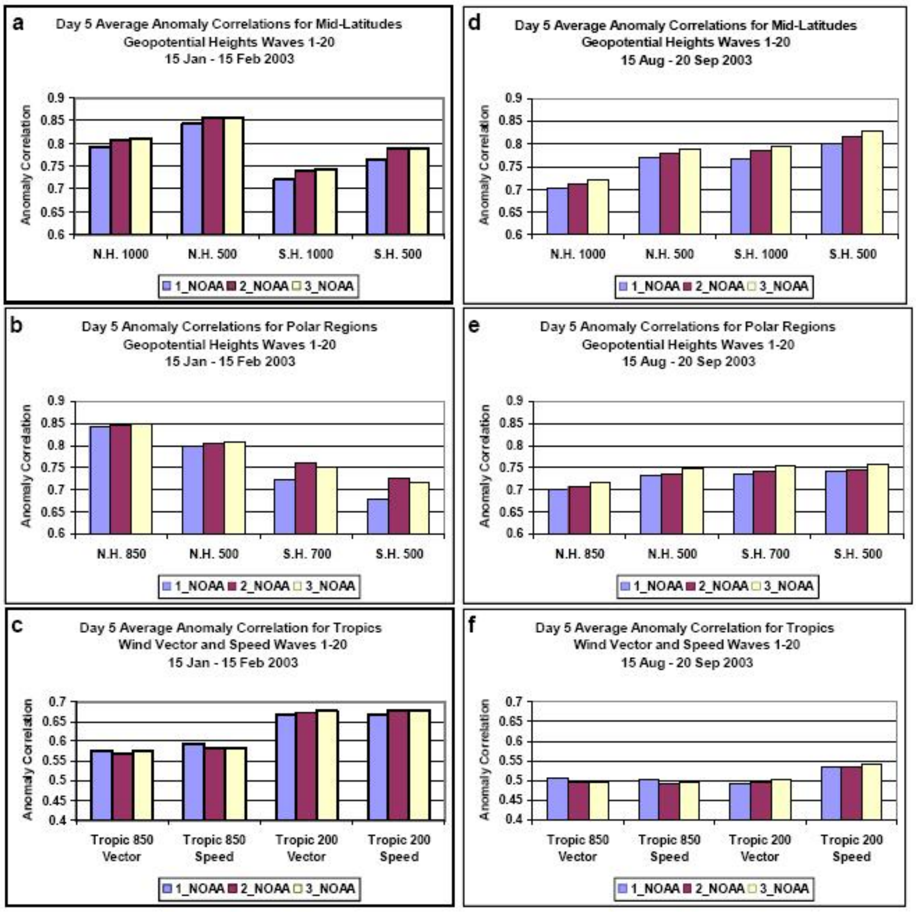


Figure 12: The day 5 anomaly correlations for waves 1-20 for the (a and d) mid-latitudes, (b and e) polar regions and (c and f) tropics. Experiments include data from 3_NOAA, 2_NOAA, and 1_NOAA satellite(s). The 15 January to 15 February 2003 results are shown in the left column and the 15 August to 20 September 2003 results are shown in the right column.

Anomaly correlations, geographical forecast impacts and hurricane track forecasts were evaluated for all experimental runs. The anomaly correlation results were partitioned into the polar regions (60°-90°) and mid-latitudes (20°-80°) of each Hemisphere. The root mean square error (RMS) for 850 and 200 hPa wind vector differences were calculated for the tropical region. The geographical distribution of forecast impact on geopotential heights, relative humidity, precipitable water and u-component of wind were examined. The influence the data types have on tropical cyclone track forecasts in the Atlantic basin were computed.

The results are summarized in Fig. 12 and demonstrate that the successive addition of each NOAA polar orbiting satellite generally increases forecast quality. They show that the use of 3 NOAA polar orbiting satellites generally provides the largest improvement to the anomaly correlation scores in the polar, mid-latitude and tropical regions. Improvements to the anomaly correlation scores are shown to be realized from the use of two polar orbiting satellites. These are generally smaller than when using three satellites, which is consistent with the increase in spatial coverage obtained with the third satellite. More detail from these experiments is available from Jung et al., 2007.

4.3. AQUA and TERRA Applications: AIRS Data and MODIS Winds Impact

Evidence of significant positive impact of AIRS data on global forecasts in *both Northern and Southern hemispheres* has been recorded in trials at the JCSDA, where all AIRS fields of

view (fovs) and 251 AIRS channels were used. The impact can be seen in Fig. 13 (a) and (b) (Le Marshall et al., 2005a,b, 2006a). The improvement in forecast skill at 6 days is equivalent to gaining an extension of forecast capability of several hours. This improvement is quite significant when compared to the rate of general forecast improvement over the last decade. A several hour increase in forecast range at 5 or 6 days normally takes several years to achieve at operational weather centers.

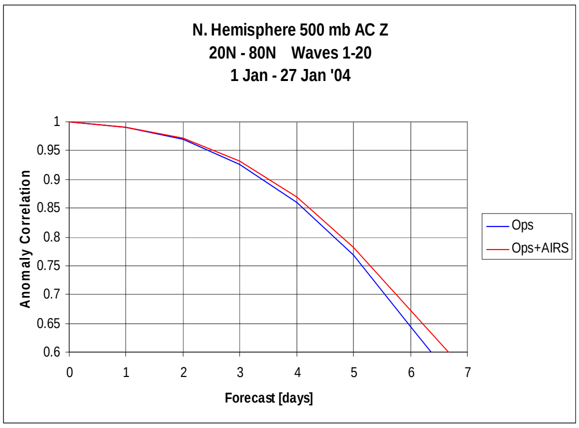


Figure 13(a) The impact of AIRS data on GFS forecasts at 500hPa (20°N - 80°N), 1 – 27 January 2004; the pink (blue) curve shows the AC with (without) AIRS data.

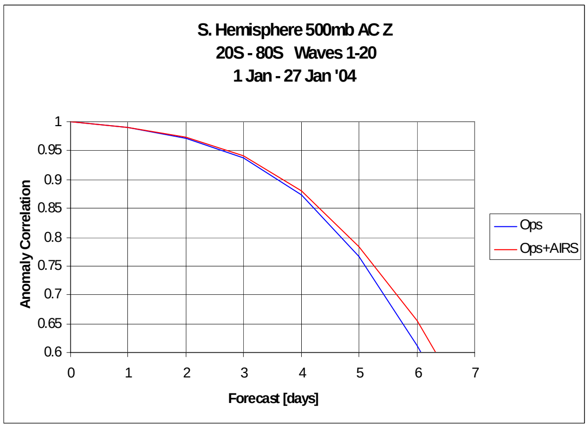


Fig.13 (b) The impact of AIRS data on GFS forecasts at 500hPa (20°S - 80°S),1 – 27 January 2004; the pink (blue) curve shows the AC with (without) AIRS data.

A number of studies in the JCSDA have also examined the *impact of full spatial resolution* AIRS data as opposed to the one in eighteen fields of view often used in NWP (Le Marshall et al. 2006b). Results for an experiment in August/September 2004 are provided (Fig. 14). In these cases using identical versions of the GFS, it is clear that using full spatial density AIRS data (SpEn) has provided improved analyses and forecasts compared to the Control (Cntl) which used one in eighteen fields of view.

Another study examining use of *full and reduced spectral coverage* AIRS data has also been undertaken (Le Marshall et al. 2006b). Results from a comparison of forecasts from i) the control (full operational database, including AQUA/ AMSU-A), ii) using the full operational data base plus full spatial resolution AIRS observations from the 115 AIRS channels whose central wavelength is between 3.7 and 9.3µm ("short AIRS"), iii) a third series of analyses, where the full operational database has been used with 152 AIRS channels (central wavelengths 3.7 to 15.4 µm) of AIRS data, "AIRS-152ch" (i.e., full spatial resolution, including 152 of the 281 channels currently available for real time NWP, a subset presently used for operational NWP) , and iv) a series of analyses and forecasts, where the full operational database has been used with all (251 channels, central wavelengths 3.7 to 15.4 µm) AIRS data, "AIRS-251ch" (i.e., full spatial resolution, including 251 of the 281 channels recently available for real time NWP), are displayed in Figure 15.

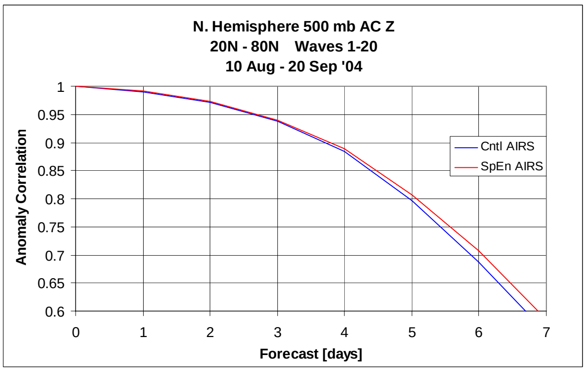


Figure 14: 500hPa height Anomaly Correlations for the GFS with thinned – one AIRS fov in 18 (Cntl AIRS) and for the GFS using all AIRS fovs (SpEn AIRS), Northern Hemisphere, August/September, 2004

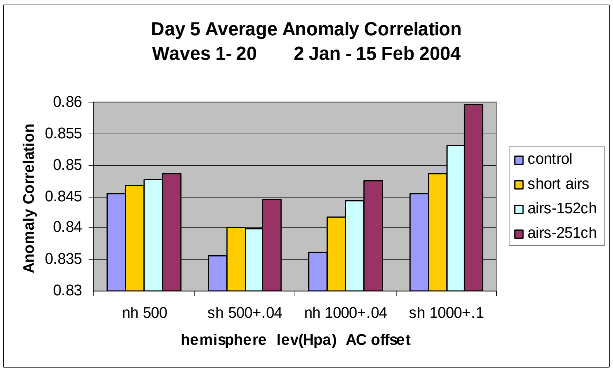


Figure 151000 and 500hPa height ACs for the GFS for the Control, Short (using 115 AIRS shortwave channels), airs-152ch using 152 out of the 281 channels available for real time NWP and airs-251ch using 251 out of the 281 channels available for real time NWP. An AC offset has been added to each Channel set to allow display on a common graph.

A bar graph shows the 1000hPa and 500 hPa geopotential height five day forecast Anomaly Correlations for the Northern and Southern Hemispheres. It was apparent in this trial that addition of the shortwave channels ("short AIRS") to the operational observation database generally provided a positive increment at five days with a larger improvement being seen in the Southern Hemisphere 1000hPa fields. It was also clear for this period, that *addition* of longwave channels (channels whose central wavelength is greater than 9.3µm, "airs-152ch", "airs- 251ch") generally provided improved forecasts in each of the categories. The clear advantage from using the full spectral range with 251 channels of AIRS data was also apparent in these experiments for this period. In summary, the introduction of hyperspectral data into operational NWP has resulted in significant positive impact in forecast skill over both northern and southern hemispheres. Enhancement to forecast skill from both increased spatial data and in particular from use of wider spectral coverage indicate the potential remains for significant improvement in the use of these hyperspectral data. A number of studies has also been completed in relation to the use of data from the MODIS instrument on AQUA.

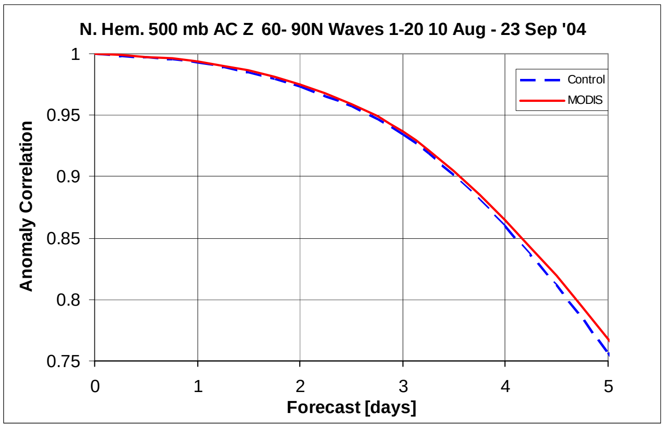


Figure 16: The 500 hPa geopotential height Anomaly Correlation for the Northern Hemisphere (60° N – 90° N), for the GFS control and the GFS control including MODIS AMVs, for the period 10 August to 23 September 2004.

Winds generated using sequential MODIS images over polar regions (Daniels et al., 2004) have been used in a series of impact studies using NCEP's operational global forecast model (Le Marshal et al., 2004a). Impacts in both northern and southern high latitudes were positive even though winds were only assimilated up to the second last analysis, to simulate existing operational data availability (Fig.16). These results are consistent with the results seen at NRL who began operational assimilation of the MODIS winds in NOGAPS in October, 2004.

4.4. Recent Data Assimilation Studies

In addition to the studies cited above, data from a considerable number of other satellite instruments have been assimilated in the JCSDA. These include data from COSMIC, CHAMP, WindSat and AMSR(E). The data from the COSMIC Constellation have been shown to have modest positive impact on forecasts, particularly near the tropopause. WindSat data have also been assimilated and shown to have positive impact on forecasts from the NCEP GDAS (Le Marshall et al., 2007b). While WindSat covers much the same areas as QuikSCAT, it improves operational forecasts using QuikSCAT and also is an in-orbit backup in case of the loss of QuikSCAT. In addition, AMSR(E) and AURA/OMI observations have also been successfully assimilated into the NCEP GSI and considerable work has been undertaken to enhance the use of AMV data within the GSI. This has involved careful quality control, determination of the correlated length scale and the correlated error, and also use of the Expected Error (Le Marshall et al., 2004b) as a quality indicator.

Combined with the data assimilation studies in the Center, with current instruments, there has been and continues to be good progress with the assimilation of data from future instruments through Observing System Simulation Experiment (OSSE) studies. One such study has been conducted (Masutani et al., 2004) to look at the impact of ADM Aeolus data on the GDAS. This has involved the generation of synthetic conventional and satellite data and subsequent assimilation of synthetic line of sight Doppler radar data. This has already allowed preparation of the GDAS for ADM data as well as providing an indication of the benefit of the data in global analysis. The clear utility of these OSSE studies in allowing early preparation for an instrument, evaluating its utility and optimizing its use is evident. At present, a new nature run and synthetic data are being prepared for a higher resolution OSSE system which will be used for similar studies.

5. The Future

A primary goal of the JCSDA in next few years is to continue to lay the groundwork for and to establish a common data assimilation infrastructure for assessing new satellite data and optimizing the utilization of these data in operational models. An important step is to make versions of operational global/regional data assimilation systems accessible to JCSDA research collaborators, to include establishment of real-time communications to JCSDA computers and real-time data bases and observation handling algorithms for continued assessment of new instruments.

Preparation for NPP, NPOESS and GOES-R and improved exploitation of current data remains high priority for the Center, which has, to date, assimilated data from well in advance of forty instruments into its forecast systems. In addition, preparation for exploitation of data from experimental instruments available through CloudSat, Calipso, ADM Aeolus and SATMOS is proceeding.

In conclusion, significant progress has been made by the JCSDA. This has been vital, as the strength of satellite data assimilation in the Center is central to the quality of future operational weather, climate and environmental analysis and forecasting in the USA.

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