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ADDITION TO BASELINE OBSERVING SYSTEM EXPERIMENT IMPACTS FROM N19-AMSU/MHS, SNPP-ATMP, AND AQUA-AIRS USING THE NCEP GLOBAL DATA ASSIMILATION SYSTEM.

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1. Introduction

Extended-length Observing System Experiments (OSEs) during two seasons are used to quantify the contributions made to forecast skill by conventional in-situ and remotely sensed satellite data. The impact is measured by comparing the analysis and forecast results of an assimilation–forecast system using a minimum of data then adding a particular observing system to the full suite of observations. The case studies chosen consist of two separate periods during August – September 2010 and December 2010 – January 2011.

The assimilation–forecast system used for these experiments is the National Centers for Environmental Prediction (NCEP) Global Data Assimilation System (GDAS) and the Global Forecast System (GFS) at a resolution of T574L64. The control run utilized almost all data types routinely assimilated in the GDAS. The baseline experiment uses all of the conventional data plus the Global Positioning System – Radio Occultation (GPS-RO). The experimental runs individually add data from the Advanced Technology Microwave Sounder (ATMS) on the Suomi NPOESS Preparatory Project (SNPP) satellite, the Advanced Microwave Sounding Unit and Microwave Humidity Sensor (AMSU/MHS) on NOAA-19, and the Atmospheric InfRed Sensor (AIRS) on the National Aeronautics and Space Administration (NASA) satellite Aqua.

The impact of each observing system is assessed by comparing the analyses and forecast results over extended periods. Anomaly correlations, Forecast Impacts, and vector Root-Mean Square Error (RMSE) are evaluated for all experimental runs during both seasons. Anomaly correlations of geopotential heights are shown at mid-latitudes. The geographical area-weighted time series of

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Forecast Impacts on various fields are also examined. The results demonstrate that each observing system (SNPP-ATMS, N19-AMSU/MHS, and Aqua-AIRS) contributes about equally to the analyses and forecast skill of the GDAS/GFS.

2. Assimilation System

The NCEP assimilation system consists of a first or early cycle with a T-3.0 to T+2.5 hour data cut-off window for all observations available by T+2.5 hours after synoptic time, where T indicates the analysis time, typically at the synoptic times of 00, 06, 12 and 18 UTC. In operational practice, an extended range forecast is issued from each analysis. For this study, only the 00 UTC forecasts are used out to 168 hours. The analysis process is repeated 6 hours later to provide the final analysis for the six hour forecast for the next early cycle first guess. This final analysis includes observational data that arrived after the cut-off for the early analysis. The final analysis is our best estimate of the atmosphere and in this study it was used as truth for the analysis and forecast quality assessment.

For these experiments, the May 2011 operational version (GFS Version 9.0.1) and resolution of the GFS was used. Comprehensive documentation of the GFS, including any recent changes, can be found online at http://www.emc.ncep.noaa.gov/GFS/doc.php. A horizontal resolution of 574 spectral triangular waves (T574) was used, with a Gaussian grid of 1152 X 578, which corresponds to approximately 0.3^o X 0.3^o latitude and longitude. The vertical domain ranges from the surface to 0.27 hPa and is divided into 64 unequally spaced sigma/pressure layers with enhanced resolution near the bottom and top of the model domain. There are 15 layers below 800 hPa and 24 layers above 100 hPa. The current Gridpoint Statistical Interpolation (GSI) analysis scheme is a three-dimensional variational (3DVAR) scheme that is similar to the Spectral Statistical Interpolation (SSI) (Derber et al. 1991: Parrish and Derber 1992), with the main difference being that the GSI analysis equation is formulated in gridpoint space rather than in spectral space. The GSI algorithm replaced the SSI in the GDAS in May 2007 as discussed in Kleist et al. (2009a, 2009b), with subsequent changes documented online at http://www.emc.ncep.noaa.gov/gmb/gdas/.

3. Experimental Design

Diagnostics presented here include statistics commonly used by NCEP and other NWP centers world-wide. The computation of Anomaly Correlations (ACs) for forecasts, produced from the GFS, is completed using code developed and maintained at NCEP. NCEP (NWS 2005) provides a description of the method of computation while Lahoz (1999) presents an overall description of what the anomaly correlation is typically used for. The fields being evaluated, which are truncated to only include spectral wave numbers 1 through 20, are limited to the zonal bands 20^o-80° of each Hemisphere.

Other diagnostic used here are the analysis differences and the Forecast Impact (FI). Analysis differences (bias) are average differences between the various experiments (ATMS, AMSU/MHS, AIRS and baseline) and the analyses with all of the data (control). The FI is an area weighted and normalized root-mean-square error (RMSE) discussed further by Zapotocny et al. (2005). For this study, the vertical time series of FI results are presented as the positive/negative impact provided by the addition of the particular satellite.

All diagnostics exclude the first 14 days of the time period. This delay in evaluating the statistics allows for the impact of the new data to be acclimated into the model initial conditions. The forecast diagnostics for this paper were also terminated at 168 hours to concentrate on the shorter term forecast impacts.

4. Results

In general, the analyses will change when data are added or removed from the data assimilation system. In a cycling system such as the GDAS, these changes will evolve and often magnify over time. These changes may eventually lead to systematic biases in various fields when compared to the control fields (generated by using all available observations). Regions with minimal bias of the perturbation analysis with respect to the control analysis indicate either that the forecast model has little bias here, or that other observations are able to keep the fields from drifting away from the control.

Zonal mean analysis differences of geopotential height, temperature, and relative humidity are shown in figures 1-3 respectively. The temperature is generally warmer when most of the satellite data were removed (base-control in figure 2). This is consistent with the heights being generally higher except over the north pole (Baseline-Control in figure 1). Adding the Aqua-AIRS data made little difference to improve the geopotential heights as the (Baseline-Control) and (Aqua-AIRS-Control) are very similar. Adding the SNPP-ATMS data has regions that were improved as well as degraded. Adding the N19-AMSU/MHS show improvements almost everywhere. This suggests that the forecast model may have a temperature drift which the data in the Baseline is unable to control. The changes to the relative humidity field in the Baseline and satellite-instrument data additions suggest the model has a moist bias in the upper troposphere (especially in the Southern Hemisphere) which is only improved by adding the Aqua-AIRS data.

The anomaly correlations and wind RMSE presented are for days 0 to 7 for the Control, Baseline, SNPP-ATMS, N19-AMSU/MHS, and Aqua-AIRS experiments in figures 4-7. The greater the difference between the anomaly correlation scores of the various experiments and the Baseline, the larger the impact the single satellite-instrument has on the quality of the forecast. The lower portion of each panel shows a statistical significance test with respect to the baseline experiment. Values outside (above or below) bars of corresponding color are significant at the 95% confidence level.

The Control simulation has the highest and the baseline experiment has the lowest average anomaly correlation at all forecast ranges. The other experiments (SNPP-ATMS, N19-AMSU/MHS and Aqua-AIRS) are generally about equal in forecast skill and between the Control and the Baseline. This suggests that each satellite-instrument contributes about equally to the mid-latitude forecast skill. The wind RMSE is used to quantify forecast skill in the tropics as changes in geopotential heights are minimal in the tropics. For these experiments, all of the satellite-instrument additions improved the wind RMSE in the tropics. The SNPP-ATMS and N19-AMSU/MHS both show improvements over the Baseline and are about equal. The

Aqua-AIRS experiment shows the greatest improvements at both levels.

The Forecast Impact (FI) is a measure of the RMSE error growth between a “truth” analysis and a forecast. For these experiments, the FI used the control analysis as the best estimate of the atmosphere for comparison with the other experiments. A negative FI indicates a forecast degradation from the control. The more negative the FI score the worse the forecast skill. With time the error in the experiment will approach the error in the control and the FI will approach zero.

The FI of geopotential heights and zonal winds are shown here in figures 8 and 9 respectively. Consistent with the anomaly correlations, the baseline experiment is consistently worse with the addition experiments about equal except for the N19-AMSU/MHS showing improvements over the others in the Southern Hemisphere. For the zonal wind (figure 9), the baseline is again worse in all 3 regions with the other experiments about equal.

The hurricane track forecasts out to 120 hours were examined for the Atlantic Basin during this time period and are shown in figure 10. The hurricane track forecast errors show the control has the smallest track errors. Surprisingly, the Aqua-AIRS has the next best track errors while the SNPP-ATMS and N19-AMSU/MHS are about equal.

5. Summary

The analysis temperature/geopotential heights are generally warmer/higher when data were removed except over the north pole. Adding the AIRS data made little difference as the (baseline - control) and (Aqua-AIRS - control) are very similar. Adding the SNPP-ATMS data has temperature and height regions that were improved and degraded. Adding the N19-AMSU/MHS shows improvements almost everywhere. This suggests that the forecast model may have a temperature drift which the conventional data was unable to control. The changes to the relative humidity field suggest the model has a moist bias in the upper troposphere (especially in the Southern Hemisphere) which is improved only by adding the Aqua-AIRS data.

The control simulation has the highest and the baseline experiment has the lowest average anomaly correlation at all forecast ranges. The other experiments (SNPP-ATMS, N19-AMSU/MHS and Aqua-AIRS) are generally about equal and between the control and the baseline. This suggests that each satellite-instrument contributes about equally to the forecast skill. Consistent with the anomaly correlations, the FI for the baseline experiment is consistently worse with the addition experiments about equal except for the AMSU/MHS showing improvements over the others in the Southern Hemisphere. For the zonal wind, the baseline is again worse in all 3 categories with the other experiments about equal.

The hurricane track forecasts out to 120 hours were examined for the Atlantic Basin during this time period. The hurricane track forecast errors show the control has the smallest track errors. Surprisingly, the Aqua-AIRS has the next best track errors while the SNPP-ATMS and N19-AMSU/MHS are about equal.

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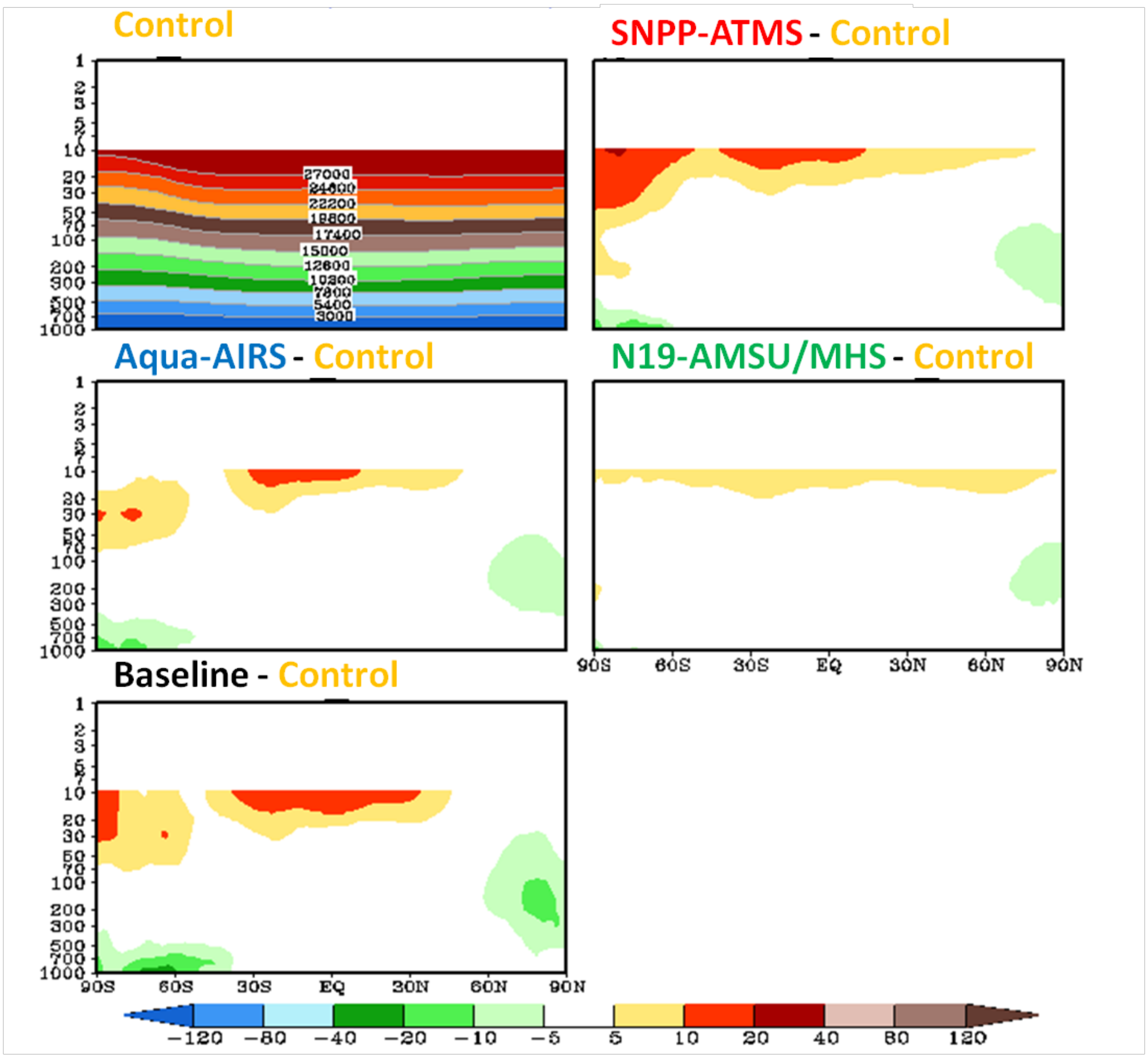

Fig 1. Average 00Z analysis latitude-height plots of geopotential height difference from the control for SNPP-ATMS, Aqua-AIRS, N19-AMSU/ATMS and the baseline experiment. Units are [m]

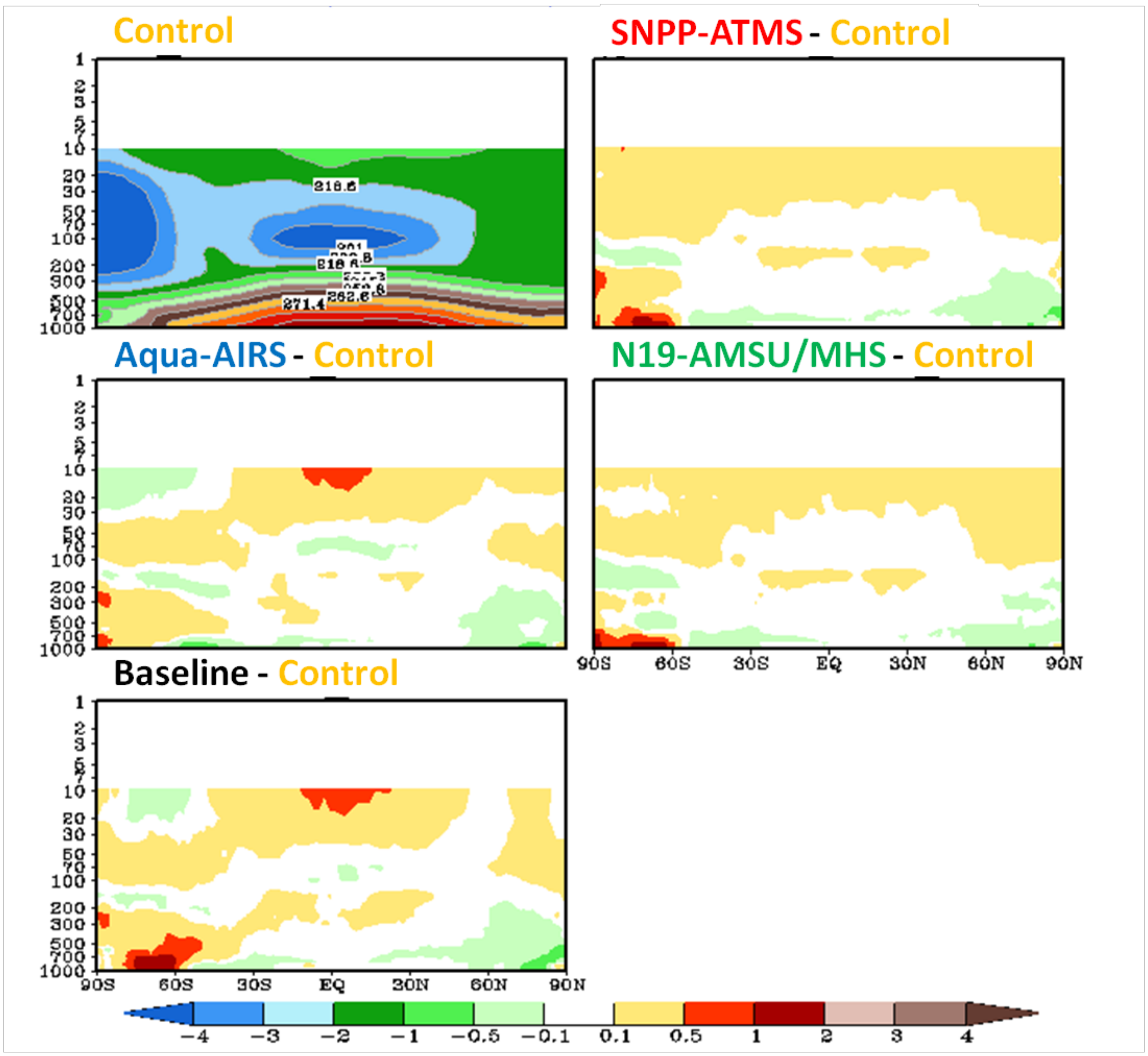

Fig 2. Average 00Z analysis latitude-height plots of temperature difference from the control for SNPP-ATMS, Aqua-AIRS, N19-AMSU/ATMS and the baseline experiment. Units are [K]

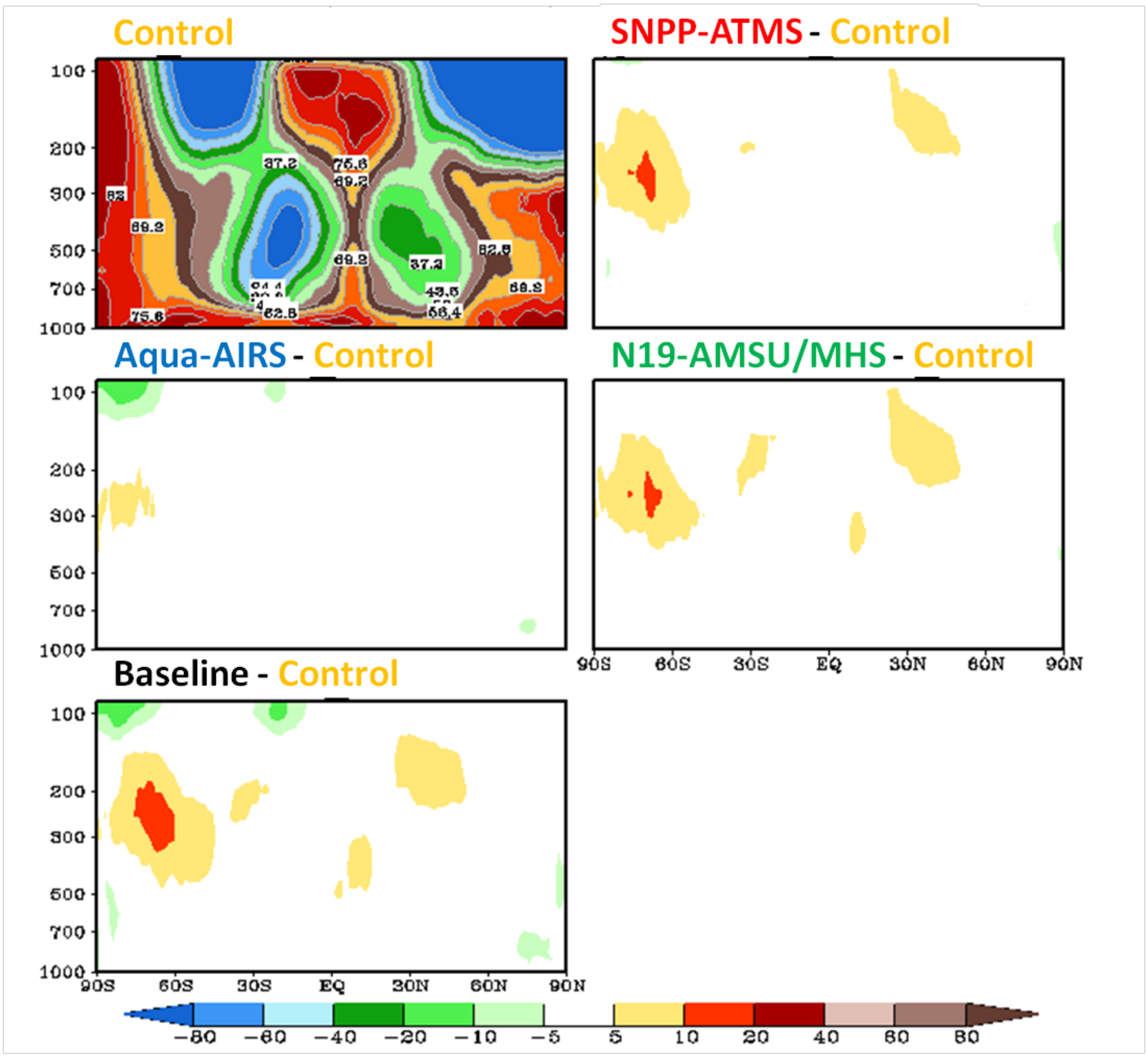

Fig 3. Average 00Z analysis latitude-height plots of relative humidity difference from the control for SNPP-ATMS, Aqua-AIRS, N19-AMSU/ATMS and the baseline experiment. Units are [%]

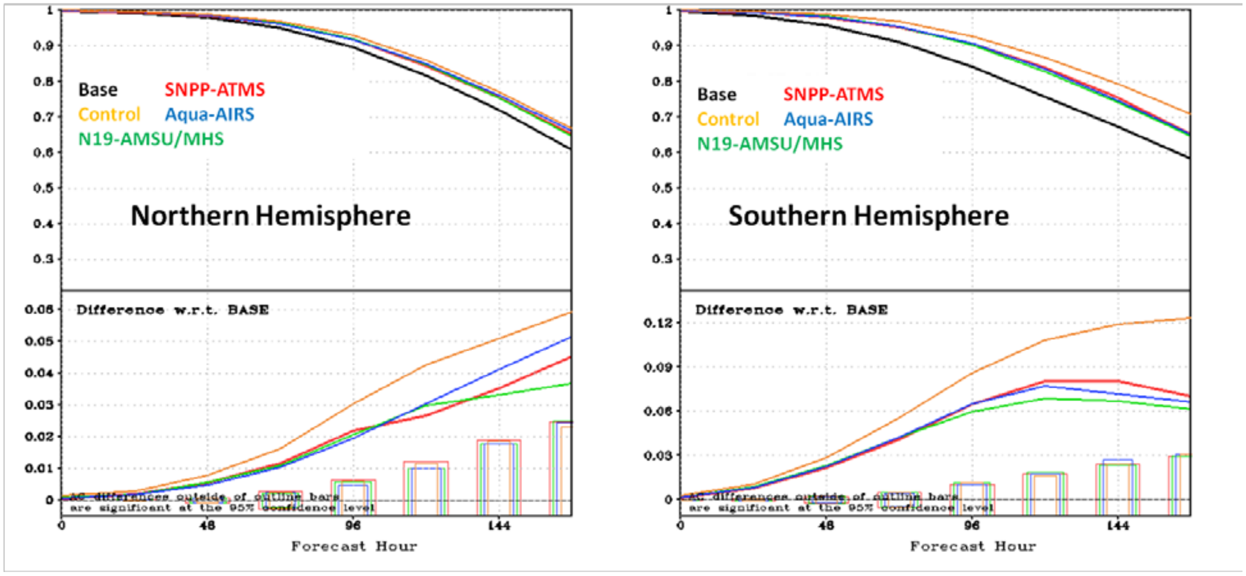

Fig 4. 250 hPa geopotential height anomaly correlations through day 7 for the Northern and Southern Hemispheres. The bottom portion of both panels are the difference between the control and each experiment with the statistical significance test. Lines outside the (above or below) the corresponding color box are significant at the 95% confidence level.

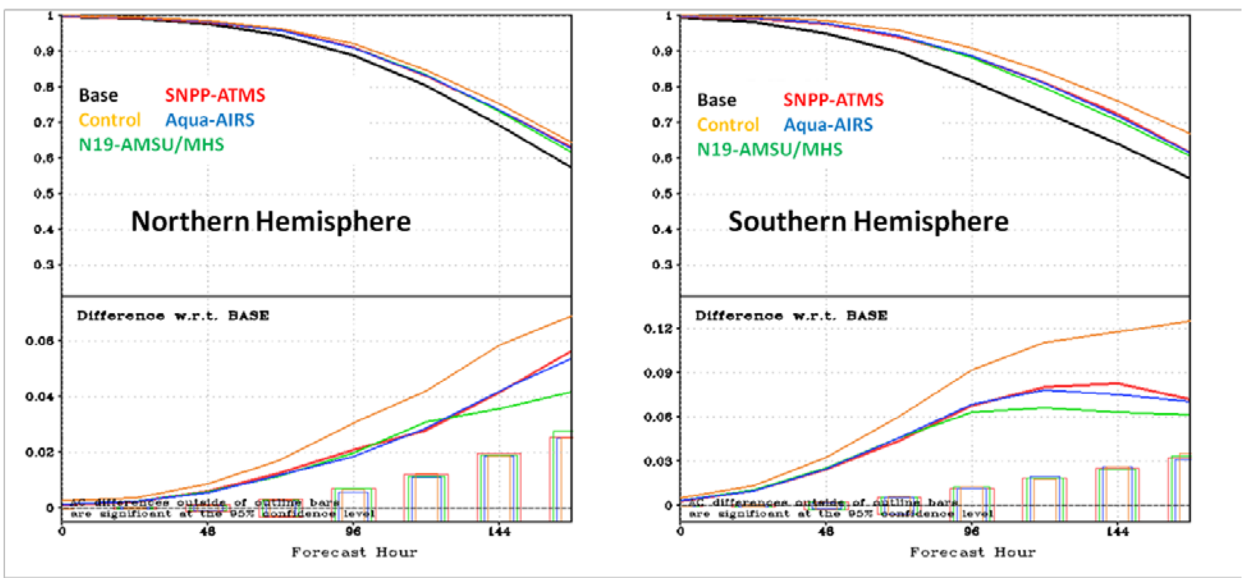

Fig 5. 500 hPa geopotential height anomaly correlations through day 7 for the Northern and Southern Hemispheres. The bottom portion of both panels are the difference between the control and each experiment with the statistical significance test. Lines outside the (above or below) the corresponding color box are significant at the 95% confidence level.

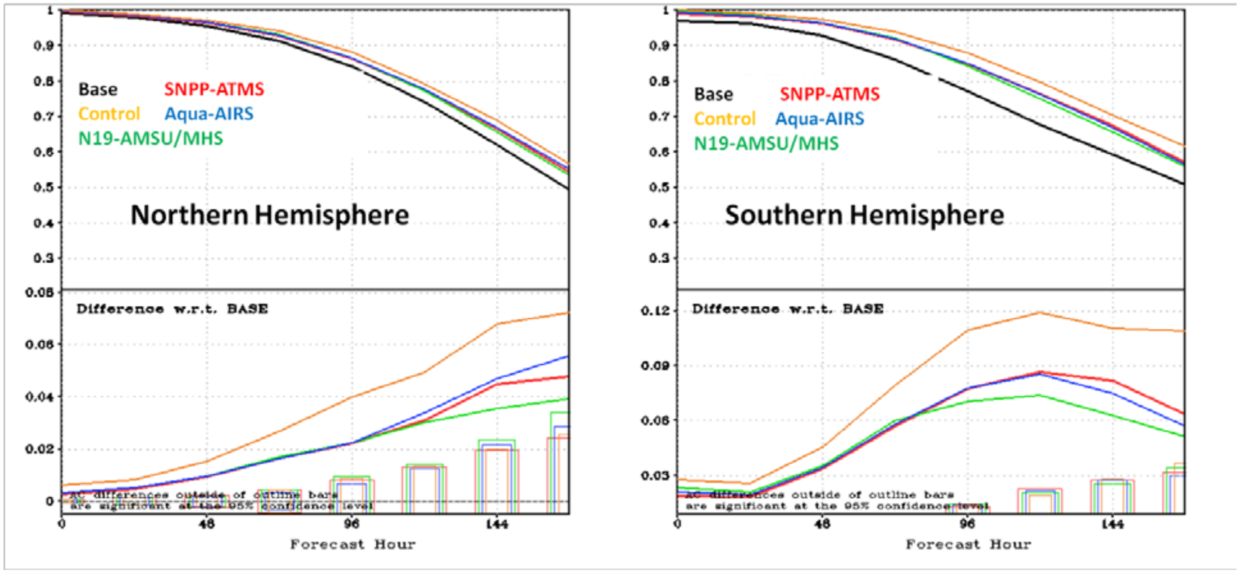

Fig 6. 1000 hPa geopotential height anomaly correlations through day 7 for the Northern and Southern Hemispheres. The bottom portion of both panels are the difference between the control and each experiment with the statistical significance test. Lines outside the (above or below) the corresponding color box are significant at the 95% confidence level.

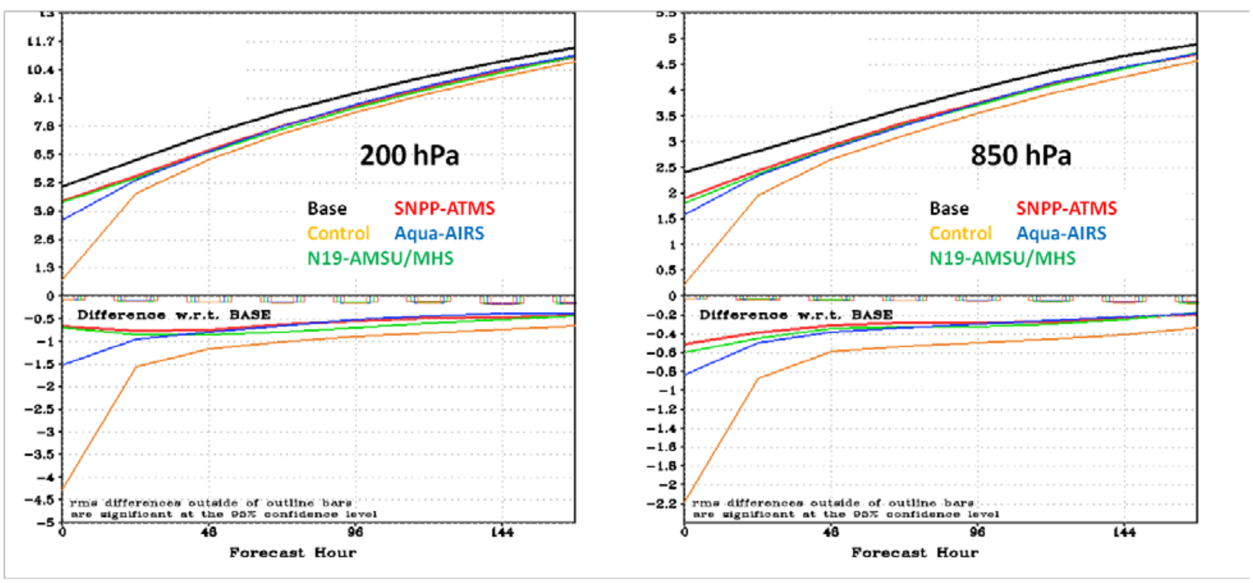

Fig 7. RMSE vector difference of the wind at 200 hPa (left) and 850 hPa (right). The bottom portion of both panel are the difference between the control and each experiment with the statistical significance test. Lines outside the (above or below) the corresponding color box are significant at the 95% confidence level.

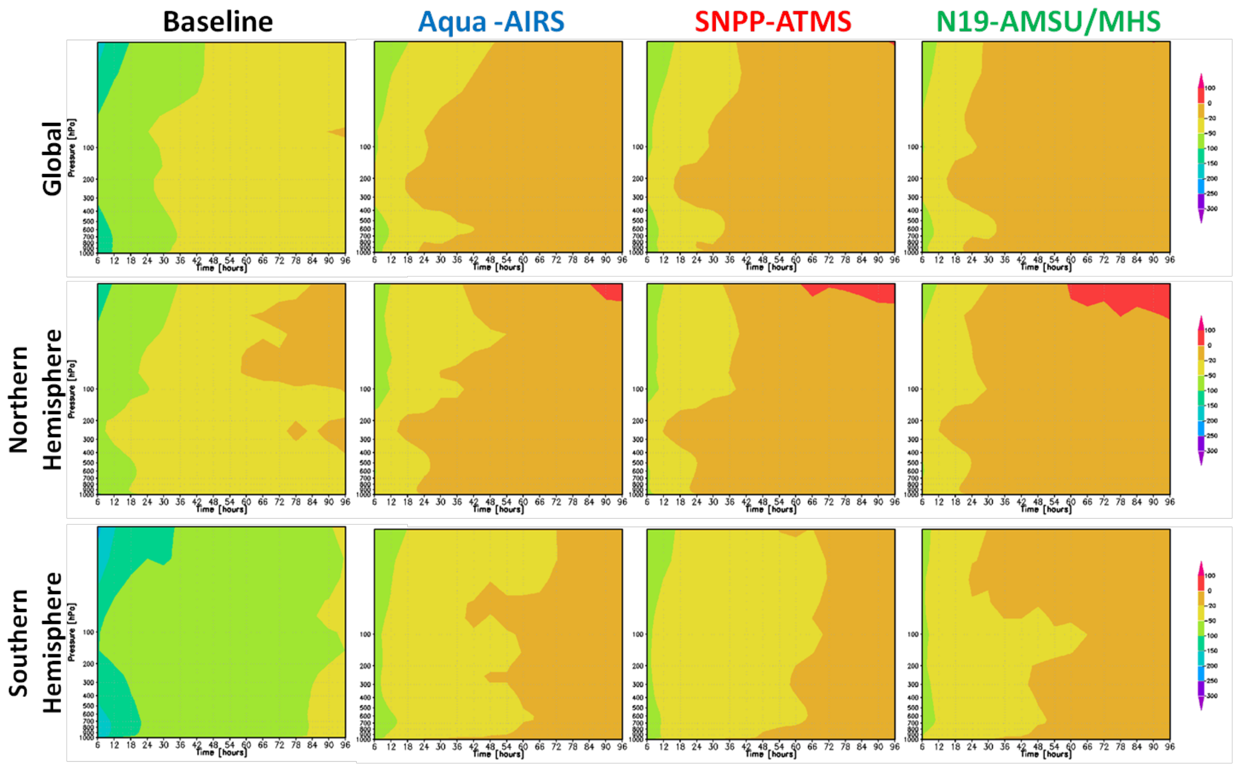

Fig. 8. Forecast impact (FI) Vertical cross section of geopotential height for the globe (top), the Northern Hemisphere (20^{o}N – 80^{o}N) (middle) and the Southern Hemisphere (20^{o}S – 80^{o}S) (bottom). The baseline, Aqua-AIRS, SNPP-ATMS, and N19-AMSU/MHS experiments are in column 1-4 respectively.

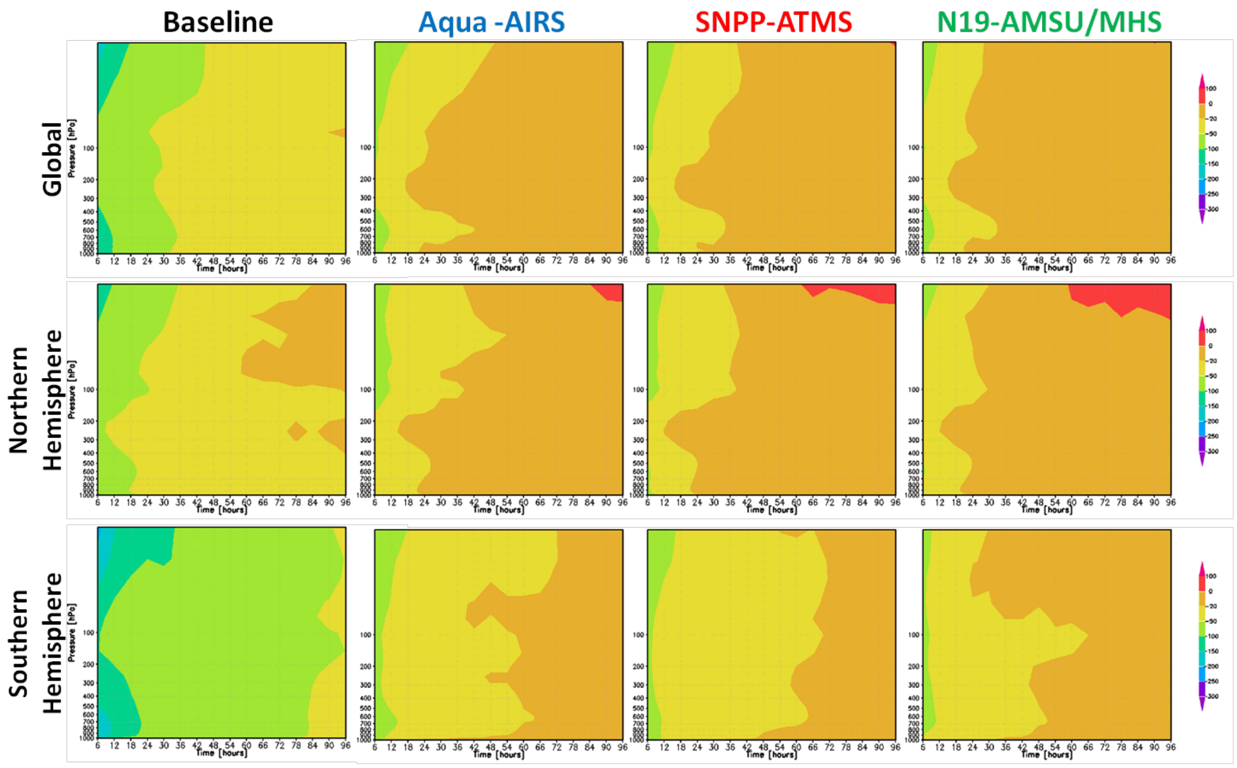

Fig. 9. Forecast impact (FI) Vertical cross section of zonal wind for the globe (top), the Northern Hemisphere (20^{o}N – 80^{o}N) (middle) and the Southern Hemisphere (20^{o}S – 80^{o}S) (bottom). The baseline, Aqua-AIRS, SNPP-ATMS, and N19-AMSU/MHS experiments are in column 1-4 respectively

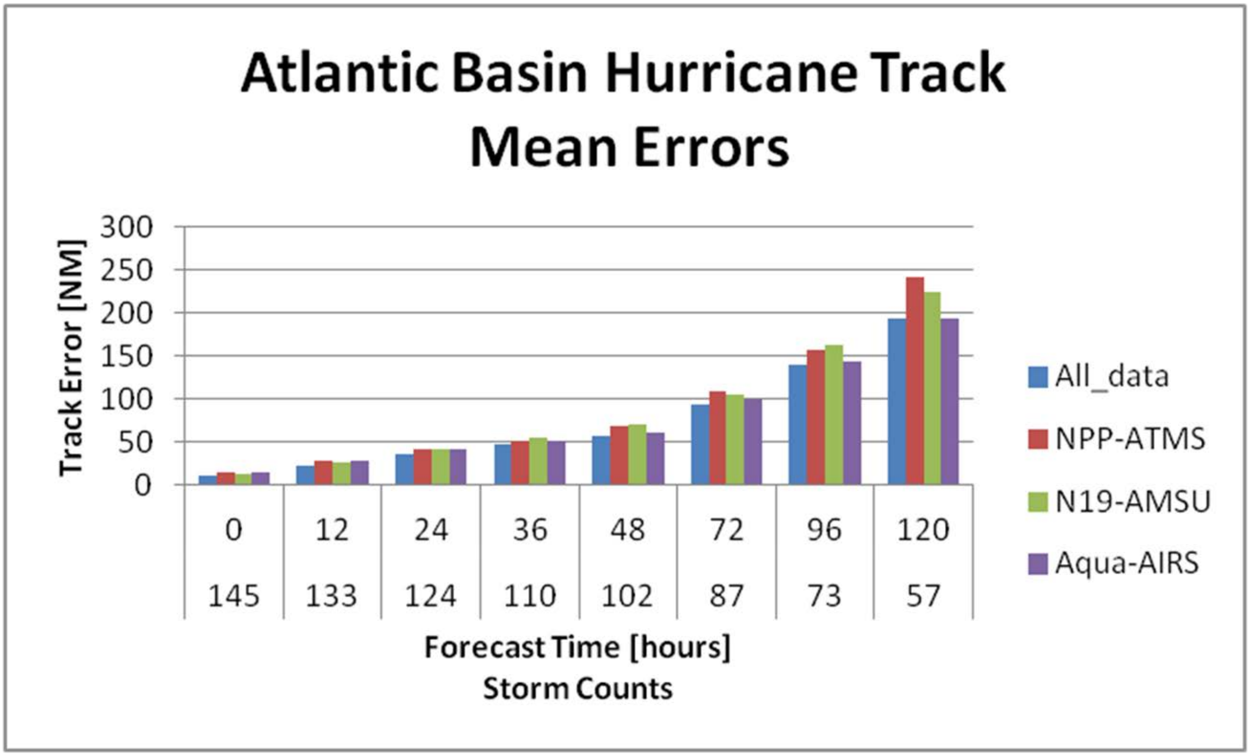

Fig 10. Hurricane forecast track statistics for the Atlantic Basin. Units are [NM].