14th Conference on Satellite Meteorology and Oceanography
Atlanta, GA, January 30-February 2, 2006

P5.4 USE OF AIRS/AMSU RETRIEVED SOUNDINGS TO IMPROVE PREDICTION OF GULF MOISTURE RETURN

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1 INTRODUCTION

In May 2002, NASA launched the polar-orbiting Earth Observing System (EOS) Aqua satellite. On board the Aqua satellite is the Atmospheric InfraRed Sounder (AIRS), a cross-track scanning infrared spectrometer/radiometer. The AIRS instrument combined with the Advanced Microwave Sounding Unit (AMSU) is designed to measure atmospheric water vapor and temperature profiles. The AIRS footprint is 13 km at nadir, with a 3 x 3 array of AIRS footprints fitting into a single AMSU footprint, providing retrieved soundings at a horizontal spacing of about 40-50km.

The core retrieval procedures for thermodynamic profile information employed by the AIRS Science Team uses a physically-based iterative least squares solution with computational and instrument noise and cloud-clearing error covariance matrices included in each step (Chahine et al. 2001). The temperature and moisture profiles, along with surface parameters like Land Surface Temperature (LST) and Sea Surface Temperature (SST), surface emissivity, and atmospheric parameters such as cloud height/pressure and emissivity are available to the user community via NASA's Distributed Active Archive Center (DAAC). The expected accuracy of these retrievals is 1 K RMS in a 1 km layer and 20% relative humidity RMS in 2 km layers at altitudes below 12km. This is a substantial improvement over satellite retrieval capabilities from the current operational NOAA polar orbiting or GOES satellites (Menzel and Purdom, 1994; Menzel et al. 1998).

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The profiles retrieved by AIRS may be utilized in model forecasts. The ability of the satellite to obtain data over the Gulf of Mexico promises to improve forecasts of air mass modification and return moisture flow from the Gulf. This could significantly impact precipitation forecasts from the southern plains to the southeast United States. One such case involves a significant error noted in the NAM (Eta) forecast for air mass modification and return flow over the Gulf of Mexico on 9 April 2005. The Corpus Christi operational rawinsonde observation for 00 UTC on April 10 had 11 g/kg of moisture at 850mb compared to only 5 g/kg forecast by the model initialized at 12 UTC.

This research uses the ARPS Data Analysis System (ADAS) to assimilate the sounding data in a high-resolution nonhydrostatic model. ADAS is a Bratseth successive correction statistical analysis that converges to optimal interpolation (Bratseth 1986, Brewster 1996). It is a very flexible system of ingesting data having varying sources and observation densities. Error characteristics of the data can be specified by each source and by height above ground level. ADAS employs a telescoping data selection and successive correction method that allows for the inclusion of data sources of widely varying spatial resolution by first correcting the background field for large-scale errors with large-scale data then continuing with iterations using higher resolution data to correct mesoscale features.

ADAS also includes a complex cloud analysis procedure that integrates cloud information from surface stations, visible and IR satellite data, and radar reflectivity. The cloud analysis system was originally based on the scheme of the Local Analysis and Prediction System, LAPS (Albers et al 1996), but has been adapted to the ARPS terrain-following coordinate and has been improved for high-resolution modeling and data assimilation purposes (Zhang et al. 1998, Zhang 1999, Brewster 2002).

This study has two components. The first involves examining the data to estimate certain comparison statistics of the data. These statistics can then be used to help determine errors associated with the data for use in ADAS as detailed in Section 2. The second component of this research tests the utility of including AIRS soundings in ADAS and ARPS, and is detailed in Section 3.

2 EXAMINATION OF THE DATA

ADAS requires error files for each of the data types it ingests. In order to use AIRS profiles in ADAS, statistics about the data must be computed. One source of available data for comparison comes from the Atmospheric Radiation Measuring Program (ARM) Southern Great Plains site (SGP) at Lamont, Oklahoma. During certain intensive operating periods dedicated sondes are launched from the SGP central faciility 45 minutes and 5 minutes before the Aqua satellite overpasses. A comparison is made between AIRS soundings and a sample of these SGP soundings taken from 29 August 2005 to 17 October 2005. This is not a complete analysis of the SGP intercomparison data, but, instead, a sample dataset chosen to get an estimate of statistics for the purposes of creating ADAS error files associated with AIRS.

The AIRS retrievals are reported as point observations, but due to the nature of the radiation measurements on which they're based, the values given at each pressure level are represented of layer averages. In order to gauge the effective layer averaging in the soundings we compare AIRS with layer-averages of the SGP data. The SGP soundings were averaged over layers of varying thickness and compared to the AIRS data to see which thickness has the best fit to the retrieved data. Figures 1 and 2 show the results from this layer-average comparison for the launches 45 min before the Aqua overpass at 850 mb, 700 mb, 400 mb, and 300 mb, for temperature and relative humidity, respectively. Potential temperature and mixing ratio were the quantities actually averaged. The graphs (not shown) for the launches made 5 minutes before the overpass are similar.

We note from Figure 1 that the RMS temperature values reach a minimum at 1500m for 300 mb and 400 mb. The RMS temperature values for 850 mb and 700 mb tend to decrease as the average layer size increases throughout the whole line. Higher values of RMS temperature difference were obtained with a direct comparison between AIRS and SGP soundings without any averaging.

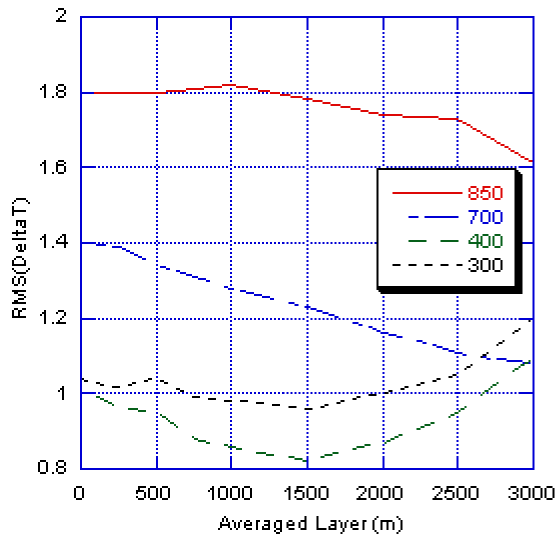

Fig. 1: RMS temperature difference (degrees K) between AIRS and a sample set of SGP soundings launched 45 min before AIRS overpass. Four pressure levels are shown.

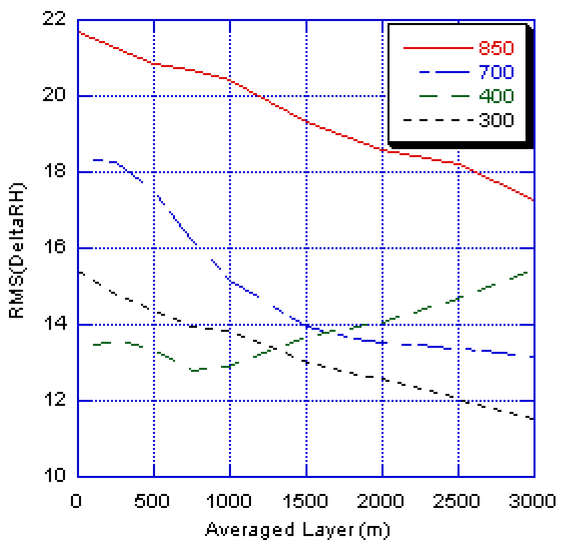

Fig. 2: Same as Figure 1 except for relative humidity (percent).

The highest RMS temperature values were found at the surface, while 500 mb had the lowest RMS temperature values. For the 45 minutes before overpass data, the 3000m averaged layer provided the lowest RMS temperature values from the surface to 700mb. Above 700 mb, the 3000 m layer switched to having the highest RMS temperature values. This is also seen in the soundings launched 5 minutes before the Aqua overpass, except the transition from lowest RMS temperature values to highest occurs around 600 mb. Larger averaged layers tend to provide the best RMS temperature values at lower levels and the worst RMS temperature values in the upper levels.

Considering the relative humidity differences between AIRS and the SGP soundings, with the exception of 300mb, a decrease in RMS relative humidity value occurs as the averaged layer increases. The highest RMS relative humidity values through the vertical are found at 850 mb and 600 mb, with the lowest values found above 400mb. Again the 3000 m averaged layer produces the best RMS values in the lower levels. Unlike temperature, it does not distinctly switch over to producing larger RMS values in the upper levels. Larger averaged layers tend to do better in the lower levels, while in the upper levels all of the values tend to be close and no clear averaged layer is best.

Although this is far from a complete analysis, we note that overall this sample of SGP comparison data yielded results comparable to the expected AIRS errors. The temperatures RMS differences were around 1 K and the relative humidity RMS differences were near or below 20%.

For the case of 9 April 2005 a similar comparison was done using soundings extracted from the ADAS background using a NAM (Eta) 7-hour forecast. In this instance, the AIRS data were grouped according to quality control flags. The quality control flags considered were: QualTempProfileTop, QualTempProfileMid, QualTempProfileBot, and QualSurf. These quality control flags focus on the quality of the temperature data. At this time the quality control flags dealing with water content are under development and are not recommended for use. The flags carry a value from 0-2 with 0 being the highest quality and 2 being do not use. There were seven distinct combinations of flags in this case as seen in Table 1. A comparison was made between the seven categories of AIRS data and the background soundings. These results along with the SGP results were then used to determine the ADAS error files used in the 9 April 2005 study. Each category of AIRS retrieval thus received its own error file.

Top	Bot	Mid	Surf	# of Soundings
0	0	0	0	182
0	0	0	1	113
0	0	0	2	132
0	0	1	1	101
0	0	1	2	37
0	2	2	2	126
2	2	2	2	4

Table 1: Quality control flag categories for the AIRS ocean profiles at 19 UTC April 9, 2005 with number of soundings corresponding with each.

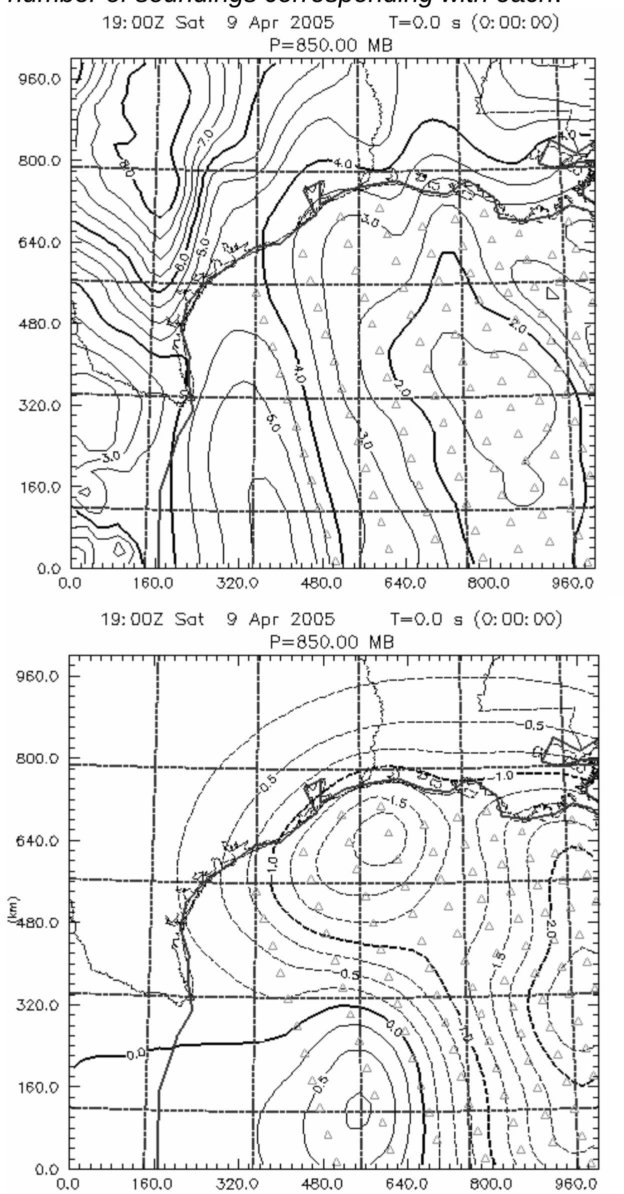

Fig. 3: Specific humidity analysis at 850mb (above) and difference from background NAM (Eta) 7-h forecast (below). Triangles show locations of AIRS retrieval soundings.

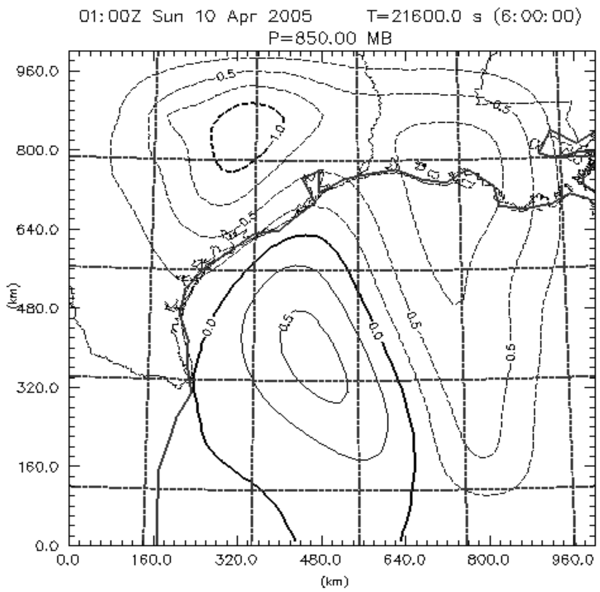

Fig. 4: 6-hour forecast of specific humidity difference between control run and experimental run of ARPS at 850mb.

3 ADAS AND ARPS ANALYSIS

As mentioned, in the case of 9 April 2005, the NAM (Eta) model underpredicted the moisture return along the Gulf coast of Texas. Since routine observations over the Gulf are very limited, this seemed like a good opportunity to test the impact of AIRS data in a forecast. The AIRS swath used in this research passed over the region around 19 UTC on 9 April, and therefore 19 UTC was used as the initialization time of the ARPS model.

Archived NAM forecasts with a 40-km resolution were used as the background field. A comparison was made between the ADAS analysis including the AIRS data, and an ADAS file at the same time without the AIRS data, containing only the background NAM field. Figure 3 shows the 850mb specific humidity difference fields between the AIRS and the background. AIRS profiles dried out the region right off the coast of Texas/Louisiana by about 1.75 g/kg. Further to the south there was a moisture increase of 0.5 g/kg. The AIRS observations were drier at the surface over the Gulf in the ADAS comparison.

The ARPS model was used to run a 24 hour forecast. The control run used only the NAM background, while the experimental run included the AIRS data. Figure 4 shows the 6-hour forecast difference between the two runs. The AIRS data contributed to a moisture increase of 0.5 g/kg just off the Texas coast. There is a moisture decrease of 1.0 g/kg north and east of the region of moisture increase. The results at 12 and 24 hours showed a smaller impact, as this difference apparently diffused. The AIRS data did not seem to make a significant difference further out. No significant difference from the background was noticed after 12 hours.

4 SUMMARY AND CONCLUSIONS

The AIRS data did not make a major impact in the long-term forecast; there are two likely reasons for this result. First, the Aqua overpass may have missed the deepest of the modifying air mass as it did not cover the extreme western portion of the Gulf on this particular pass, and there was a gap between this pass and the next orbit at this latitude. Considerations for design of future remote sounding instruments should such avoid gaps in retrieval swaths, noting that the retrieval swaths are narrower than typical imaging swaths, e.g. from MODIS on Aqua.

Another possible cause is the way ADAS handles the assimilation of AIRS profiles. The ADAS analysis showed that AIRS contributed to a decrease in moisture over the Gulf. However, a comparison done between AIRS data and buoy data suggests that the AIRS surface observations are not far from the truth. A look at the AIRS profiles showed a rapid decrease in moisture at 850mb. AIRS RMS values tended to be highest around 850mb for moisture. ADAS makes a direct comparison between the values of the AIRS profile and the NAM profiles. It could be that the assimilation process is causing some of the dry bias at 850mb to affect the surface values.

One way to possibly correct this problem would be to average the background profiles in layers and comparing them to AIRS. This process would be similar to that described in Section 2 with the SGP profiles and will be tested in the future.

In the future we will also be considering the Tropical Western Pacific (TWP) ARM site for AIRS comparison along with SGP. TWP is an oceanic site and would provide a better comparison since we are using oceanic retrievals over the Gulf. Although the SGP site is much closer to this domain, retrievals in its area are land retrievals, which may have slightly different statistics, especially near the surface. We expect that examination of data from TWP will build on our knowledge of AIRS statistics and be useful in our handling of errors associated with AIRS.

5 ACKNOWLEDGMENTS

This research is funded by a grant from the NASA Science Mission Directorate, NNG04GM66G. The opinions expressed here are solely those of the authors and not the sponsoring agency.

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