P3.5 REGIONAL ASSIMILATION OF NASA ATMOSPHERIC INFRARED SOUNDER (AIRS) DATA

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1. INTRODUCTION

The NASA Short-term Prediction Research and Transition (SPoRT) Center (Goodman et al. 2004) seeks to accelerate the infusion of NASA Earth Science Enterprise (ESE) observations, data assimilation and modeling research into NWS forecast operations and decision-making. The Atmospheric Infrared Sounder (AIRS) is expected to advance climate research and weather prediction into the 21st century. It is one of six instruments onboard Aqua, a satellite that is part of NASA's Earth Observing System. AIRS, along with two partner microwave sounding instruments, represents the most advanced atmospheric sounding system ever deployed in space. The system is capable of measuring the atmospheric temperature in the troposphere with radiosonde accuracies of 1 K over 1 km-thick layers under both clear and cloudy conditions, while the accuracy of the derived moisture profiles will exceed that obtained by radiosondes (Aumann et al. 2003**)**.

It is imperative that the scientific community is prepared to take full advantage of next-generation satellite data that will become available within the next decade. The purpose of this paper is to describe a procedure designed to optimally assimilate AIRS data at high spatial resolution over both land and ocean. Results will focus on quality control issues associated with AIRS, optimal assimilation strategies, and the impact of the AIRS data on subsequent numerical forecasts at 12 km horizontal resolution.

2. ANALYSIS SCHEME

The assimilation system used in this study is the Local Analysis and Prediction System (LAPS, Albers et al. 1996) developed at the NOAA Forecast System Laboratory (FSL) and used extensively around the globe. The LAPS is designed to address the problem of local-scale data assimilation and real-time numerical weather forecasting. It provides a means to combine different sources of local meteorological data into a single, coherent three-dimensional description of the atmosphere. The data sources can be from satellite, mesonet, profiler, radar, aircraft, etc., and are combined to satisfied basic geometric constraints through a combination of successive correlation method and variationally applied splines. A dynamical adjustment step that forces the fundamental equations to be satisfied to a desired level of accuracy within the domain is applied to create a balanced representation between the model mass and momentum fields.

3. AIRS DATA

The AIRS instrument provides 2378 channels in the thermal infrared spectrum, ranging from 649.6 to 2665.2 cm^{-1}, with a spatial resolution of 15 km at nadir. While the instrument provides exponentially more data than prior infrared sounders, its coarse spatial resolution can result in cloud-contaminated radiance measurements. Thus, this data, along with collocated measurements from the Advanced Microwave Sounding Unit A (AMSU-A) and the Humidity Sounder for Brazil (HSB, failed Feb. 2003), can be combined to derive cloud-cleared radiances. These derived radiances can then be used to derive temperature and moisture profiles of the atmosphere in both clear and cloudy regions (Susskind, et. al 2003) with a 50 km spatial resolution at nadir.

Vertical profiles from the Level 2 data are available on isobaric levels. Temperature and moisture are retrieved at mandatory levels and 600 mb. Quality assessment flags assigned by the AIRS Science Team and are provided to indicate the validation status and processing history of each vertical sounding. The processing history refers to the final status of a given retrieval, be it a failed, partial, or full retrieval. Further information on retrieval validation and quality assessment is available online from the official AIRS website (http://airs.jpl.nasa.gov).

4. EXPERIMENT DESIGN

4.1 *Case Study*

The period of study occurred on 18 February 2004. The area and feature of interest is the eastern U.S. and the western flank of a large amplitude synoptic trough located just off the eastern seaboard, respectively. The relatively cloud-free condition over the study area (Fig. 1) allows a maximum number of AIRS soundings to be available for ingest into LAPS. The event also presents an opportunity to examine how the AIRS soundings affect the analysis of the strong mid-level baroclinic zone (Fig. 2) between the thermal trough off the East Coast and the thermal ridge over the Mid-West.

4.2 *LAPS Configuration*

The LAPS configuration used in this study consists of 150 by 150 horizontal grid points with 15 km spacing, and covers almost eastern half of the United State (Fig. 2). The LAPS analysis uses 41 vertical levels on constant pressure surface at 25 mb intervals from 1100

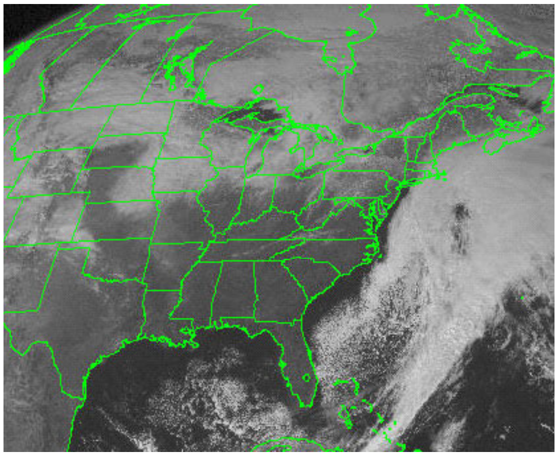

Fig. 1. GOES12 visible image of 1815 UTC 18 February 2004.

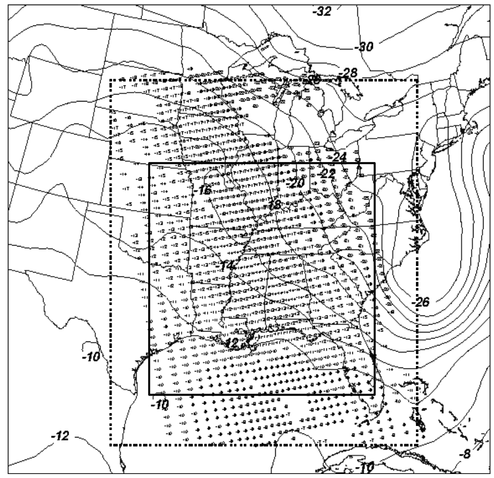

Fig. 2. The 500 mb temperature field at 19 UTC 18 February 2004. Dotted box indicates the LAPS domain and solid box indicates the MM5 domain. The numerical numbers indicate the location of the AIRS profiles.

mb to 100 mb. The AIRS profiles data are emulated as radiosondes for LAPS ingest and configured in the NetCDF format. The Level 2 AIRS data are contained in granules each consisting of 1350 profiles. Two consecutive AIRS granules are required to cover the LAPS domain. To assure the best quality data for ingestion, only those soundings that pass the full retrieval status were used for implementation. Among the 2700 available profiles, a total of 1440 were located within the LAPS domain. A total of 1116 passed quality control and were used for the LAPS temperature analysis. Figure 2 shows the distribution of profiles within the LAPS domain.

LAPS was designed to take advantage of the high density of wind observations available during asynoptic times via ACARS. As a result, the variational balance scheme (McGinley et al. 2001) is configured to weight the wind field more than the geopotential (McGinley, personal communication). In the present application, it is desirable to retain most of the changes due to the AIRS temperature ingestion by applying more weight on the temperature field than on the wind field in the balance scheme. Therefore, the temperature weighting factor was increased by a factor of g^2 (g is the gravitational acceleration) and the wind weighting decreased by the same factor.

4.3 *Model Configuration*

The forecast model used to study the impact of AIRS profiles on short-range local forecast is the fifth-generation Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Model Version 5 (MM5, Dudhia 1993). It is a limited-area, nonhydrostatic primitive equation model with multiple options of physical prarmeterization schemes. The model has 27 staggered terrain-following sigma levels with the top-level pressure at 100 mb and with finest resolution near the boundary layer. Table 1 summarizes the physical options used for this study. The model is initialized at 19 UTC 18 February 2004 and is executed for 24 hours.

Table 1. MM5 physical options

Convection scheme	Kain-Fritsch
Microphysics	Schultz
PBL scheme	MRF
Radiation	RRTM
Soil scheme	Multi-layer soil model

4.4 *Numerical Experiments*

Two forecast experiments are conducted. A control (CTRL) run initialized with the stand-alone LAPS analysis. A second run (AIRS) is identical to CTRL in every aspect except that AIRS data is used in the LAPS initialization process. The National Centers for Environmental Prediction (NCEP) Rapid Update Cycle (RUC2) 40 km analyses (Benjamin et al. 2002) provide the first guess for LAPS and are used to generate the lateral boundary conditions for MM5.

5. PRELIMINARY RESULTS

5.1 *Impact of AIRS on Initial Analysis*

The impact of the AIRS profiles on the temperature analysis is examined at 700 and 400 mb. Figure 3a shows the relatively strong and large-scale east-west temperature gradient at 700 mb. The difference field (AIRS minus CTRL) in Figure 3b shows the impact of the AIRS data on the analysis. A general area of cooling in excess of 3.0 °C and 4.5 °C is found in northern Alabama-Mississippi and in southern Ohio, respectively. This cooling strengthens (weakens) the thermal gradient southwest (northeast) of the cooling

(a) (b)

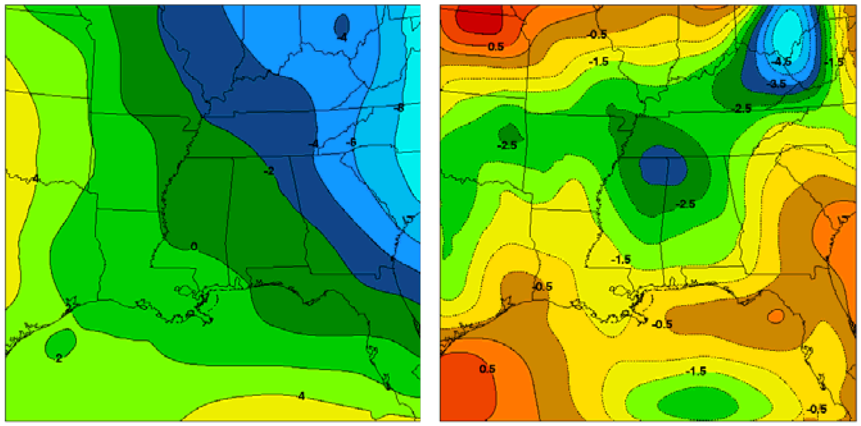

Fig. 3. (a) Temperature (ºC) of CTRL and (b) temperature difference of AIRS and CTRL at 700 mb.

centers. At 400 mb the thermal gradient is oriented more northeast to southwest as shown in Figure 4a. Introduction of the AIRS data into the LAPS analysis has a less pronounced impact on the temperature field than observed at 700 mb. Differences between the AIRS and CTRL analyses are typically on order of 0.5 °C across the domain.

5.2 *Simulation Verification Statistics*

Fig. 5 shows the temperature bias of the 5 h and 17 h forecasts valid at 00 and 12 UTC 19 February, respectively. The validation is based on 10 radiosonde profiles located within the model domain. In general, the MM5 produces a better temperature forecast in the lower atmosphere with or without AIRS data. Verification statistics at 5 h indicates mixed results. The AIRS data is found to improve the forecast in the upper troposphere at 300 and 250 mb but degrades it at lower atmosphere, most notably at 700 mb. The impact of AIRS data on the 17 h forecast is not as large (Fig. 5b) as indicated by the similar bias for CTRL and AIRS.

Examination of the dew point bias (Fig. 6) shows the MM5 produces a better overall forecast in the upper atmosphere where the bias is generally less than 0.5 °C. The bias becomes quite large and moist at 500 mb and below and is a maximum of 6.2 °C at 500 mb. Again, the moisture bias shows mixed results on the impact of the AIRS moisture data on the 5 h forecast. The 17 h forecast exhibits a similar bias for AIRS and CTRL forecasts.

The small difference between AIRS and CTRL at 17 h is not surprising given the experimental design. It is most likely associated with the decreasing influence of the AIRS analysis with time and increasing influence of lateral boundary conditions over the model domain.

(a) (b)

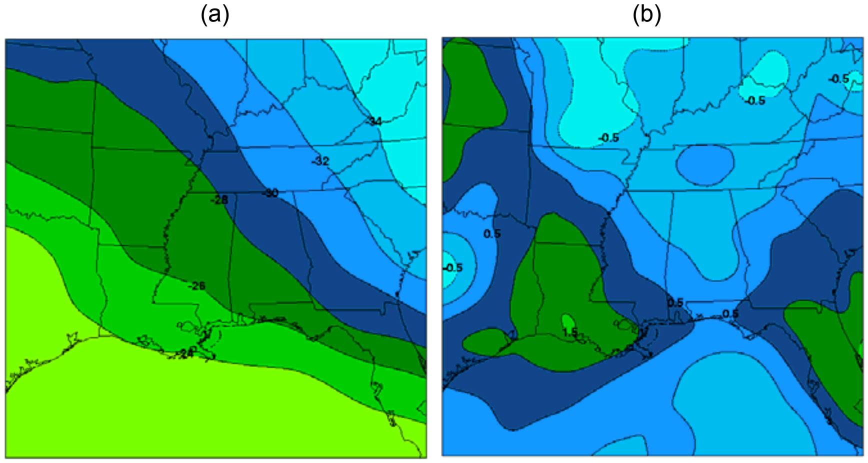

Fig. 4. Same as Fig. 3, except for 400 mb.

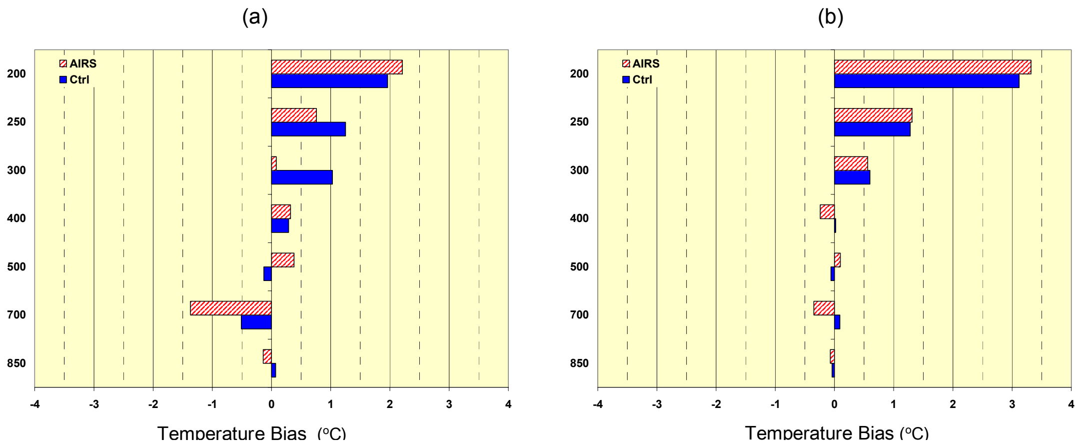

Fig. 5. Temperature bias at (a) 5 h and (b) 17 h forecast.

This is to be expected given the high data density over the model grid at the time of the analysis. The ideal experimental set up would be to expand the size of the MM5 domain to include the western Atlantic and examine the impact of AIRS downstream of the highest data density. While this could have been easily accomplished, no significant verification data exists over the Ocean. Our intent here is to examine the impact of AIRS at short time scales (0-12 h)

The fact that the cold bias of the AIRS temperature forecast at 700 mb coincides with the general cooling in the analysis due to the AIRS data (Fig. 3b) suggests that the model performs as expected (and, in a lesser degree, the 400 mb forecast). In order to fully utilize the potential of AIRS data in regional numerical forecasts, better quality AIRS profiles are needed. This requires better calibration, validation, and retrieval algorithm of the Level 2 AIRS products. The AIRS Level 2 products have a spatial resolution of 45 km that is three times larger than the 15 km LAPS grid employed. Future work will emphasize use of the AIRS profiles at higher (~15 km) resolution.

6. CONCLUSIONS

A procedure has been developed to incorporate the AIRS temperature and moisture data into the LAPS package. The impact of the AIRS data assimilation on regional short-term forecast is conducted using two different initial LAPS analyses: One with and without AIRS profiles of temperature and moisture.

Preliminary numerical experiments show the AIRS data have the potential to improve the short-term forecasts. Several suggestions of improving model performance are identified: improving the quality of AIRS products and increasing the spatial resolution of the data.

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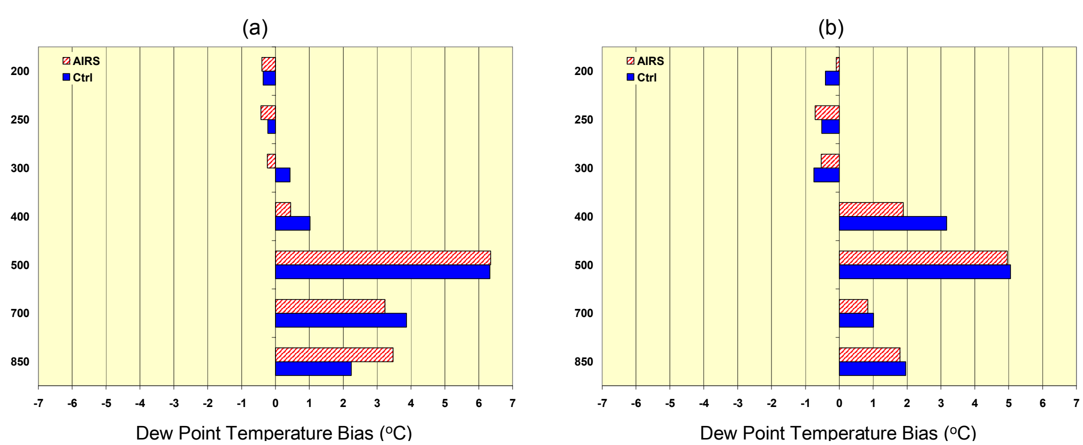

Fig. 6. Dew point temperature bias at (a) 5 h and (b) 17 h forecast.

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