P2A.11 IMPROVING REGIONAL FORECAST BY ASSIMILATING ATMOSPHERIC INFRARED SOUNDER (AIRS) PROFILES INTO WRF MODEL

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1. MOTIVATION

- **To improve weather forecasts using AIRS temperature and moisture profiles**

2. USE OF AIRS PROFILES

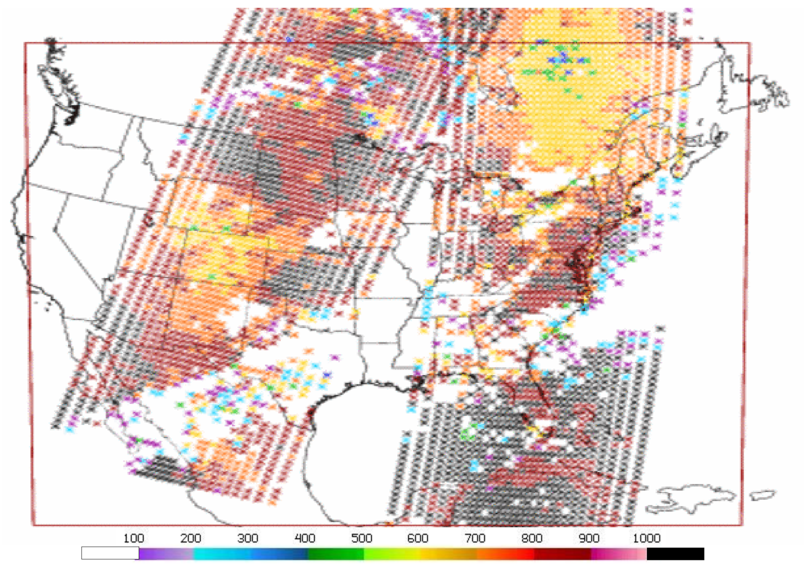

Fig. 1. Three-dimensional distribution of AIRS profile data assimilated at 0800 UTC on 17 January 2007. The red rectangle denotes the bounds of the WRF domain.

- **Version 5 L2 *temperature* and *moisture* profiles over *land* and *water***
- **Level-dependent quality indicators (QIs) determine maximum pressure level above which quality data should be assimilated (colored points in Fig. 1)**
- **Separate observation errors are used for the land and water soundings**
  - **Land: from Tobin et al. (2006)**
  - **Water: from AIRS instrument specs**

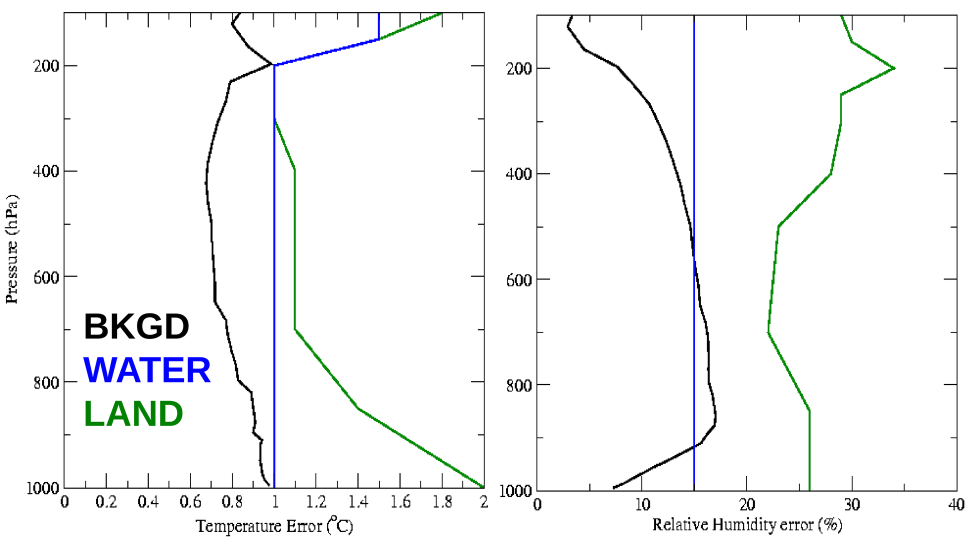

Fig. 2. Background (black line) and observation (blue: AIRS water, green: AIRS land) errors for WRF-Var analysis. It is the ratio of the background vs. observation errors that controls the magnitude of the analysis increment during the assimilation process.

3. ANALYSIS/FORECAST MODEL

- **12-km resolution, 450 x 360 horizontal grid; 37 vertical levels topped at 50 hPa**
- **ARW initialized at 0000 UTC each day using 40-km NAM**
- **6-8h ARW forecast used as first-guess for WRF-Var; AIRS profiles assimilated at observation time**
- ***B* matrix generated using NMC Method using control WRF forecasts**

4. ANALYSIS IMPACT

- **AIRS profiles cooler than background over FL and Great Lakes; Warmer over SE US (Fig. 3a); they are generally moister except in the region from the Florida panhandle to coastal South Carolina (Fig. 3b).**
- **Analysis increments show similar T and q patterns compared to innovations.**
- **Temperature and moisture soundings of AIRS-enhanced analysis lie between those of background and AIRS profiles below 300 hPa (Fig. 4)**
- **AIRS profile closer to RAOB than background**
- **Addition of AIRS produces analysis more comparable to radiosondes than background at mid- and lower troposphere**

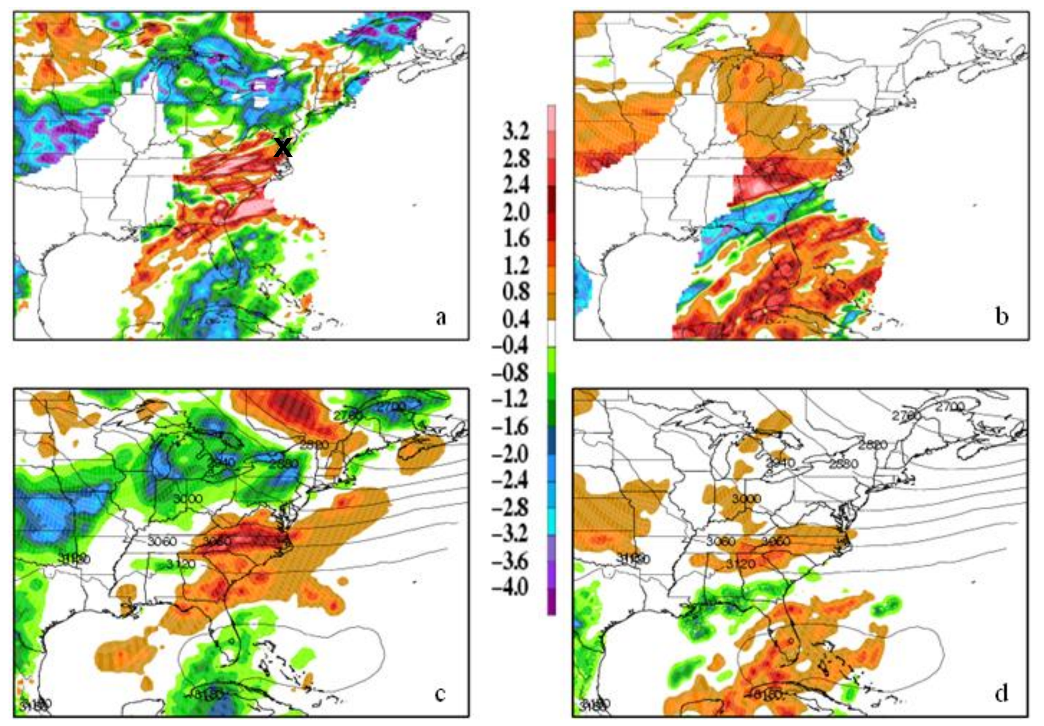

Fig. 3. Analysis impact of AIRS at 700 hPa for 0800 UTC 17 January 2007. The top row shows innovation fields (AIRS minus background) for a) temperature (°C) and b) mixing ratio (g/kg). The corresponding analysis increments (analysis minus background) are shown in c) and d). The "x" in a) denotes the location of the Wallops Island, VA (WAL) sounding station.

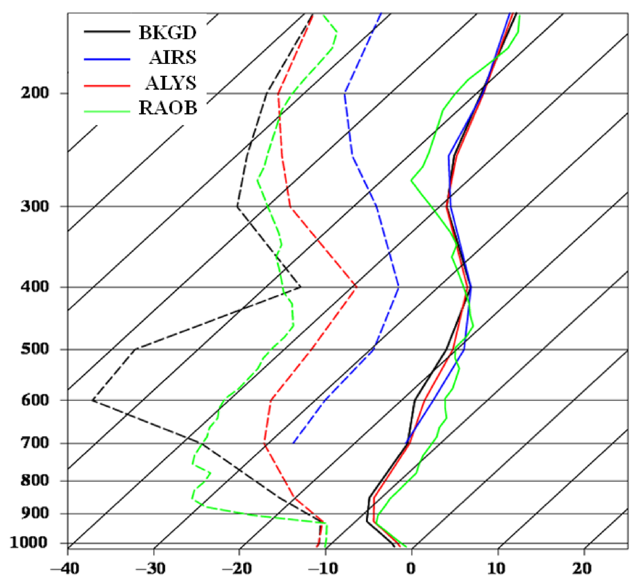

Fig. 4. Profiles of temperature (solid) and dew point (dashed) near Wallops Island, VA (WAL for 0800 UTC 17 January 2007. The background (black) and WRF-Var (red) profiles are for the nearest grid point. The AIRS profile (blue) is for the highest-quality retrieval closest to the grid point. The radiosonde (green) is a linear interpolation of the 0000 and 1200 UTC soundings to 0800 UTC.

5. FORECAST IMPACT: 37-DAY CASE STUDY 17 JANUARY TO 22 FEBRUARY 2007

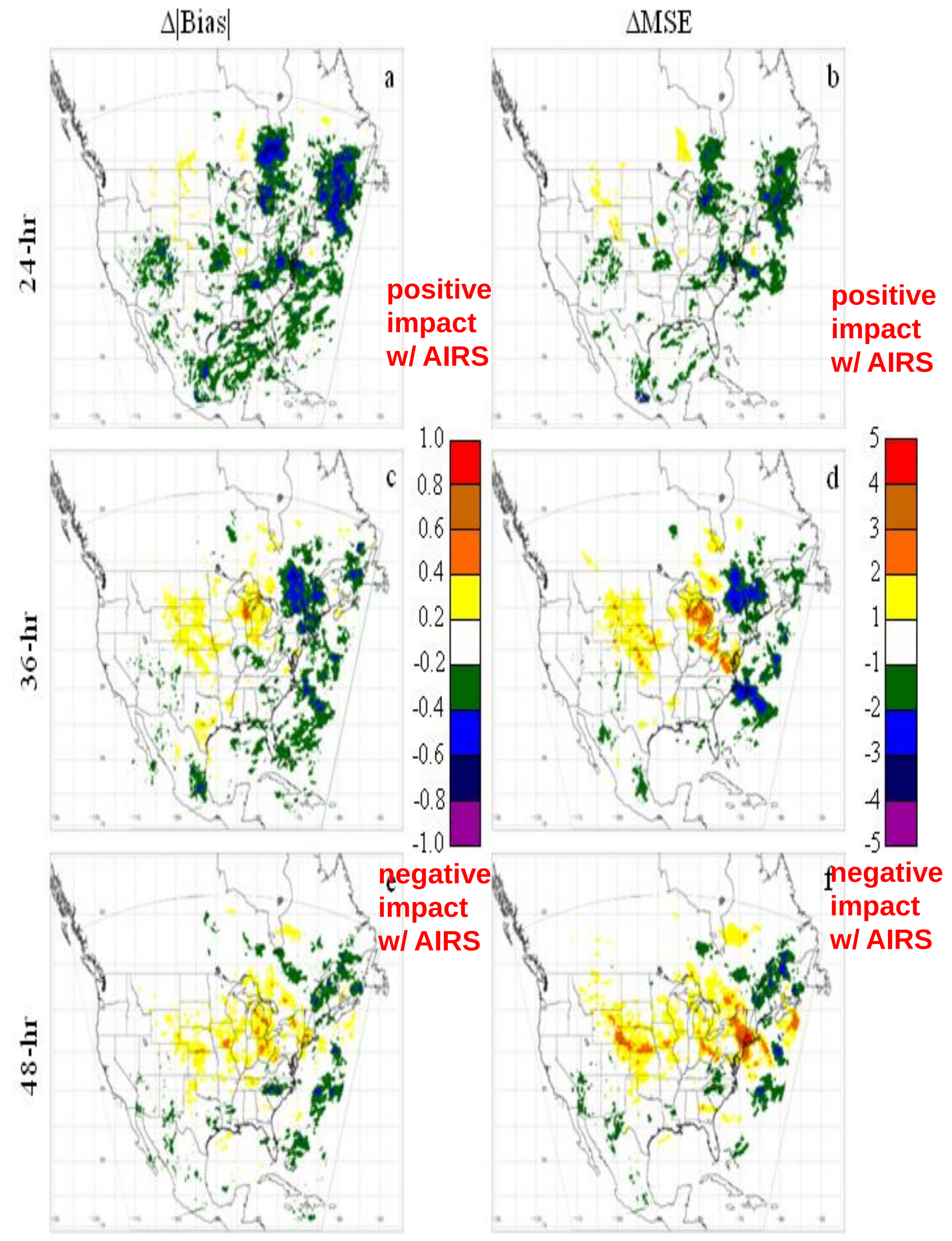

Fig. 5. 700 hPa temperature absolute bias difference (°C; left column) and mean squared error differences (°C²; right column) between AIRS and CNTL forecasts compared to corresponding NAM analyses for entire case study period for a) and b) 24-hr forecasts, c) and d) 36-hr forecasts, and e) and f) 48-hr forecasts.

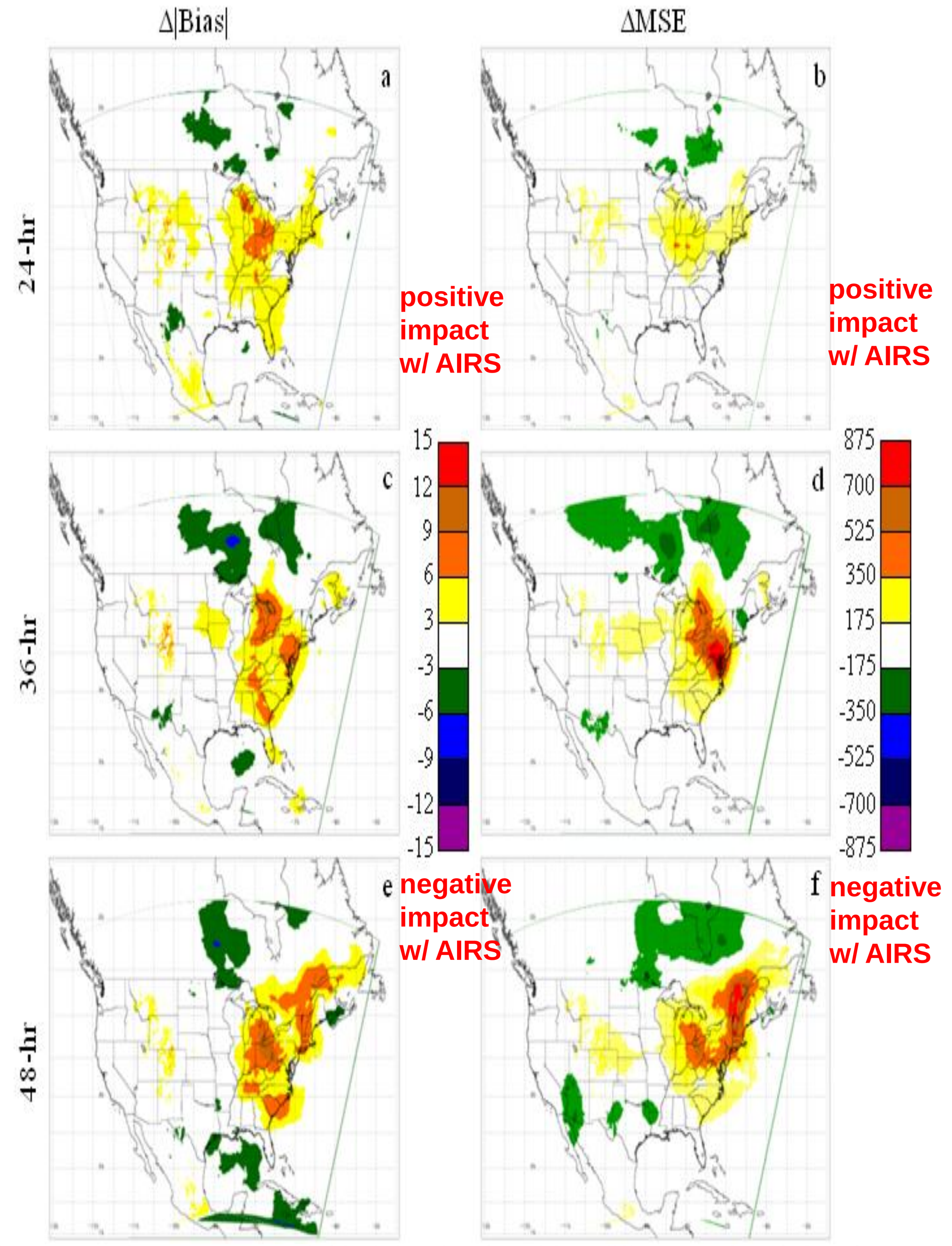

Fig. 6. 500 hPa geopotential height absolute bias difference (°C; left column0 and mean squared error differences (°C²; right column) between AIRS and CNTL forecasts compared to corresponding NAM analyses for entire case study period for a) and b) 24-hr, c) and d) 36-hr, and e) and f) 48-hr forecasts

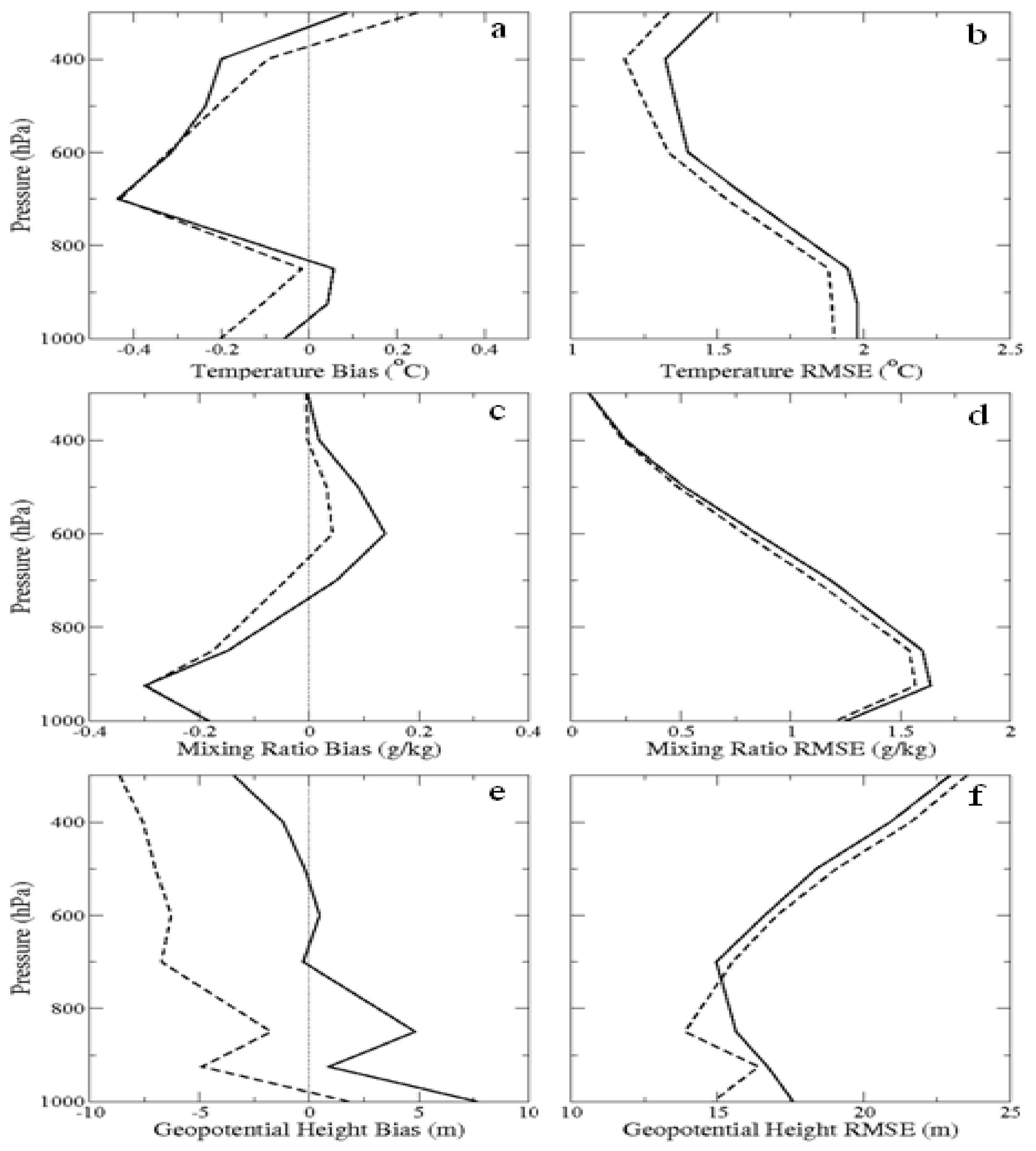

Fig. 7. Evaluation statistics of all forecasts compared to corresponding NAM analyses for all grid points east of 105°W. Bias (forecast minus analyses) for a) temperature (°C), c) mixing ratio (g/kg), and e) geopotential height (m) as well as root mean square error (RMSE) for b) temperature (°C) and d) Mixing ratio (k/kg), and f) geopotential height (m) for 37 days between 17 January and 22 February 2007 are shown. Dashed lines represent the CNTL cases; solid lines represent the AIRS cases.

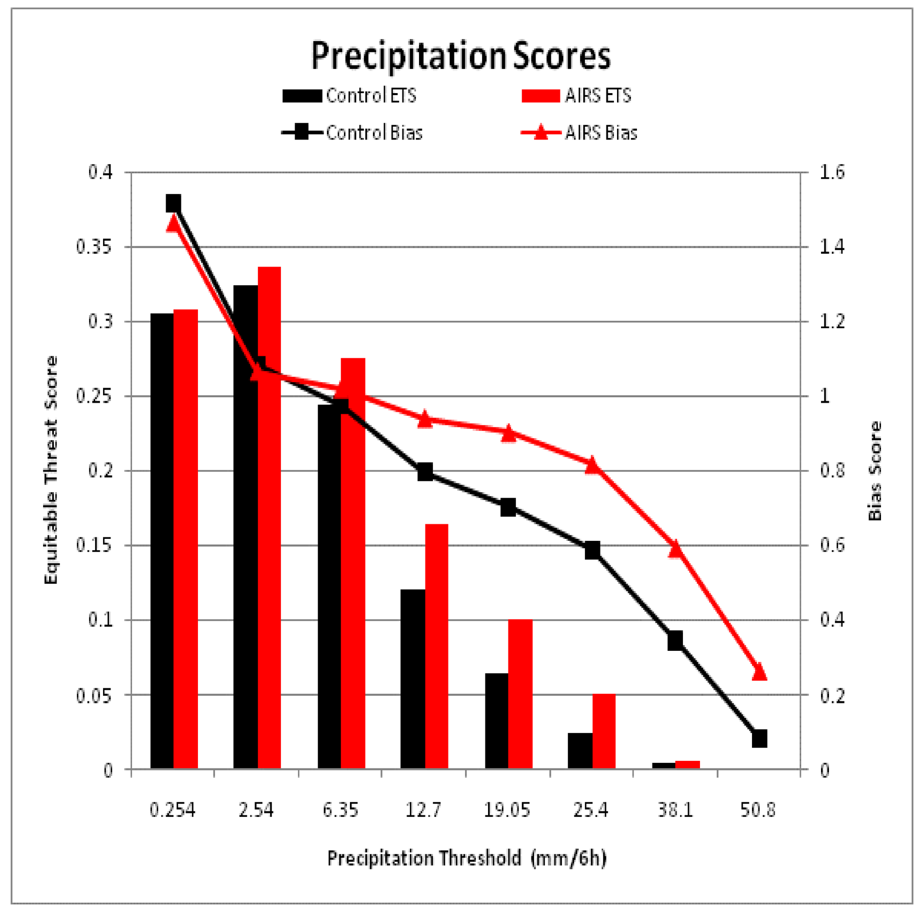

Fig. 8. Equitable Threat Score (ETS; bars, left axis) and Bias Score (lines, right axis) for 6-h cumulative precipitation for all forecasts during case study period

Temperature Results:

- **CNTL too cool in lower troposphere and too warm in upper troposphere**
- **AIRS warms lower levels and cools upper levels reducing bias (Fig. 7a)**
- **RMSE is slightly degraded over entire profile (Fig. 7b)**
- **Temperature forecasts are degraded over large part of domain at early forecast hours**
- **Later forecast hours, though, show broad area of improved forecasts across the Great Lakes (Fig. 5)**

Mixing Ratio Results:

- **CNTL too dry below 700 hPa but within 0.1 g/kg of the NAM analyses in the mid- and upper troposphere (Fig. 7c)**
- **AIRS tends to moisten the whole atmosphere and improves the 900 and 700 hPa levels**
- **RMSE is slightly degraded with AIRS (Fig. 7d)**

Geopotential Height Results:

- **CNTL heights too low in the mid- and upper-troposphere but close to zero bias near surface**
- **AIRS raises heights at all levels degrading bias near surface but improving aloft (Fig. 7e)**
- **RMSE improved aloft but degraded near surface (Fig 7f)**
- **Overall, height forecasts show broad area of improved forecasts across the Great Lakes at all forecast times with larger area coverage and magnitude of improvement at later forecast times (Fig. 6)**

6-h Cumulative Precipitation Bias Score Results (Fig. 8):

- **Bias score > 1 means over forecasting; bias score < 1 means under forecasting**
- **ETS takes into account forecast hits and misses and give some degree of certainty above random results**
- **Inclusion of AIRS improves ETS and bias scores at all precipitation thresholds**

6. CONCLUSIONS/FUTURE WORK

- **Prudent assimilation of AIRS thermodynamic profiles and quality indicators can improve initial conditions for regional weather models**
- **In general, AIRS-enhanced analysis more closely resembles radiosondes; forecasts with AIRS profiles are generally closer to NAM analyses than CNTL for sensible weather parameters**
- **Assimilation of AIRS cloud-cleared radiances in WRF-Var**
- **Comparison of AIRS profiles and AIRS radiances using GSI**