Regional Data Assimilation of AIRS Profiles and Radiances at the SPoRT Center

Brad Zavodsky (UAH/MSFC), Will McCarty (UAH/MSFC), Shih-hung Chou (MSFC), Gary Jedlovec (MSFC)

AIRS Science Team Meeting

Greenbelt, MD

October 15, 2008

Regional Data Assimilation of AIRS Profiles at the SPoRT Center

Brad Zavodsky (UAH/MSFC), Shih-hung Chou (MSFC), Gary Jedlovec (MSFC)

AIRS Science Team Meeting

Greenbelt, MD

October 15, 2008

NASA's Short Term Prediction Research and Transition (SPoRT) Center

Mission: Apply NASA measurement systems and unique Earth science research to improve the accuracy of short-term (0-24 hr) weather prediction at the regional and local scale (http://weather.msfc.nasa.gov/sport/)

- Test-bed for rapid prototyping of new products
- Development of new products is end-user driven
- Transition research capabilities/products to operations
  - real-time MODIS and GOES data and products to NWS weather forecast offices and private companies (e.g. Worldwinds,Inc., The Weather Channel)
- Development of new products and capabilities for transition
  - MODIS SST composites, AMSR-E rain rates, ocean color products
- AIRS Data Uses/Plans
  - Regional assimilation of L2 temperature and moisture profiles into regional model (Chou, Zavodsky)
  - Regional assimilation of L1B radiances into regional model (McCarty)
  - L2 temperature and moisture profile product
- All work with AIRS has application to future hyperspectral sounders

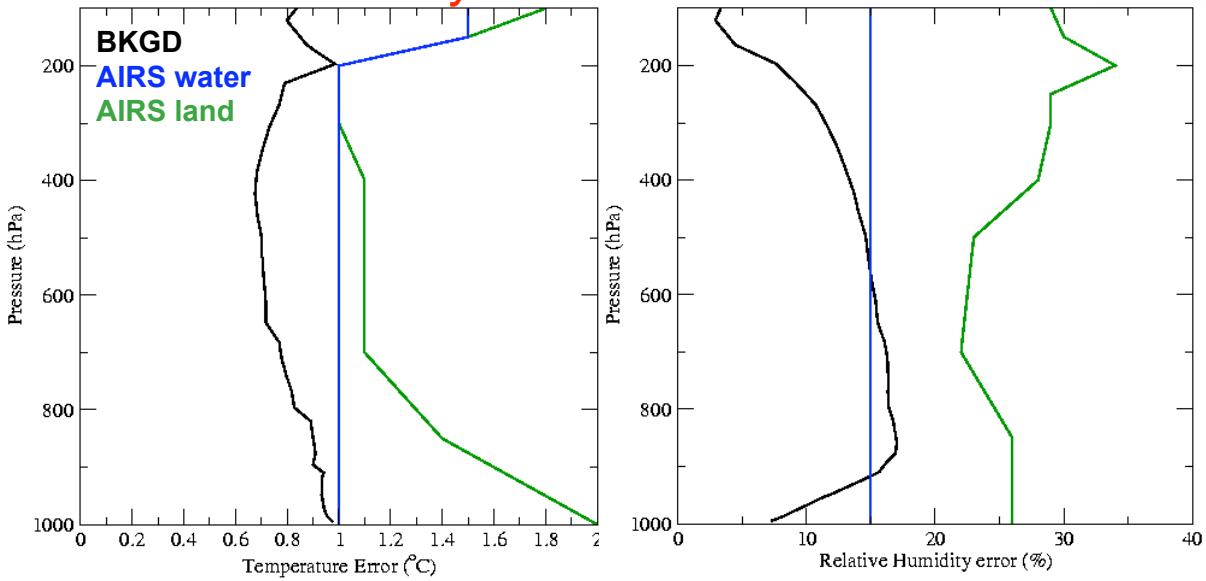
Transition from ADAS to WRF-Var

- Previously used ADAS to assimilate AIRS profiles
- Inconsistencies in first forecast hours initialized with ADAS analysis pointed to physical model/analysis imbalances
- Developed and tuned WRF-Var system to assimilate AIRS L2 temperature and moisture profiles for more realistic-looking analyses and forecasts
  - generated background error covariance matrix using control WRF forecasts and internal "gen_be" software (NMC method)
  - altered source code to add AIRS profile data sets as separate land and water sounding data types with separate error characteristics
- The knowledge gained through these experiments can be applied to other hyperspectral sounder data (e.g. IASI, CrIS, etc.)
- Have examined over a month of analyses and forecasts
- What follows is a discussion of the methodology for assimilating AIRS profiles along with analysis and forecast results using an example case study day (19 January 2007)

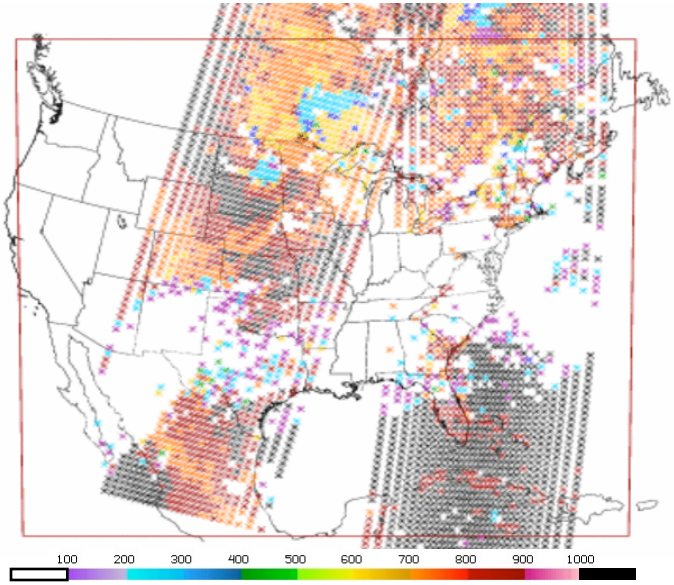
WRF-Var Setup

- L2 Version 5 temperature and moisture profiles
- standard product
  - problematic vertical correlations in support product
- land and water soundings w/ separate errors
  - instrument specs over water; Tobin et al. (2004) errors over land
- Quality control using P_{best} value in each profile

Analysis Error Characteristics

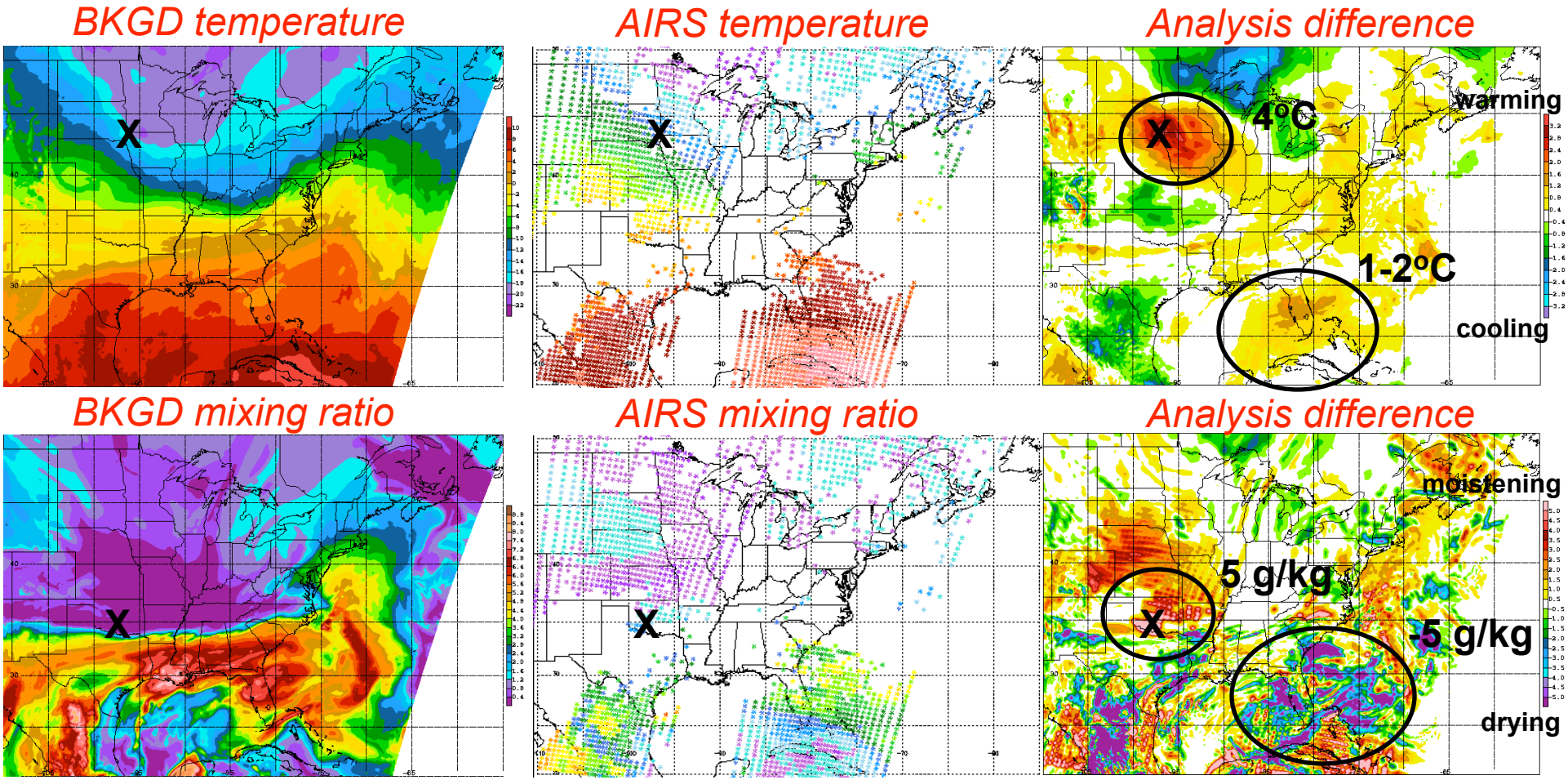


AIRS QI's for 19 Jan 2007



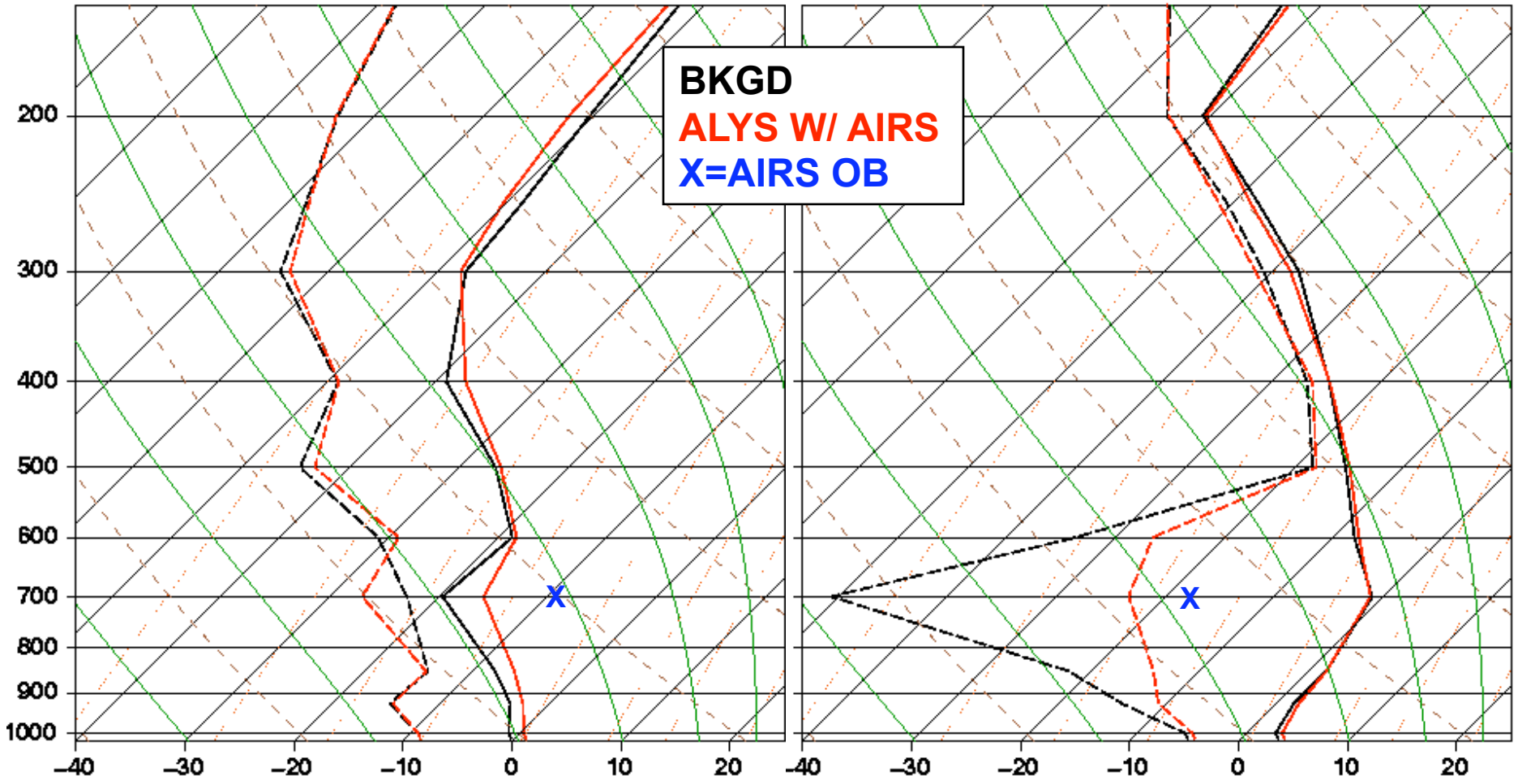
- WRF initialized with 40-km NAM at 0000 UTC
- 12-km analysis and model grid
- short WRF forecast used as background for analysis

Analysis Impact: 700 hPa



- Initial sanity check on 2-D plane shows that analysis moves towards AIRS observations for T and q

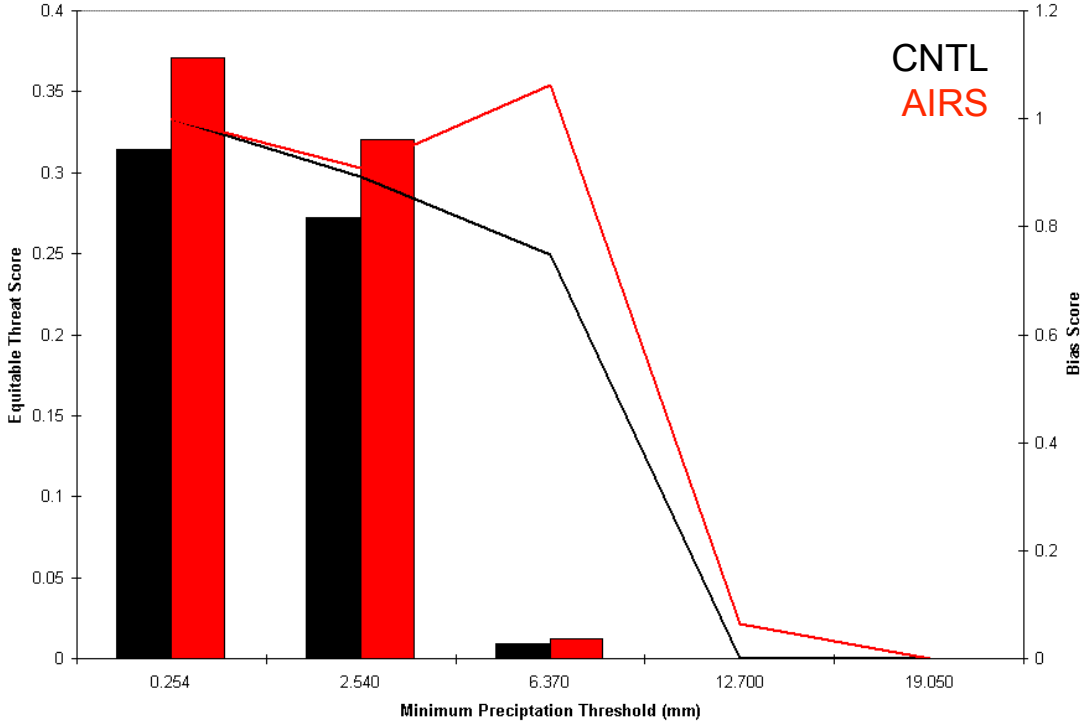
Analysis Impact: Soundings

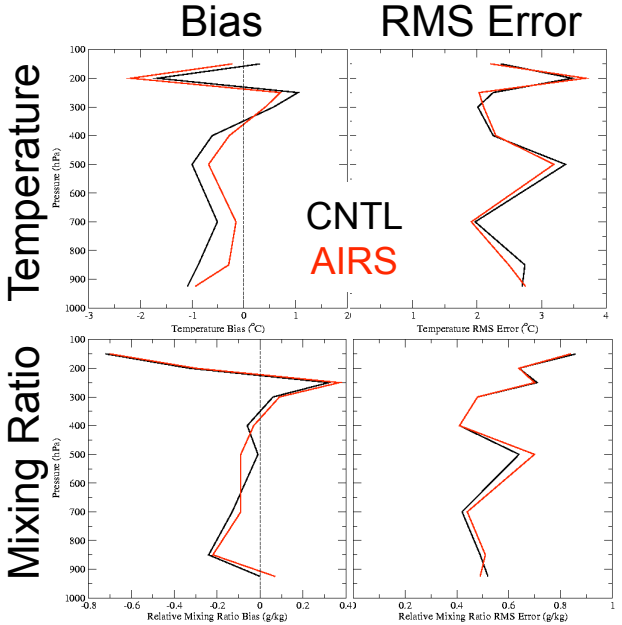


- Second sanity check shows that analysis moves towards AIRS observations for T and T_d

Forecast Impact: 48 Hour Forecast

- AIRS reduces temperature bias at most levels by 0.5-1.0°C in troposphere; small reduction in RMS error
- Smaller improvement in moisture below 700 hPa; increase in RMS error
- Consistent with overall tendency at other forecast hours





- 6-hr cumulative precipitation improves with AIRS profiles
  - Larger ETS (bars) indicates improvement in predicted precipitation location and amount
  - Bias scores (lines) closer to 1.0 suggest improvement in coverage of precipitation features

AIRS Profile Assimilation Summary

- SPoRT now running WRF-Var for AIRS profile assimilation studies
  - generated background error covariance matrix
  - added separate land and water observation data sets to source code with separate error characteristics
  - standard profiles to avoid vertically correlated soundings
  - quality indicators used to selected only the highest quality data from each sounding
- Analyses show impact from AIRS of up to 4°C and 5 g/kg in the direction of the AIRS observations
- Results show improvement in 48-hour forecast of temperature, moisture, and precipitation
- The knowledge gained through these experiments can be applied to other hyperspectral sounder data (e.g. IASI, CrIS, etc.)
- Future work:
  - prepare and submit manuscript
  - AIRS error estimates to populate off-diagonal terms in observation error matrix
  - AIRS averaging kernels to decorrelate soundings in the vertical for maximum observation impact

AIRS Radiance Assimilation at the SPoRT Center:

Lessons Learned

Will McCarty

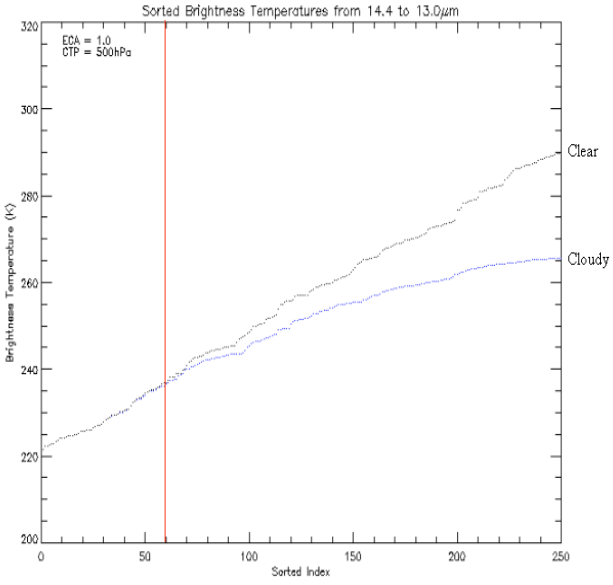
AIRS Science Team Meeting

Greenbelt, MD October 2008

WHY

Weather forecasting is an initial value problem – the better you represent the atmosphere / surface in the initial conditions, the better the forecast.

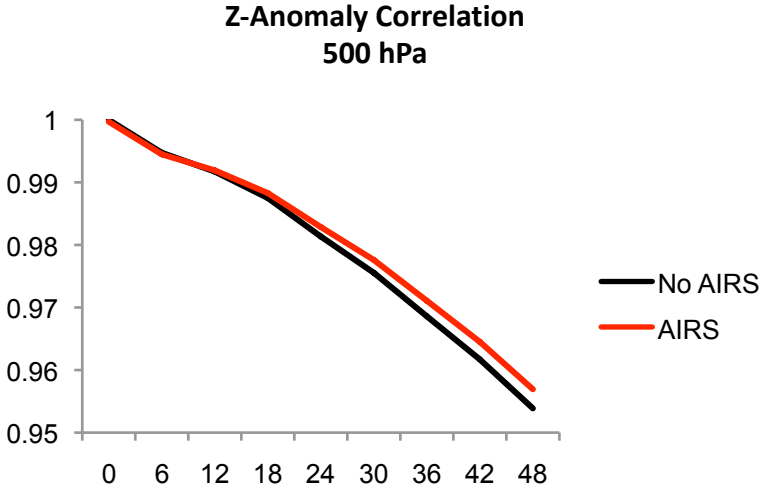
- The methodologies to incorporate AIRS measurements into a data assimilation system are ***inherently different*** within a regional modeling system, as compared to a global system
- Horizontal grid spacing, vertical model extent, and absorbing constituents as model variables result in ***more IFOVs*** (locally, less globally), but ***less channels***, being applicable for assimilation
- The work also incorporated a new approach, the ***CO_2 sorting*** approach, to determining cloud contamination within an IFOV
- The technique showed promise when utilizing the full AIRS spectrum, but the performance degraded when limited to the 281 channel subset

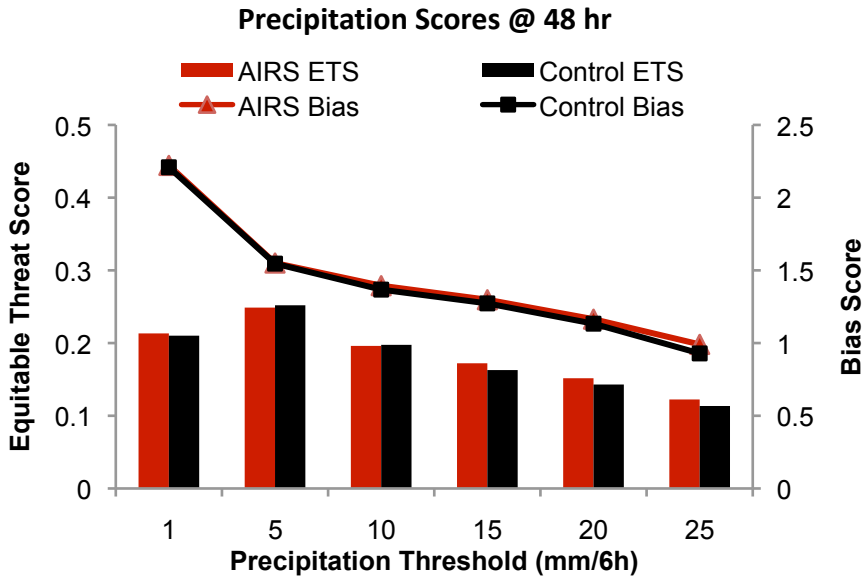


Assimilation of AIRS Radiances into the North American Mesoscale Model (NAM)

RESULT / IMPACT

- 48 h NAM forecasts run 4x/day for a week
- The data assimilation system employed is the Gridpoint Statistical Interpolation (GSI) system, which acts as the operational system for NOAA/ NCEP's NAM and Global Forecast System, NOAA/ ESRL's Rapid Refresh system, and NASA/GSFC/ GMAO's GEOS-5
- Transition technologies for inclusion in operational forecast model
  - *improved weather forecasts to the public*
- Results from the addition of AIRS measurements result in a ***forecast improvement of 2.4 hours*** at 48h at 500 hPa (middle troposphere)
- Largest precipitation score improvements, both in BIAS and ETS, are seen in ***high impact events*** over the study period.





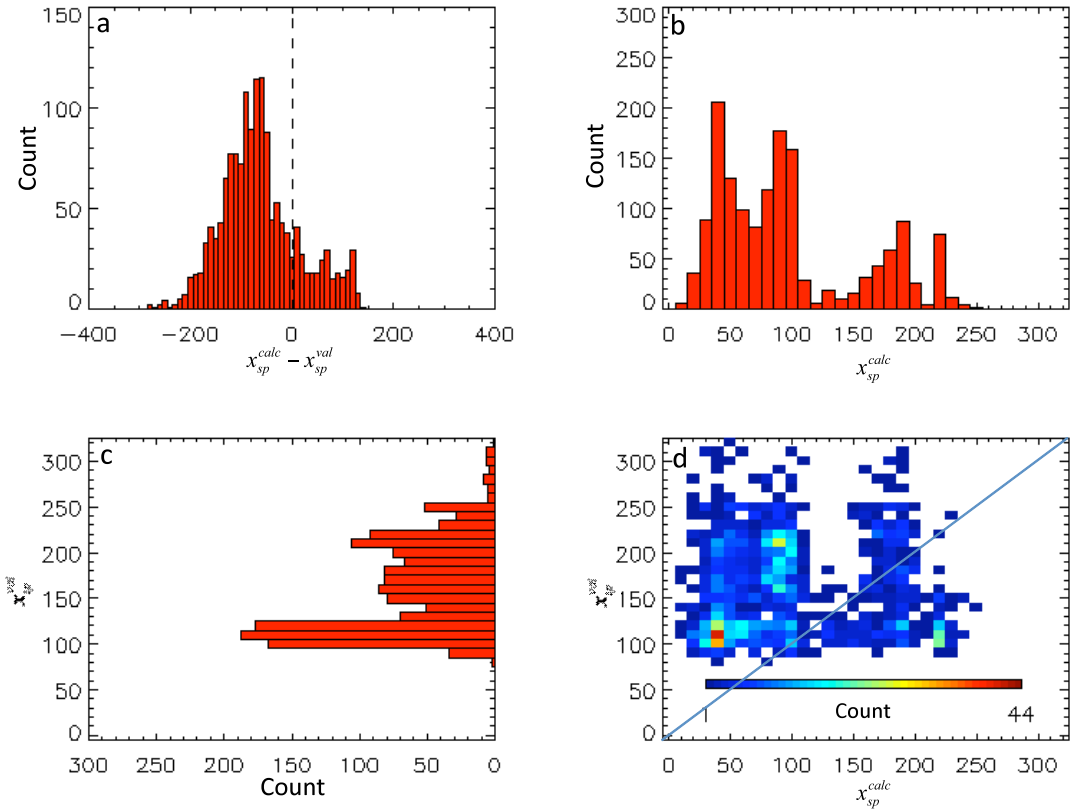
Direct Validation of Sorting Technique

Validation Dataset

- Manually created for a variety of environments
- Separation Point, a nonphysical quantity, is difficult to validate directly from MODIS or CloudSat

Distributions

- Calculated SP biased towards high clouds, but shows some skill for low clouds
- Validation data shows notable peak for low SP (high clouds)



Differences and bivariate distribution show technique tends to be conservative, with reduced skill with lower clouds

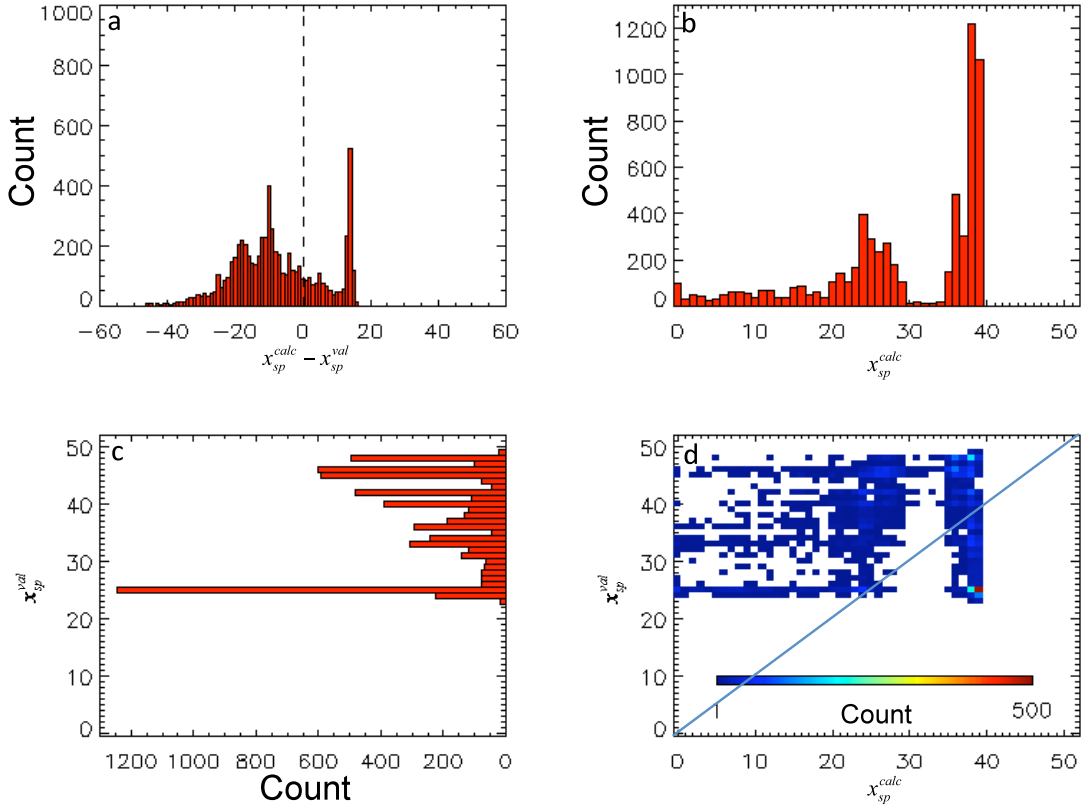
Sorting Technique with 281 Subset

Operational Subset

- The technique was adapted to the 281 channel subset
- Two tests of Separation were inapplicable
- Generally conservative tests inapplicable
- Validation Dataset same, but spectrally reduced

Distributions

- Calculated SP biased shows degradation and more aggressive performance
- High cloud peak in validation not retained



Lessons Learned

UAH

The use of AIRS measurements within a data assimilation system showed improvement in short-term (0-48h) weather forecasts

- The use of AIRS in a pseudo-operational assimilation system had, overall, a positive impact on the short-term weather forecasts
- There were signs in my work that cloud detection in challenging, particularly polar, regions is still potentially problematic
- The sorting technique showed skill in determining cloud contamination, but the technique's performance was degraded by the operational constraint
  - The technique does not, though, require anything more than forward radiative transfer calculations (no tangent linear or adjoint calculations are necessary)
- Work performed with AIRS is essential to the accelerated integration of IASI and CrIS into the operational systems.