Bias Correction for Assimilation of Retrieved AIRS Profiles of Temperature and Humidity

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Abstract

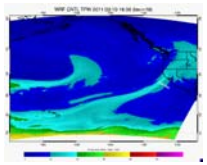
The Atmospheric Infrared Sounder (AIRS) is a hyperspectral radiometer aboard NASA's Aqua satellite designed to measure atmospheric profiles of temperature and humidity. AIRS retrievals are assimilated into the Weather Research and Forecasting (WRF) model over the North Pacific for some cases involving "atmospheric rivers". These events bring a large flux of water vapor to the west coast of North America and often lead to extreme precipitation in the coastal mountain ranges. An advantage of assimilating retrievals rather than radiances is that information in partly cloudy fields of view can be used.

Two different Level 2 AIRS retrieval products are compared: the Version 6 AIRS Science Team standard retrievals and a neural net retrieval from MIT. Before assimilation, a bias correction is applied to adjust each layer of retrieved temperature and humidity so the layer mean values agree with a short-term model climatology. WRF runs assimilating each of the products are compared against each other and against a control run with no assimilation. Forecasts are against ERA reanalyses.

REWRITE?

Atmospheric Rivers

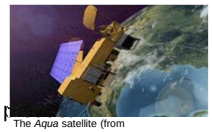
Atmospheric rivers are transient, narrow regions in the atmosphere responsible for the transport of large amounts of water vapor. These phenomena can have a large impact on precipitation. In particular, they are often responsible for intense rain events on the west coast of North America during the winter season



The Atmospheric Infrared Sounder (AIRS)

The Atmospheric Infrared Sounder (AIRS: Aumann et al., 2003) is a radiometer aboard NASA's polar-orbiting *Aqua* satellite. It measures infrared radiation in 2378 frequency bands ranging from 3.7 to 15.4 microns. AIRS has a cross-track scanning geometry, observing 90 fields of view per scan, with a resolution of 13.5 km at nadir and a swath width of about 1600 km. The observed top-of-atmosphere radiation is dependent on atmospheric temperature and the concentration of water vapor and other constituents of the atmosphere. Through an inversion process, profiles of temperature and water vapor are retrieved from AIRS radiometric observations. Since clouds are opaque to infrared radiation, profiles cannot be retrieved inside or below clouds, but useful retrievals can be obtained above clouds (as well as information on cloud top properties). Coupled with a microwave radiometer (AMSU), AIRS is also able to retrieve profiles in partly cloudy regions.

Description of MIT p



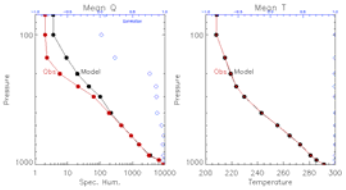
The *Aqua* satellite (from airs.jpl.nasa.gov).

Background and Motivation

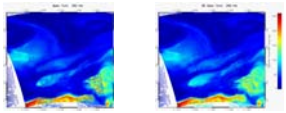
- Operational GSI assimilates AIRS radiances but excludes cloudy areas. AIRS profiles (JPL) are produced which have useful information above the cloud tops. This is an effort to best utilize those profiles to get more data in and around cloudy regions.
- Previous results (Blankenship et al. 2013) showed that assimilation of AIRS retrieved profiles of temperature and moisture can resolve the atmospheric river as a narrower feature, but there was an overall systematic drying trend in the analyses using AIRS.
- It was difficult to validate the impact of AIRS profile assimilation due to biases between the profiles and model humidity at upper levels.
- Also, validation against a CIRA Total Precipitable Water product was complicated by biases between the model and the TPW product.
- Operational NWP centers routinely use bias correction of satellite radiances do ensure that satellite observations do not, on average, change the model climatology of temperature and moisture. . Data assimilation algorithms are generally designed for use with unbiased observations (Dee 2005).

Description of Bias Correction

- These plots show the mean profiles of temperature and moisture by layer for our WRF model run and for the AIRS profiles. Also plotted in blue (upper scale) are the correlations.
- Temperature bias is low at all layers
- Humidity bias is low at low levels.
- For upper levels (150 mb and higher), there is very low correlation between model and observations, suggesting poor retrieval skill or model skill, or both. Do not assimilate data at these levels.
- For intermediate levels (250 mb to 400 mb), there is a significant bias but high correlation between model and observations, suggesting that bias correction has a large potential benefit for those layers.



- For this first test, we simply derive a regression relationship for each level between model and observations for all collocated points in the current run.
- Apply this relationship to produce "corrected" observations.
- This ensures the DA step does not bias the model background up or down, but preserves the spatial information in the AIRS retrievals.
- The following figures illustrate the effect of the correction on the assimilated observations. The background field is the same in both cases, showing the model specific humidity at 250 mb. The small crosses indicate the locations of the AIRS profiles and are colored according to their 250 mb humidity. The left panel has the raw observations and the right panel has the bias corrected observations, which agree more closely with the range of nearby values in the model field.



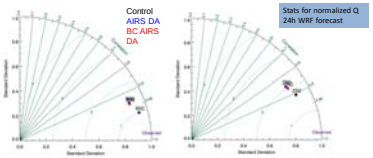
Experiment

- Atmospheric River on XX date
- WRF domain in eastern North Pacific and western North America at XX resolution
- WRF 48-hr forecast initialized on XX
- Initial and boundary conditions come from GFS, which incorporates assimilation of various observation types including AIRS radiances (but not in cloudy areas)
- Data assimilation using Gridpoint Statistical Interpolation (GSI)
- Model runs:
  - No GSI (control)
  - AIRS V6 profile assimilation
  - Bias-corrected AIRS V6 profile assimilation

Results--Maps

Description of Experiment
WRF setup
Bias Correction
Data Assimilation

Results—Stats
Taylor Diagrams and Tables



Discussion of Results

Ongoing Work

- Test robustness of correction from day to day and season to season, investigate proper timescale to update correction.
- Do a cycling model run for a period of weeks to the impact of continued assimilation.
- Further validation, including against rainfall analyses on the west coast.
- Perhaps validation of forecast cloud cover vs. satellite observations.

References

Aumann, H.H. et al., 2003: AIRS/AMSU/HSB on the Aqua mission: Design, science objectives, data prodcucts, and processing systems. IEEE Trans. Geoscience and Rem. Sens., 41, 2: 253-264.
Dee DP. 2005. Bias and data assimilation. Q. J. R. Meteorol. Soc. 131: 3323–3343
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