Impact of AIRS Thermodynamic Profiles on Precipitation Forecasts for Atmospheric River Cases Affecting the Western United States

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Atmospheric Rivers

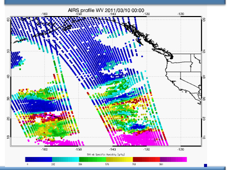
Atmospheric rivers are transient, narrow regions in the atmosphere responsible for the transport of large amounts of water vapor. These phenomena can have a large impact on precipitation. In particular, they are often responsible for intense rain events on the western coast of North America during the winter season due to orographic lifting. These rain events can cause flooding and/or landslides that may result in property damage or loss of life.

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.

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

AIRS 500mb SH



Hypothesis

The Global Forecast System, an analysis and prediction system based on WRF and run operationally by NCEP/EMC, routinely assimilates AIRS radiances. However, these radiances are used only in cloud-free areas, Data from areas that are partly cloudy or have low cloud cover, such as those associated with atmospheric rivers, are excluded. Since AIRS can retrieve useful information on temperature and moisture above clouds, we expect that using the available profile data in cloudy regions can augment the currently utilized observations and improve WRF model analyses and forecasts.

Experiment

We test the impact of assimilating AIRS temperature and humidity profiles above clouds and in partly cloudy regions, using the three-dimensional variational Gridpoint Statistical Interpolation (GSI) data assimilation system to produce a new analysis. Forecasts of WRF initialized from the new analysis are compared to control forecasts without the additional AIRS data. WRF and GSI configurations are based on those used in the GFS. We verify the forecasts by comparison to the CIRA Blended Total Precipitable Water product (http://amsu.cira.colostate.edu/gpstpw/) and to profiles from dropsondes deployed during the Winter Storms and Pacific Atmospheric Rivers (WISPAR) field campaign (Ralph et al., 2011). We focus on some cases where atmospheric rivers caused heavy precipitation on the US West Coast.

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.

Ralph, F.M. et al., 2011: Research aircraft observations of water vapor transport in atmospheric rivers and evaluation of reanalysis products. American Geophysical Union Fall Meeting 2011, A11A-046.

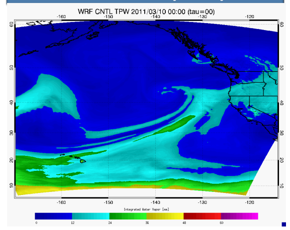
AIRS retrieved profiles of temperature and humidity from a +/-3 hour window were assimilated at 00Z on 11 Mar 2011 (below, left) .

Left: WRF Total Precipitable Water at initial analysis time, control run.

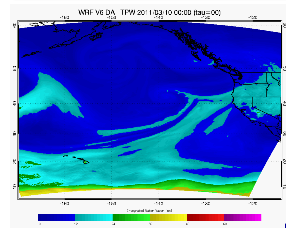
Center: Assimilation run at initial time, after assimilation.

Right: Assimilation increment of TPW due to AIRS profile assimilation (shading), with locations of AIRS observations (small circles, colored according to lowest cloud-free level). Where there is no data assimilated, increments are generally small. The AIRS profiles have a negative bias relative to the GFS but positive increments do occur.

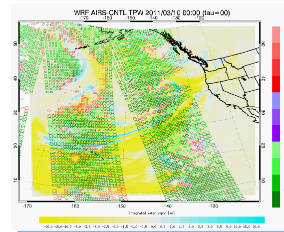
Initial Field (TPW)



Initial AIRS DA Field (TPW)



TPW Increment



Left: 18h forecast TPW, control run.

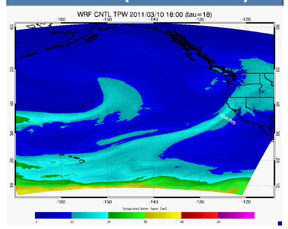
Center: 18h forecast TPW, assimilation run

Right: Difference (assimilation minus control)

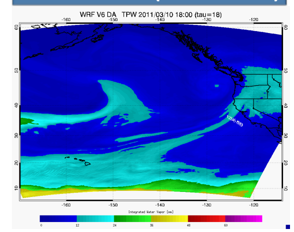
WRF forecasts appear similar but the atmospheric river approaching the west coast has been narrowed and average TPW values have been reduced.

Numbers 1-9 in white (traversing atmospheric river off of California coast) indicate positions of dropsondes used for validation, below.

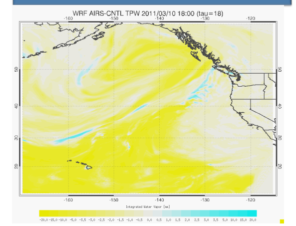
Ctrl field (18h forecast)



AIRS DA field (18h forecast)



18h forecast difference



CIRA TPW Comparison

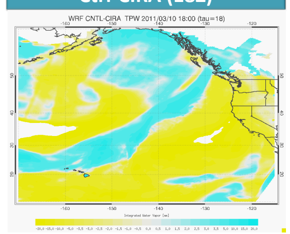
Left: Control minus CIRA TPW at 18Z.

Center: Assimilation run minus CIRA TPW at 18Z.

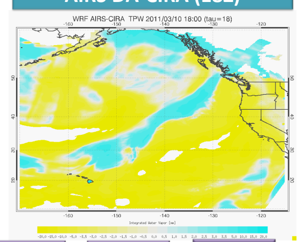
Right: CIRA TPW field at 18Z.

Validation against CIRA fields is ongoing. We need to account for the biases since CIRA TPW values are systematically larger than the GFS value.

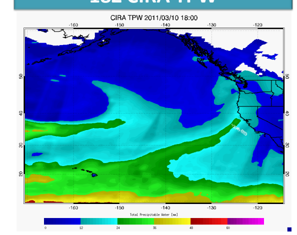
Ctrl-CIRA (18Z)



AIRS DA-CIRA (18Z)

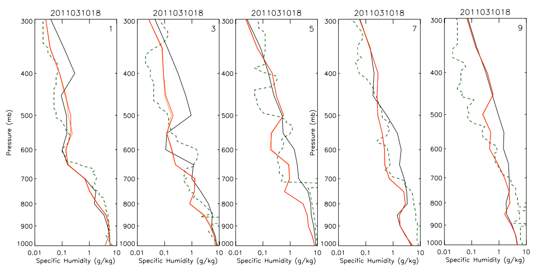


18Z CIRA TPW

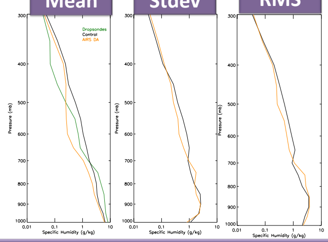


Validation vs. Dropsondes

Below: Control (black) and Assimilation Run (orange) profiles of forecast (18h) specific humidity at dropsonde locations, along with dropsonde-measured profiles (green, dashed). Positions are indicated in white (numbers 1-9) on the 18h forecast maps, above.



Mean Stdev RMS



Above: Mean profiles of control, assimilation run, and dropsonde specific humidity, at the dropsonde locations. Profiles of error standard deviation and RMS error of both WRF runs. The AIRS assimilation run has smaller errors in the middle troposphere (roughly 400 to 700 mb). This is consistent with expectations, since assimilating partly cloudy observations should result in improved depiction of the middle troposphere.

Future Work

- Examine additional atmospheric river cases.
- Do a scaling correction on the CIRA data (bias removal) before doing a quantitative analysis.
- Investigate the effect of changing from version 5 of the AIRS profiles to version 6. Initial investigation shows reduced bias relative to GFS.

Acknowledgement

We thank John Forsythe of CIRA for supplying the blended TPW analyses.