A Summary for the ARRA Project on AIRS data assimilation
30 September 2010

There are two objectives in the ARRA project. The first objective is to investigate the effectiveness of the assimilation of moisture channels from AIRS in the GEOS-5 data assimilation system. The second objective is to test performance of the new transmittance algorithms in the JCSDA Community Radiative Transfer Model (CRTM) on the assimilation of AIRS radiances in GEOS-5.

The GEOS-5 system to perform the ARRA task is GEOS-5.6.1, which includes the latest forecast model (Fortuna-2_1_p2) with modified moisture physics and turbulence parameterization, the updated adjoint-based tool for assessing the impact of the observing systems on forecast errors, and the newly released CRTM version 2.02. In this particular version of CRTM, two transmittance models are included. One is ODAS (Optical Depth in Absorber Space), which is equivalent to the default algorithm – Compact OPTRAN in previous releases (e.g., CRTM_v1.2). An alternative model is named ODPS (Optical Depth in Pressure Space), which is similar to the RTTOV-type of transmittance algorithm. There are several important features in ODPS model: (1) CO_2 is a user input variable absorber; (2) up to six user input variable absorbers (H_2O, CO_2, O_3, N_2O, CO and CH_4) can be included for hyper-spectral sensors; (3) OPTRAN algorithm is used for water vapor line absorption; (4) water vapor continua transmittance is treated separately. In addition to transmittance model updates, a bi-directional reflectance distribution function (BRDF) is implemented in this version to account for reflected solar radiation in affected short-wave infrared channels, and the reflectivity for down-welling infrared over all surfaces has been changed from Lambertian (isotropic) to specular (non-isotropic). These new features in CRTM, especially changes in the transmittance algorithm for water vapor channels, are expected to impact the assimilation results from satellite radiances.

The GEOS-5 experiments designed to perform the ARRA task are listed in Table 1. Three experiments were planned to assess the impact of BRDF, ODAS, and ODPS from CRTM and the performance of water vapor channels from AIRS in GEOS-5 system. All experiments were configured to run at d-grid (1/2°) resolution with all operational observation data, for the time period July-August 2010. The control experiment performed with GEOS-5.5.3 is similar to current GEOS-5 operational run (e540_fp), but with the additional adjoint-based tool to assess the impact of observations on the forecast skills. The assessment metrics to evaluate the impacts are: the fit of the background and analysis profiles to Rawinsonde observations; the anomaly correlation score for the 5-day forecast of the 500 hPa height over various geographical regions; and the adjoint-based tool measuring the reduction in 24-hour forecast error from each observing system. The results from these experiments are discussed in this report.

The global total impact of various observing systems and the impact per observation for each observation type on the reduction of the 24-hr forecast errors from experiment d561a1 are shown in Figure 1a and 1b, respectively. The impacts from experiment d561a1 and d561b1 are very similar. All observing systems provide positive total impact on forecast error reduction. Globally, both rawinsondes and AMSU-A radiances have the largest total impact (Figure 1a) of all observing systems, with smaller, but still significant contributions from AIRS and IASI radiances, GPSRO, commercial aircraft observations and satellite winds. The rawinsondes dominant the impact in the Northern Hemisphere while AMSU-A is dominant is the Southern Hemisphere (not shown). Globally, GPSRO demonstrates significant impact per observation. In general, larger forecast error reduction per observation is found in the Southern Hemisphere (Figure 2a and 2b).

The benefit of using the OPDS alternative from CRTM in the assimilation can be seen from hyper-spectral Infrared instruments such as AIRS and IASI. The channel statistics from AIRS shows that more data can be assimilated for most channels in the experiment using OPDS (Figure 3a). The fit of the model background to observation is significantly improved for temperature channels (Figure 3b-e). The similar behavior is also observed in IASI (Figure 4a-e).

There are 120 channels from AIRS and 165 channels from IASI assimilated in these experiments. On average, 80% of the AIRS channels have positive contribution to the 24-hr forecast error reduction (Figure 5), while only 65% of the IASI channels show positive impact (Figure 6). Both IASI and AIRS provide significant positive impact in the troposphere from temperature channels. However, most of the window (surface) channels from both instruments show negative impact on the 24-hr forecast error reduction. A few moisture channels from AIRS slightly degrade the 24-hr forecast; most of them are low peaking channels. Overall, the number of channels showing positive impact from both AIRs and IASI increases slightly for experiment with OPDS. More water vapor channels from AIRS contribute positively to the 24-hr forecast error reduction for experiment with OPDS.

The results from this project indicate that the negative impacts on forecast skill scores from moisture channels in hyperspectral sounders appear to be related to the way the data is used. The assimilation of these channels can still be improved through improvements in the assimilation machinery, including the radiative transfer models.

References

Ronald Gelaro and Yanqiu Zhu, 2009. Examination of observation impact derived from observing system experiments (OSEs) and adjoint models. Tellus, Volume 61 Issue2, Pages 179-193.

Yong Chen, Yong Han, Tong Zhu, and Fuzhong Weng, 2010. CRTM Multiple Transmittance Models. JCSDA 8th Workshop on Satellite Data Assimilation at UMBC, May 4-5, 2010.

JCSDA CRTM v2.0 User Guide

Table 1. List of GEOS-5 experiments

Experiment ID	GEOS-5 Tag	Features
d553	GEOS-5.5.3 (D-grid)	CRTM_v.1.2 ODAS No BRDF
d561a1	GEOS-5_6_1_p4 (D-grid)	CRTM_v.2.02 ODAS BRDF added
d561b1	GEOS-5_6_1_p4 (D-grid)	CRTM_v.2.02 ODPS BRDF added

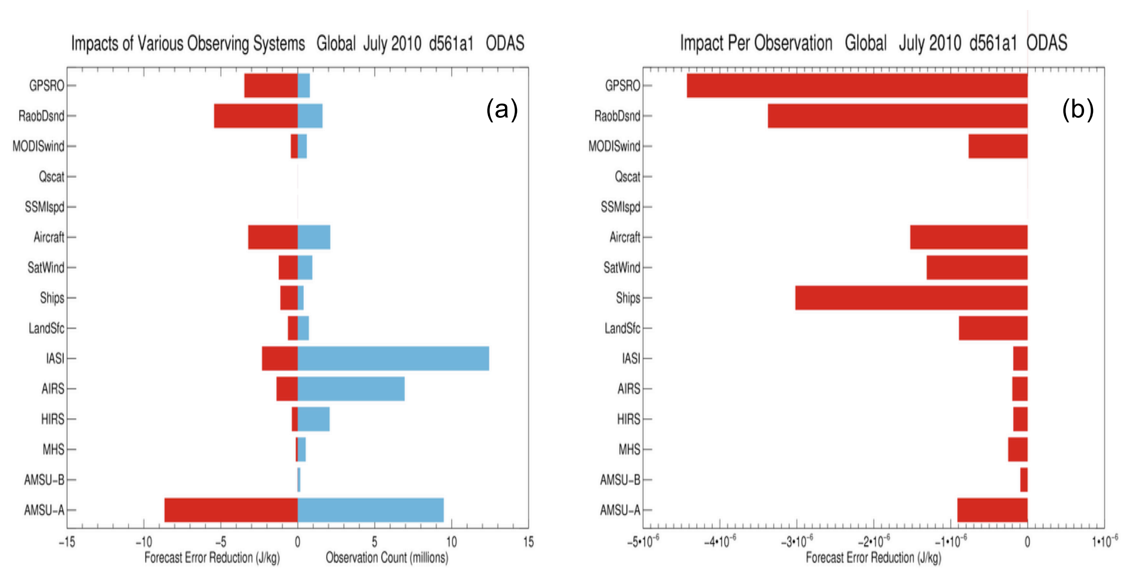

Figure 1. Impact of various observing systems on the 24-hr forecast from 00Z analysis during July 2010 for d561a1: (a) total impact of various observation types (in red) and observation count (in blue) and (b) impact per observation. The unit for the data count is millions. The unit for the impact is J/kg. Negative values indicate forecast improvement.

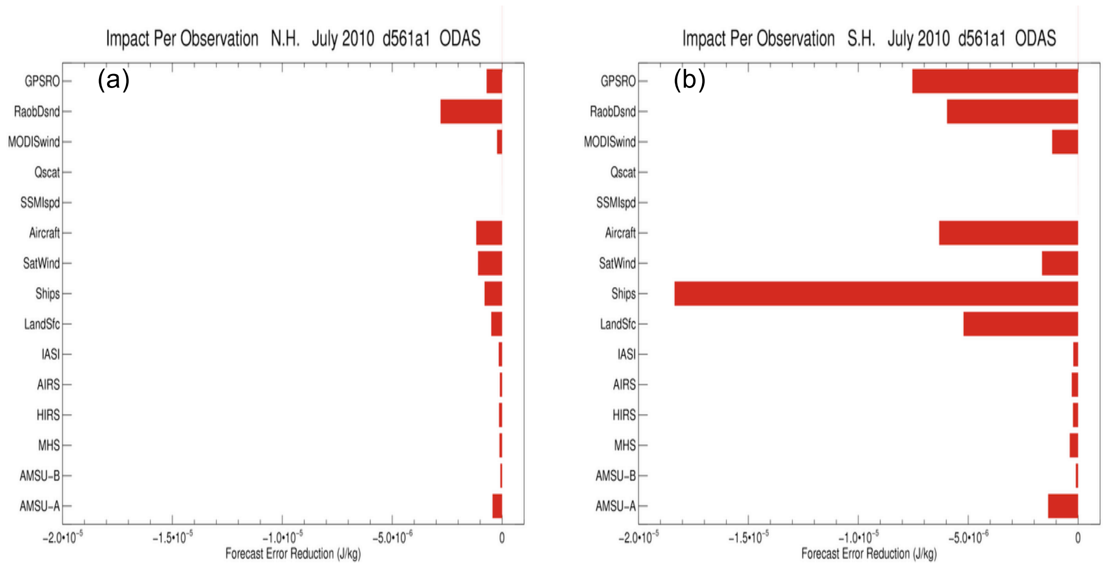

Figure 2. The impact per observation on the 24-hr forecast from 00Z analysis for d561a1 during July 2010 in: (a) Northern Hemisphere and (b) Southern Hemisphere. The unit for the impact is J/kg. Negative values indicate forecast improvement.

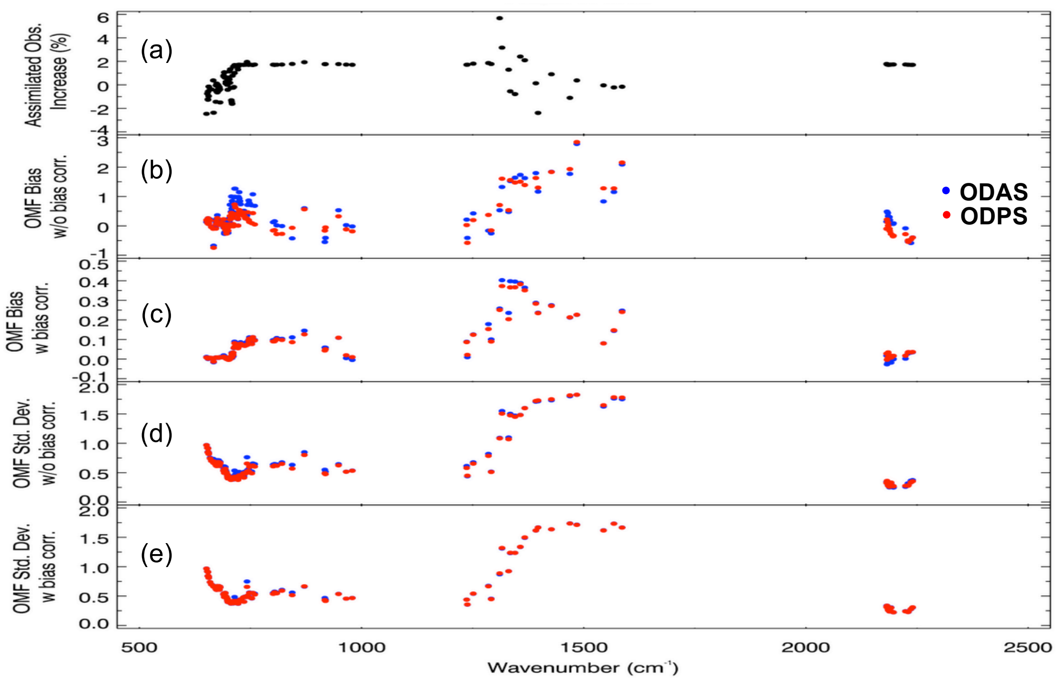

Figure 3. Channel statistics of AIRS data for experiment d561a1 and d561b1 respectively: (a) the percentage increase in number of AIRS assimilated; (b) OMF mean without bias correction; (c) OMF mean with bias correction; (d) OMF standard deviation without bias correction; (e) OMF standard deviation with bias correction.

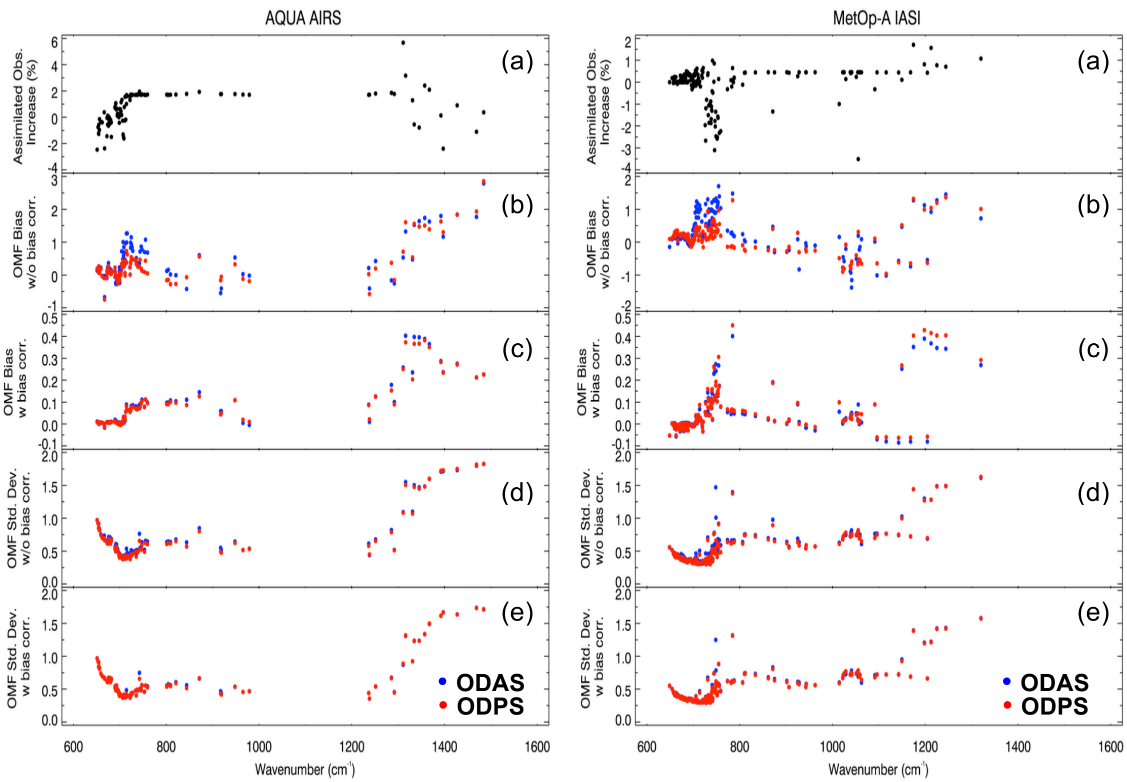

Figure 4. Same as Figure3, except channel statistics between 600 cm^{-1} and 1500 cm^{-1} for AIRS and IASI are shown on the left and right panel respectively.

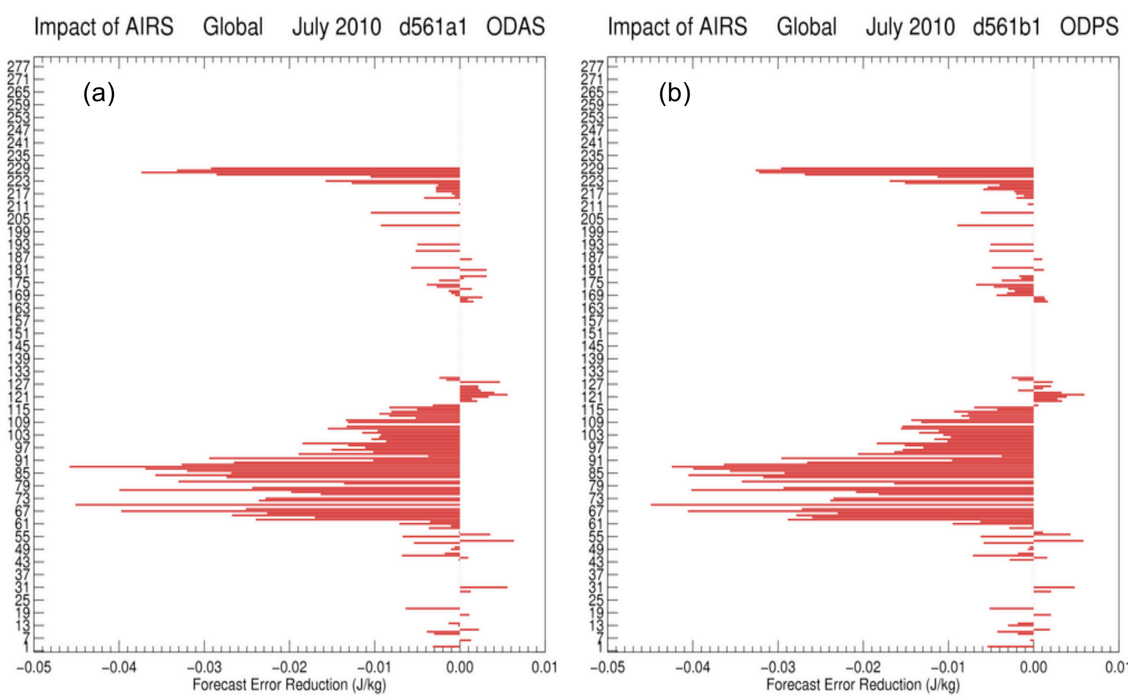

Figure 5. The total impact of each AIRS channel assimilated on the 24-hr forecast from 00Z analysis during July 2010: (a) d561a1 (ODAS) and (b) d561b1 (ODPS). The unit for the impact is J/kg. Negative values indicate forecast improvement.

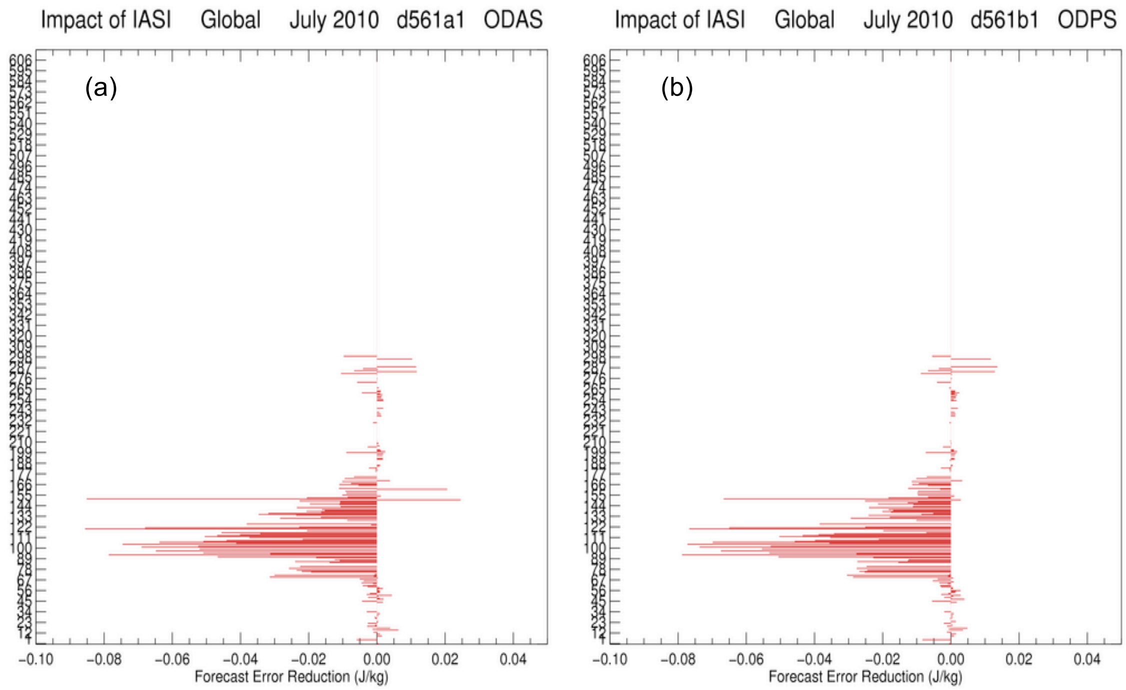

Figure 6. The total impact of each IASI channel assimilated on the 24-hr forecast from 00Z analysis during July 2010: (1) d561a1 (ODAS) and (b) d561b1 (ODPS). The unit for the impact is J/kg. Negative values indicate forecast improvement.