USING HYPERSPECTRAL INFRARED RADIANCE GLOBAL DATA SETS TO VALIDATE WEATHER AND CLIMATE ANALYSES

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There is growing consensus that persistent and increasing anthropogenic emissions are increasing atmospheric temperatures, increasing sea levels, melting ice caps and glaciers, increasing the occurrence of severe weather, and causing regional shifts in precipitation patterns. Changes in these parameters or occurrences are responses to changes in climate forcing terms, notably greenhouse gases. The NASA Atmospheric InfraRed Sounder (AIRS) [Aumann et al., 2003], launched in May of 2002, is the first high spectral resolution infrared sounder with nearly complete global coverage on a daily basis. High spectral resolution in the infrared provides sensitivity to nearly all climate forcings, responses and feedbacks. The AIRS radiances are sensitive to changes in carbon dioxide, methane, carbon monoxide, ozone, water vapor, temperature, clouds, aerosols, and surface characteristics. The AIRS data are applied to generate the first ever spectrally resolved infrared radiance (SRIR) dataset (2002- 2006) for monitoring changes in atmospheric temperature and constituents and for assessing the accuracy of climate and weather model analyses and forecasts [Goldberg, 2009]. The SRIR dataset is a very powerful climate application. Spectral signatures derived from the dataset confirmed the largest depletion of ozone over the Arctic in 2005, and also verified that the European Center for Medium Range Weather (ECMWF) model analysis water vapor fields are significantly more accurate than the analyses of the National Centers for Environmental Prediction (NCEP). The NCEP moisture fields are generally 20% more moist than those from ECMWF. Applications included computations of radiances from NCEP and ECMWF atmospheric states and comparison of these calculated radiances with those obtained from the SRIR dataset. Comparisons showed very good agreement between the SRIR data and ECMWF simulated radiances, while the agreement with NCEP values was rather poor. However, further comparisons with the SRIR dataset in 2006 found degradation in the ECMWF upper tropospheric water vapor fields due to an operational change in ECMWF assimilation /modeling procedures. This unexpected result demonstrates the importance of continuous routine monitoring. The SRIR climatology will be extended into the future using AIRS and the EUMETSAT Infrared Atmospheric Interferometer Sounder (IASI) and the NPOESS Cross-track Infrared Sounder (CrIS). The current SRIR dataset will be extended to 2009 by the end of 2010.

Key factors in generating climate quality products from high spectral resolution infrared sounders are adequate spectral resolution and coverage, excellent signal to noise performance and long term stability. AIRS and IASI have been successful in meeting those factors. The radiometric accuracy and stability of AIRS and IASI radiances have been confirmed by several fundamentally different types of comparisons, including the results of the daily measurements of sea surface temperature (SST) [Aumman et al., 2006], direct spectral radiance comparisons from aircraft observations [Tobin et al., 2006]; and more recently direct intercoomparisons between IASI and AIRS, which have shown that both AIRS and IASI are extremely stable and accurate. The differences between both AIRS and IASI are approximately 0.1 K with a projected stability of 0.1 K per decade [Tobin et al., 2008], [Wang et al, 2009ab]. Fig. 1 shows the expected change in radiances due to changes in the state field. For example, in this figure one can see that a 15% increase in ozone results in a brightness temperature reduction of approximately 2 K, and a 15% increase in water vapor causes a reduction of approximately 1.25 K

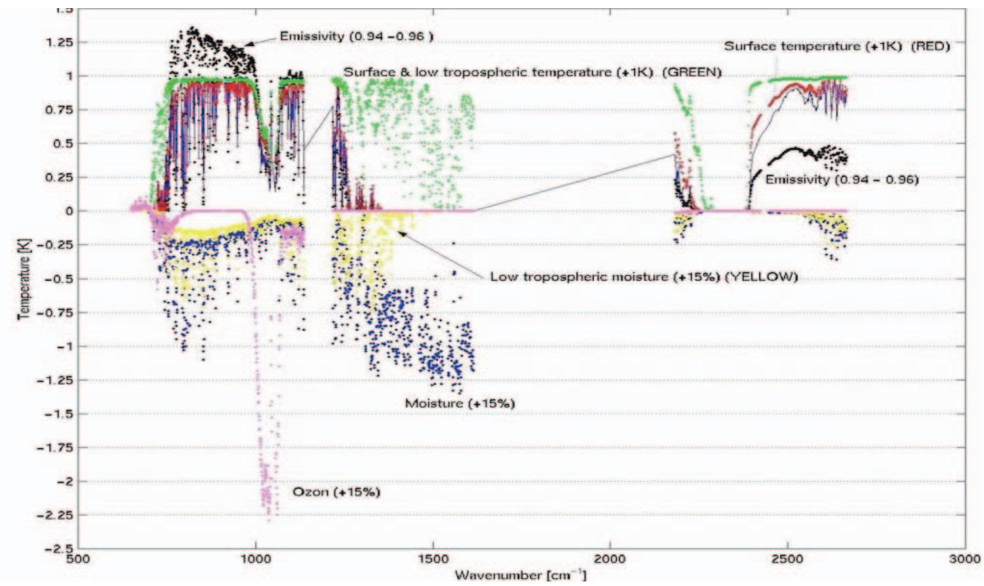

Fig. 1: Response in brightness temperatures due to a change in atmospheric and surface parameters

A very important application of the radiance climatology is to compare model analyses simulated radiances with observed radiances to help determine which model is more accurate. For example in Fig. 2 we show that the NCEP integrated water vapor content above 500 mb is higher than ECMWF in 2003 and 2004 by about 20%.

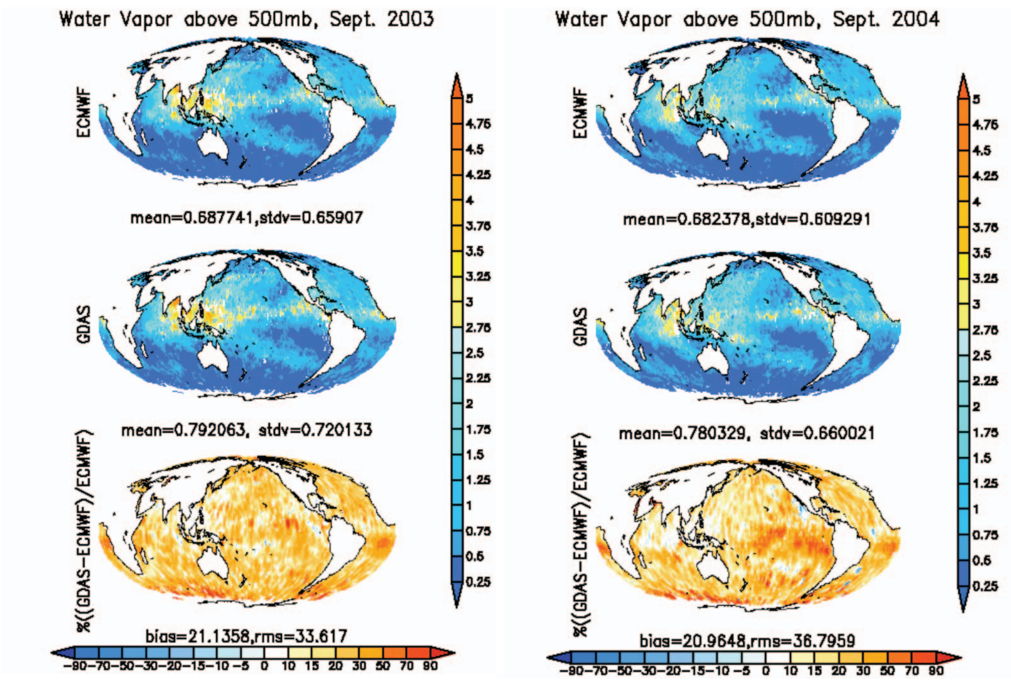

Fig. 2: Comparisons of ECMWF and GDAS (NCEP) above 500 mb integrated water vapor for September 2003 and 2004

Shown in Fig. 3 are the observed AIRS minus simulated ECWMF brightness temperatures for the 1519.07 cm^{-1} channel, which is sensitive to upper tropospheric water vapor with a peak sensitivity near 300 mb, for September 2003, 2004 and 2005. Fig. 4 shows the comparable figure using the NCEP analysis. Fig. 3 shows smaller biases for all three periods, demonstrating that ECMWF analysis water vapor fields were relatively accurate even before AIRS was assimilated in 2004. However the rms was reduced by about 0.3 K and there is an absence of locally large deviations after 2003. In Fig. 4 there was a very large reduction in the bias (September 2005) after AIRS was used operationally by NCEP. The NCEP bias is about 1.5 K larger in 2003 and 2004, which is consistent with a 20% increase in moisture as inferred by Fig. 1.

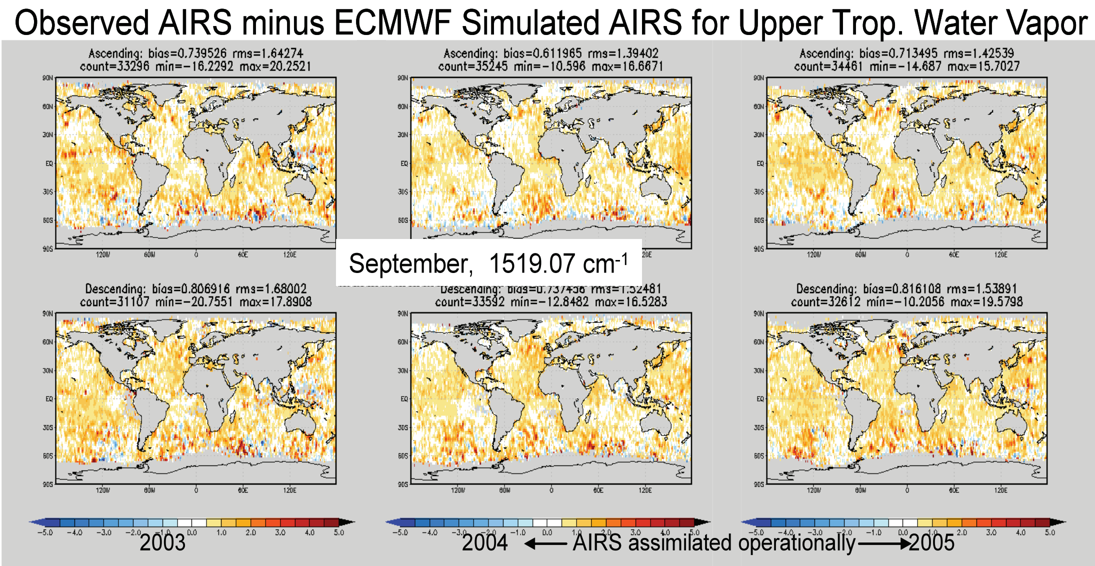

Fig. 3: Observed AIRS minus ECMWF simulated AIRS for upper tropospheric water vapor channel at 1519.07 cm^{-1} wavenumber.

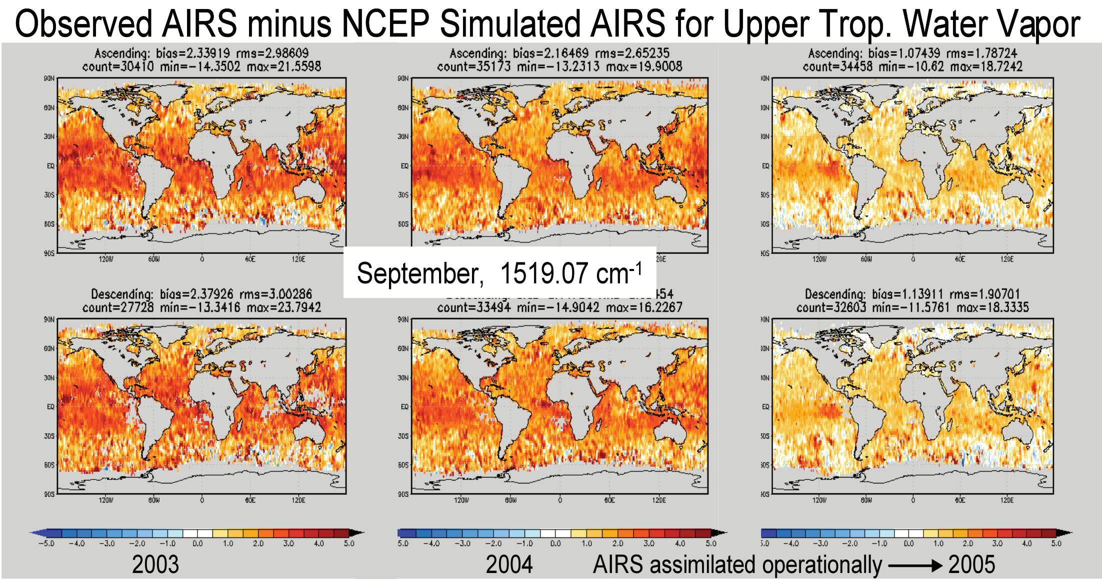

Fig. 4: Observed AIRS minus NCEP simulated AIRS for upper tropospheric water vapor channel at 1519.07 cm^{-1} wavenumber.

Based on the above results, one can conclude that, for the period of 2003 to 2005, ECMWF's analyses appear to be more accurate than NCEP's and in excellent agreement with AIRS observations. Unfortunately, in 2006 the AIRS radiance climatology detected degradation in the ECMWF water vapor analysis, underscoring the importance of the AIRS data for ongoing validation. After a number of operational upgrades of the ECMWF data assimilation system including revisions to the cloud scheme, the implicit computation of convective transports, and variational radiance bias adjustments, the bias in the upper tropospheric water vapor channel for September 2006, shown in Fig. 2, increased significantly to 1.55 K from 0.71 K in September 2005 and is now larger than that of NCEP.

To summarize, we observed that the integrated column water vapor above 500 mb from the NCEP analysis is 20% more moist than ECMWF for 2003 and 2004. These differences are consistent with brightness temperature differences given in Figs. 1, 3 and 4. In 2005, after NCEP started to assimilate AIRS, the difference between NCEP and ECMWF was reduced to 11%. In 2006, the difference was reduced to nearly zero, but this was due to an erroneous change to the ECMWF model. We found that above 200 mb, the mean water vapor from the ECMWF analysis nearly doubled from 2005 to 2006. **This underscores the importance of the SRIR dataset for the long-term monitoring of models.** Results have also shown that the operational changes in 2006 are in the latest ECMWF climates reanalysis. In 2004, the ECWMF reanalysis is moister than the ECMWF weather analysis by 12%.

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