

Chian-Yi Liu^{1,*}, Jun Li¹, W. Paul Menzel¹, and Timothy J. Schmit²

¹Cooperative Institute for Meteorological Satellite Studies (CIMSS) / University of Wisconsin-Madison, USA *E-mail: cylieu@ssec.wisc.edu

²Center for Satellite Applications and Research, NOAA/NESDIS, Madison, Wisconsin, USA

1. Objective

Hyperspectral infrared (IR) sounder from low earth orbit (LEO) provides temperature and moisture soundings with high accuracy and high vertical resolution, however, due to its low temporal coverage rate (twice every day for one sounder instrument), data are usually missing during short range convective storm development. The Advanced Baseline Imager (ABI) onboard the next generation of geostationary (GEO) satellite, on the other hand, provides very fast coverage rate but lower vertical resolution and less accurate profiles. Combination of LEO hyperspectral IR sounder data and GEO ABI measurements may provide atmospheric evolution with high temporal resolution and fairly vertical structure. An algorithm is developed for monitoring the sounding evolution from combined LEO IR sounder and GEO imager data. The collocated geolocation of LEO sounder and GEO imager systems can (1) provide LEO sounder sub-pixel cloud characterization (mask, amount, phase, layer information, etc.) within the large sounder footprint; (2) be used for LEO sounder cloud-clearing for partly cloudy footprints; (3) provide background information in variational retrieval of cloud properties with sounder cloudy radiances; (4) provide real-time background information for GEO imager instantly without Numerical Weather Prediction (NWP) forecast. The Moderate-Resolution Imaging Spectroradiometer (MODIS) and the Atmospheric Infrared Sounder (AIRS) measurements from the Earth Observing System's (EOS) Aqua satellite provide the opportunity to study the synergistic use of advanced imager and sounder measurements. The combined MODIS and AIRS data for various scenes are analyzed to study the utility of synergistic use of ABI products and LEO sounder radiances for better retrieving atmospheric soundings and cloud properties. The combination of ABI and LEO hyperspectral IR sounder for legacy sounding evolution will be studied using SEVIRI and IASI.

2. Radiative Transfer Models and Retrieval Schemes

The atmospheric temperature and moisture retrieval algorithm in this study is a statistical regression for MODIS and eigenvector regression for AIRS under clear skies followed by an optional non-linear physical iterative approach. To derive the regression coefficients, both MODIS and AIRS infrared (IR) radiances are calculated from a global set of RAOBs to quantify a range of atmospheric state. An ensemble of computed radiances with associated atmospheric profiles is created for the regression relationship. The MODIS radiative transfer model and its linearization are described in Seemann *et al.* (2003), while the radiative transfer calculation of the AIRS sounder spectral radiances is performed using a fast transmittance model called Stand-Alone Radiative Transfer Algorithm (SARTA v1.06) (Strow *et al.*, 2003). This model has 101 pressure level coordinates ranging from 0.05 to 1100 hPa and uses line-by-line radiative transfer model calculations based on the high spectral resolution transmission molecular absorption spectroscopic database HITRAN 2000 (Rothman *et al.*, 1998). Both MODIS and AIRS radiances calculations take into account the satellite zenith angle, absorption by water vapor and ozone, and surface emissivity. The AIRS radiances calculation is also including well-mixed gases such as nitrogen, oxygen, and carbon dioxide.

3. Training Dataset and Retrieval Simulation

The regression training set (Borbas *et al.*, 2005) consists of approximately 12000 globally distributed temperature, moisture, ozone profiles (including surface parameters), and their associated computed radiances which were generated by the models described previously. The training set is classified based on the brightness temperature (BT) in the longwave window region (Band 31 for MODIS; wavenumber near 910.0 cm^{-1} for AIRS) and viewing angles. The AIRS eigenvector regression is similar to Weisz *et al.* (2007). In addition to the simulated IR radiances, the surface pressure, latitude are also used as predictors. The sounder retrieved troposphere temperature (100 to 1013 hPa), moisture (300 to 1013 hPa) profile and surface skin temperature are used as additional predictors while doing the synergistic retrieval for imager/sounder systems.

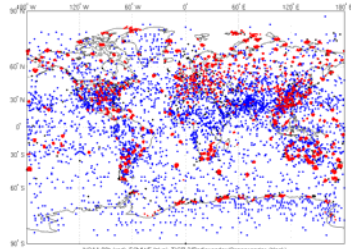


Figure 1. Distribution of global training profiles from RAOB (red) and ECMWF analysis (blue).

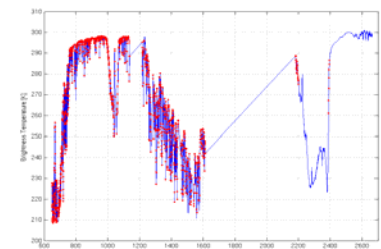
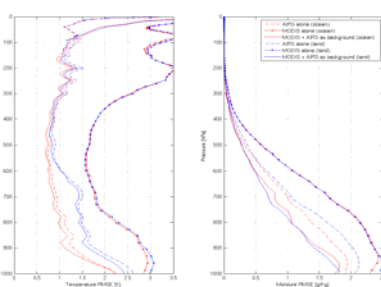


Figure 2. Sample calculated AIRS brightness temperature spectra for the profile over ocean. Those optimal selected 1450 channel for eigenvector regression are shown on red dots.

In order to analyze the performance of combined MODIS/AIRS retrieval approach, we choose 90% of the profiles and the associated radiances in the dataset for the regression coefficients calculation, then apply the regression coefficient to the rest 10% of the radiances for the retrieval testing. Both temperature and moisture root-mean-square error (RMSE) over open water and land surface for 100 satellite scan angles ranging from 0 (nadir) to 49.5 degrees at 0.5 degree increment are shown on the right figure. Due to the lacking of temperature weighting function peaks at high pressure levels above 300 hPa in MODIS IR bands, the hyperspectral IR sounder system can reduce the RMSE significantly in these levels. The simulation also demonstrates the advantage of the combined imager and sounder over either system alone.



4. MODIS/AIRS Combination Study with Hurricane Isabel of September 13, 2003

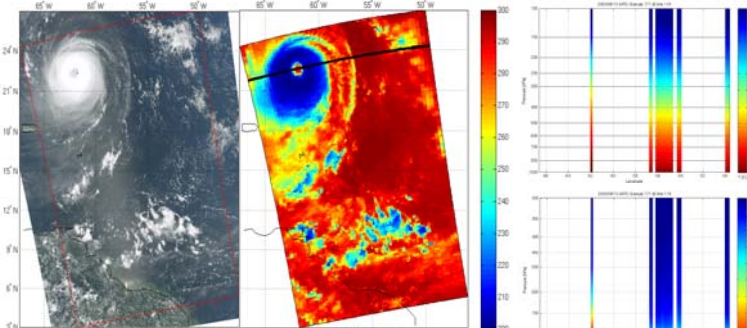
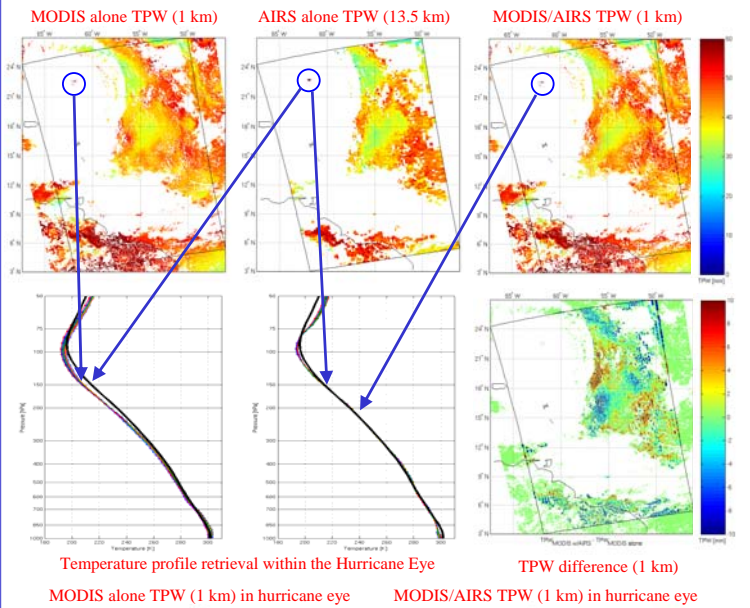


Figure 4. Composite Hurricane Isabel MODIS true color image (left) and its corresponding AIRS window channel (919.467 cm^{-1}) brightness temperature (middle) around 1705 UTC on September 13, 2003. The right panels are the retrieved vertical temperature (top) and moisture (bottom) profiles along the 119th scanline in this AIRS granule.

Derived Product Comparisons of Retrieval Schemes



Temperature profile retrieval within the Hurricane Eye



5. Combing ABI and LEO Hyperspectral IR Sounder for Sounding Evolution

Approaches:

- Develop physical retrieval approach for hyperspectral IR alone SFOV soundings in both clear and cloudy skies.
- Use IASI and AIRS data to test the hyperspectral IR alone SFOV sounding algorithm.
- SEVIRI and IASI/AIRS will be used as proxy to evaluate the sounding improvement from combined high temporal ABI and hyperspectral CrIS over that from ABI alone.
- Radiosonde observations, ECMWF analysis, and ground in-situ measurements will be used to evaluate the impact of GEO/LEO combination.

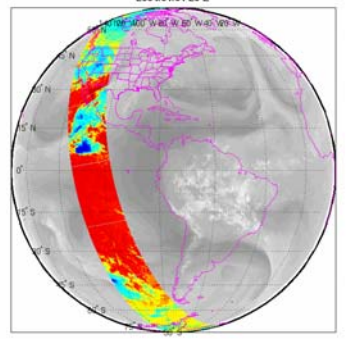


Figure 5. One hour AIRS coverage (911 cm^{-1} BT) overlay on GOES-12 band 3 water vapor image (black/white) on January 1, 2004 2045 UTC.

6. Summary

- Hyperspectral infrared sounder from LEO provides atmospheric temperature and moisture sounding with high accuracy and vertical resolution;
- GEO Imager provides data with high spatial resolution very fast spatial coverage rate;
- The combination of LEO hyperspectral IR sounder data and GEO imager measurements can provide atmospheric evolution with high spatial resolution, high temporal resolution and fairly vertical structure;
- The combination of ABI and LEO hyperspectral IR sounder for legacy sounding evolution will be studied using SEVIRI and IASI
- Combination of ABI and LEO hyperspectral IR data under cloudy skies will also be studied.

References

- Seemann, S. W., J. Li, W. P. Menzel, and L. E. Gumly, 2003: Operational retrieval of atmospheric temperature, moisture, and ozone from MODIS infrared radiances. *J. Appl. Meteor.*, **42**, 1072-1091.
- Strow, L. L., S. E. Hannon, S. De Souza-Machado, H. E. Motzler, and D. Tobin, 2003: An overview of the AIRS radiative transfer model. *IEEE Trans. Geosci. Remote Sens.*, **41**(2), 303-313.
- Rothman, L. S., and Coauthors, 1998: The HITRAN Molecular Spectroscopic Database and HAWKS (HITRAN Atmospheric Workstation): 1996 edition. *J. Quantitative Spectroscopy and Radiative*, **60**, 665-710.
- Borbas, E., S. Seemann, H.-L. Huang, J. Li, and W. P. Menzel (2005): Global profile training database for satellite regression retrievals with estimates of skin temperature and emissivity, paper presented at 14th International ATOVS Study Conference, NASA, Beijing.
- Weisz, E., J. Li, J. Li, D. K. Zhou, H.-L. Huang, M. D. Goldberg, and P. Yang, 2007: Cloudy sounding and cloud-top height retrieval from AIRS alone single field-of-view radiance measurements. *Geophys. Res. Lett.*, **34**, L12802, doi:10.1029/2007GL030219.

Acknowledgement

This work was partly funded by NOAA GOES-R grant NA07EC0676 and NASA MODIS contract NASS-31367.