Combined use of polar imager and sounder measurements for enhanced sounding capability

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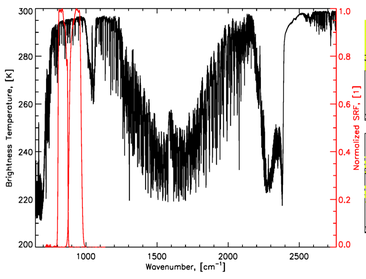
Abstract

We will present ongoing work to improve infrared soundings from polar satellite instruments such as AIRS, IASI, and CrIS by using collocated imager measurements from MODIS, AVHRR, and VIIRS. Work presented will include improvements to cloud-clearing using the imager measurements, the retrieval of aerosol (Saharan dust and/or volcanic ash) from IR sounder measurements, and assessment of the effect of aerosol on IR sounder temperature and moisture retrievals.

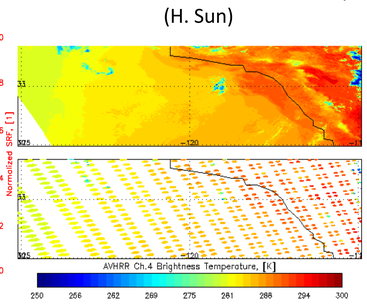
Introduction and Motivation

Typical IASI spectrum and AVHRR Spectral Response Functions



Spectral convolution of IASI to AVHRR resolution

Top: CLAVR-X AVHRR CH. 4 BTs (A. Heidinger), Bottom: AVHRR collocated to IASI footprints (H. Sun)

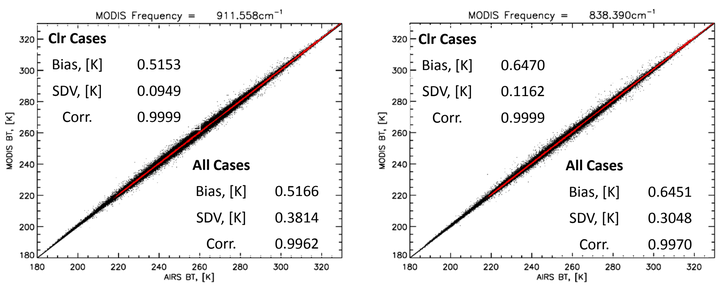


Spatial collocation and convolution of AVHRR to IASI footprints

We want to exploit the high spatial resolution of the multispectral AVHRR (MODIS) data to improve IASI (AIRS) retrievals:

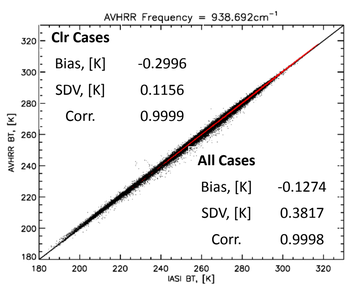
1. QA cloud cleared radiances using spectrally convolved IASI (or AIRS) – spatially convolved AVHRR (or MODIS) to compare apples to apples.
2. Utilize subpixel (1km AVHRR/MODIS vs. 12-15km IASI/AIRS resolution)/multispectral (visible/NIR) information about clouds from AVHRR and MODIS to improve/validate cloud-clearing, improve the 'clear estimate' required for cloud clearing, and/or other retrievals (cloud retrieval).

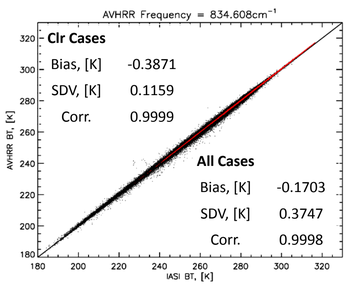
Collocation of Sounder and Imager



•Collocation between the sounder and imager uses an algorithm developed for use with AIRS and MODIS data on NASA's Aqua satellite (Sun, et al. 2006) and is an extension of the algorithms described in Li, et al. (2005). Explained briefly, this algorithm finds the closest imager observation to the center of the sounder footprint and performs an outward search to find all of the imager pixels falling within the sounder footprint.

•A weight, herein termed the Integrated Point Spread Function (IPSF), is assigned to each collocated imager pixel. For IASI and AVHRR (below) the weighting is a simple function of the angular distance of each pixel relative to the center of the IASI FOV. For AIRS and MODIS (above), the IPSF is complicated due to the front entrance optics filters and scanning scene integration characteristics. See Schreier, et al., 2010 for more details.





References and Acknowledgements

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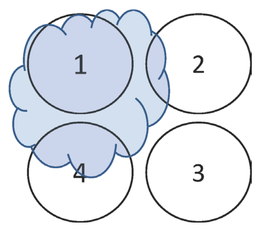
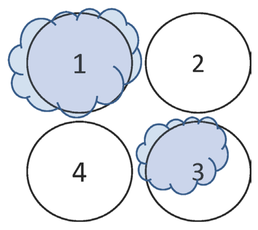
Strategies for sounding in cloudy and partially cloudy-sky scenes

Case I: Clear pixels are averaged – Hole Hunting



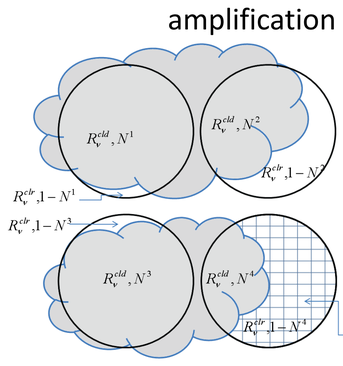
$$R_\nu^{cc} = R_\nu^{FOV_3}$$



$$R_\nu^{cc} = \frac{1}{2}(R_\nu^{FOV_2} + R_\nu^{FOV_4})$$

And so on …

Case II: Cloud-clearing using 2-FOVs which yield best agreement with subpixel imager clear radiances and lowest noise amplification

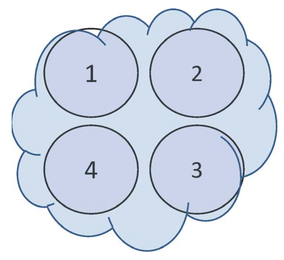


$$R_\nu^{FOV_1} = R_\nu^{clr}(1-N^1) + R_\nu^{cld}N^1$$
$$R_\nu^{FOV_2} = R_\nu^{clr}(1-N^2) + R_\nu^{cld}N^2$$
$$R_\nu^{FOV_3} = R_\nu^{clr}(1-N^3) + R_\nu^{cld}N^3$$
$$R_\nu^{FOV_4} = R_\nu^{clr}(1-N^4) + R_\nu^{cld}N^4$$

$$R_{A_i}^{clr} = \sum_j IPSF_j R_{A_i}^{clr,j}$$
$$R_{A_i}^{FOV_j} = \sum_\nu SRF_{i,\nu} R_\nu^{FOV_j}$$

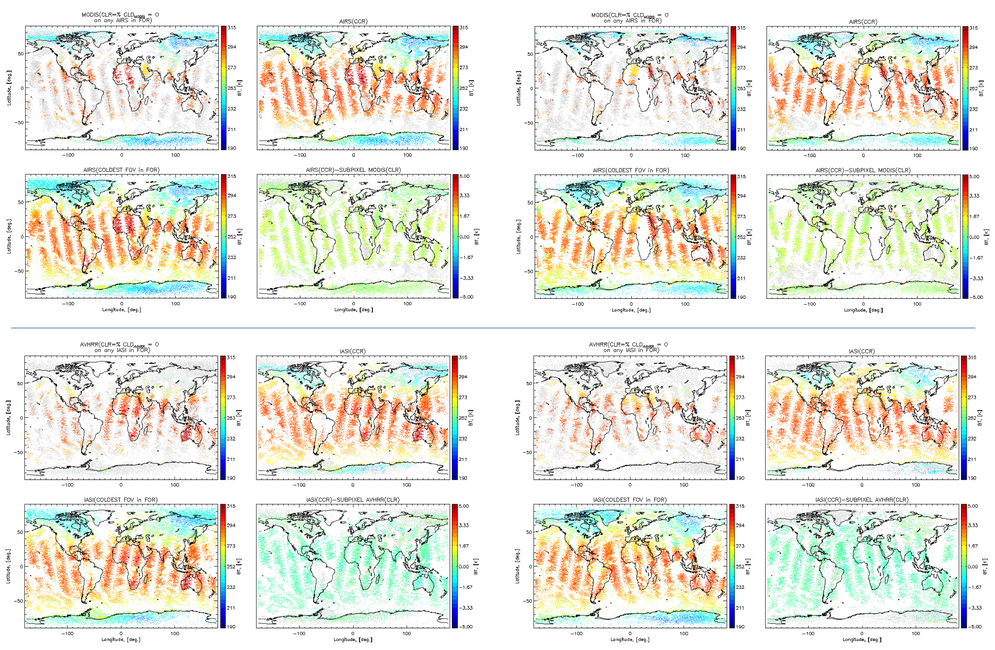
$$\eta(j,k) = \frac{\sum_i \frac{1}{\sigma_i}[R_{A_i}^{clr} - R_{A_i}^{FOV_j}][R_{A_i}^{FOV_j} - R_{A_i}^{FOV_k}]}{\sum_i \frac{1}{\sigma_i}[R_{A_i}^{FOV_j} - R_{A_i}^{FOV_k}]^2}$$

Case III: Overcast – We could use calculations using NWP or Microwave to estimate clear-column radiances, model the clouds.



For now we punt …

Summary of results for MetOP-A AVHRR/IASI and Aqua MODIS/AIRS all granules for 02/03/2013



• In each of the four, four-panel figures, (top left): expected yield (global coverage) of a clear only algorithm using the imager cloud-mask to determine clear-sky field-of-views(FOV); (top right): yield of the 2-pronged hole-hunting/cloud-clearing algorithm; (bottom left): coldest FOV as aproxy for cloudiness; (bottom right): cloud-cleared radiance spectrally convolved to imager SRF minus sub-pixel imager clear-sky pixels spatially integrated onto the sounder FOV.

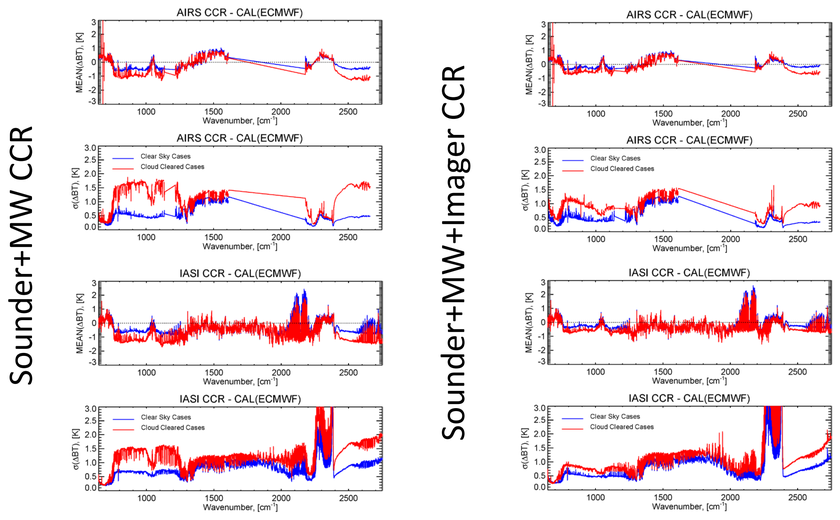
• Top figures show results for AIRS/MODIS cloud-clearing, Bottom two figures show results for IASI/AVHRR cloud-clearing for the split window 11 micron channel.

• A statistical summary of the daily accepted AIRS and IASI cloud-cleared radiances spectrally convolved to the imager spectral response minus the clear-sky imager measurements spatially integrated onto the sounder footprint is given below.

Satellite Instrument	Channel [cm^{-1}]	Bias [K]	SDV [K]	Corr. Coef.
(AIRS/MODIS)	905.69	0.2153	0.7187	0.9996
(IASI/AVHRR)	928.15	-0.1821	0.5639	0.9994

•Excellent agreement for both satellite instrument pairs! Similar results for 8 micron split window channel.

Comparison of operational algorithm to research algorithm AIRS and IASI cloud-cleared radiance minus calculations using ECMWF statistics for ocean nighttime cases for 02/03/2013

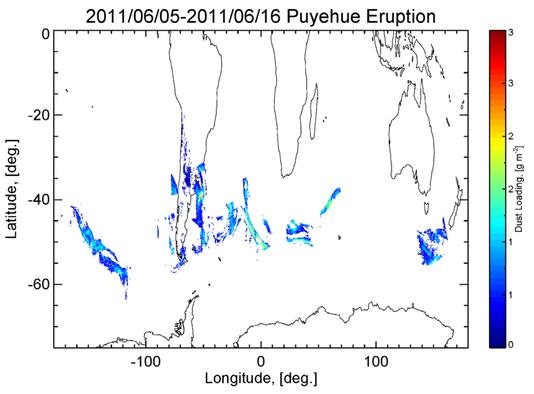


• Top panels show average and the standard deviation cloud-cleared radiance minus calculations using ECMWF (Obs-Cal) over nighttime ocean cases for AIRS. Bottom panels shows the same for IASI. The left plots are the current offline AIRS and operational IASI algorithm. The right panels show statistics calculated using the imager enhanced cloud-clearing methodology.

•The same cases went into the statistics for cloud-cleared cases (red line) in the leftmost and right most panels for each instrument pair. We also show statistics for cases determined by each algorithm to be clear in blue. For instance, in calculating statistics for the leftmost plots, only AMSU+sounder measurements were used to determine clear-sky scenes, while the statistics shown in the rightmost plots used AMSU+sounder+collocated imager cloud-mask to determine clear-sky cases. Note the smaller standard deviation and bias for the latter.

•The average bias and standard deviation of the Obs-Cal shown in the rightmost plots is 1.5-2 times smaller than the statistics of the Obs-Cal calculated without the use of imager measurements.

Future Research and Next Steps



•AIRS, IASI, and CrIS like retrieval algorithms are sensitive to the presence of aerosol within the sounders' FOV (Maddy, et al., *GRL*, 2012). This warrants an investigation into the ability of these sounders (and imagers) to retrieve aerosols.

•Left: AIRS tracks volcanic ash from the 2011 Puyehue Eruption in Chile as it travels around the globe. In collaboration with UMBC (S. De-Souza Machado, L. Strow) and using their SARTA_PCLSAM model, we've retrieved dust loading, particle size and heights and compared these loadings with MODIS Collection 6 products.

•Right top: Comparison of AIRS retrieved dust loadings with MODIS AOD_Average_Ocean product over ocean and DB_AOD_550_Land (blue) over land. Collocations between AIRS and MODIS show a good correlation between MODIS AOD and AIRS retrieved AOD (Corr. Coef. ~0.88) and similar timeseries (bottom panel).

•Similar results should be obtainable from IASI and CrIS enabling retrieval of dust and volcanic ash 4 or more times per day.