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IASI and AIRS Validation and Intercomparisons with SARTA

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Overview

- AIRS/IASI/CrIS promise to give us a 20+ year hyperspectral time-series of climate
- How well can we tie together the AIRS and IASI records? (AIRS won't be around for CLARREO.)
- RTA performance and issues for climate
- A new method for deriving spectroscopy from radiances??

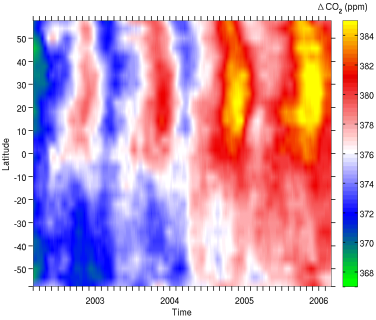
Spectroscopy is not Climate-Quality

- AIRS stability is $<$0.01K/year, probably sufficient for climate trends. IASI appears to have very good stability as well.
- Spectroscopy is only good to, at the very best, 0.1-0.2K
- Climate studies using retrievals require consistent RTA's, making intercomparisons among groups very difficult
- Retrievals sensitive to prior (assimilation), and cloud clearing performance (limited in troposphere in mid-, higher-latitudes)
- At present, I do not have a statistical set of high-quality coincident sondes measurements for IASI. Do they exist?
- IASI and AIRS agree far better than the spectroscopy

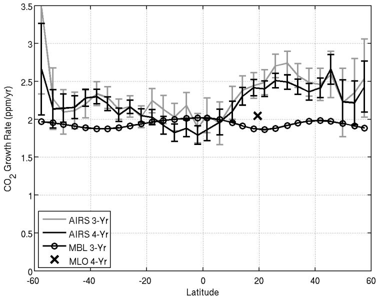
Capabilities of AIRS/IASI for Climate

Forcings not sensitive to clouds: CO_2, CH_4, dust, etc.

Total CO_2 signal = 0.54K



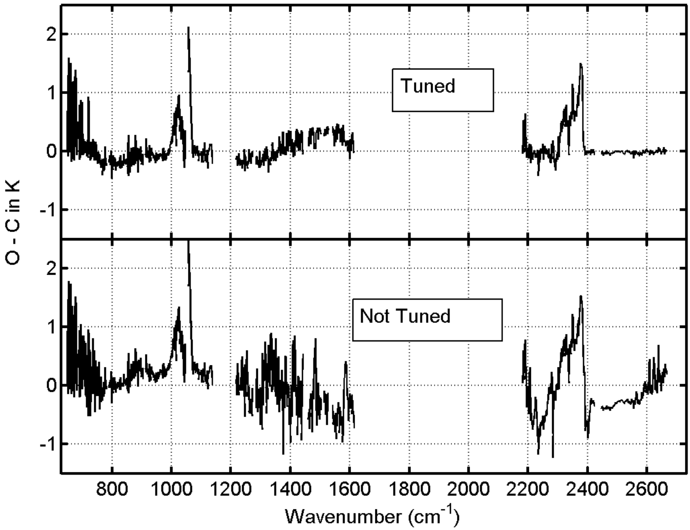
2 ppm/yr growth rate = 0.06K



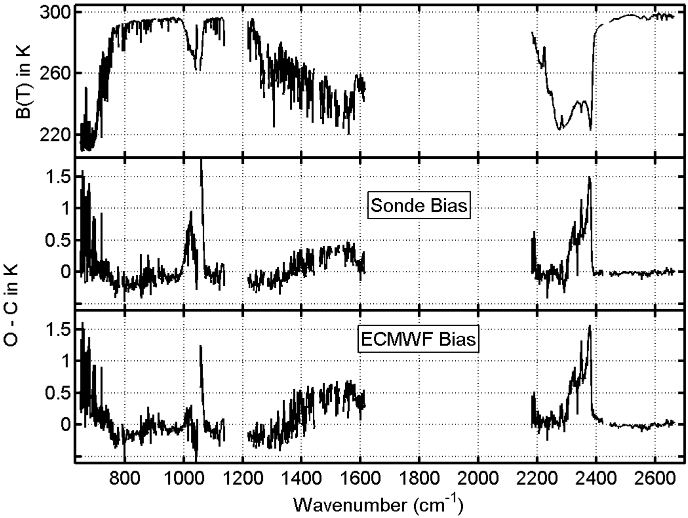
Status of SARTA RTA's

- AIRS V5 RTA: tuned, older spectroscopy
- Tuning used ARM TWP (tested with ARM SGP) RS-90, Frost-Point hygrometer coincident radiosondes
- This work:
  - V6 RTAs
  - HITRAN 2004+ (ozone, water are main changes)
  - Presently "untuned", giving poorer performance, but our baseline
  - IASI clearly needs same tuning, but for different SRFs
- Biases shown are larger than used in AIRS V5 system. NOAA/NESDIS is using V6 RTA for IASI.
- AIRS frequency calibration on per-granule basis complete. Analysis not yet included in these results. Errors $<$0.05K and mostly random.

Amount of Tuning

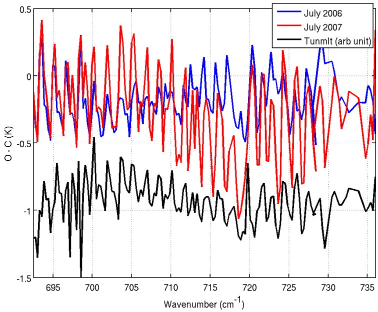


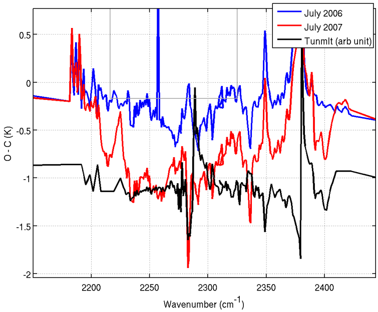
ECMWF CO_2 Channels Agree Well with Sondes



After Feb. 2006 ECMWF Better in Upper-Trop

So, need for tuning even more important?





Approach: IASI/AIRS Radiance Intercomparisons

Use two independent techniques to intercompare IASI and AIRS radiance.

1. Simultaneous nadir overpasses (SNOs).
   - IASI and AIRS in different orbits, so tight time/space overlaps limits SNOs to $\pm$73.8 degrees
   - SNOs are relatively cold spectra, esp. in window regions.
2. Double-differences of sensor biases versus model (ECMWF)
   - RTA calculations using ECMWF model data can reproduce radiances for clear ocean-only FOVs to within $\sim$0.2 - 1.0K in many channels.
   - Double differences; $(obs - cal(ECMWF))_{IASI} - (obs - cal(ECMWF))_{AIRS}$ removes most inaccuracies in the RTA and ECMWF
   - Essentially ECMWF used to interpolate over the 4 hour time difference in the orbits

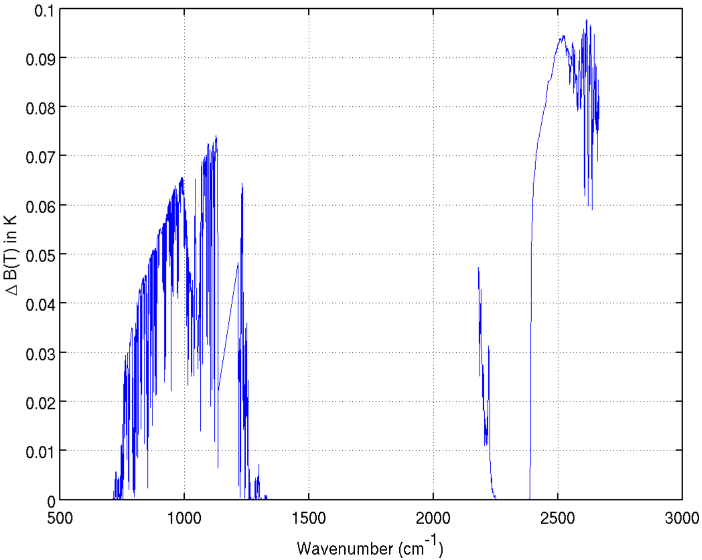
SNO Details (from Dave Tobin)

- Data from May 2007 to Feb. 2008
- Matchup thresholds are Δt = 2 minutes, Δd= 30 km, from nadir orbit crossing point
- This resulted in 284 SNO's each containing 3-4 IASI FOVs and 6-8 AIRS FOVs. Standard deviations of these individual measurements are made and propagated into means over the 284 SNO's.
- Except for shortwave, statistical errors in AIRS-IASI BT differences are roughly equivalent to the mean differences. SW statistics are not as good.
- Cross-convolve each radiance with other instrument's SRF

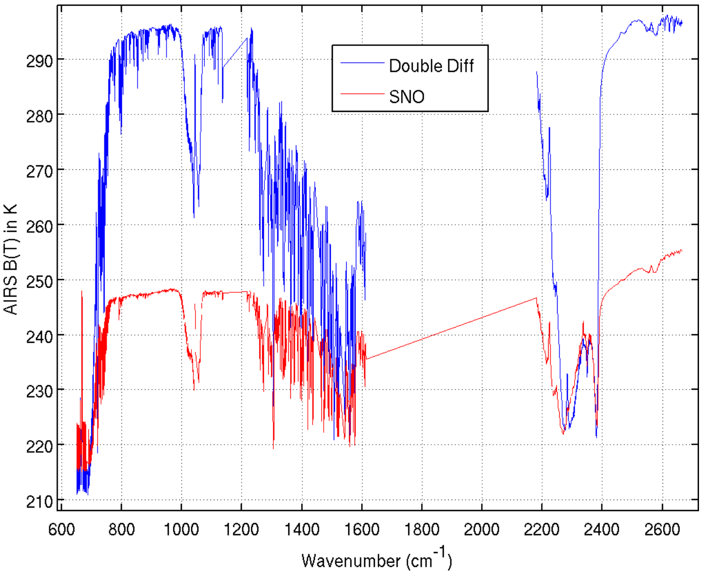
Double-Difference Details

- Observations are clear ocean FOVs for month of July 2007 for latitude range of $\pm$25 degrees, where ECMWF is very good, diurnal variations smallest
- Essential that the RTA for both instruments has identical spectroscopy.
- Avoid channels with high sensitivity above 70 mbar
- Added correction for diurnal change in SST (not done in ECMWF)
- Cross-convolve each radiance with other instrument's SRF
- In doing this work, we found a small, sampling error in our IASI RTA production that can give $\sim$0.2K errors that vary pseudo-randomly with frequency.

Diurnal Correction

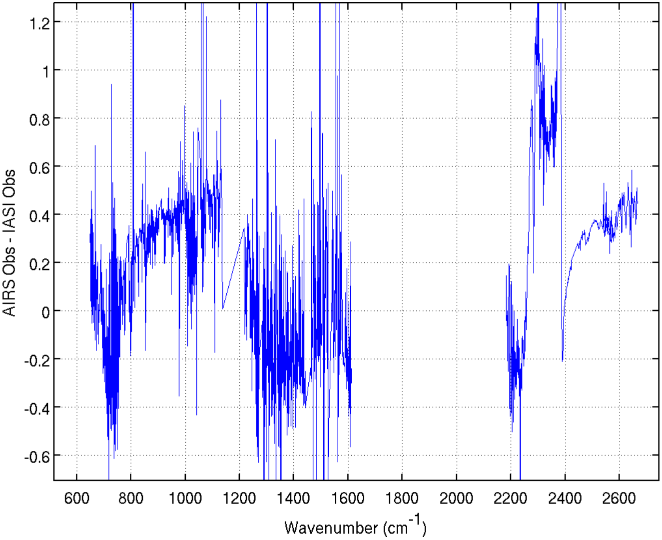


Average Spectra for SNOs and Double-Diffs

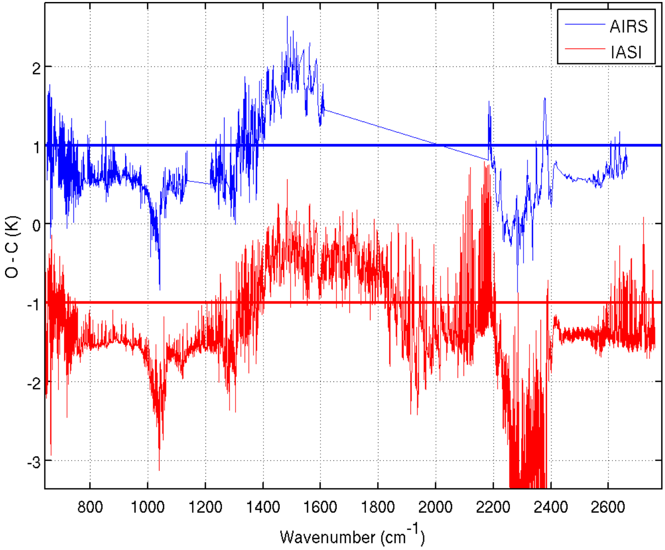


Double-Differences: Obs AIRS-IASI B(T)s

Therefore NO ECMWF calculations in this result

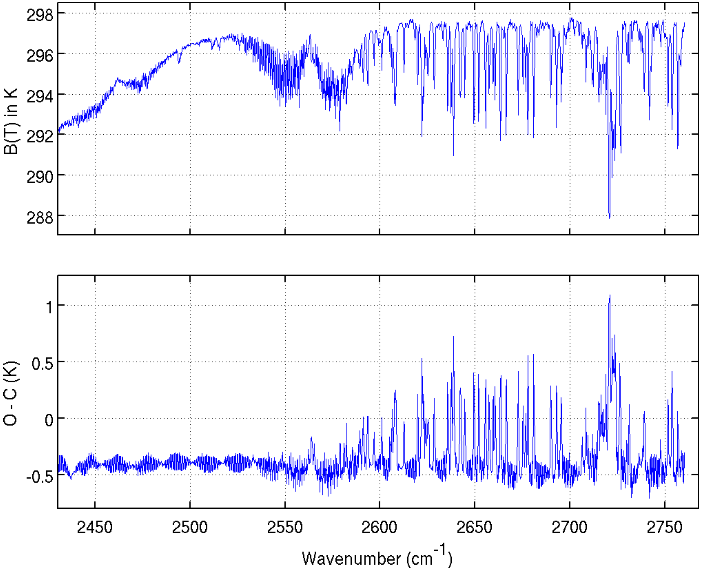


AIRS and IASI Biases vs ECMWF
No Cross Convolutions Done Yet



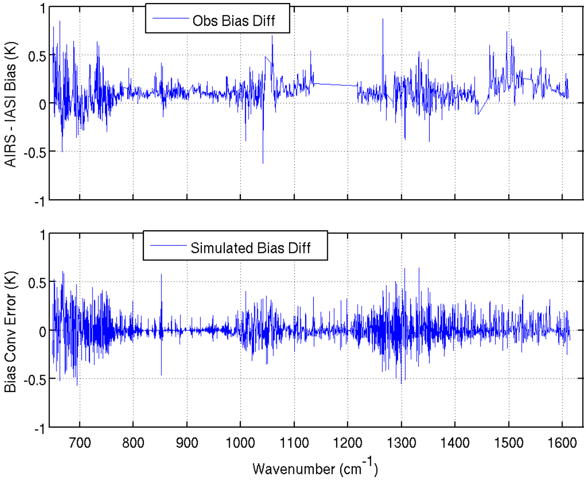
IASI Contains "Fringing" in the ShortWave

The cross-convolution with AIRS SRF averages out "fringing"

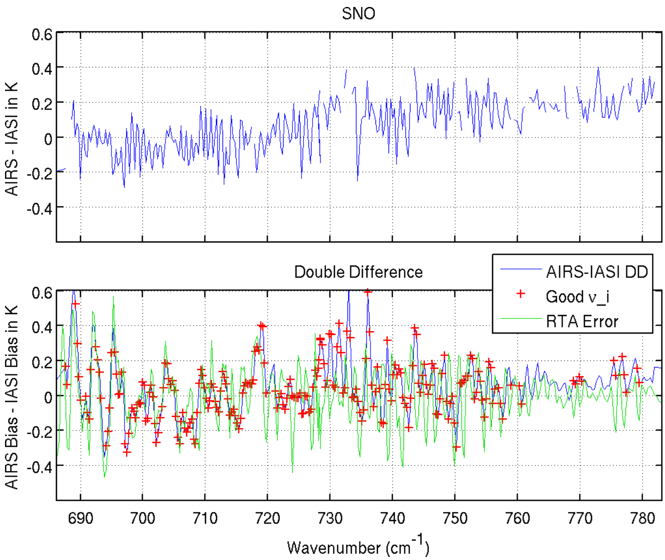


Simulated Error in Double Diff

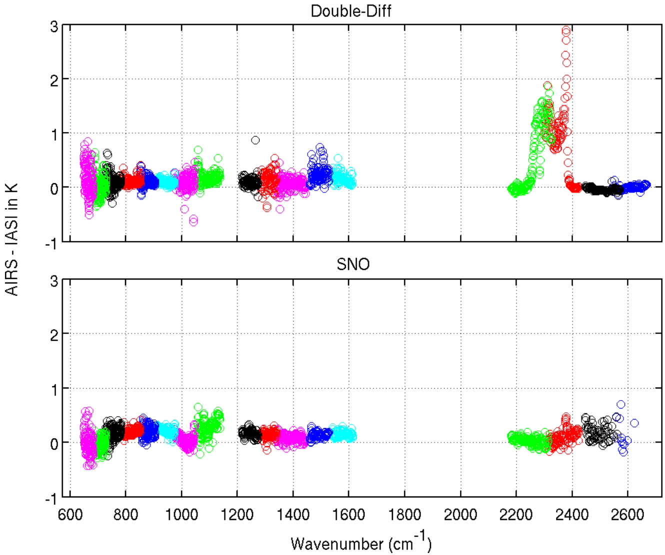
Due to need to down-sample monochromatic spectra years ago to save memory. Will be fixed ASAP! Hurts strong high-altitude lines.



Double-Differences and SNO's: LW

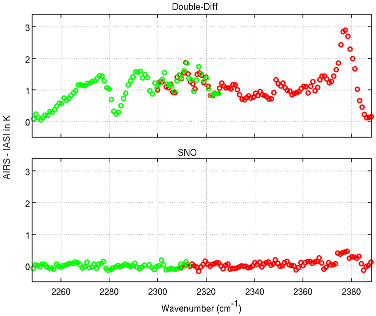


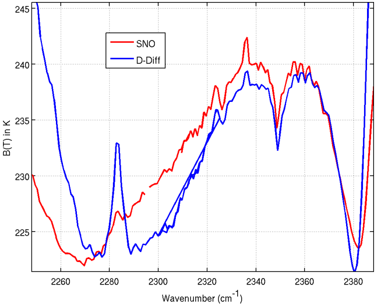
AIRS-IASI B(T) Comparisons: Summary



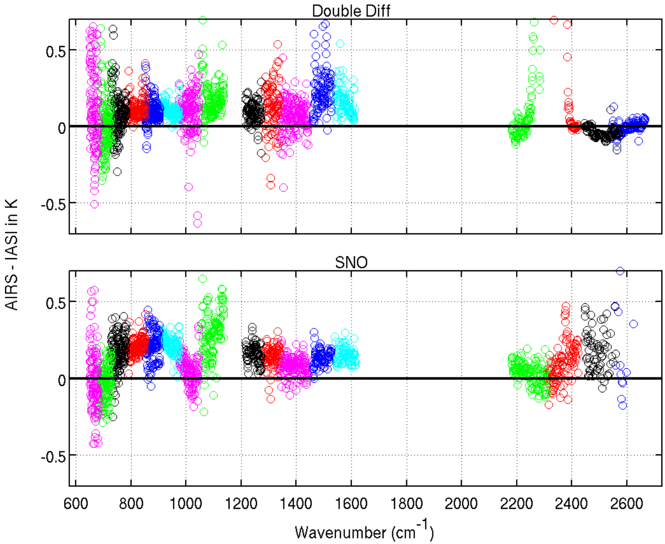
ShortWave Shows Large Differences for Double-Diff

Double-Diff B(T)'s are generally colder in this region.





Double-Differences and SNO's: Zoom



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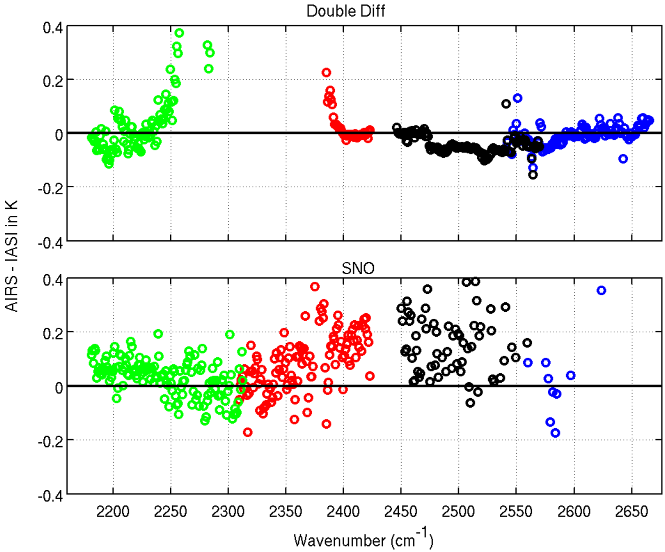

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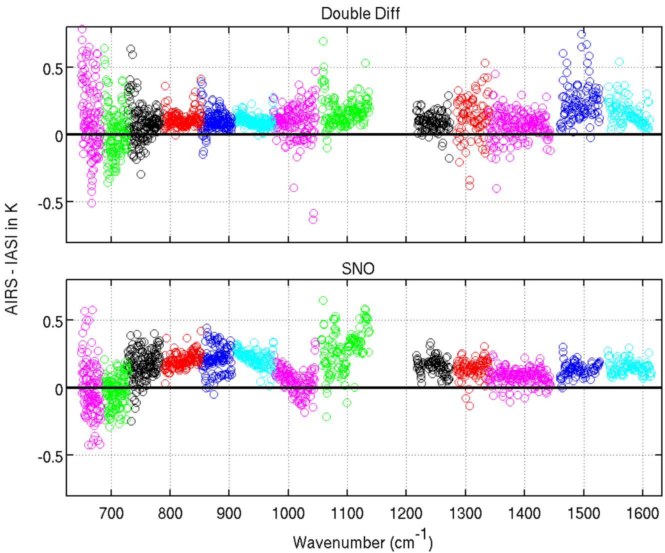

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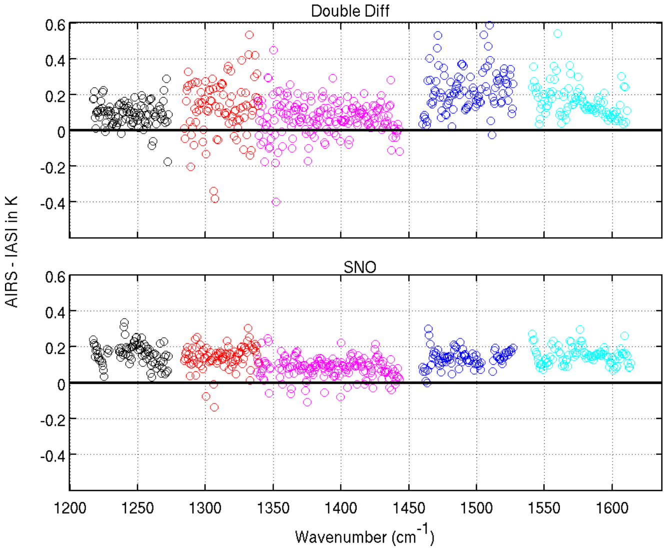
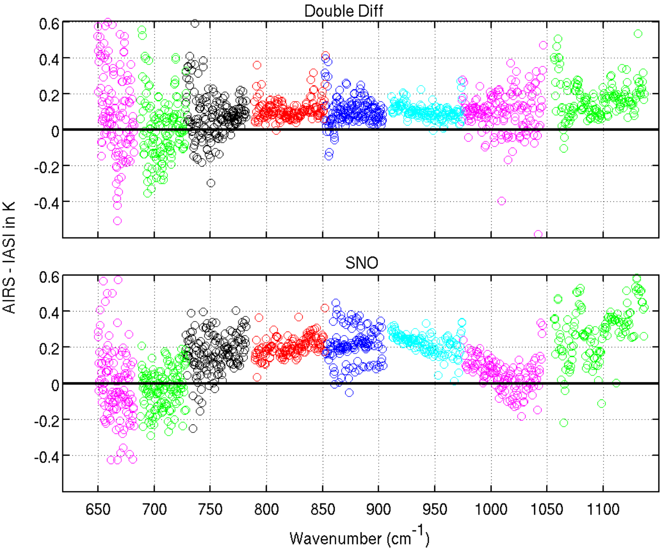
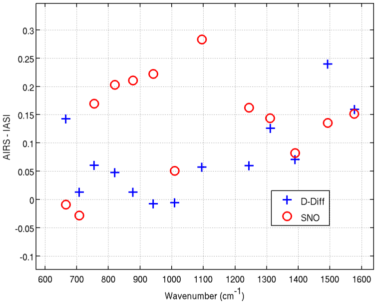
Double-Differences and SNO's: Zoom

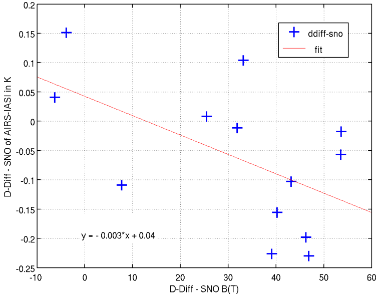


Double-Differences and SNO's: Zoom



Summary by AIRS Module





Module Statistics

For Ddiff < 1650 cm^{-1}, all channels for P < 70 mbar: 0.10 +- 0.12 K

f_mod	DDiff	SNO	DDiff-SNO	
665.46	0.10	-0.01	0.11	
707.55	-0.00	-0.03	0.03	0.02 +- 0.1
754.26	0.08	0.17	-0.09	
819.98	0.11	0.20	-0.09	
876.99	0.10	0.21	-0.11	
941.95	0.10	0.22	-0.12	-0.08 +-0.07
1009.05	0.10	0.05	0.05	
1095.32	0.16	0.28	-0.13	
1244.23	0.10	0.16	-0.06	
1311.09	0.13	0.14	-0.02	
1492.98	0.22	0.14	0.09	-0.00 + 0.05
1576.75	0.14	0.15	-0.01	
1389.12	0.07	0.08	-0.01	
2251.54	0.29	0.03	0.25	
2506.70	-0.04	0.18	-0.22	
2359.98	0.20	0.10	0.11	
2602.30	-0.01	0.15	-0.16	

Summary: AIRS vs IASI

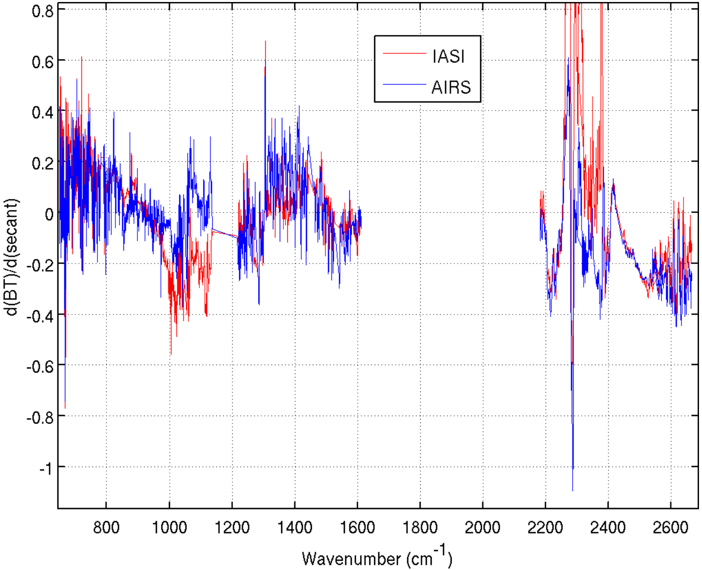
- Two approaches to IASI, AIRS inter-calibration show similar results
- Frequency calibration of AIRS not done here, will be at the 0.05K level or lower, will be ready soon for implementation
- Small IASI RTA errors limiting result, esp. standard deviations. We will build a new IASI RTA to fix this.
- Results suggest we are hitting the 0.1K level. Agreement between two approaches is getting below 0.1K
- Variability with AIRS arrays seen, suggesting adjustments may be warranted.
- More statistics needed.

Biases vs ECMWF Vary with Secant of Viewing Angle

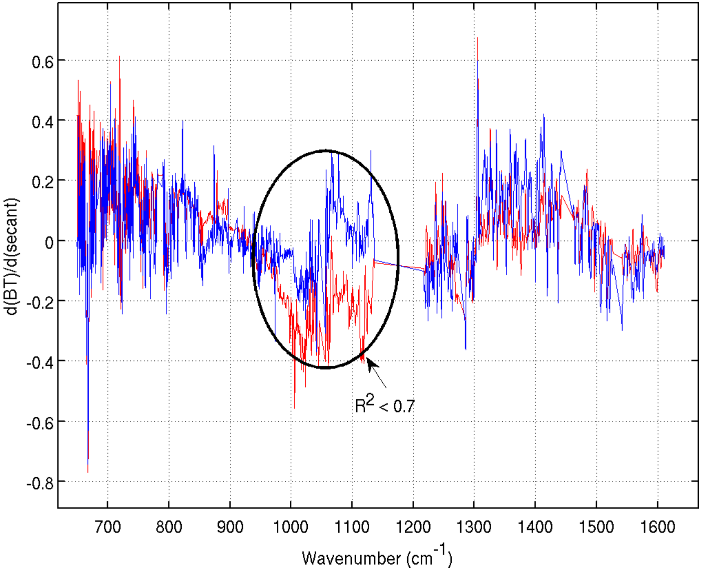
- Empirical corrections used average biases
- Spectroscopy, constituent abundance errors will vary with viewing angle/secant
- Assume ECMWF errors do not depend on secant angle
- Fit $dbias = offset + slope \times \Delta secant$; $offset$ very small
- If assume $bias = (inst\_bias, model\_bias) + slope \times secant$ can use above fit to determine slope, and then solve for (inst_bias,model_bias)
- Still need atmospheric constituent amount/profile to get spectroscopy

Fit Results: Slope of dbias/dsec

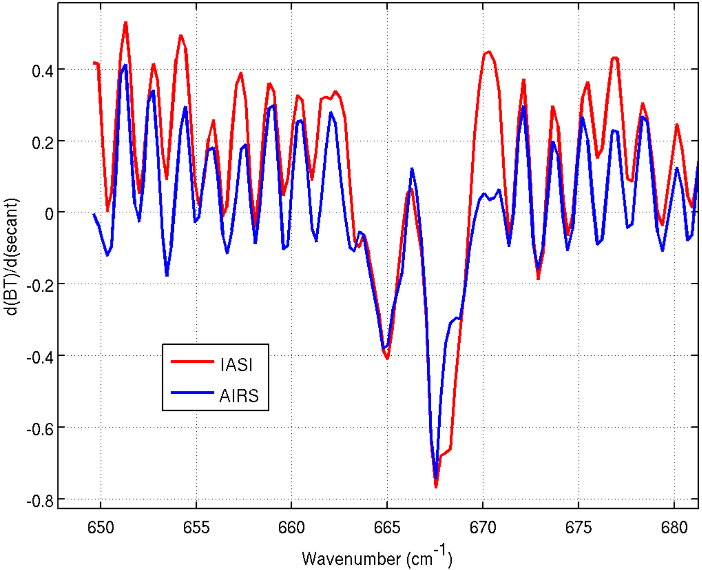
Secant varies from 1 to 1.37



Fit Results: Slope of dbias/dsec, zoom



Fit Results: Slope of dbias/dsec, zoom

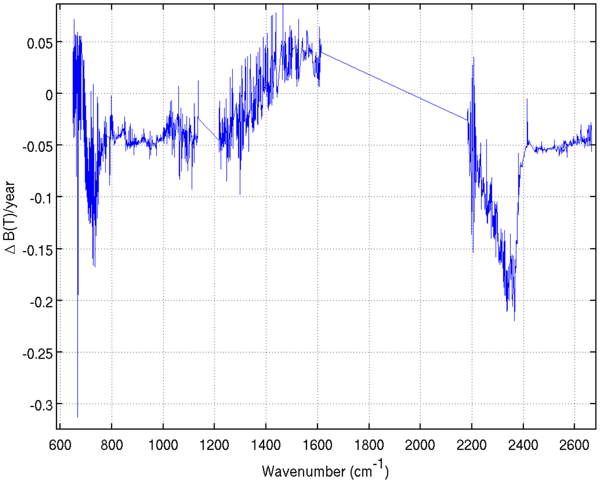


Observed B(T) Trends

- Are clear scene observed B(T) trends useful?
- Possibly for long-lived forcing constituents, like CO_2
- And for strat versus trop temperature changes?
- Input data are clear, ocean FOVs average over 1 month

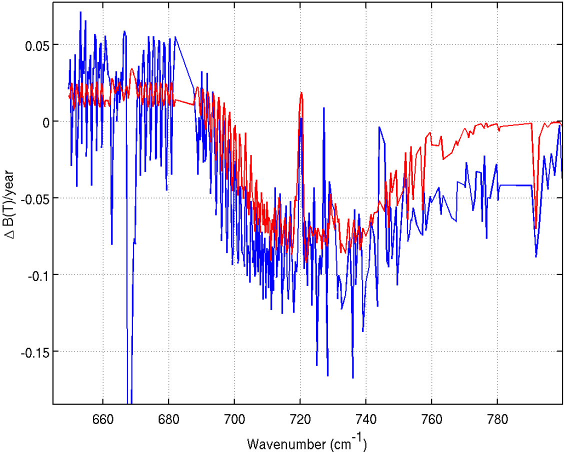
Trends in Clear-FOV B(T)'s
Rate Plotted

$$Obs\_BT(t) = C + Rate \times t + \sum_{i=1}^{4}[a_i \sin(2\pi i t + \phi_i)]$$

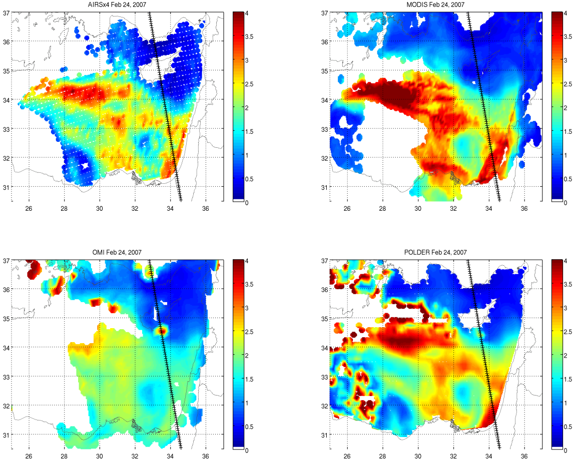


Trends in Clear-FOV B(T)'s

Red is dBT/dt for a CO_2 growth rate of 2.2 ppm/year



ODs : All instruments



TL : AIRS
TR : MODIS
BL : OMI
BR : PARASOL

Summary

- RTA accuracy might be ∼0.2K. Spectroscopy error from secant variation close to Slide 7 results from coincident sondes
- IASI and AIRS agree to better than 0.1K. Radiometric errors may depend on observed B(T). AIRS hotter by 0.1K?
- Further progress on Std. Dev. requires new IASI RTA, attention to AIRS frequency calibration
- Extremely small trends seen in clear FOV data, combination of CO_2, temperature, and H_2O
- Water trends probably not useful - clear FOVs only introduces sampling errors.