Lessons From The Airs, Iasi And Cris Hyperspectral Infrared Sounder Data

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Summary

Lessons from:

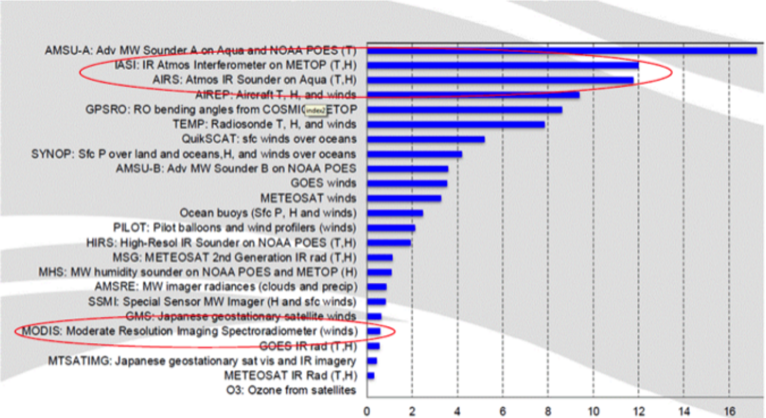
- Data Assimilation
- Calibration (esp. inter-calibration of instruments)
- Climate Studies (just starting)

We concentrate on meteorological parameters, not minor gases.

AIRS, IASI, CrIS

- Launch
  - AIRS May 2002, 1:30 PM
  - IASI Oct. 2006, 9:30 AM
  - CrIS Oct. 2011, 1:30 PM
- Data availability
  - AIRS Launch + 4 months: Sept. 2002 –
  - IASI Launch + 7 months: May 2007 –
  - CrIS Launch + 6 months: April 2012 –

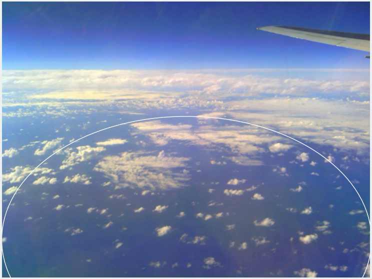
Both AIRS and IASI have more positive forecast impact than any other single instrument being assimilated



Goldberg, 2013

NWP Assimilation

Of the 3 million AIRS and 2 million IASI spectra generated every day, only 1.5% from AIRS (45,000) 8% from IASI (160,000) are typically ingested (by ECMWF), less than 0.1% are assimilated are “used”. Fewer than 350 channels are used.



A 15 km diameter nadir footprint seen from 12 km altitude 30 degree latitude N. of Hawaii

Can we improve NWP data usage?

- Build a 1 km spatial sounder to avoid clouds
- Lower data rate with intelligent filtering

Calibration

- NWP assimilation is relatively insensitive to calibration accuracy, "bias corrected" Obs-Calc is assimilated.
- However, the multiple detectors on IASI and CrIS must agree extremely well for NWP (if used).
- BUT: EMCWF only ingests:
  - Warmest of 3x3 AIRS footprints
  - Footprint #2(?) for IASI
  - Center footprint of the CrIS 3x3 focalplane
- Instrument support teams use:
  - Clear ocean (obs-calc) relative to NWP analysis
  - Simultaneous Nadir Overpasses (**SNO**) between sensors
  - Underflights of well-calibrated aircraft sensors
  - Random Nadir Samples (**RNS**)
- Climate applications require very stable calibration with overlap, and/or highly accurate calibration

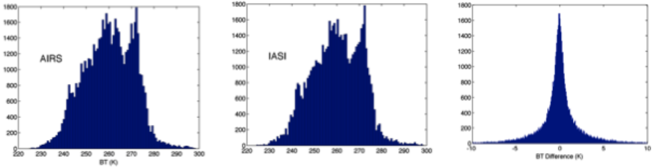
Calibration Issues for Climate

- Clear scene analysis (mostly tropical scenes)
  - Establishes stability using 2 external standard
    - SST climate data records
    - Highly accurate in-situ measurements of CO_2 growth
  - AIRS, IASI anomaly trends are $+0.8 \pm 1.1$, $+1.2 \pm 0.9$ mK/yr.
  - Stability appears to be of “climate quality”.
  - Absolute sensor intercomparison difficult: clear screening slightly dependent on observation time and FOV geometry.
- Sensor comparisons for “all scene” data needed
  - **SNO**: (AIRS,CrIS) w/ IASI limited to high latitudes, AIRS w/ CrIS can probe **all-scene** inter-calibration
  - **RNS**: (Random Nadir Samples) can, in principle, also probe **all-scene** inter-calibration

Concentrate on One Channel: 900 cm^{-1} Window

For SNO at Arctic and Antarctic latitudes AIRS and IASI agree to within 100 mK

Steps in the AIRS IASI SNO analysis



AIRS data. IASI data point by point difference.

Since AIRS and IASI are in different orbits, the SNO are in two narrow latitude band near 73N and 73S.

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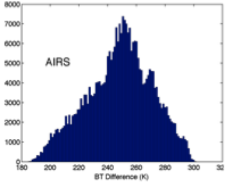
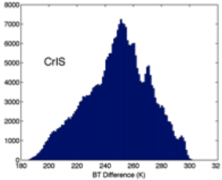
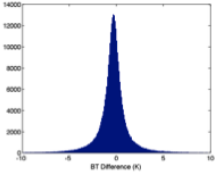
SNO from AIRS and CrIS heavily biased toward Arctic and Antarctic conditions agree within 100 mK



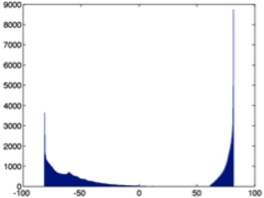
AIRS data.



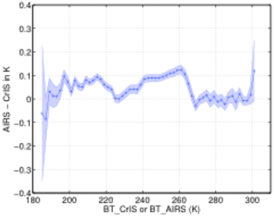
CrIS data



point by point difference.



Latitude



These results still have strong high-latitude weighting.

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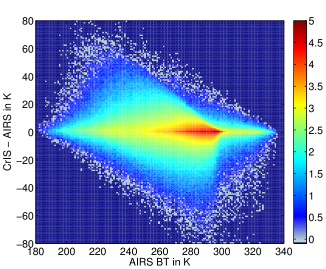
SNO Statistics vs Scene Temperature

Concentrate on window channels sensitive to clouds

SNO data highly non-gaussian, esp. tropical window channels.



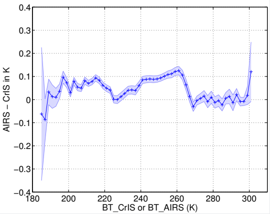
Sample population is **union** of scenes in bin for both instruments.

Different sampling shown below exhibit difference of up to 0.2K

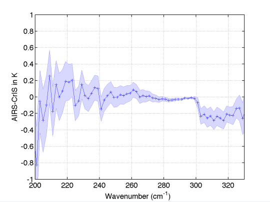
3-Sigma differences removed from both Global and Tropical SNOs

Tropical SNOs: $\Delta T \sim 12 min$, $\Delta x \sim 13 km$

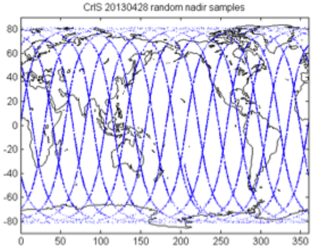
Global SNOS

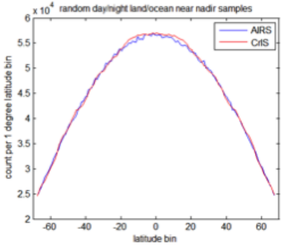


Tropical SNOs (3-Sigma Errors)



Random Nadir Samples (RNS) can be used to evaluate the calibration under global conditions





For AIRS, IASI and CrIS we use 20,000 samples per day from a 50 km wide nadir strip.

The samples are thinned at high latitudes to be area representative.

Since the orbits of AIRS, CRIS and IASI repeat every 16 days, the entire globe is covered once every 16 days.

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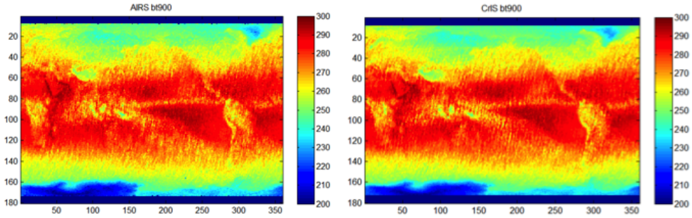
Are the RNS un-biased?

Random Nadir Samples (RNS) represent an unbiased observation of global conditions needed climate analysis



The comparison of binned mean value images on a 200K-300K scale is only a zero order test of the quality of the calibration.

We analyze PDFs generated from RNS

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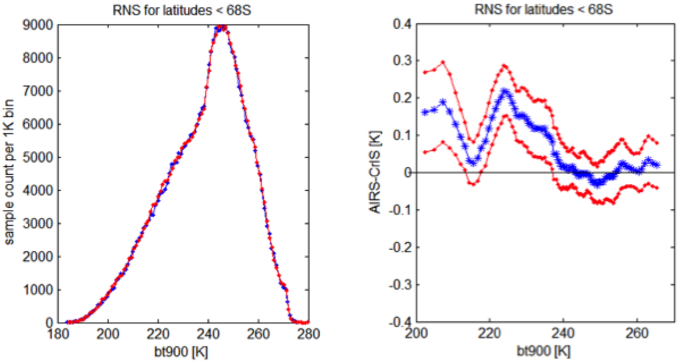
Below 68S the AIRS and CrIS PDF agree within 100 mK for temperatures warmer than 230K



AIRS mean=239.0991 xsig=16.4441 343674 pts. PE=0.02805
CrIS mean=239.1559 xsig=16.3955 305756 pts. PE=0.029651
The mean PDF from AIRS and CrIS agree within 55mK.

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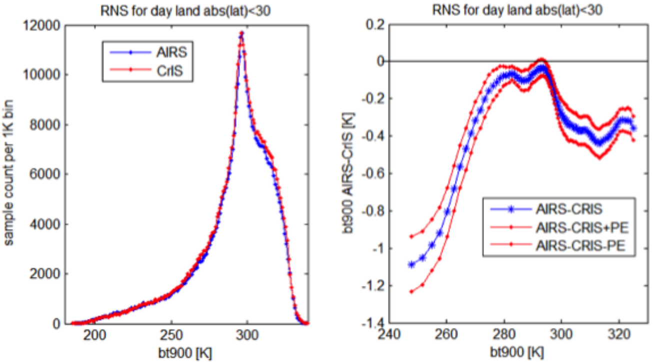
For day tropical land CrIS is much warmer than AIRS bt900<270K. The cause for this is under investigation.



The AIRS mean is 291.95K (PE=0.04K), CrIS mean is 292.32K (PE=0.04K)
The mean CrIS bt900 is 0.4K warmer than AIRS.

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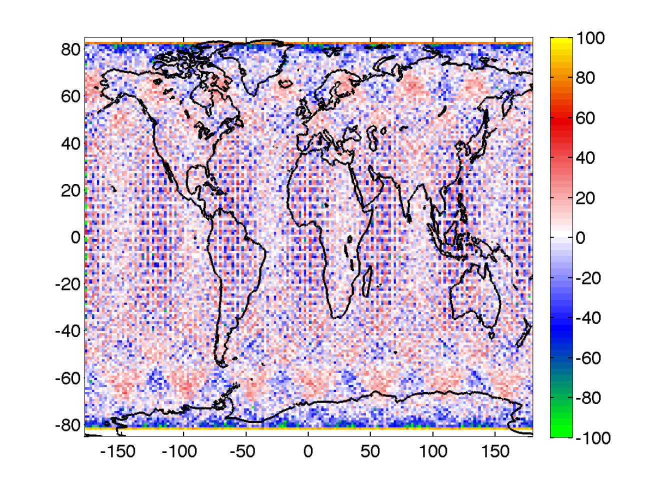
Average Time Differences: AIRS - CrIS for RNS

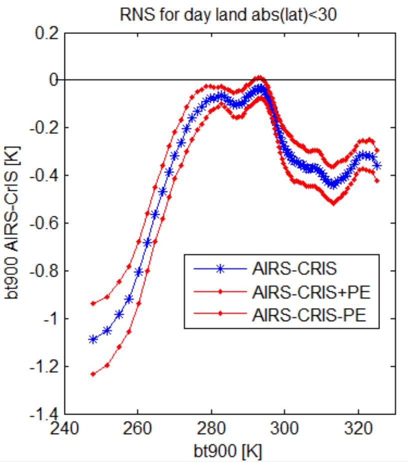
This pattern *could* lead to statistical differences among RNS data sets. Especially for relatively infrequent cold scenes.



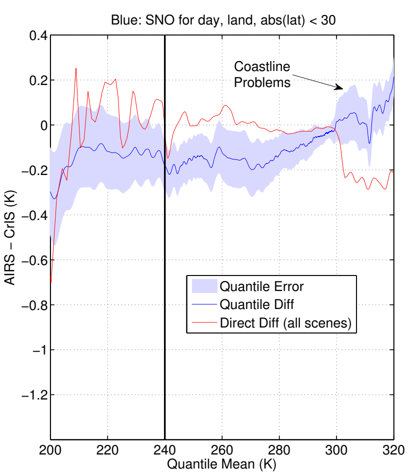
Treat SNO Data as Two Independent Data Sets

Quantile Analysis: Compare BTs with identical probabilities

RNS Approach



SNO: 2 ways

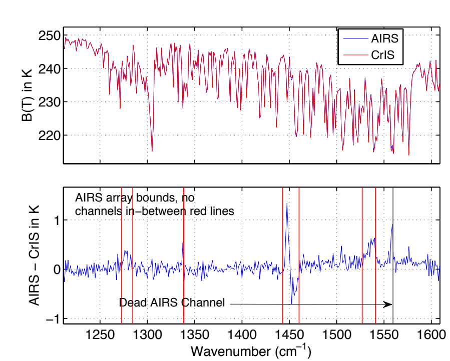


Quantile results for tropics, land, day very similar to results with all data! Is nadir enough for RNS approach?

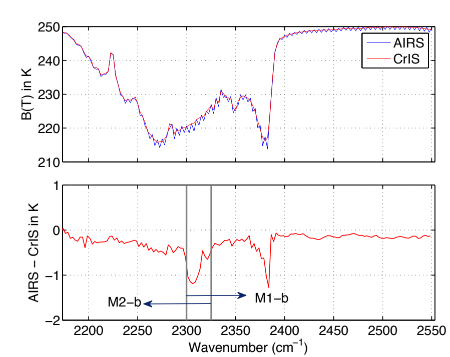
AIRS to CrIS Spectral SNOs

Pre-requisite to scene dependent SNO intercomparisons for many channels

Mid-Wave



Short-Wave
Every other point averaged



When averaged over all scenes, CrIS generally nearly identical to AIRS, or slightly warm. No statistics since the AIRS to CrIS conversion was run on averaged spectra only.

Calibration Lessons Learned

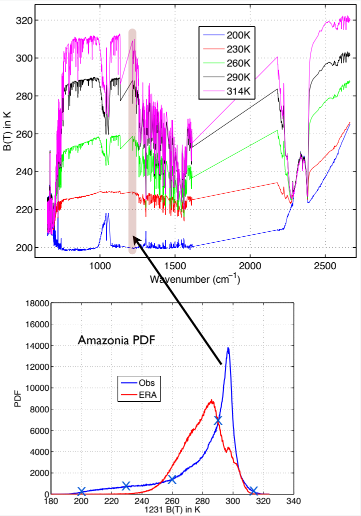
- Satellite inter-comparisons vs scene type are not easy, even if in same orbit
- Random sampling not trivial
- SNO direct differences: very non-gaussian
- SNO quantile analysis: “identical” sampling, very powerful
- Tropical AIRS/CrIS SNOs are very similar (for one window channel). Implies? CrIS image motion compensation is working well.
- Does this give us confidence in AIRS/CrIS vs IASI SNOs versus scene temperature? 2nd author thinks yes.
- SNO differences and associated errors approaching climate quality

Application of Lessons Learned to Climate Analysis?

- Assimilation, L2 retrievals have sampling problems (clouds)
- Use radiances "as long as possible" for climate trending to retain robust error estimates before converting to geophysical units
- Propose a PDF-based L3 radiance climatology
  - Hyperspectral radiances are not gaussian in space/time
  - Separate radiances into PDF bins of B(T) to achieve (a) gaussian sampling, (b) reduce non-linearity in L3 radiance averaging
- Trends in radiance PDFs should reduce radiometric accuracy requirements (see next slide)

PDF Measurement Approach

Do not average all-sky radiances.



Retain more information: PDF rates, not Radiance Rates

- Averaging clear with cloudy scenes destroys information
- Bin (create PDFs) versus variable related to cloudiness
- I used 1231 cm^{-1} channel B(T): clearest window channel
- Data Set: 10 years of AIRS, only FOVs on each side of nadir
- Bins of B(T) 1231 cm^{-1}, from 190:1:320K
- Mean BT spectra in each bin are stable versus time
- All the information is in the PDFs in each bin

AIRS and IASI PDF 5-Year Trends: High Sensitivity

Mean BT Rates (AIRS) -0.03K, -0.08K (IASI) 0.01K, 0.01K, all $2\sigma \sim 0.15K$