CrIS Spectral Calibration and Trending

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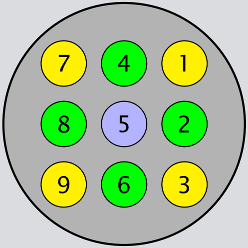
Overview

- Spectral calibration and apodization corrections
- High spectral resolution mode validation
- Methodology: Measuring excess “sinc ringing”
- Methodology and Update: Analysis of cold-scene SNOs

Terminology

LW = Long-wave band1
MW = Mid-wave band2
SW = Short-wave band3
ν = Frequency

Focal Plane FOV Definitions

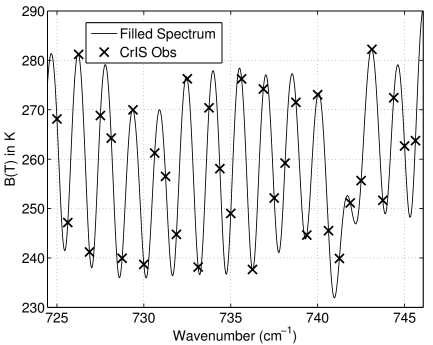


Spectral Calibration Sensitivity

Remove self-apodization and shift frequency scale

Apodization Corrections

- Adjust asymmetric off-axis FOV ILS to on-axis
- Shift spectra to fixed ν scale
- Performed with CMO operator
- Requires: focal plane geometry, ν of metrology laser



Adjustments can be very large: 20K+

1 ppm ν calibration error = $\pm$0.06K in B(T)

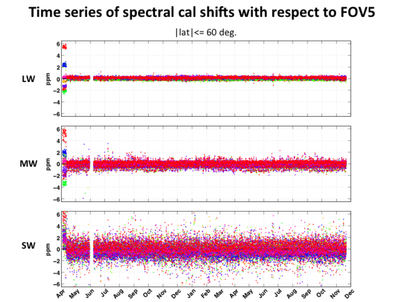
CrIS ν calibration specification is 10 ppm

NWP applications require uniform calibration among FOVs

Relative ν Calibration

- ν calibration relative to center FOV (FOV-5)
- Provides FOV positions relative to interferometer optical axis which are used to generate self-apodization corrections.
- Tables below are ν calibration errors (ppm) relative to FOV-5.

From Dave Tobin/SSEC



LW		
0.20	0.03	0.03
0.15	0	0.03
0.15	0.12	-0.01

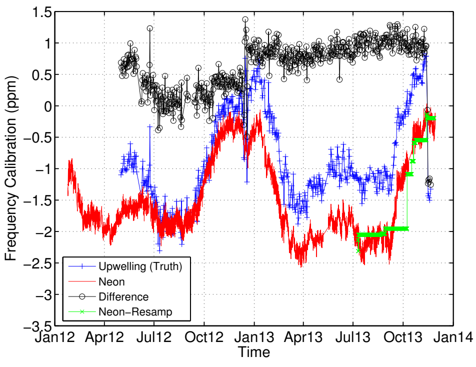
MW		
-0.23	-0.12	-0.31
0.14	0	0.00
0.03	0.12	-0.18

SW		
-0.06	-0.41	-0.68
-0.04	0	0.10
0.27	-0.64	-0.08

Self-apodization parameters well characterized and very stable. FOV frequency mismatches due to incorrect focal plane geometry should be well below the 1 ppm level except possibly for short-wave.

Absolute ν Calibration (units are ppm)

- Based on CCAST radiances
- Feb. 2012 CCAST agreement with TVAC Neon Cal: 0.6 ppm, so Neon cal *not changed*
- Absolute ν calibration with IDPS SDRs problematic: Neon lamp value used in CMO unknown until Nov. 2013
- Largest ν error: IDPS requires 2 ppm Neon change to update



Absolute LW ν Calibration (CCAST SDRs in Feb. 2012)

0.1	-0.0	0.0
0.1	-0.6	-0.5
-0.8	-1.0	-0.4

SW Aug. 28 ν Cal (hi-res mode)

0.08	-1.37	-1.25
-0.72	-0.53	-1.85
-0.46	-1.10	-1.16

Mean/Std over FOV: -0.93 $\pm$ 0.58 ppm

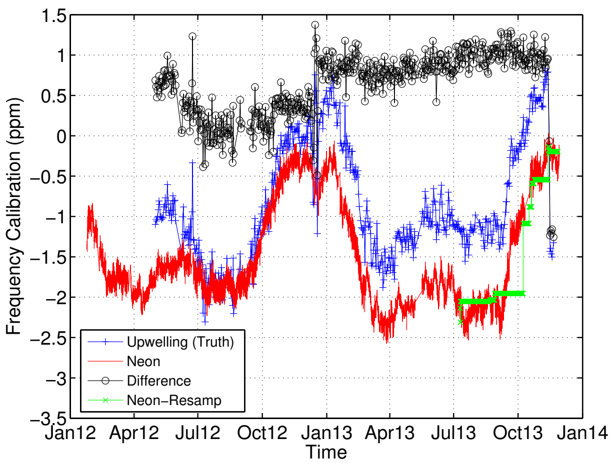
LW ν Cal minus Short-wave ν Cal

0.02	1.37	1.25
0.82	-0.07	1.35
-0.34	0.10	0.76

Mean/Std over FOV: 0.58 $\pm$ 0.67 ppm

The LW and SW spectral calibration agree to <1 ppm (using CCAST).

Absolute ν Calibration: Figure ZOOM

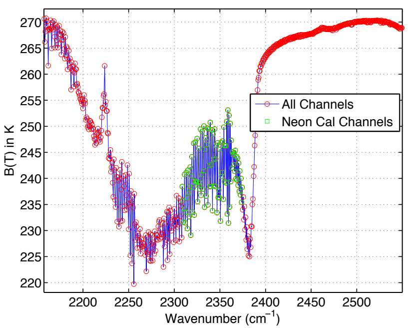


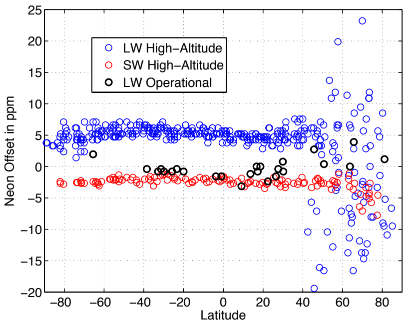
- Data using IDPS long-wave SDRs; Very few updates due to 2 ppm threshold
- SDR's exhibit ~3 ppm variability
- Correct operation of CMO generation started in Nov. 2013

IDPS Upgrade

- Feb. 2012: IDPS ILS parameters for FOVs (1:4, 6:9) fudged due to suspected SDR algorithm code errors for FOV 5. CCAST SDR results did not show these errors.
- Yong Han found three errors in computation of FOV5 CMO operator, fixed in ADL.
- Fudge removed in new ENGR packets and tested via 1-day of ADL runs done at UW. Now using original CCAST derived ILS parameters.
- UW relative ν calibration and UMBC absolute ν calibration from new ADL SDR radiances proved that IDPS FOV-5 errors had been corrected.
- IDPS may start using corrected SDR code and new ENGR packet in Feb. 2014.

Short-Wave ν Calibration



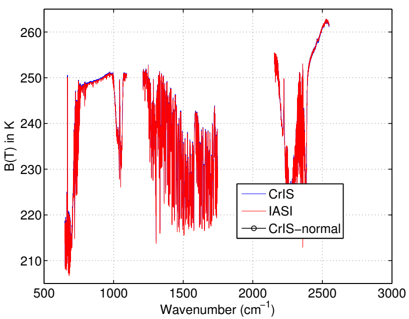


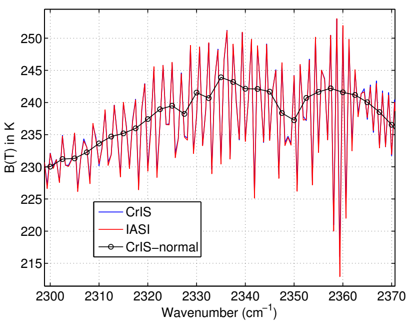
- Shortwave (SW) at high spectral resolution provides very good ν calibration
- Spectral region used by IASI for all ν calibration
- SW channels emit in upper-strat/mesosphere. This will allow nearly continuous spectral calibration during each orbit, unlike LW.

High Spectral Resolution Validation

- Validate Aug. 2013 high-spectral resolution data
- CCAST used to generate high-spectral resolution SDRs
- Lien: No non-linear corrections for mid-wave (coming soon)
- Validation approach 1: SNOs versus IASI converted to CrIS ILS
- Validation approach 2: Analyze biases versus computed radiances using ECMWF and SARTA Radiative Transfer Algorithm (RTA)

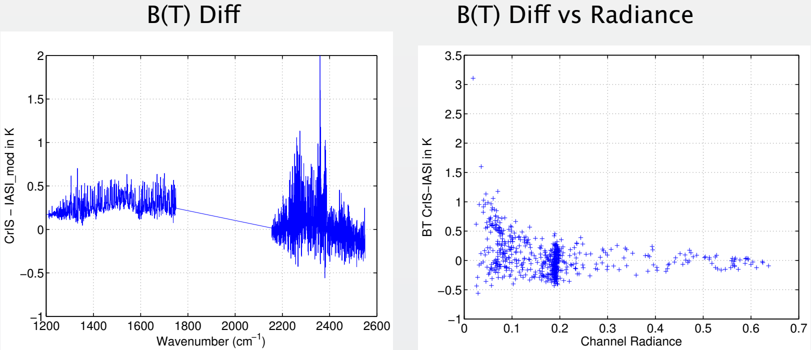
High Spectral Resolution SNOs with IASI





- SNO agreement is very good
- Black circles on right graph show CrIS at normal mode resolution
- Line structure in 2330 cm^{-1} region provides very good spectral calibration throughout most of an orbit

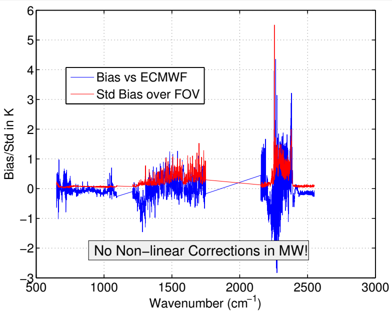
High Spectral Resolution SNOs with IASI: Details



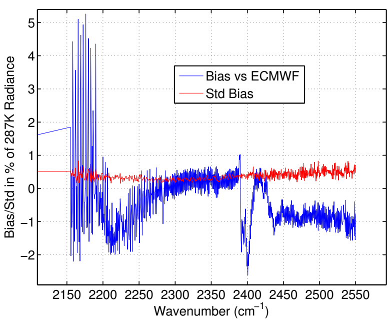
- Note: No non-linear corrections in mid-wave band
- Short-wave agreement very good (this is sinc ILS!)
- Larger BT differences in cold channels, noise related.

High Spectral Resolution NWP Biases

B(T) Bias
STD over FOVs



% Radiance Bias
STD versus ECMWF



- Relatively good agreement with ECMWF (clear ocean tropical)
- Std of bias over FOV implies accurate SW ILS corrections
- Ringing in short-wave accentuated by cold scene temperatures
- Short-wave % radiance bias shows ringing is constant over band
- Incorrect CO in RTA gives high bias errors

Method for Observing Excess Sinc Ringing

(See Dan Mooney's presentation for more information.)

- The CrIS ILS specification is sinc ILS.
- Most RTAs simulate apodized radiances.
- Ringing artifacts far smaller than RTA + NWP simulations.
- Enhance visibility of non-sinc ringing with differences ($D_{1,2,3}$)

$$D_1 \equiv \text{bias}_{ILS} = BT_{obs,ILS} - BT_{calc,ILS}$$

where ILS = Hamming or Sinc. $BT_{calc,Hamming}$ is RTA simulation from ECMWF. The Hamming forward operator reduces sinc ringing by an order of magnitude. Create $BT_{calc,Sinc}$ with the inverse Hamming operator.

$$D_2(sweep\_dir) \equiv (\text{bias}_{sinc} - \text{bias}_{Hamming})_{sweep\_dir}$$

highlights non-sinc ringing. *sweep_dir* selected using odd or even FORs. Differential ringing bias with sweep direction is then

$$D_3 \equiv D_2(odd\_FOR) - D_2(even\_FOR)$$

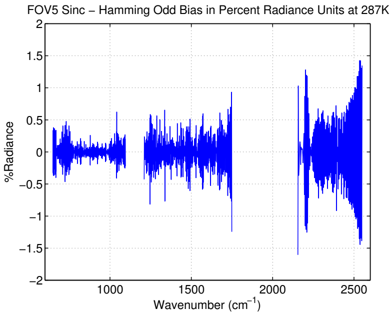
This approach removes model, RTA, and smooth radiance calibration errors, leaving non-sinc ringing in D2 and D3.

Examples of Sinc Ringing Metric

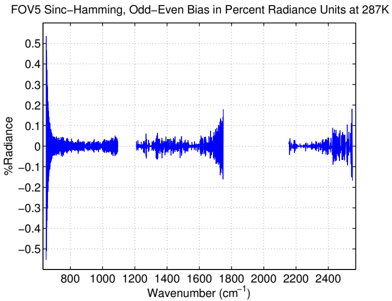
Errors shown as percent of a 287K blackbody radiance

- Left hand side: This shows the excess (non-sinc) ringing in the CrIS spectra for odd FORs. It is quite large for the short-wave.
- Right hand side: Here we form the triple difference, by subtracting the odd FOR ($\mathrm{bias}_{sinc} - \mathrm{bias}_{Hamming}$) from the same quantity but for even FORs.

$D_2(odd\_FOR)$



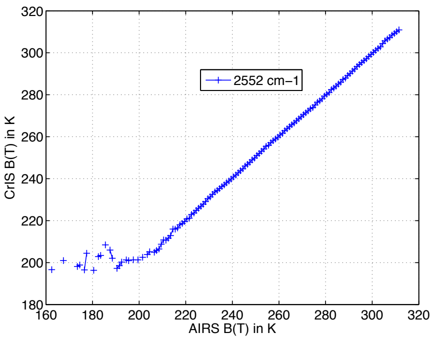
D_3



SNOs: Improved Methodology

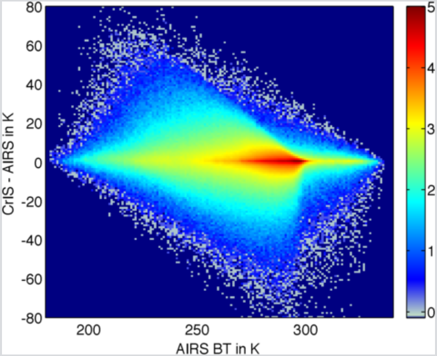
Corrects error in last SDR Review

Last Review



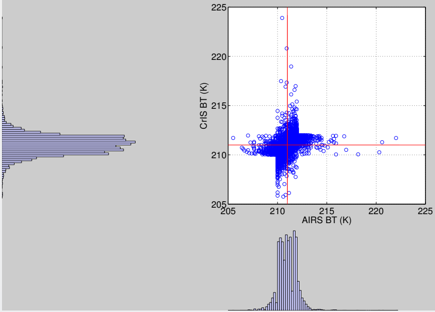
CrIS B(T)'s are warmer when AIRS SNO B(T)'s are cold.

Methodology Error

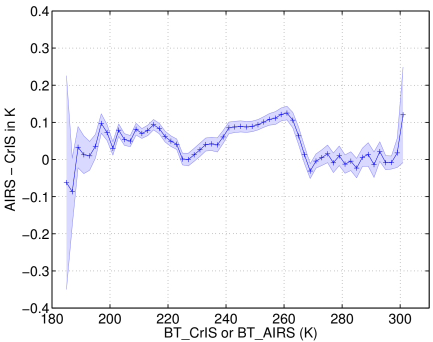


Scene subset selection based only on one sensor is biased and non gaussian. Subset on union of scenes with AIRS *and* CrIS B(T)'s within some B(T) bin. Color scale: log(counts).

Proper SNO Scene Selection and Binning



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

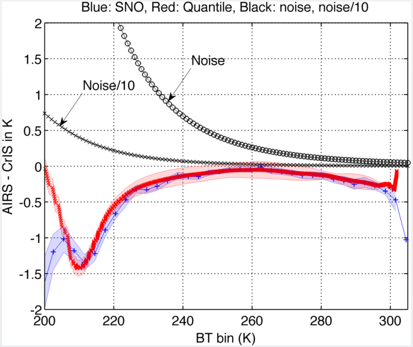


Global SNO versus scene temperature for ν=900 cm^{-1}.

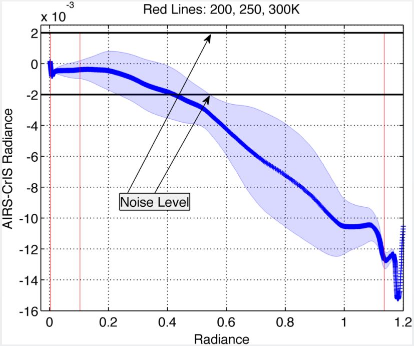
See Dave Tobin's presentation for detailed SNO results.

Shortwave Cold Scene SNOs

Re-visit data shown in previous review



No 10K issues as before. SNO differences *far* below noise. Both standard SNO and quantile results shown.



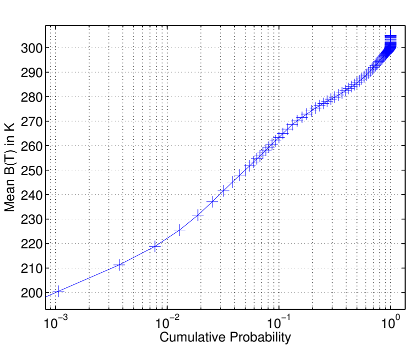
Same data as on left, but plotted versus scene radiances instead of B(T). Note noise level. This is quantile result.

Short-wave cold scenes: Too sensitive to noise, avoid. However, inter-comparisons with AIRS are very good, but not perfect. No cold scene issues relative to AIRS.

Conclusions

- CrIS IDSP SDR spectral calibration good to ~3 ppm.
- CrIS instrument and up-welling ν calibration capable of ~1ppm absolute and <0.5 ppm relative ν calibration.
- Achieving instrument capabilities require removal of IDPS 2 ppm threshold for computation of new CMO. Can be achieved by interpolation of CMO operators (very smooth) as done by CCAST.
- Metrology laser drifts track instrument temperature variations. (Not discussed.)
- High-spectral resolution mode working very well, short-wave agreement with IASI to ~0.1K, accurate ILS corrections.
- High-spectral resolution mode spectral calibration very accurate, can be used over much of each orbit.
- Improved methodology for SNOs shows that CrIS and AIRS agree very well for cold scenes (in all bands).

Quantile Analysis of SNO Data



Why Quantile Approach?

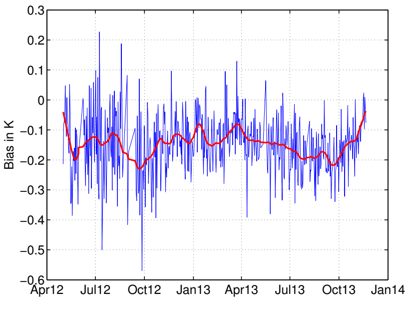
- Tropical SNOs have large differences (small cold clouds)
- Limited # of cold SNOs, poor statistics
- Quantile analysis quantifies statistical distribution of each instrument SNO radiances independently
- Allows larger data sets?

- Select a cumulative probability vector $p = 0.0001{:}\delta P{:}1.0$
- Sort radiances by value, find mean radiance in each δP bin.
- Distribution difference is difference in radiance/B(T) associated with same cumulative probability bin.

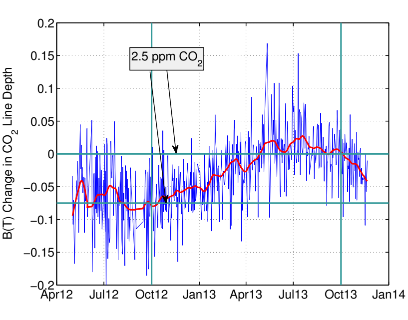
Does not require subtraction of SNO pairs, which may have very large B(T) differences (especially in the tropics).

CrIS Radiometric Stability

Relative to SST, CO_2



- Tropical ocean clear
- 1-Year differences far below 0.1K. Red curve is smoothed time series.



- CO_2 from ECMWF bias (791.5 cm^{-1}) - 0.27*bias(790 cm^{-1}).
- Second term removes any SST, H_2O variability.
- Oct 2012 through Oct 2013 shows 2.5 ppm growth rate (0.06K).