CrIS SDR Product Review
UMBC Validation Status

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October 23, 2012

Overview

- Frequency calibration
- Short-wave high-resolution mode results
- Radiometric validation
  - Internal consistency (among FOVs)
  - Relative to AIRS, IASI (SNOs)
  - Relative to AIRS, IASI (Double Differences)

Main Results

- Frequency calibration working very well
- SDRs exhibit boxcar ringing inconsistencies: up to 1K
- Hamming apodization reduces these problems significantly
- Comparisons to AIRS, IASI within 0.2K or less
- Evidence for a ~0.2K systematic calibration error in far long-wave
- High resolution works very well!

CrIS Frequency Calibration: Two Distinct Parts

Pseudo ν Cal: Alignment of detectors (Tobin)

- Detector offsets from interferometer axis produces frequency shifts
- Corrected with CMO operator, once 3x3 positions known
- In-orbit 3x3 positions determined from *relative* frequency offsets
- Original plan: Absolute shifts using B(T) Obs vs Calcs, gives both offsets and Neon cal.
- Relative approach more accurate (Tobin), < 1 ppm LW, MW, SW maybe 2-3 ppm?

Absolute Calibration: Upwelling ⟶ Neon Lamp ⟶ Met Laser

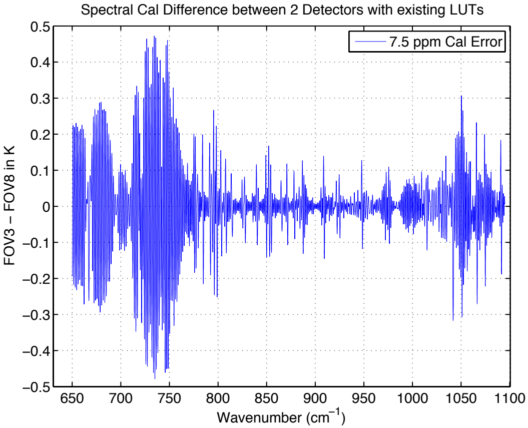
- Neon spectral calibration and alignment to interferometer axis needed.
- ITT expected 1/month Neon calibration (so far not needed).
- In-orbit Neon calibration done using LW window regions, sharp water lines on flat background. Limits one to very clear ocean scenes.
- Unable to achieve similar accuracy with opaque channels in LW or MW.
- SW hopeless for Neon calibration with 0.2 cm OPD.

Present Focal Plane Positions and Neon Calibration

- The Neon lamp calibration was determined using data from Feb. 25 LW window region observations.
- Errors in treatment of FOV5 in IDPS SDR code forced us to “fudge” the positions of the remaining 8 detectors in the LW and MW arrays.
- These adjustment were small, LW=1.4 and MW=2.2 ppm. Not sufficient information to modify SW.
- Formal monthly Neon calibrations are presently not being done. Only offline at UMBC.
- Has production of new CMO operator happened? Maybe soon?

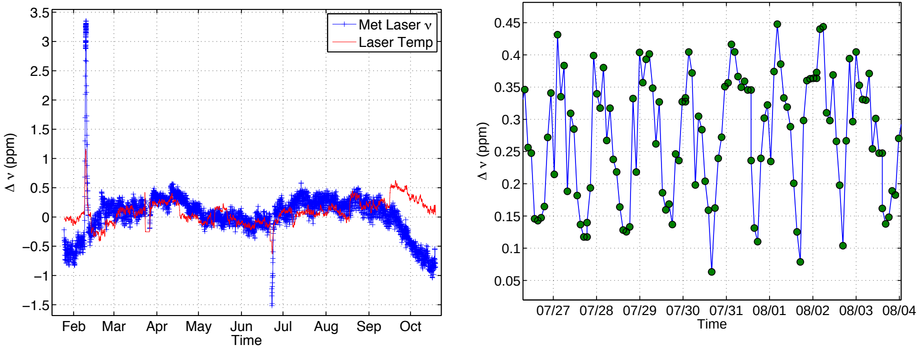
ν Calibration Overview

- CrIS In-orbit Neon Cal unchanged from TVAC!
- Examine time series of Neon calibration using (a) Long-wave and (b) Mid-wave bands.
- Calibration done daily using clear ocean tropical subsets



Metrology Laser Wavelength vs Time

Left: Metrology laser λ (and temperature) versus time a/c to Neon lamp, **Right:** Zoom showing daily variation.

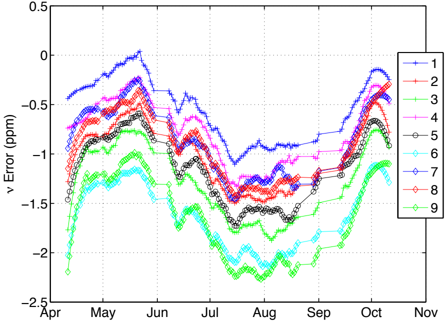


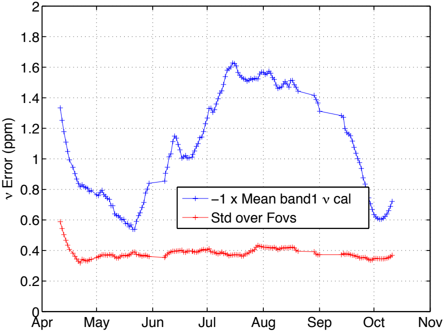
Linear drift starting in mid-September when temperature offset occurred?

CrIS Frequency Calibration vis Upwelling Radiances

Using Long-wave Band

Left: All fovs, Right: Mean and Std (over FOVs)



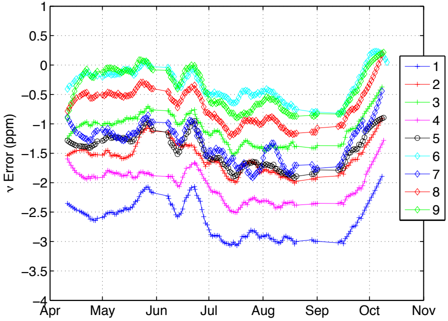


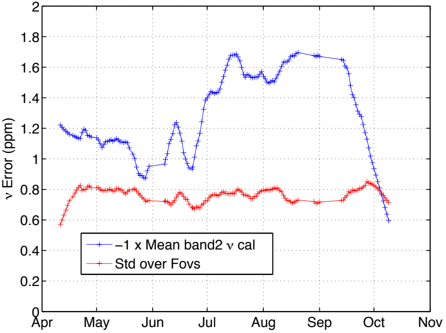
Upwelling frequency calibration mirrors the Neon calibration of the metrology laser. If the CMO has not been updated (waits for a 2 ppm change), this means the metrology laser has indeed drifted. If the Neon was drifting, we would not see the same shift in the upwelling spectra (again assuming the CMO operator remains unchanged). Slight differences among FOVs.

CrIS Frequency Calibration vis Upwelling Radiances

Using Mid-wave Band

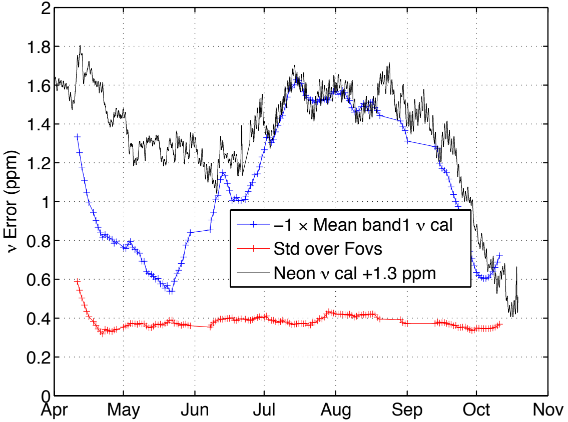
Left: All fovs, Right: Mean and Std





The mid-wave frequency calibration shows a frequency drift very similar to long-wave. I do not know why the mid-wave frequency calibration varies by up to 3.5 ppm among FOVs. We saw this in the Feb. 25 data. D. Tobin's relative calibration indicates this is incorrect.

Neon vs Upwelling ν Calibration

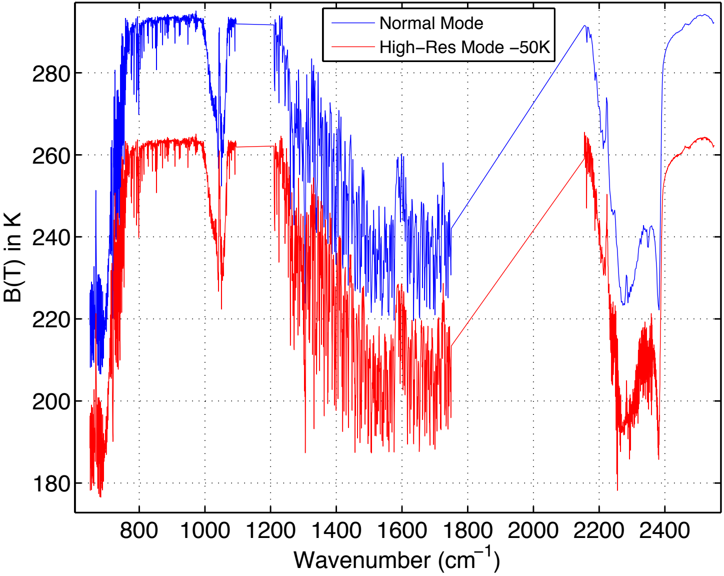


SDR algorithm waits for a 2 ppm Neon shift to re-compute new CMO
Presumably that has not yet happened, so cannot test
Thus, upwelling calibration *roughly* follows Neon
Differences may be upwelling algorithm issues?

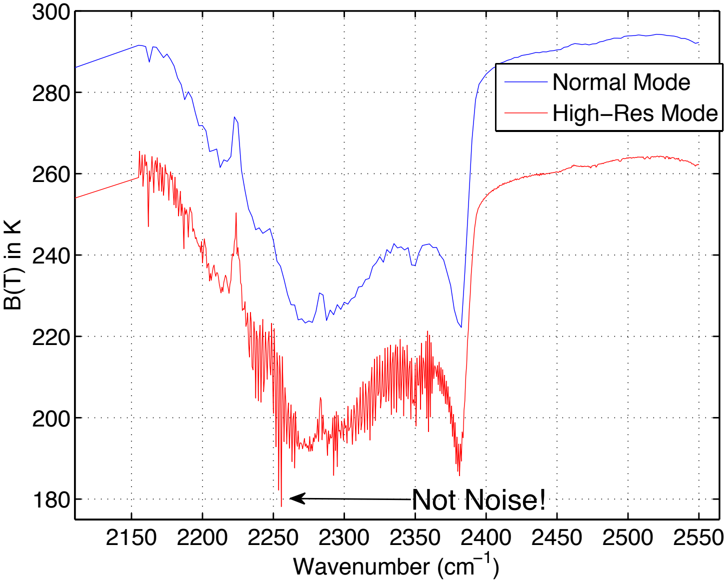
CrIS High Resolution Mode

- UMBC has processed all the CrIS high-resolution mode data from Feb. 23, 2012 into calibrated radiances using CCAST
- Liens on these radiances:
  - Non-linear correction not applied (no effect on shortwave)
  - Nominal geolocation (good enough for most purposes)
  - Not in SDR format
  - Uses our best-effort CMO apodization removal operators from the July time-frame.
  - These data recorded with the old FIR decimation filter
- We have computed clear-sky observed radiances for every observation
- For a single southern ocean granule we have compared these data to IASI data in the same region, suitably degraded to CrIS 0.8 OPD resolution.

Example High-Resolution Spectra

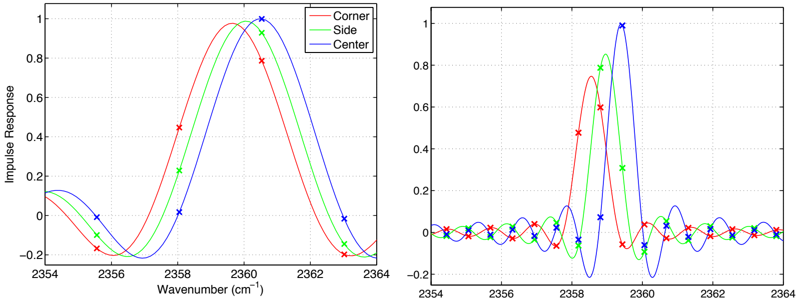


Example Spectra: Shortwave Only



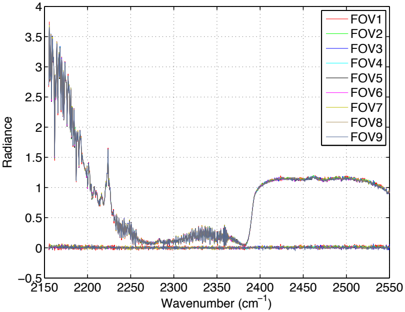
High-Resolution CMO Operator

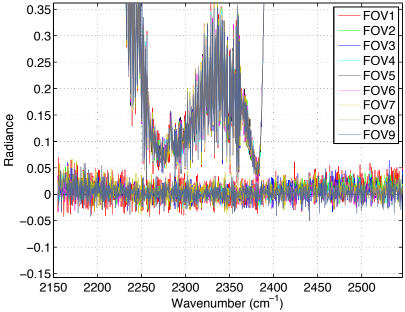
- UMBC developed a high-resolution CMO operator
- Matrix inversion to derive CMO operator condition number goes from 1 for center FOV to 10^6 for corner FOVs.
- With careful filtering, high condition number can be handled
- Note below: large relative ν offset of off-axis spectra; Left: Normal Mode, Right: High-resolution Mode



Relative Error in CMO Corrections

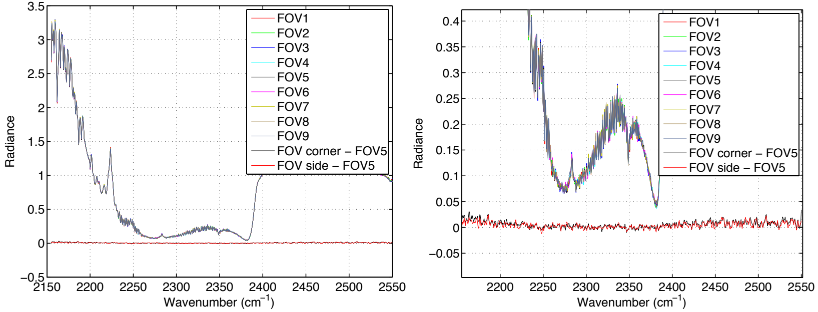
Plot shows single uniform 3x3 spectra
Difference curves (from FOV5) are uniform in frequency
Correction errors close to radiances values for cold observations.





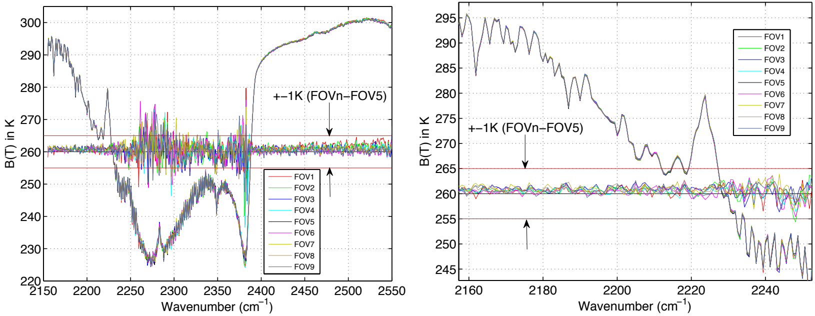
CMO Correction Errors Reduced with Hamming Apodization

Same data as in previous slide, but Hamming apodized

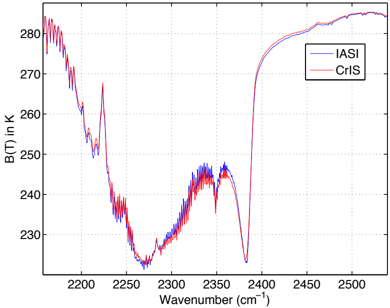


CMO Correction Errors in Brightness Temperature: Hamming

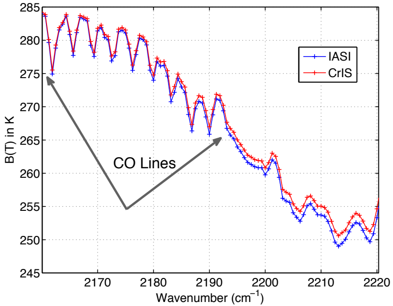
FOVn-FOV5 differences multiplied by 5X and offset by 260K



High-Resolution Validation: CrIS vs IASI B(T)



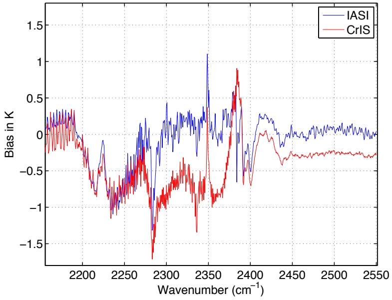
(a) CrIS/IASI Obs, Hamming Apodized.



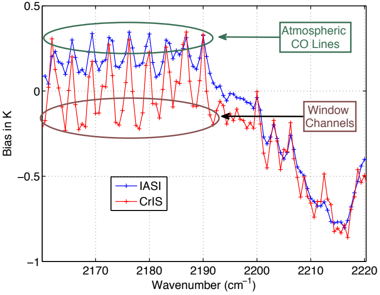
(b) CrIS/IASI Obs, Hamming Apodized: Zoom.

High-Resolution Validation: CrIS vs IASI Biases

Biases with respect to ECMWF



(c) CrIS/IASI Bias, Hamming Apodized.

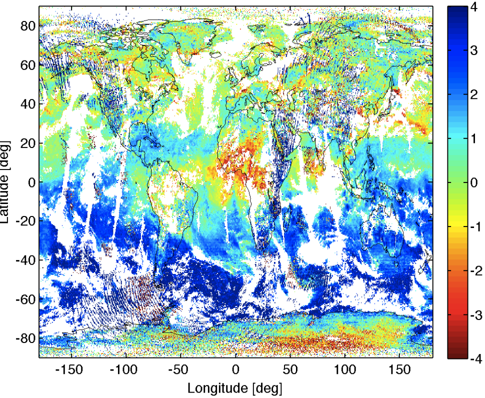


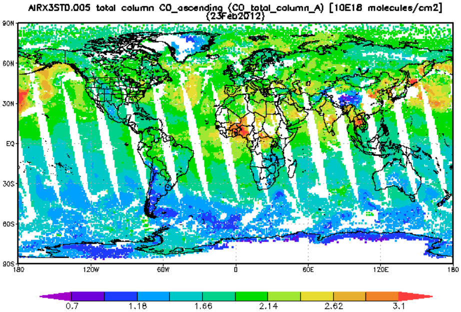
(d) CrIS/IASI Obs, Hamming Apodized: Zoom.

Note in (c,d) above, one expects IASI and CrIS window channels to differ by 0.1K due to diurnal variation in the SST. Here we use a constant diurnally averaged SST. Thus, the bias difference between CrIS and IASI is about 0.1K less than shown here for window channels!

CO Retrievals from High-Resolution Mode Spectra

Left: CrIS, Right: AIRS   Color Scale in K

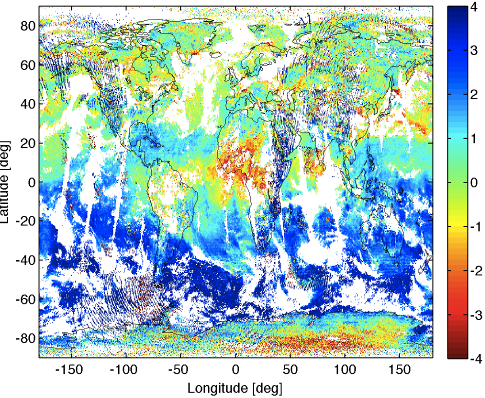


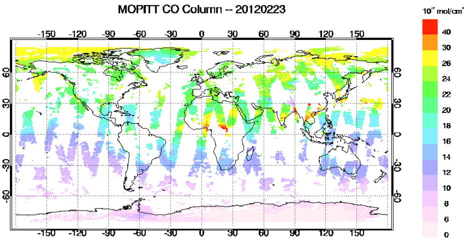


"Retrieval" is just bias between Obs and Calc radiances for a single CO channel.
Calc radiances use ECMWF.
Remove scenes where window radiance bias > 5K (Clouds).

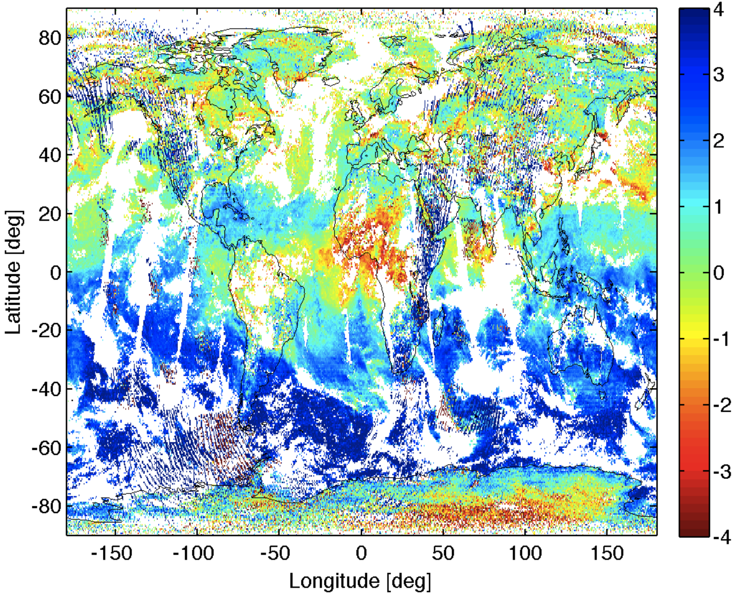
CO Retrievals from High-Resolution Mode Specta

Left: CrIS, Right: MOPPIT





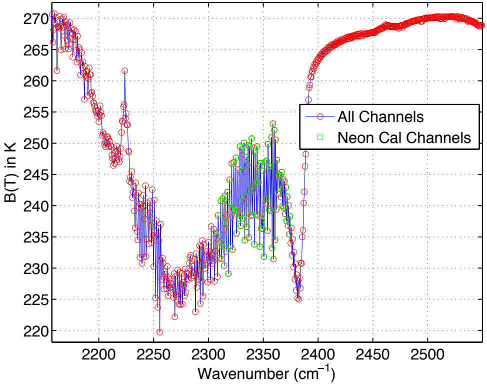
CO Retrievals from High-Resolution Mode Specta



Frequency Calibration Using High-Resolution Short-Wave

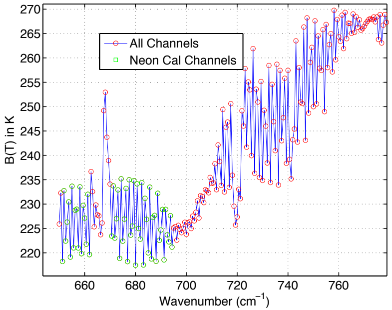
- High-resolution data used to calibration Neon, 1 day's worth
- High-resolution brings out very stable features with spectral contrast

High-Resolution SW Calibration of Neon

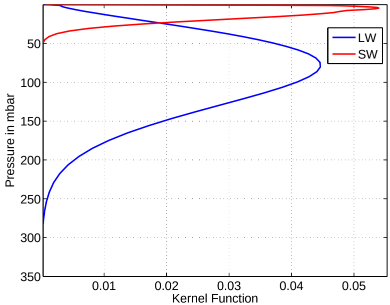


- Existing Neon calibration limited to non-polar clear ocean scenes (more below).
- As previously stated, unable to achieve high Neon calibration accuracy with opaque LW, MW channels, which would allow calibration over the entire orbit.
- High-resolution in the SW allows us to use the very high-peaking lines in the 2350 cm^{-1} region, indicated by green circles above.

LW Opaque Channel Calibration of Neon



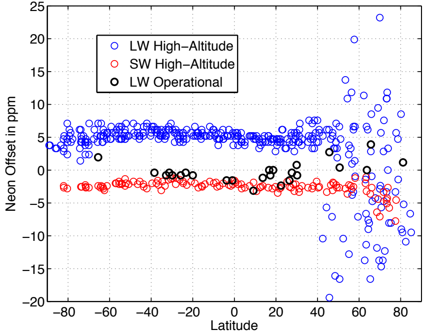
(e) LW opaque Neon cal channels.



(f) LW vs SW cal channel kernels.

- Opaque LW channels include emission from 200 mbar. Leads to inaccurate NWP calculations (clouds, polar) with poor performance in the polar night.
- Moreover, LW opaque channel frequency calibration not accurate; presumably due to NWP radiance calculation errors.
- With high-resolution, can use extremely high-peaking CO_2 channel (5-10 mbar, 30+ km) with very good performance.

Final Results: Neon Frequency Calibration



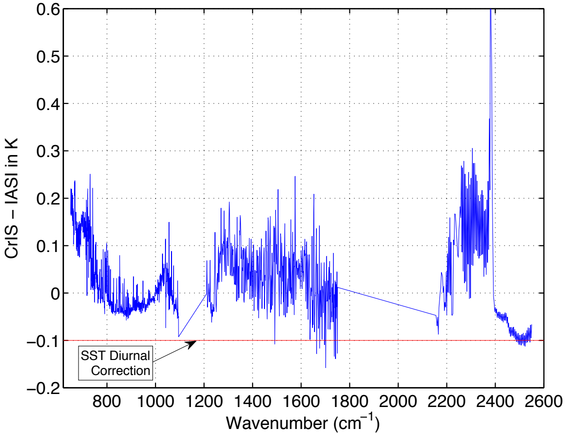
Each circle represents a 360 second period that allowed an accurate calibration.

- Present operational Neon: black circles, LW window, $\pm$ 40 degrees latitude.
- LW opaque channels provide more observations (blue circles). But, apparent 5 ppm offset, and very poor performance in the polar night.
- SW opaque using CrIS high-spectral resolution mode gives extremely good performance, low noise, well into the polar night portion of the orbit.
- SW high-resolution agrees very well with LW window region Neon calibration, maybe 1 ppm.
- IASI (METOP-A/B) uses these channels for all metrology laser calibration for all three bands.

Radiance Intercomparisons

Following slides are a small sample of radiometric intercomparisons between CrIS and AIRS/IASI.

CrIS and IASI Double-Difference

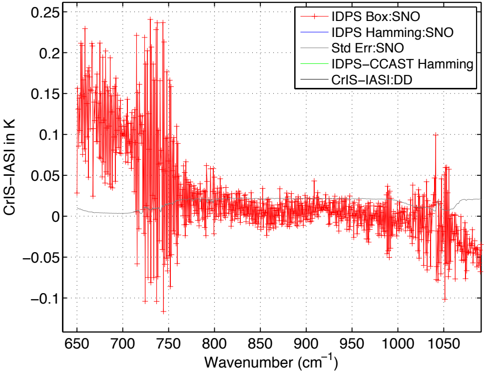


CrIS Bias vs IASI Bias (relative to ECMWF), tropics, ocean only

Very good agreement. But SST in calcs off by 0.1K! (maybe)

CrIS and IASI SNOs + DDs: SNOs for May 2012 (LW)

SNOs from JPL Sounder PEATE: 10 min, 8 km windows, S. Hemis: -73 deg S.



CrIS-IASI boxcar apodization has large ringing. Uncertain to cause, used all 4 IASI FOVs, all 9 CrIS FOVs for now.

Significant (for climate) offset in the longwave!

Red curve is CrIS from CCAST (UW/UMBC Matlab SDR testbed algorithm). CCAST much closer to IASI, but more work needed.

CrIS-IASI DD is bias double-difference from ECMWF

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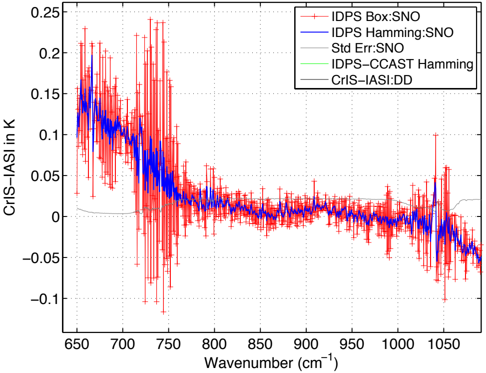

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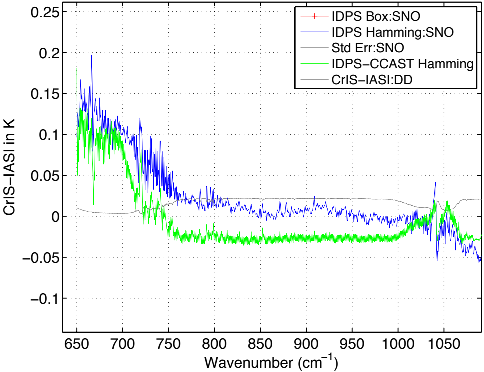

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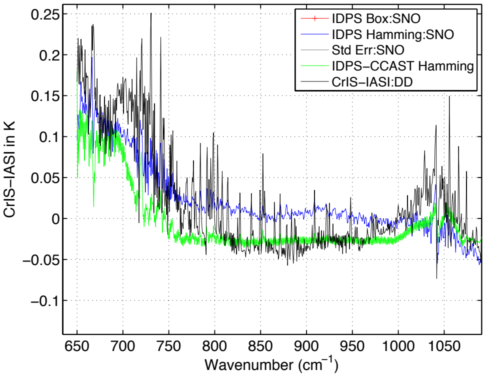

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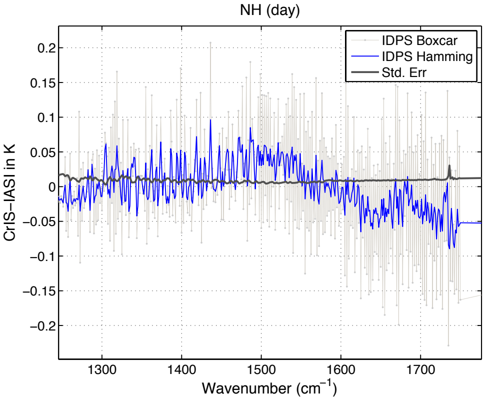
CrIS-IASI DD is bias double-difference from ECMWF

CrIS and IASI SNOs: Data for May 2012 (MW)

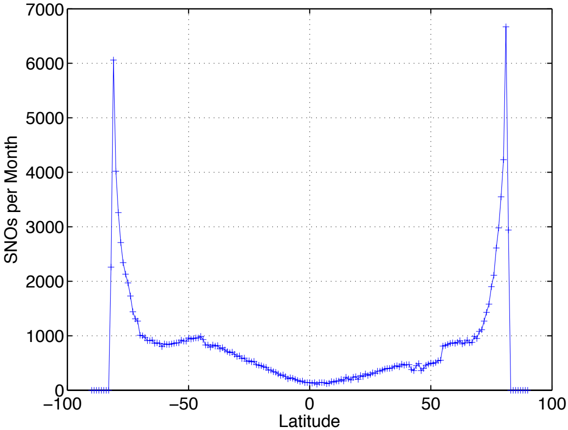


CrIS-IASI boxcar apodization again has ringing.

Very good agreement. Can we determine interconsistency below 0.05K?

CrIS-AIRS SNOs Locations

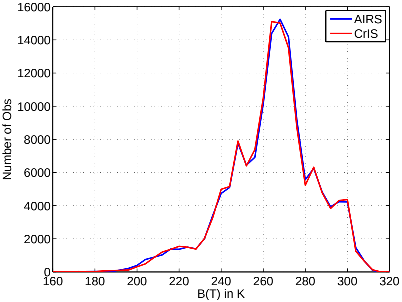
With 10-min,8 km window obtain full latitude range!

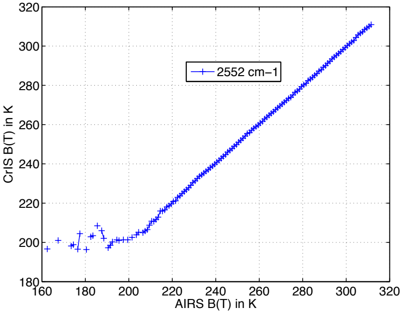


Unlike IASI-AIRS or IASI-CrIS, wide latitude range of SNO's.

This allows very detailed inter-comparisons as a function of scene type. Here we examine SNO differences with scene temperature for one channel.

2552 cm^{-1} SNOs for AIRS, CrIS



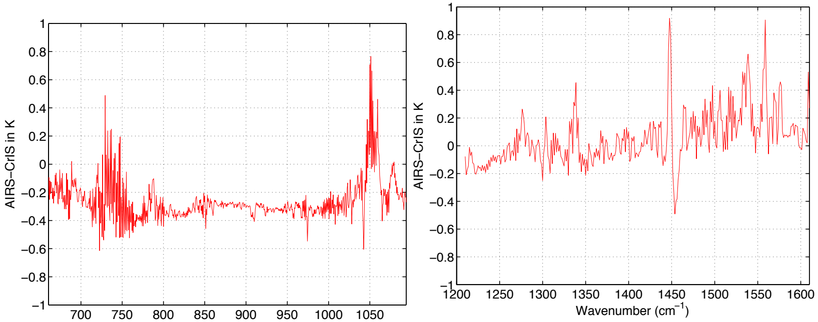


Good number of SNOs over a large range of B(T)'s

CrIS hits a B(T) floor around 200K.

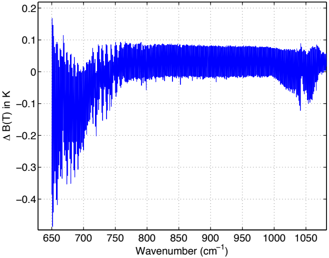
SNO AIRS-CrIS: Longwave

Early Global SNO Comparisons Using AIRS-to-CrIS Conversion

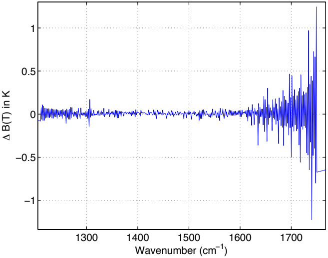


CCAST vs IDPS: Avg Radiometric Differences

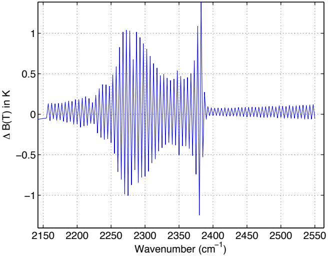
Longwave



Midwave: 0.006K



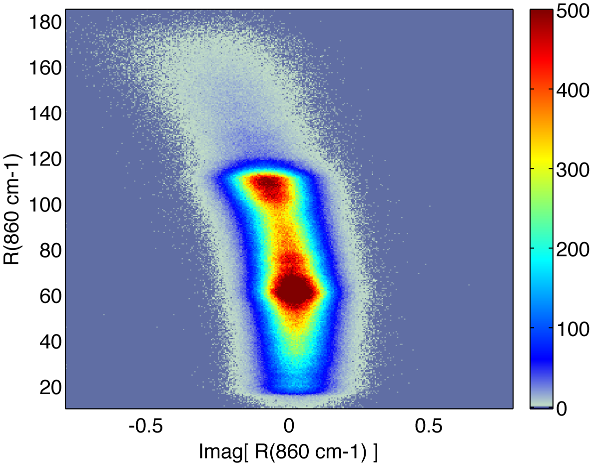
Shortwave: 0.03K



- Longwave: FOVs 1-3,4-6
- Midwave: FOVs 1,6,9
- Averaged over all FOVs for shortwave (no non-linear)

Possible Errors for High Temperature Scenes

Real part of 860 cm^{-1} vs Imaginary Part



Color scale is number of observations