CrIS Spectral Calibration

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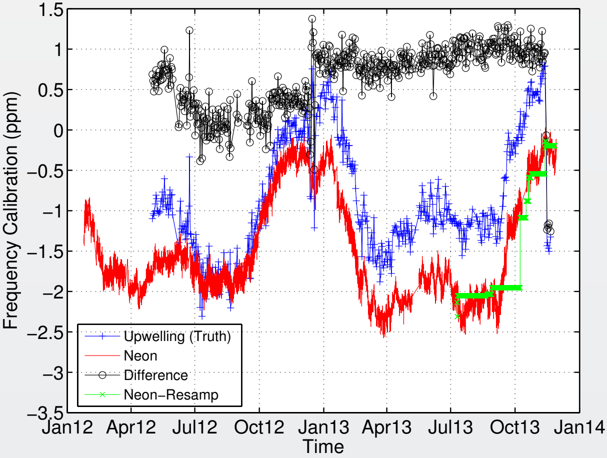
Overview

- Spectral calibration performance: Neon stability
- High-resolution spectral improvements: Period Sinc basis
- Full spectral comparison with AIRS via SNOs

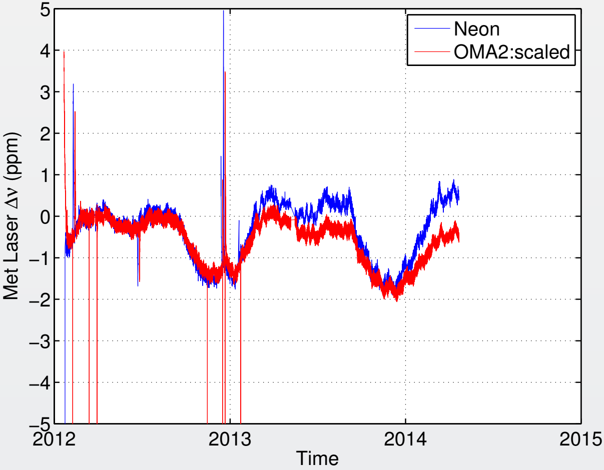
Absolute ν Calibration: IDPS SDRs



- 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

2-Year Neon Calibration Record

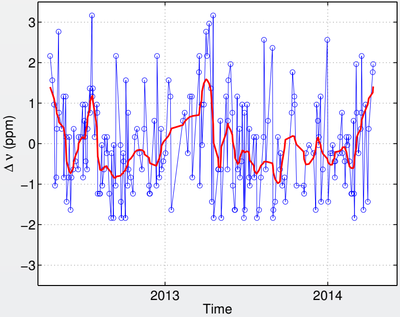
Metrology Laser Wavelength Follows Thermal Environment?



- Question: Is any of this drift due to the Neon lamp? Original plans were to update the Neon calibration via up-welling radiances 1/month.
- Difficult to use IDPS SDR record for this since Neon cal used in IDPS uncertain until Nov. 2013.

2-Year Neon Calibration from CCAST

CCAST: UW/UMBC SDR Testbed Code



- Reprocess 2 years of SDRs with CCAST using metrology laser that follows Neon calibration exactly.
- Normal ν-cal compares observed to NWP simulated radiances: not yet finished.
- Here: compare (via cross-correlation) April 2012 scene radiances to time series of a small clear subset of CCAST output.
- Regression of drift over 2 years: -0.07 ppm ± 0.54 ppm
- Excellent long-term stability

This approach introduces noise, we will soon finish matching 2-years of CCAST output to NWP (ECMWF) and will have a much lower noise Neon calibration to determine if it is drifting and needs any updates.

The results shown here suggest no long-term drifts, but possibly a small seasonal drift with solar heating of the instrument.

CCAST SDR Cal Approach for This Work

$$r_{\mathrm{OBS}} = F \cdot r_{\mathrm{ICT}} \cdot f \cdot \mathrm{SA}^{-1} \cdot f \cdot \frac{\mathrm{ES} - \mathrm{SP}}{\mathrm{IT} - \mathrm{SP}}$$

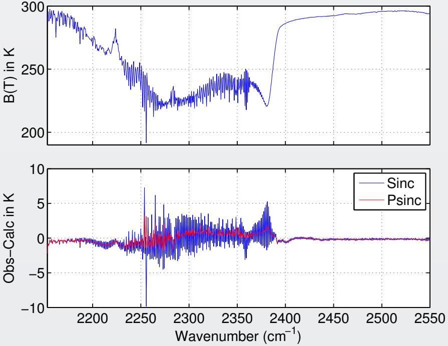
- r_{OBS} is calibrated radiance at the user grid
- F is Fourier interpolation from sensor to user grid
- f is a raised-cosine bandpass filter
- r_{ICT} is expected ICT radiance at the sensor grid
- SA^{-1} is the inverse of the ILS matrix
- ES is earth-scene count spectra
- IT is calibration target count spectra
- SP is space-look count spectra

Periodic Sinc Applied to High-Resolution Spectra

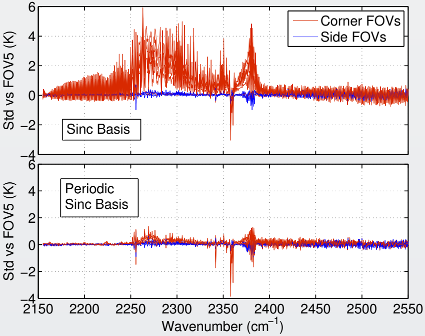
- Periodic sinc (psinc) is the correct basis for the instrument line shape (ILS)
- Thanks to Dan Mooney, see next talk
- IDPS and previously CCAST used sinc, not psinc

Two metrics for spectral performance

Observed - Computed (NWP)
100 Clear Ocean Scenes

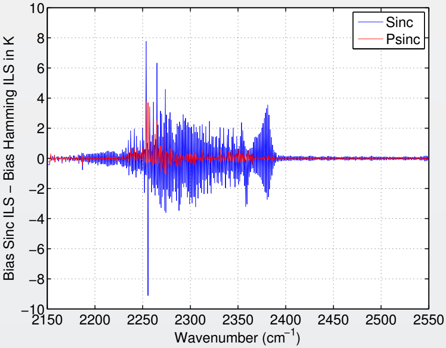


Standard Deviation of FOV5-FOV*n*
Large global dataset FORS=15,16

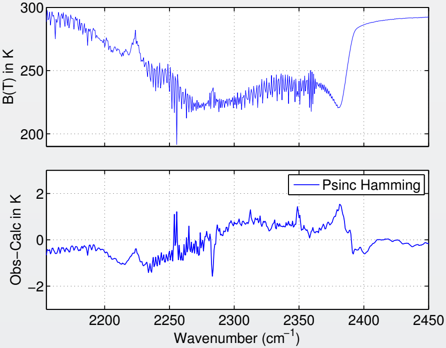


Periodic Sinc: Details

Bias Psinc/sinc - Bias Hamming
A clean metric for excess ringing



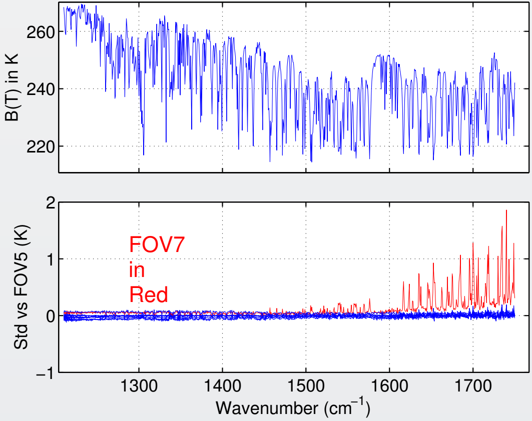
Observed - Computed (NWP)
Psinc apodized to Hamming



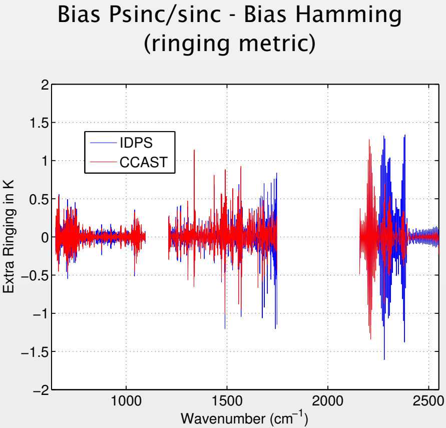
- This is a major improvement to the high-resolution short-wave data
- Periodic sinc mostly improves corner FOVS, where the self-apodization correction is largest, SA matrix is more poorly conditioned.
- Should help improve absolute spectral calibration once CrIS is in high-resolution mode

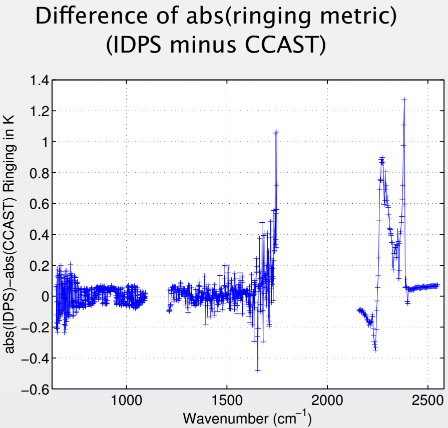
FOV7 Non-Linearity in High-Resolution Data

- High-res mid-wave water vapor line centers very cold
- Below: Std. Dev. of FOV5-FOV*n* for global data set. IDPS non-linear coefficients (Feb. 20, 2014 +).
- FOV7 non-linearity may need a more refined correction



Periodic Sinc Applied to Normal Resolution SDRs


Bias Psinc/sinc - Bias Hamming (ringing metric)

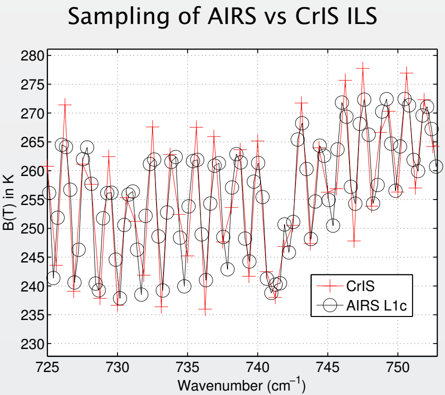

Difference of abs(ringing metric) (IDPS minus CCAST)

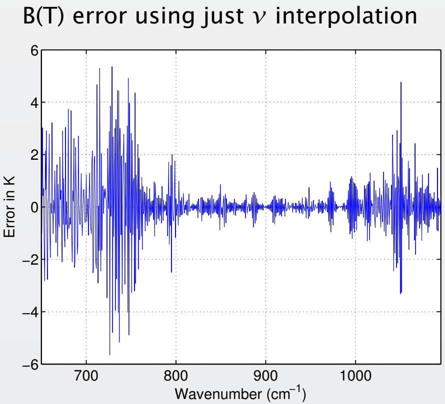
- Periodic sinc only clearly better at high wavenumber end of mid-wave band and most of short-wave band.
- Other contributors to non-sinc ringing dominate

CrIS/AIRS SNOs using Native CrIS ILS

- Intercalibration of AIRS and CrIS can only be done with L1b data in winow regions.
- ILS (Instrument Line Shape) differences cause large (4+K) differences between AIRS and CrIS for
- We convert AIRS (L1c) radiances using a deconvolution, reconvolution approach.
- The AIRS⟶CrIS data may provide the best approach for building a seamless AIRS + CrIS L2 time series.

AIRS L1c: Mismatch due to ILS Differences





AIRS ⟶ CrIS Conversion

This topic is beyond the scope of this talk, so just a summary.

Basic methodology

Let S_a be a matrix whose rows are AIRS SRFs on a 0.1 cm^{-1} grid, c AIRS channel radiances, and r radiances on the same 0.1 cm^{-1} grid. Then we can write

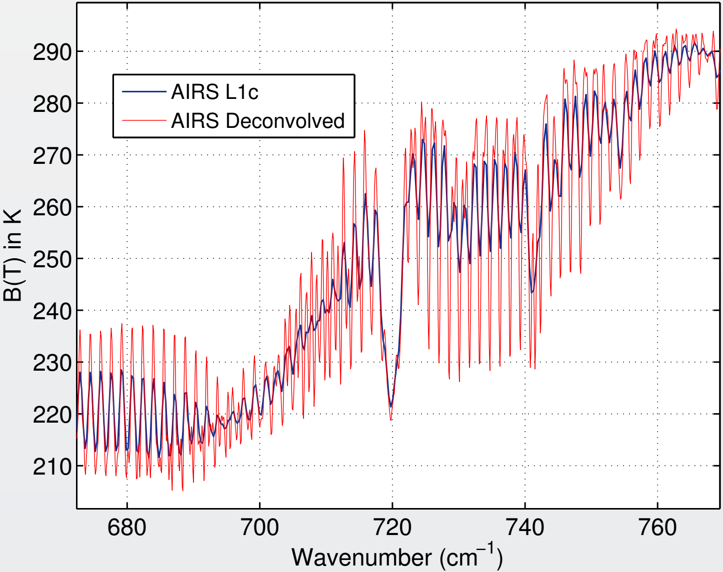
$$c = S_a r,$$

expressing the channel radiances as the convolution of observed radiance. In practice we have c and don't know r, but we can approximate it by taking the pseudo-inverse S_a^{-1} and applying it to c,

$$r = S_a^{-1} c.$$

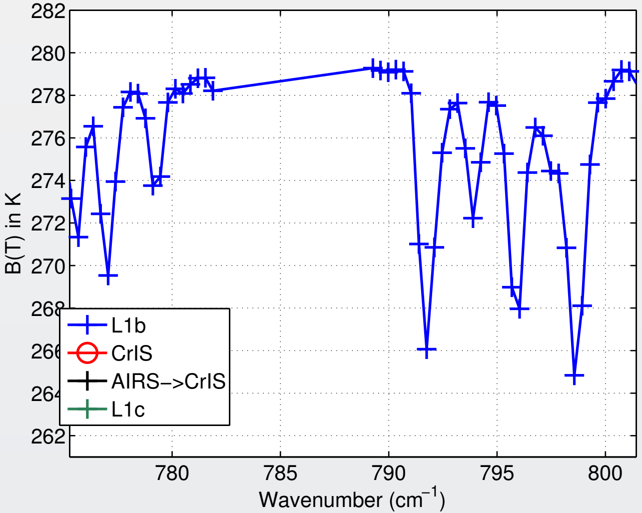
This is the deconvolution. This regularly spaced r can then be convolved to CrIS radiances at the user grid, taking into account band differences. The key in practice is that the L1c channel set gives a relatively well-conditioned S_a.

Example of De-convolved AIRS Spectrum



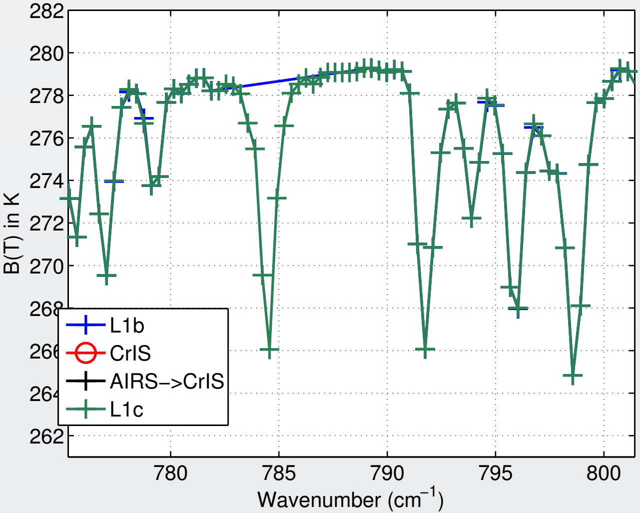
Example of AIRS L1c and Conversion to CrIS

L1b



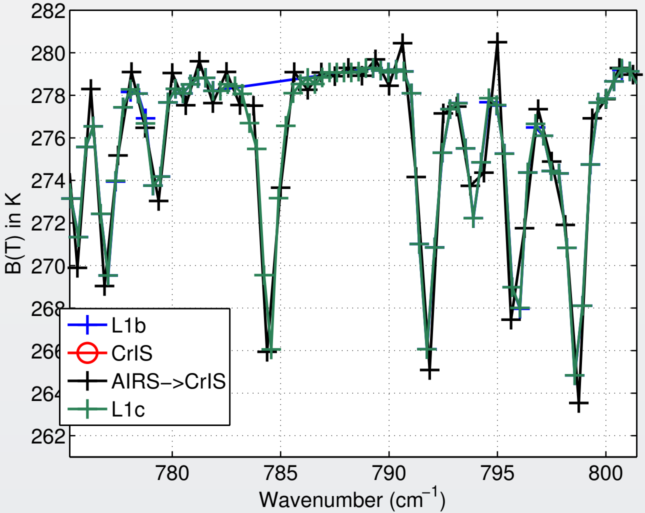
Example of AIRS L1c and Conversion to CrIS

L1b + L1c



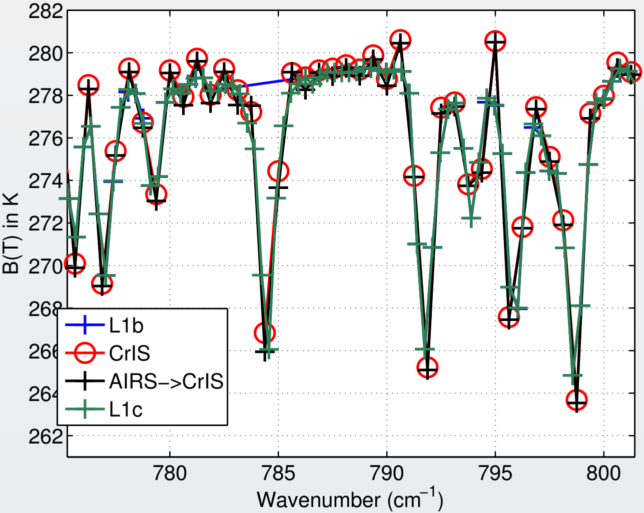
Example of AIRS L1c and Conversion to CrIS

L1b + L1c + L1c⟶CrIS



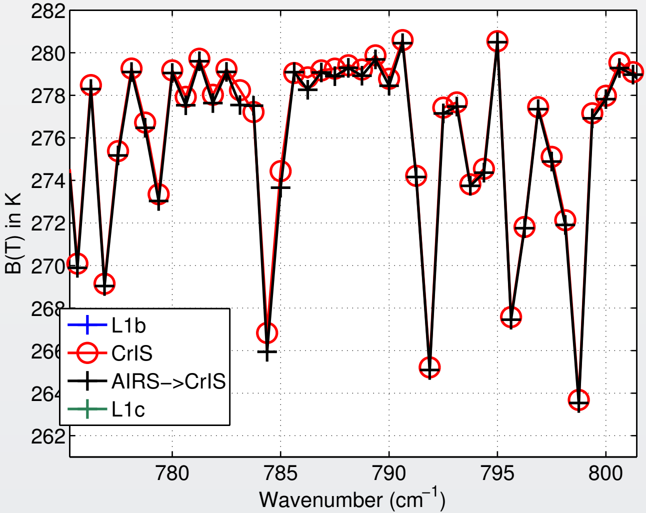
Example of AIRS L1c and Conversion to CrIS

L1b + L1c + L1c⟶CrIS + CrIS



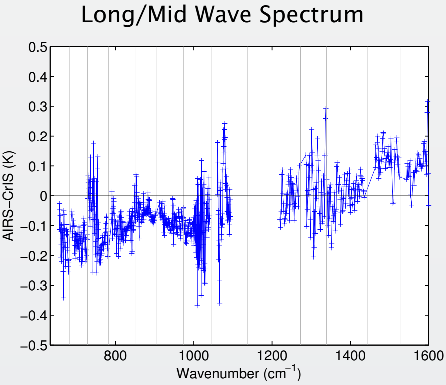
Example of AIRS L1c and Conversion to CrIS

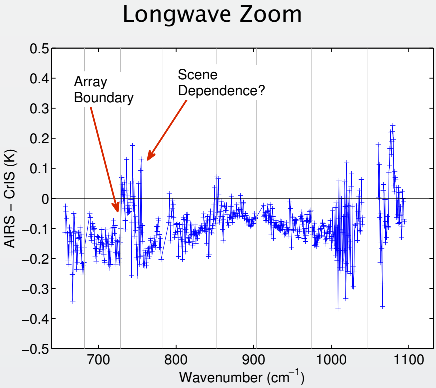
L1c ⟶ CrIS + CrIS



Full Spectrum Differences (Pre-Feb. 2014 Non-Linearity)

Hamming Apodization



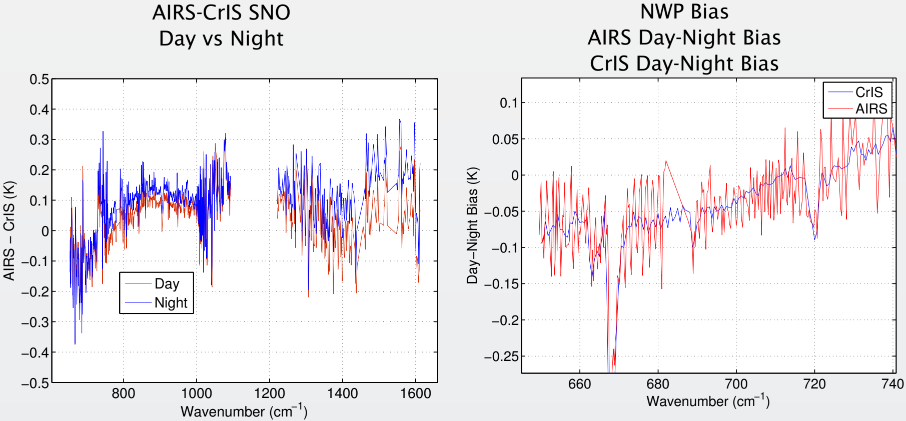


0.2K “ringing” may be due to lack of frequency calibration

The standard error is extremely small. ±50° latitude SNOs, 2 million+ samples.

Full Spectrum Differences (Post-Feb. 2014 Non-Linearity)

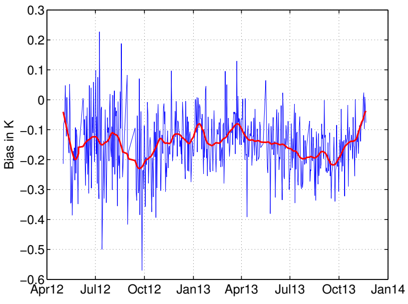
Day versus Night



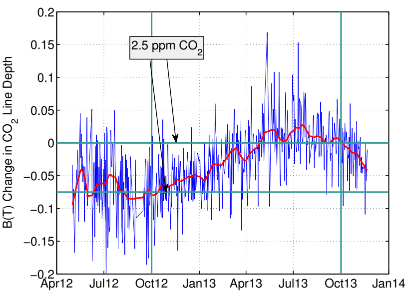
- Differences between CrIS vs AIRS day/night larger than statistical errors
- Thermal issues on one of these instruments?
- NWP day vs night biases similar for AIRS, CrIS in 650-700 cm^{-1} region, but very different for water vapor due to sampling differences
- AIRS “ringing” due to me not doing AIRS frequency calibration before forming SNOs. TBD.

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).

Conclusions

- CrIS spectral calibration continues to be stable and accurate
- UMBC will complete full analysis of Neon stability in the near future using CCAST
- CrIS high-resolution short-wave SDRs improved using period sinc basis function for apodization corrections.
- FOV-7 improvements needed for high-spectral resolution mode.
- AIRS/CrIS SNOs exhibit $\sim \pm 0.1$K agreement on a channel-by-channel basis with AIRS ($\sim$1080 channels).
- AIRS/CrIS comparisons will improve once AIRS SNOs are frequency calibration (by UMBC).
- AIRS ⟶ CrIS conversion will make a combined AIRS, CrIS radiance climate data set possible, now at 11+ years length.