Tradeoffs in Selection of CrIS L1b Algorithm

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Overview

- Provide context for why need inter-instrument stability
- Calibration Equations
- Radiance and O-C bias differences with different calibration equations

Note: (a) We are talking about really small B(T) differences here, and (b) Both approaches are technically valid (in my opinion) but serve different purposes.

Overview

Climate Context

- Fundamental records are the L1(b/c/d) radiances
- NASA is asking for an AIRS + JPSS(1-4)-CrIS climate record
- We must somehow reconcile radiance differences among these instruments at the 0.01K/year level

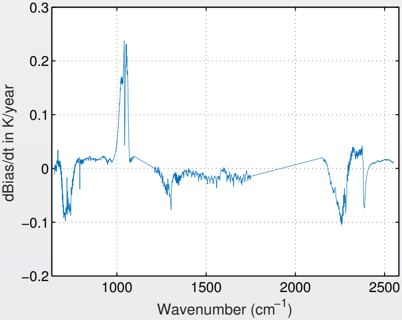
Possible Approaches

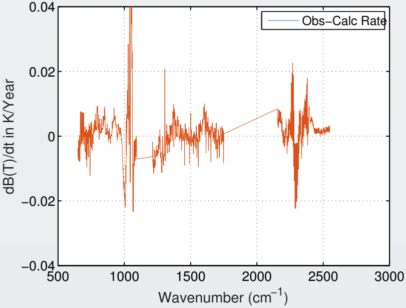
1. Do nothing. “Merge” L2 from different instruments with different RTAs. How? Errors?
2. Convert AIRS L1c to CrIS ILS and do retrievals with a consistent L1b record and single RTA.
3. Produce popular climate records (L3 trends and anomalies) directly from trends and anomalies in merged radiance record

Use SNO’s to adjust inter-instrument radiance offsets.

Instrument Stability

- Hyperspectral IR should be able to provide climate trends of T and Q with unprecedented accuracy and vertical resolution (but may compete with GPSRO).
- Comparisons of AIRS, IASI, and CrIS radiances trends (clear-sky subset over ocean) to independently available CO_2 and SST trends indicate stability well less than 0.01K/year for these instruments (with some minor caveats for AIRS).

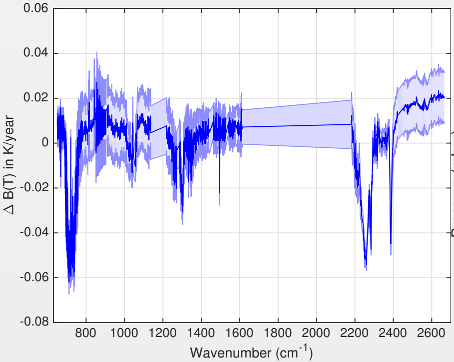


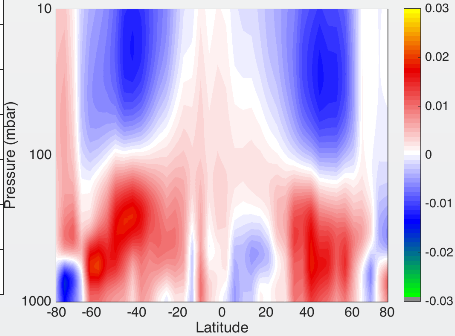


AIRS Global 12/13-Year Radiance and T(z) Trends

Left: Global B(T) Rate 12 Years

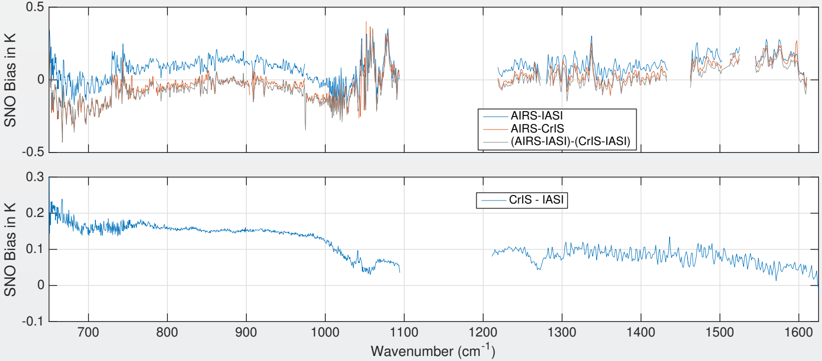
Right: Zonal Retrievals from Radiance Rates





Inter-instrument Calibration

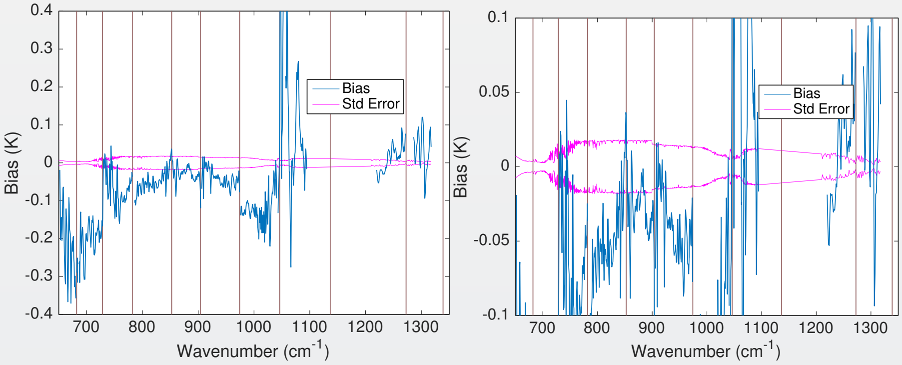
Use SNO's to Intercalibrate



Note: This figures shows that we can use a "third party" (IASI) to connect AIRS to CrIS.

CNES recently showed that understood errors in their non-linearity corrections are largely responsible for the CrIS–IASI differences!

Inter-instrument Calibration Uncertainties



Mainly note small standard error in offsets. Due to large number of observations, probably more work needed to fully characterise uncertainties (scene dependence).

Basic Message

- Instrument stability is high, overlap can be well characterized
- Climate trending requires 0.01K/year or lower relative accuracy
- Radiance trends can be converted into accurate geophysical trends
- *Small shifts matter*

CrIS L1b Calibration Equations

Calibration Equation Definitions

For this talk the term “UMBC” denotes the CCAST reference calibration equation while “NOAA” refers to the proposed JPSS-1 (and NASA NPP?) calibration equation. Univ. Wisc. is adding more refinements to this with changes to interferograms after Nov 2015.

UMBC:

$$r_{\mathrm{ES}} = F \cdot f \cdot SA^{-1} \cdot f \cdot (SA \cdot r_{\mathrm{ICT}}) \frac{ES - \langle SP \rangle}{\langle ICT \rangle - \langle SP \rangle}$$

NOAA-C4:

$$r_{\mathrm{ES}} = r_{\mathrm{ICT}} \frac{F \cdot f \cdot SA^{-1} \cdot f \cdot \left\{ \frac{\Delta S_1}{\Delta S_2} \cdot \Delta |S_2| \right\}}{F \cdot f \cdot SA^{-1} \cdot f \cdot |\Delta S_2|}$$

$$\Delta S_1 = FIR^{-1}(ES - \langle SP \rangle), \quad \Delta S_2 = FIR^{-1}(\langle ICT \rangle - \langle SP \rangle)$$

- r_{ES} is calibrated earth-scene radiance at the user grid
- F is resampling from sensor to user grid
- r_{ICT} is the expected ICT radiance (incorrect in NOAA-C4)
- f, UMBC: is a raised-cosine bandpass filter with wings at or inside the instrument responsivity, NOAA: modified ATBD filter
- SA, UMBC: Periodic sinc ILS wrapping at the sensor grid, NOAA: Periodic sinc wrapping at the undecimated sensor grid.
- Non-linearity corrections are included
- $\langle SP \rangle$ and $\langle ICT \rangle$ are averages over 9 scans

The Essential Difference: (Note SA^{-1} Corrections are BIG)

Simplified Math to Illustrate (not technically correct)

$$\text{UMBC:}\quad SA^{-1}\left(r_{\text{ICT}}\frac{\Delta S_1}{\Delta S_2}\right) = SA^{-1}\left(r_{\text{ICT}}\frac{ES - \langle SP\rangle}{\langle ICT\rangle - \langle SP\rangle}\right)$$

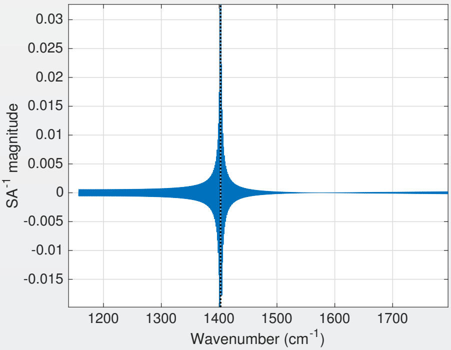
$$\text{NOAA-C4:}\quad r_{\text{ICT}}\frac{SA^{-1}(\Delta S_1)}{SA^{-1}(\Delta S_2)}$$

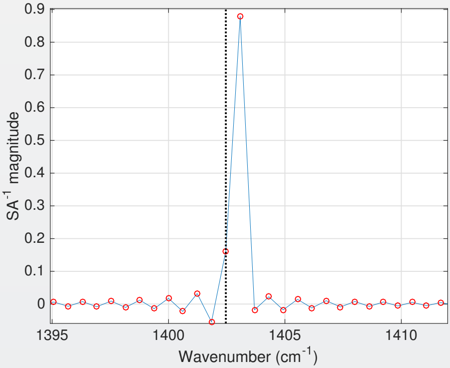
- NOAA-C4 is a new approach, not used in the past.
- NOAA-C4 applies apodization correction operator to signal counts, so includes shape of instrument spectral filtering
- UMBC applies apodization correction operator to calibrated radiance

Implications

- NOAA-C4
  - Minimizes 650 cm^{-1} band-edge ringing
  - "Requires" instrument filter function to be used in RTA
  - Does not formally return a sinc ILS
- UMBC
  - Produces some 650 cm^{-1} ringing
  - We think gives better Obs-Cal in the water band
  - RTA for any instrument filter shape is sinc ILS

What Does Inverse of SA Look Like?

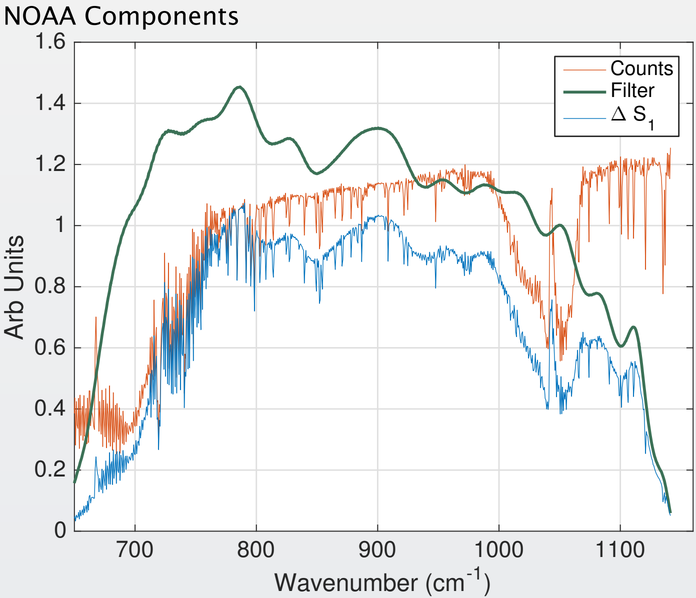




One row of SA^{-1} centered at 1402.46 cm^{-1}. The corrected radiance for 1402.46 cm^{-1} is the sum of element-by-element product of this row of SA^{-1} times the observed instrument radiance (or counts).

Components Operated on by Inverse(SA) Matrix

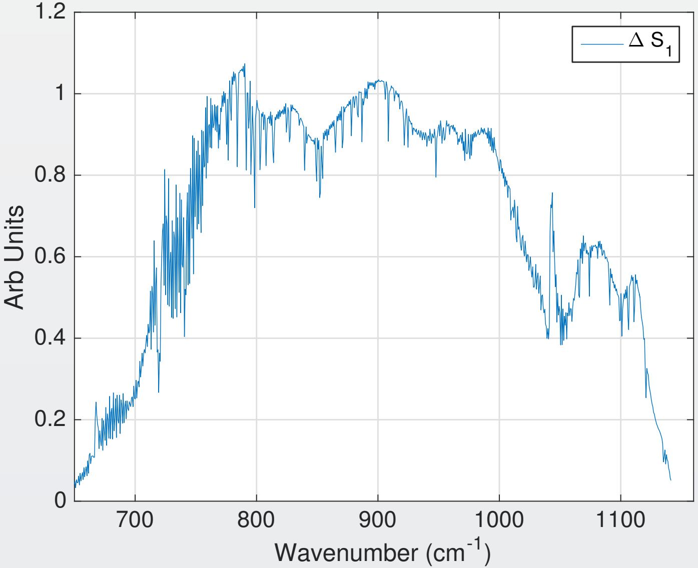
ΔS_2 is smooth, the issue is ΔS_1



Components Operated on by Inverse(SA) Matrix

ΔS_2 is smooth, the issue is ΔS_1

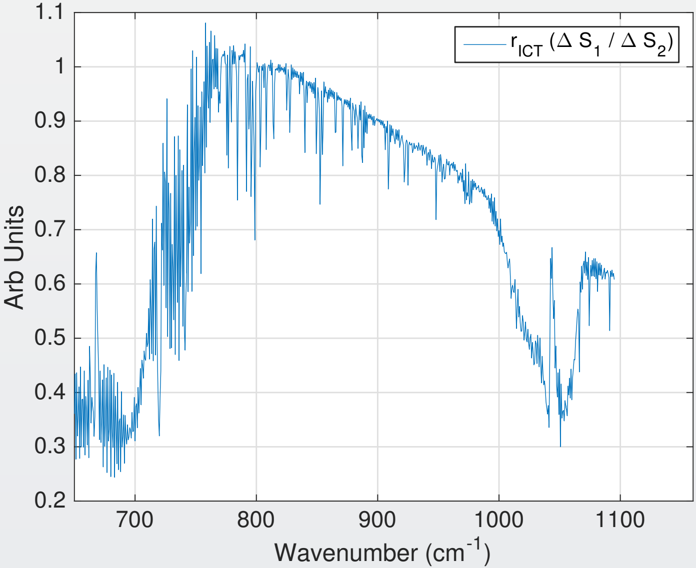
NOAA operates on:



Components Operated on by Inverse(SA) Matrix

ΔS_2 is smooth, the issue is ΔS_1

UMBC operates on a radiance, just like normal RTA:



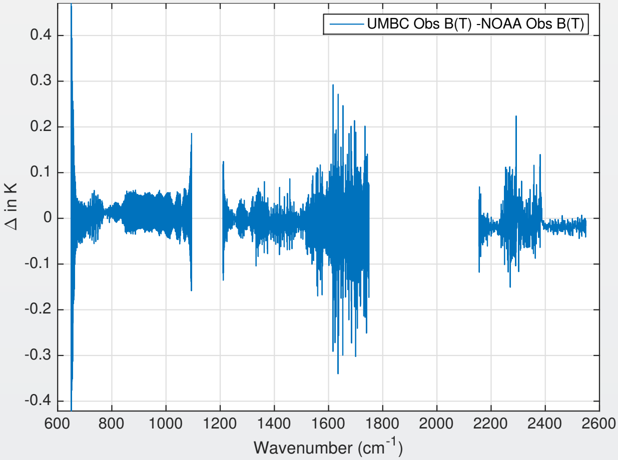
Some Observations

- NOAA-C4
  - $r_{calc} = (1/P_r)\ FFT^{-1}(OPD)\ FFT\ P_r\ r_{mono}$
  - P_r is instrument responsivity (ΔS_2)
  - r_{calc} needs P_r (and is not a sinc ILS (my opinion))
  - P_s changes *slightly* with iFOV, instrument, temperature
- Standard Approach (UMBC)
  - $r_{calc} = FFT^{-1}(OPD)\ FFT\ f_{bandpass}\ r_{mono}$

NOAA approach: apodization corrections mix in fine structure of spectrum with different amplitudes, OK since same done in r_{calc}. Not a sinc ILS>

Standard (UMBC) approach provides sinc ILS up to issues of out-of-band signal (which are pt-by-pt oscillations).

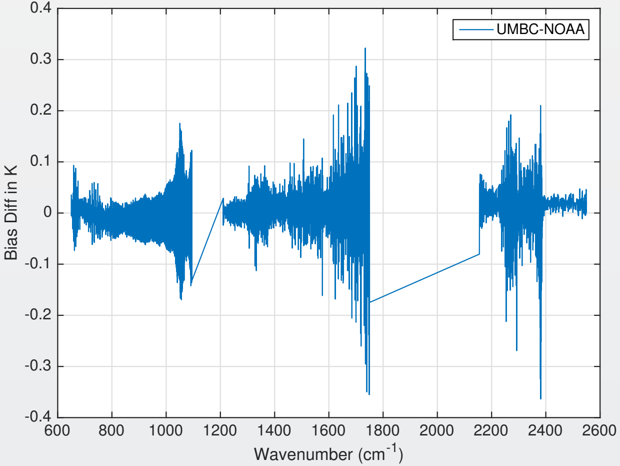
L1b Spectra are Different!



Extra 650 cm^{-1} ringing in normal UMBC approach.

NWP Bias Difference between NOAA and UMBC

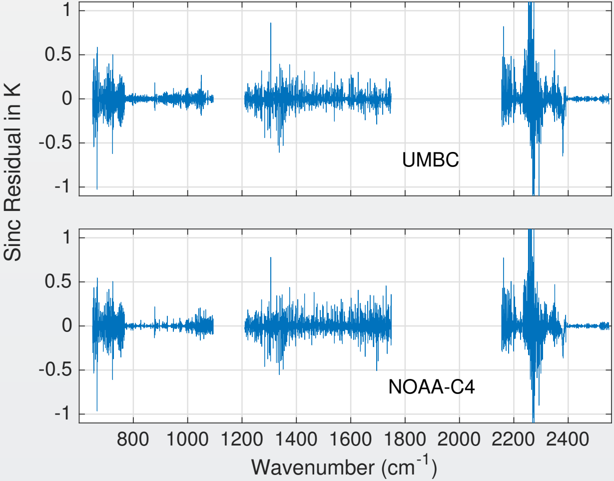
Ringing only, quite small.



Each measurement used the RTA appropriate for the L1b calibration equation used to calibrate the radiances. This all-fov average minimizes problems with UMBC 650 cm^{-1} ringing that varies with FOV ID!!

Ringing Diagnostics

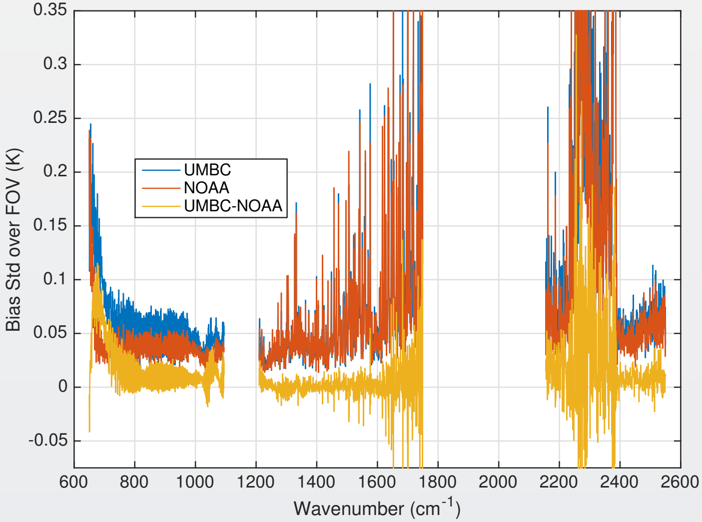
Showing $Bias_{Hamming}$-$Bias_{Sinc}$



These average over all 9 FOVS, which minimizes UMBC ringing errors near 650 cm^{-1}.

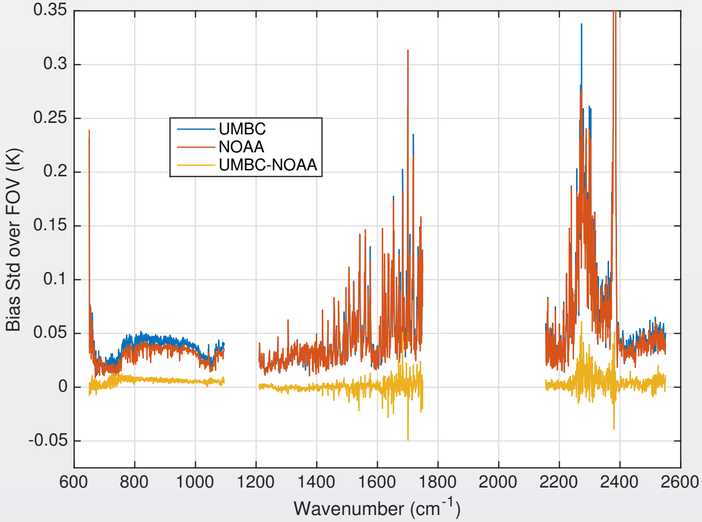
SDR Variability over FOV ID: Sinc ILS

NOAA has smaller variability over FOV, esp. in long-wave



SDR Variability over FOV ID: Hamming ILS

With Hamming ILS, larger UMBC is gone.



Conclusions

- New approach could modify radiances if follow-on CrIS instruments have different shape to filters (or the present one changes)
- Differences in ringing between both approachs is very small if Hamming apodized
- Different RTA needed for each instrument
- ILS no longer strictly sinc (or sinc with simple overall bandpass)
- Trending at the 0.01K level over many years could be compromised.
- Ability to convert AIRS radiance to CrIS radiance *may* be harder with NOAA-C4 since we do spectral space convolutions.

Main lien of UMBC approach is some ringing at 650-670 cm^{-1}. However that is suppressed with Hamming.

NOAA-C4 is a new approach, technically valid, but ties the RTA to the instrument responsivity, which I think is inappropriate for a radiance climate product.