CrIS, Three Years of Operation, Stability and Comparison to AIRS

Chris Hepplewhite, L. Larrabee Strow, Howard Motteler,
Sergio De Souza-Machado, and Steven Buczkowski

UMBC
Department of Physics *and*
Joint Center for Earth Systems Technology

AIRS Science Team Meeting
Greenbelt, MD, 13 - 16 October 2015

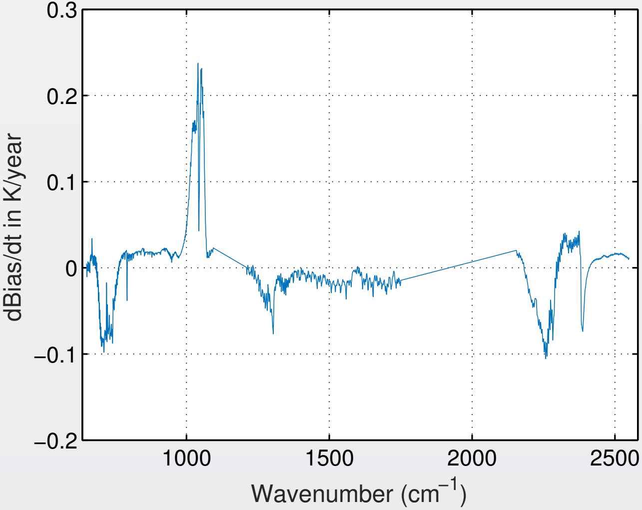
What, Why and How

- Goal: create climate data records from different hyperspectral sensors
- Requirement: need well understood error characteristics, inter-instrument biases, and instrument stability
- Approach: Convert individual instrument radiance records to a common spectral grid
- This Work:
  - Demonstrate CrIS sensor stability
  - Overview of AIRS–>CrIS conversion
  - AIRS - CrIS bias with common spectral grid
  - Stability of the above bias with time

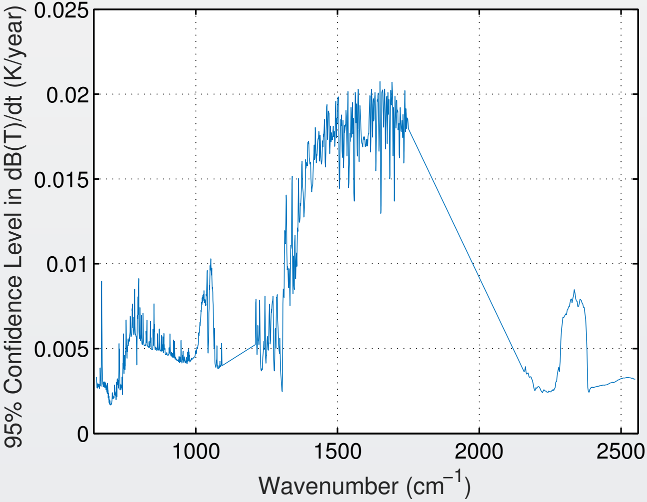
Estimation of CrIS In-Orbit Stability: Approach

- Start with CCAST processed SDRs (stable algorithm)
- CCAST converts to normal-resolution post Dec. 2015
- Subset for clear, ocean tropical scenes (uniformity filter)
- Match each scene of ERA Interim re-analysis and compute simulated radiance
- Create daily average of observed and simulated radiances (365 x 3) long time series.
- Fit time series bias (Obs-Simulated) for linear rate (and seasonal terms).
- Perform an Optimal Estimation retrieval on bias time series (d(bias)/dt) spectrum to determine geophysical time derivatives. (O_3 is only column offset.)

CrIS Linear B(T) Bias Rate over Three Years



2-σ Uncertainty in CrIS Linear B(T) Bias Rate



OE Fit Results

Units are all **per year**

CO2 (ppm)	2.35 +- 0.008	Full rate
O3 (%)	-1.22 +- 0.006	Relative to ERA
N2O (ppb)	0.82 +- 0.014	Full rate
CH4 (ppb)	7.79 +- 0.182	Full rate
CFC11 (ppt)	0.10 +- 0.016	Full rate
SST (K)	0.016 +- 0.000	Relative to ERA

Comparison to In-Situ for CO_2

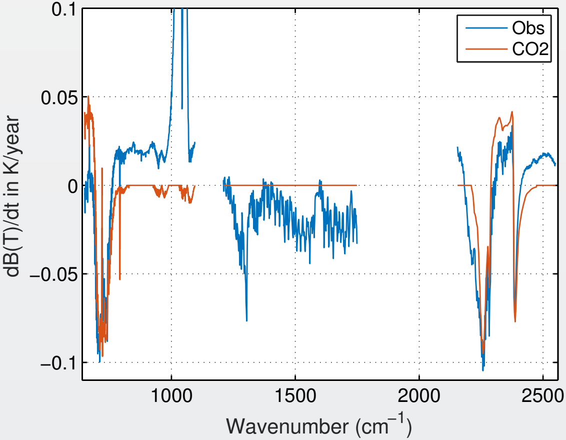
- NOAA/ESRL Global Mean CO_2 Rate for 2012-2014: 2.25 ppm/year
- CrIS - ESRL = 0.1 ppm/year implies CrIS stability of 0.005K/year.

Comparison to In-Situ for SST

- ERA SST is a measurement: GHRSST
- CrIS - ERA = 0.016K/year

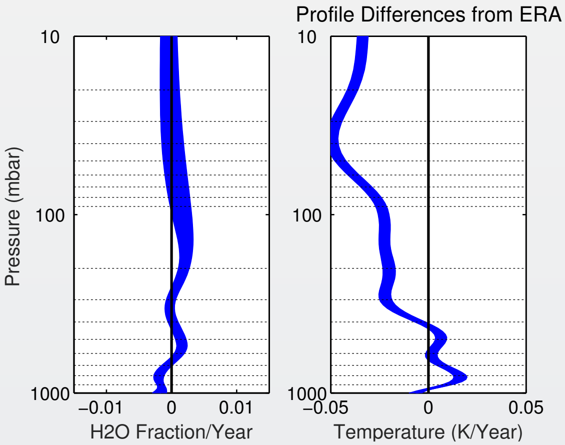
NOAA/ESRL CH_4 from 2012-2015 varies from 5-10 ppb/year

CO_2 Contribution to Spectral Bias



Issue in stratospheric sounding channels, we should differ from ERA by 0.04K/year! Could ERA not be able to bias correct for CO_2 in the upper strat?

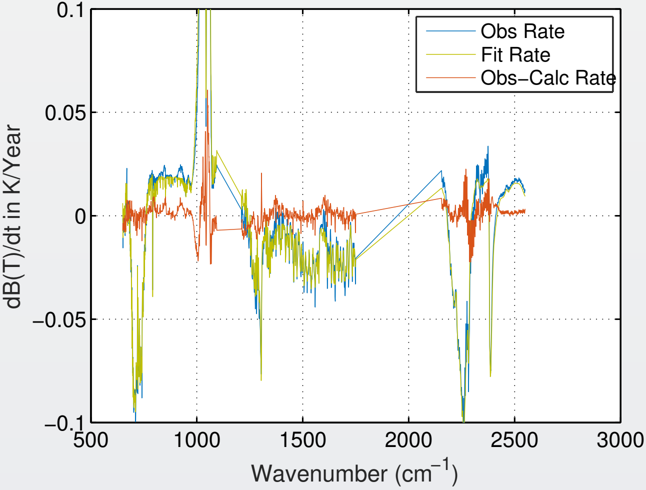
OE Profile Differences from ERA



For these altitude it is difficult to find a standard for temperature bias correction? Or is the CO_2 rate not constant with altitude?

Fit Residuals

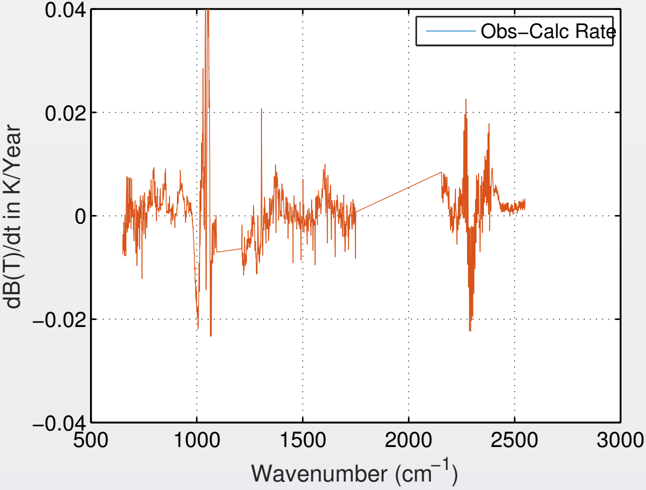
Requirements for Inter-Instrument Agreement



How well can we fit CrIS radiance time derivatives?

Fit Residuals

Requirements for Inter-Instrument Agreement



How well can we fit CrIS radiance time derivatives?

AIRS–>CrIS SRF Conversion: Basis of Method

Objectives

- To create a common radiance climate record for different sensors.
- To aid comparison and bias estimates between different sensors.
- In this case use the CrIS standard resolution as the common and convert the measured AIRS and IASI signal to CrIS, but in principle to any other.
- Method developed by Howard Motteler

Source code for deconvolutions:

- `https://github.com/strow/airs/deconv.git`
- `https://github.com/strow/iasi/decon.git`

Basis of Method

Background

- Use the AIRS SRFs from TVAC to deconvolve the measured spectral radiance to a finer user grid (0.1 cm^{-1}) is optimum.
- Reconvolve to the common sensor spectral response (CrIS).
- Works best for continuous spectral band with uniform response and sensors with parameterized ILS.
- AIRS conversion uses L1C which fills gaps and repairs bad channels.
- Method validated using TOA radiance calculated for 49 atmospheric profiles that cover wide dynamic range.
- TOA calculated using kcarta LBL at native 0.0025 cm^{-1} resolution.

CrIS ⟶ AIRS Conversion

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

Basic methodology

S_a is a matrix of AIRS SRFs on 0.1 cm^{-1} grid.

$$c = S_a r,$$

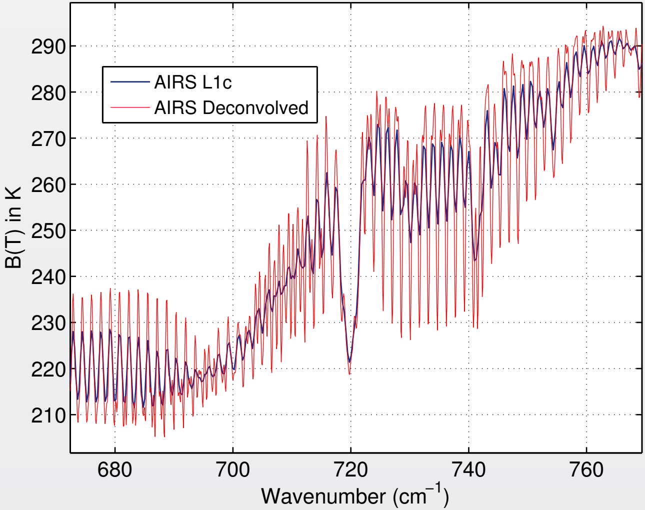
where: c = AIRS observed channel radiances, r = higher resolution representation of true radiances, on 0.1 cm^{-1} grid. (For best results, as in forward model development, we use a 0.0025 cm^{-1} spacing.) Then

$$r = (S_a)^{-1} c$$

and we can obtain simulated CrIS by convolving r with the CrIS ILS. S_a condition number is very high for L1b, and drops to ≈250 for **L1c** if we drop four channels. The key is a uniform channel spacing.

Example of De-convolved AIRS Spectrum

De-convolved SRF similar to 0.2 wide sinc



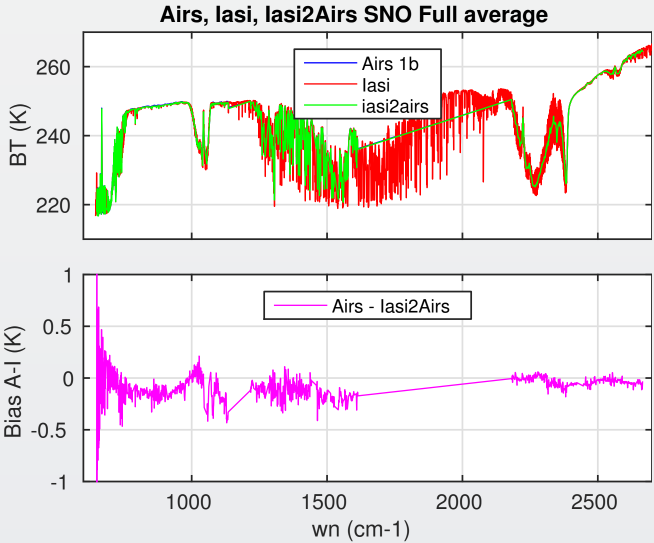
Basis of Method
IASI to CrIS

IASI to CrIS is an easy translation because IASI spans the CrIS bands and has a nominal (though strongly apodized) higher resolution. The main steps, for each CrIS band, are

- apply a bandpass filter to the IASI channel radiances to restrict them to a single CrIS band with a rolloff outside the CrIS user grid
- take the filtered radiances to an interferogram with an inverse Fourier transform
- apply the pointwise inverse of the IASI Gaussian over the IASI 1 cm *opd* and truncate this to the 0.8 cm CrIS *opd*.
- take the interferogram back to radiance at the CrIS 0.625 *wn* channel spacing with a forward Fourier transform

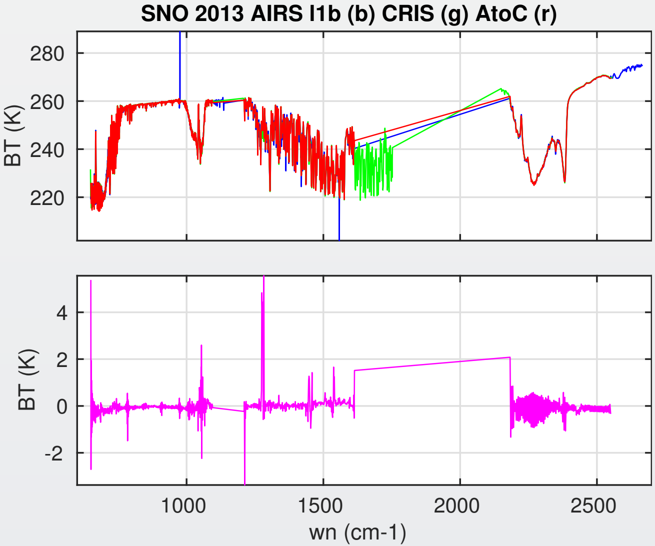
AIRS IASI SNOs

2014 average

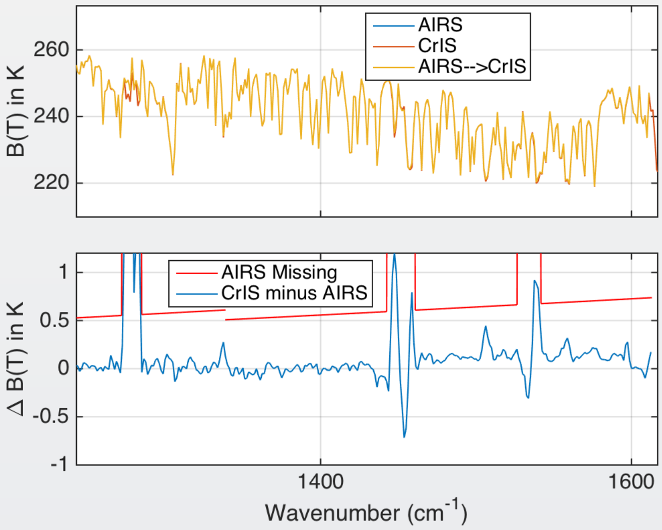


AIRS CrIS

2014 average

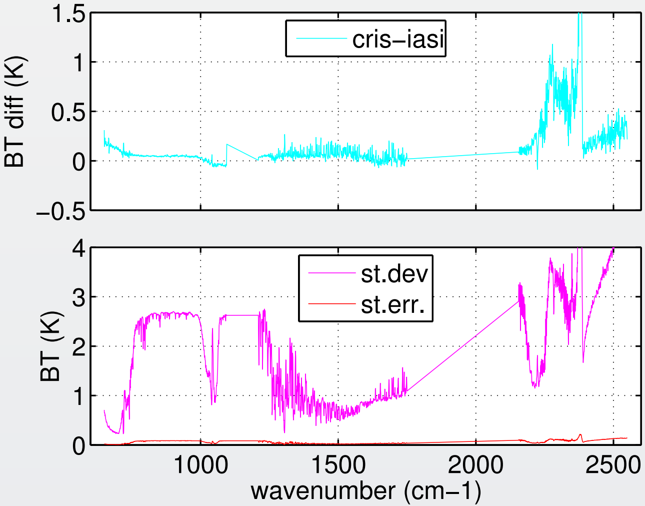


AIRS CrIS Zoom



CrIS (HR) IASI SNO

2013 average



CrIS Bias from SNO

Bias Trending

- Take CCAST standard resolution CrIS and AIRS L1b converted to L1c.
- but note - these AIRS data are not spectrally corrected for drift (my next task!).
- Create SNO based on 20 minute 13 km separation of FOVs from May 2012 to current time.
- Get approx 650 SNO days. Restrict to Tropical ocean (< 40 latitude) and drop > 3-sigma samples.
- Evaluate bias for averages of each SNO day, and trend (as you like!).
- Investigate and compare to IASI CrIS bias (to do).

CrIS AIRS Bias from SNO

LW band

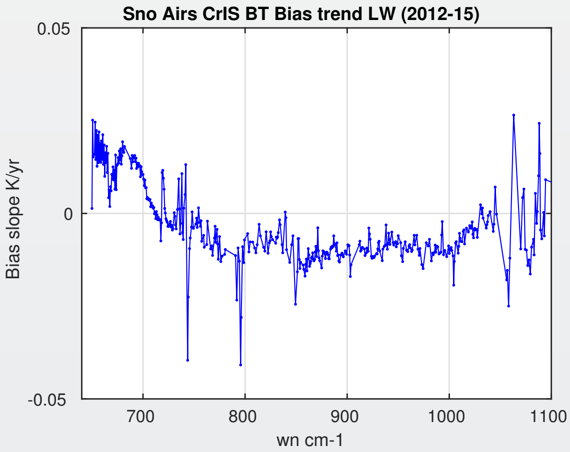
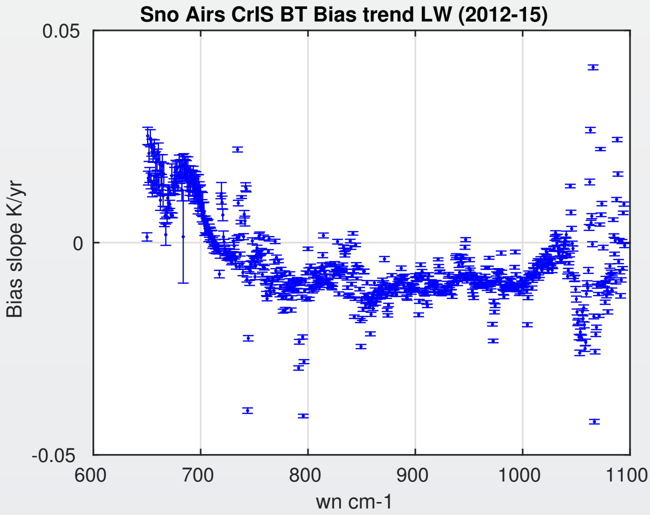


Figure: LW band AIRS CRIS SNO Linear fitted

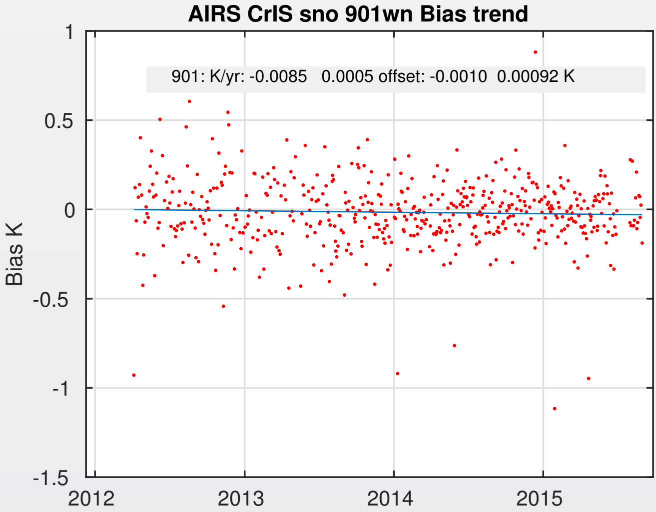
CrIS AIRS Bias from SNO

LW band with std. dev.



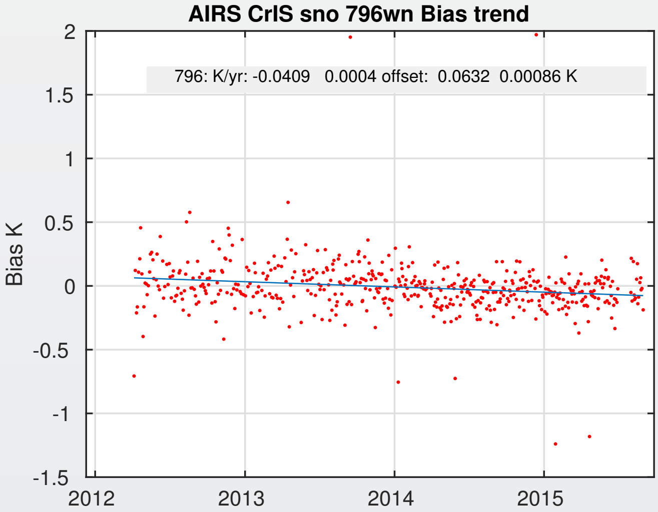
CrIS AIRS Bias from SNO

Window channel detail



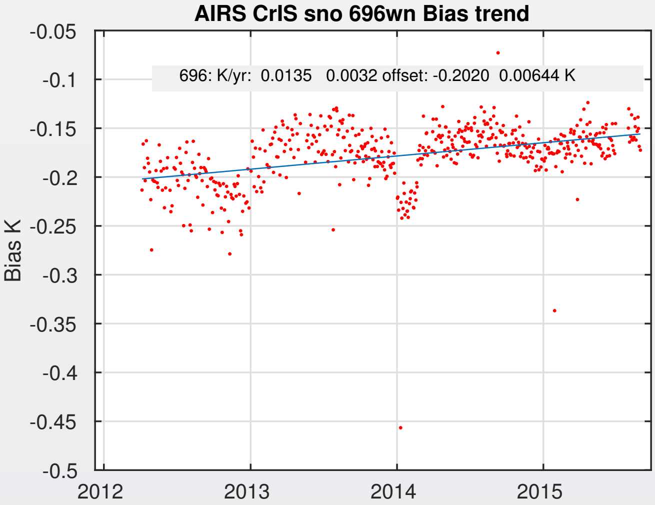
CrIS AIRS Bias from SNO

Channel at 796 wn detail



CriS AIRS Bias from SNO

Channel at 696 wn detail



Conclusions and Future Work

- Comparison with CO2 growth rates indicates CrIS is stable to about 5 mK/year.
- Comparison with SST linear rate indicates CrIS is stable to 16 mK/year (includes cloud leakage).
- Premature to conclude comparison with AIRS and CrIS, worst case from this work suggests they are within 9 mK/year of each other (LW window region).
- Apply frequency correction to AIRS and repeat. Compare with IASI.
- Evaluate uncertainty of method (SNO method alone doesnot tell who is nearer the truth, but is guide to stability).
- Evaluate optimum method to null out the bias of (merge) the two radiance records.