A Climate Hyperspectral InfraRed Product (CHIRP)

AKA: A Long-Term Homogeneous Hyperspectral Radiance Time Series: AIRS2CrIS

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Introduction

- We have a mult-instrument hyperspectral radiance record (AIRS, CrIS(2), IASI(2)
- NASA has asked for continuity products, with an emphasis on climate
- For climate, the radiances are a "product" used by the scientific community

Instrument Characteristics (AIRS vs CrIS vs IASI)

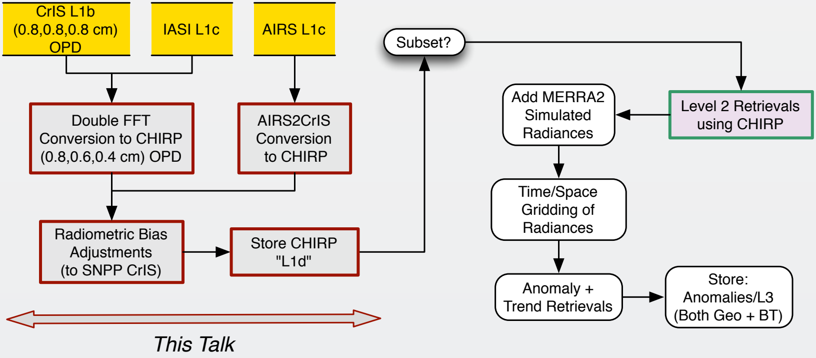
- Different Spectral Response Functions (SRF)
- Different channel center frequencies (ν_i)
- Different, but similar absolute calibration accuracy (~0.1-0.3K)
- BUT: *Their radiometric stability is at least ~100 X BETTER then absolute calibration accuracy!*

Possible Continuity Requirements (that provide same observation sensitivities)

- Same SRFs
- Same ν_i
- Same Radiative transfer model (RTA)
- Same noise?
- Same retrieval algorithm

Proposed Solution: CHIRP

CHIRP + Radiance Based L3 Retrieval Data Flow

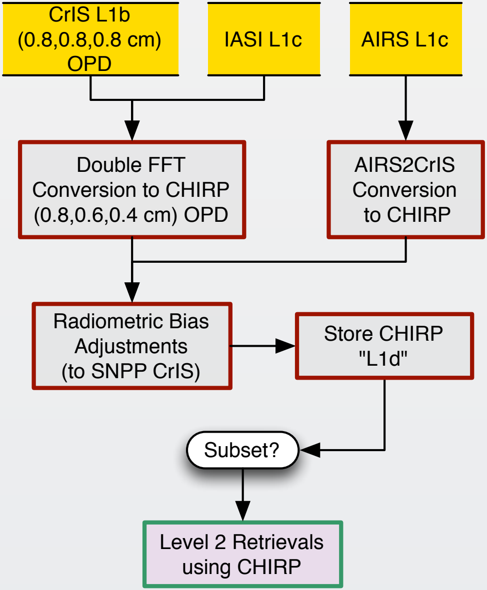


- *OPD:* Close to 0.8 / 0.6 /0.4 cm
- *With Spectral Spacing:* 0.0625 / 0.0833 / 0.1250 cm^{-1}

Requirement: High-quality conversion of AIRS to CHIRP ILS

CHIRP = (1) AIRS2CrIS (2) CrIS modified SRF, (3) IASI modified SRF

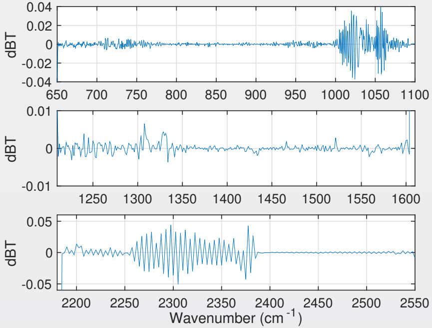
CHIRP only Data Flow: Useful for Level 2 Retrievals?



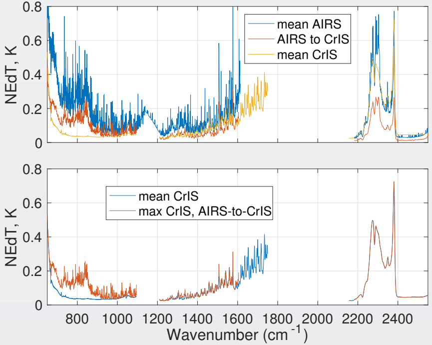
AIRS2CrIS Algorithm

- Simple deconvolution to 0.1 cm^{-1} grid
- $S_a r = r_A$, $r_o = S_a^{-1} r_A$ using Moore-Penrose pseudoinverse
- $r_{A2C} = S_c \circledast r_o$
- Small additional terms using linear regression (mostly bias)
- Errors below assume AIRS ILS functions are perfect

AIRS2CrIS Mean Error (std. similar)



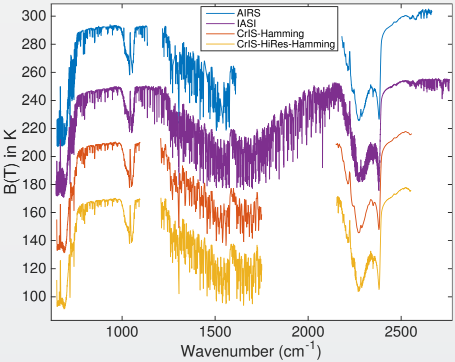
AIRS2CrIS Noise



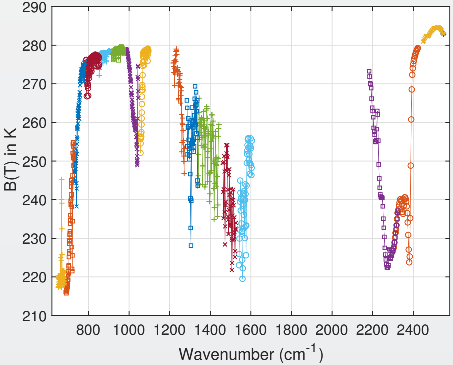
Shortwave sounding region max noise dominated by CrIS

Spectral Differences Among AIRS, CrIS, IASI

AIRS/CrIS/IASI Spectra



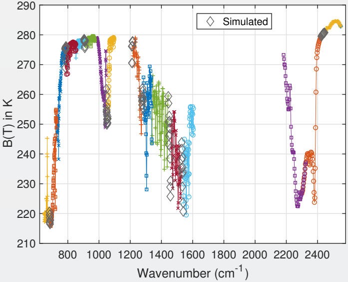
CHIRP Spectrum (from AIRS)



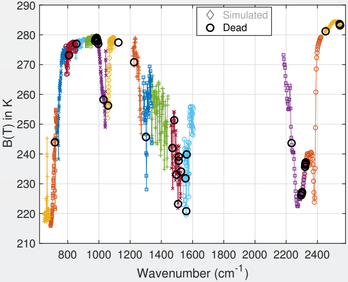
AIRS modules shown in different colors in CHIRP spectrum. This is CrIS-NSR, final CHIRP will be between CrIS NSR and FSR (MW/SW).

Bad CHIRP Channels are Flagged

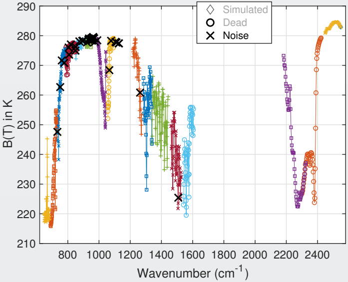
Simulated Channels



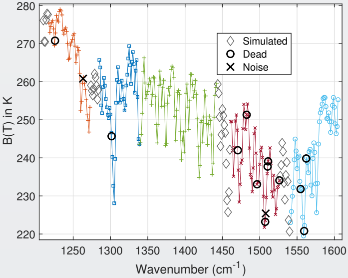
Dead Channels



Noisy Channels



Midwave Zoom: Dead and Noisy Chanels

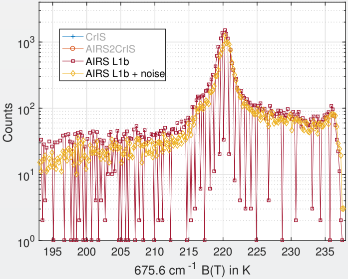


Validation: PDF's of Single Channels

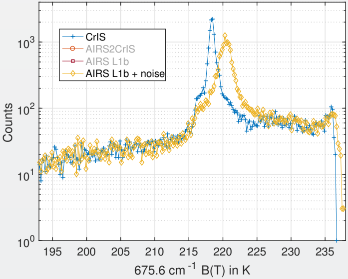
- How closely will AIRS2CrIS (CHIRP) compare to CrIS for single scenes?
- We collected a large random statistical set of AIRS and SNPP-CrIS observations for the 675.6 cm^{-1} channels (closest matches)
- Examine the PDFs (histograms) of (a) AIRS native SRF (b) AIRS2CrIS, with (c) CrIS.

PDF's for a Single CHIRP Channel Compared to CrIS

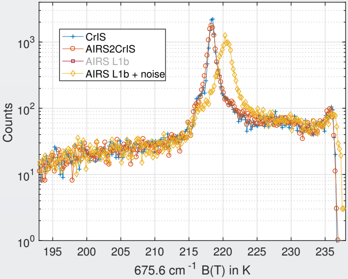
AIRS only, Noise added



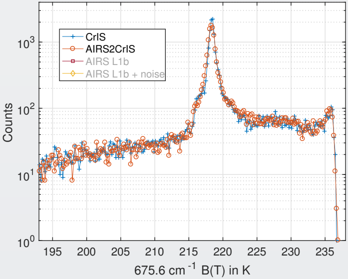
PDF for closest CrIS Channel



Convert AIRS to CrIS SRF



CrIS versus CHIRP

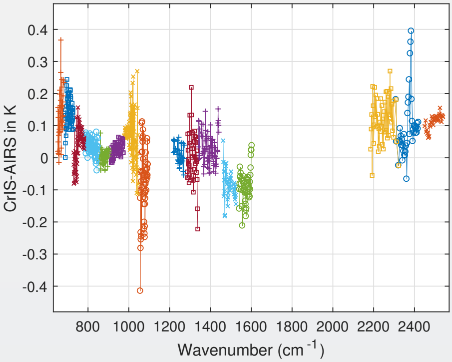


Validation: SNOs between CrIS and AIRS/CHIRP

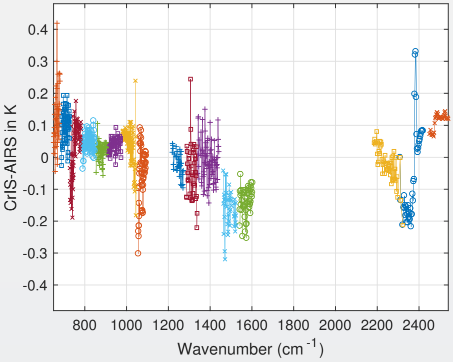
- SNOs are Simultaneous Nadir Overlaps
- We generate them for combinations of AIRS, CrIS, and IASI
- And convert AIRS to AIRS2CrIS (CHIRP)
- Allows *channel-by-channel* inter-comparisons (instrument offsets)
- We also use AIRS2CrIS as a transfer standard to intercompare SNPP-CrIS to NOAA20-CrIS since SNPP and NOAA20 do not have nadir overlaps
- See Chris Hepplewhite's talk on Friday for more details

SNPP versus AIRS: SNOs and Large Random Samplings

2016 SNOs



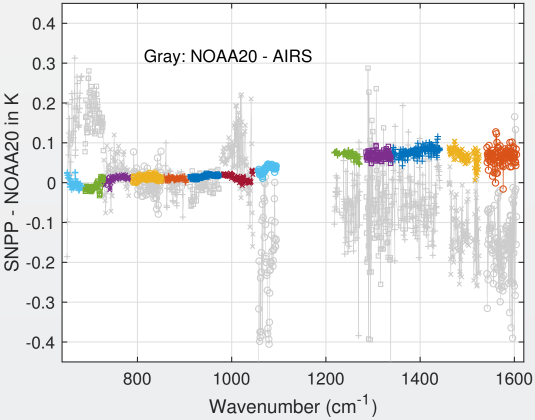
2016 Random Comparisons



Sources for Differences

- Differential calibration AIRS modules
- AIRS SRFs (widths and centroids)
- Non-linearity: CrIS, AIRS?
- etc.

SNPP vs NOAA20 CrIS (via AIRS Snos)



- *Preliminary*, NOAA20 CrIS non-linearity will be updated in July 2018
- Connecting CrIS instruments together will be easier!
- So far spatial, spectral, and sampling among CrIS instruments will be identical

Time Series Tests

(See talk by Chris Hepplewhite on Friday)

Compared AIRS only to CHIRP Time Series

Start with a 1% random subset of AIRS and CrIS observations:

- Series A: 10-year AIRS2CrIS time series trends
- Series B: CHIRP (CrIS NSR SRF)
  - First 5-years is AIRS2CRIS
  - Second 5-years is CrIS
- Correct AIRS2CrIS for radiometric offsets with CrIS
- Intercompare 10-year trends between Series A and B

Results show climate level agreement between both.

Note: AIRS and CrIS do have sampling differences, very minimal with zonal averaging (which is what we did).

Pros of CHIRP

- Only way I know to correct for inter-instrument radiometric offsets
    - Certainly needed for AIRS vs CrIS+
    - Maybe needed for CrIS vs CrIS
- Use of a single RTA for retrievals, using "same" channels
- Use of a single Level 2 retrieval algorithm (noise issues, although these can be normalized)
- Essential for providing a long-term Level-3 radiance data set of climate quality (next talk)
- A simpler dataset for users in 20+ years
- Lowers manpower efforts in a time of decreasing funding

Cons of CHIRP

- Lowers spectral resolution of AIRS in the long-wave (after Hamming apodization)
- Lowers spectral resolution of CrIS-FSR a little in the mid-wave, short-wave
- *If* you need similar noise figures, will need to add (a little) noise to either AIRS2CRIS or CrIS depending on the spectral region
- The first two items may impact minor gas retrievals (CH_4, HDO, CO) depending on the instrument
- BUT, you can always "import" the native resolution radiances into your algorithm for the minor-gas part of the retrieval. Adds complexity and a separate RTA.
- Its new.

Future Work

- AIRS L1c is a pre-requisite for AIRS2CrIS
  - Ready except for frequency calibration (orbital + drift and Doppler corrections)
  - These should be ready in the next few months
  - UMBC can produce L1c with these corrections now
  - UMBC proposed L1c frequency set delivered to JPL
- CHIRP Algorithm
  - AIRS2CrIS is on github at https://github.com/strow/airs_deconv.git
  - JPL SIPS is starting on integration and data formats
  - UMBC needs to formalize quality flags
  - Document performance
    - Algorithm paper accepted: Motteler et. a., IEEE Geophysical Transactions, 2018
- CHIRP RTA
  - UMBC has produced CrIS FSR=0.8/0.8/0.8 and NSR=0.8/0.4/0.2 OPD RTAs
  - However, they use different spectroscopy (FSR more up-to-date, HITRAN 2012)
  - We plan a new set of updates using HITRAN 2016 and new CO_2-H_2O collision spectroscopy (see Sergio DeSouza-Machado's talk) in the next 6+ months? Can also do CHIRP.
  - Similar plan for AIRS L1c RTA
  - Near term: could do proof-of-principle testing with CrIS NSR resolution for CHIRP