

# **A Climate Hyperspectral InfraRed Product (CHIRP)**

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

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# Introduction

- We have a 15+ year multi-instrument 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)

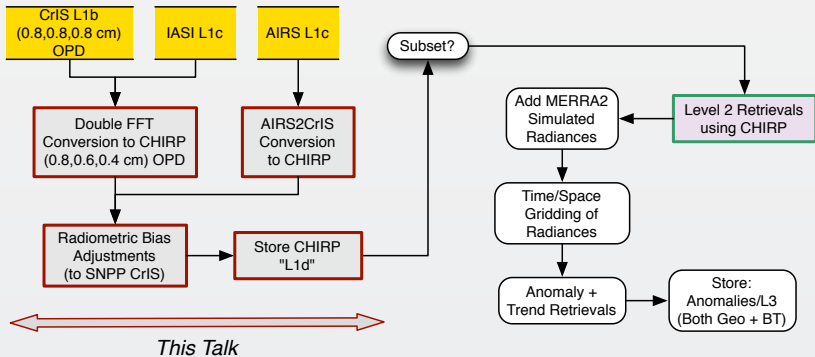
- Different Spectral Response Functions (SRF)
- Different channel center frequencies ( $\nu_i$ )
- Different, but similar absolute calibration accuracy ( $\sim 0.1$ - $0.3$ K)
- BUT: *Their per year radiometric stability is at least  $\sim 100$  X **BETTER** than absolute calibration accuracy!*

## Continuity Requirements (that provide same observation sensitivities)

- Same SRFs
- Same  $\nu_i$
- Same Radiative transfer model (RTA)
- Same noise?
- Same retrieval algorithm

Proposed Solution for Radiances: **CHIRP**

# CHIRP + Radiance Based L3 Retrieval Data Flow

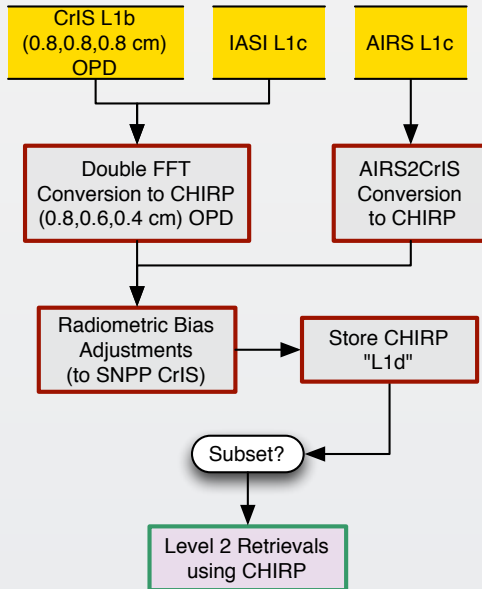


- *OPD*: Close to 0.8 / 0.6 / 0.4 cm
- *With Spectral Spacing*: 0.0625 / 0.0833 / 0.1250  $\text{cm}^{-1}$

Requirement: High-quality conversion of AIRS to CHIRP ILS

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

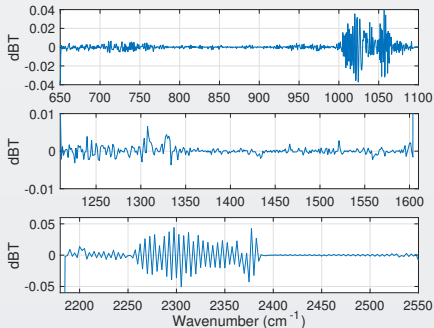
# CHIRP only Data Flow: Useful for Level 2 Retrievals?



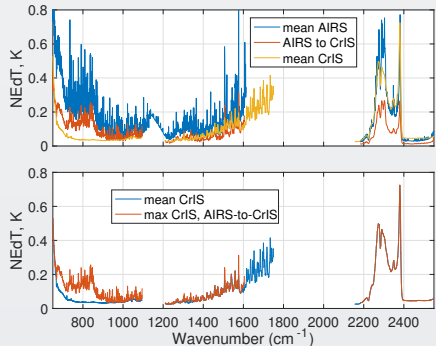
# AIRS2CrIS Algorithm

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

AIRS2CrIS Mean Error (std. similar)



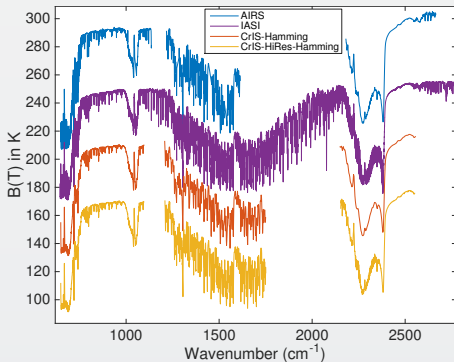
AIRS2CrIS Noise



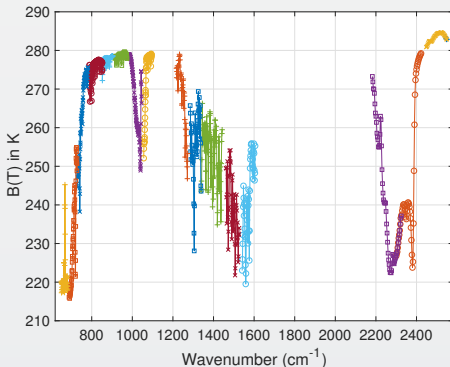
Shortwave sounding region max noise dominated by CrIS

# Spectral Differences Among AIRS, CrIS, IASI

## AIRS/CrIS/IASI Spectra



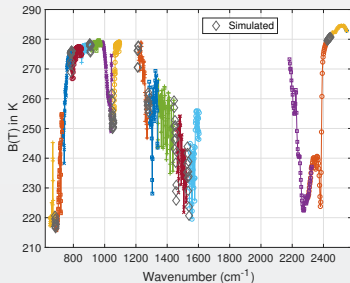
## CHIRP Spectrum (AIRS2CrIS)



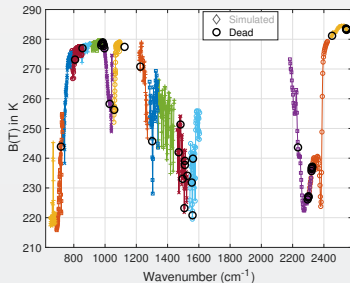
AIRS modules shown in different colors in CHIRP spectrum. This is CrIS-NSR, final CHIRP will be between CrIS NSR and FSR (MW/SW).

# Bad AIRS2CrIS Channels are Flagged

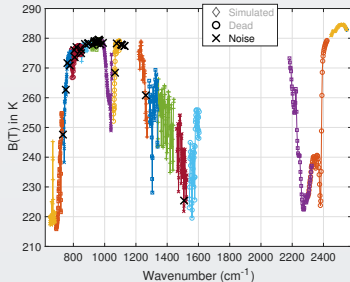
## Simulated Channels



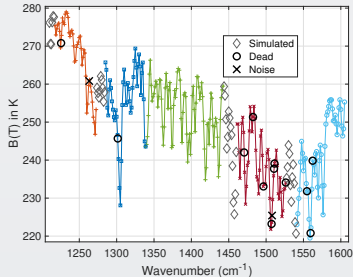
## Dead Channels



## Noisy Channels



## Midwave Zoom: Dead and Noisy Channels



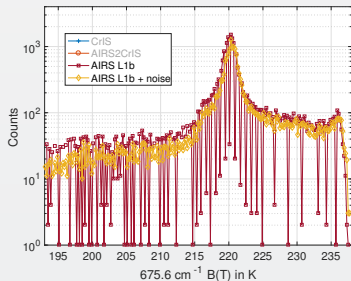
## Validation: PDF's of Single Channels

- 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  $675.6\text{ cm}^{-1}$  channels (closest match)
- Examine the PDFs (histograms) differences for:
  1. AIRS native SRF
  2. AIRS2CrIS
  3. CrIS

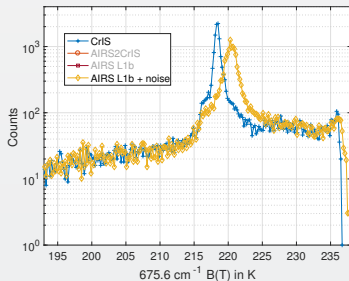


# PDF's for a Single CHIRP Channel Compared to CrIS

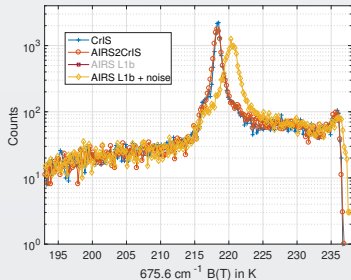
## AIRS only, Noise added



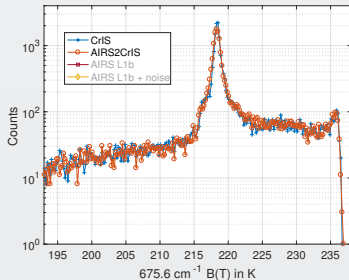
## PDF for closest CrIS Channel



## Convert AIRS to CrIS SRF



## CrIS versus CHIRP

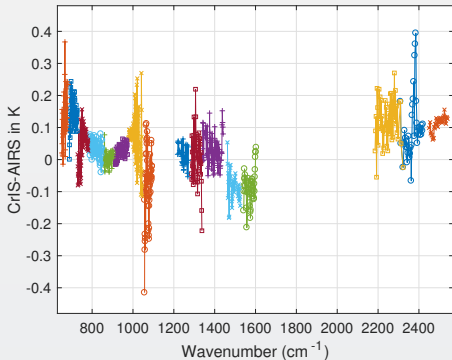


## Validation: SNOs between CrIS and AIRS2CrIS

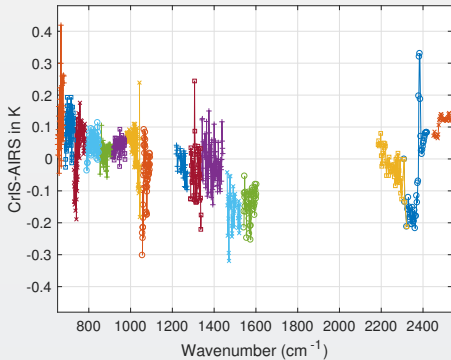
- SNOs are Simultaneous Nadir Overlaps
- We generate them for combinations of AIRS, CrIS, and IASI
- And convert AIRS to AIRS2CrIS (CHIRP)
- Allows *channel-by-channel* inter-comparisons (instrument offsets)
- We also use AIRS2CrIS as a transfer standard to intercompare SNPP-CrIS to NOAA20-CrIS since 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

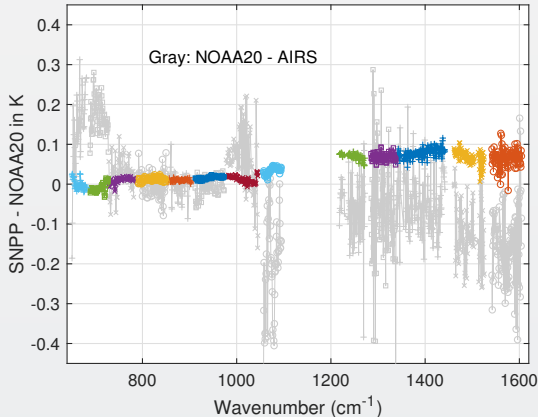


2016 Random Comparisons



SNOs and Random Comparisons in good agreement. Random averages have  $\sim 0.2K$  adjustment to compensate for CrIS having a larger mean secant angle than AIRS.

# SNPP vs NOAA20 CrIS (via AIRS Snos)



- NOAA20 and SNPP calibration may be updated in the future
- AIRS L1b calibration updates by Tom Pagano under consideration
- AIRS used as a "third party" cross-calibration transfer sensor!

# 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 ( $\text{CH}_4$ , 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.
- It's 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



## Future Work: CHIRP Algorithm

- AIRS2CrIS is on github at [https://github.com/strow/airs\\_deconv.git](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

## Future Work: 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<sub>2</sub>-H<sub>2</sub>O 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