Climate Hyperspectral InfraRed Product (CHIRP) Combining AIRS, CrIS, and IASI

AIRS Science Team Meeting

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A Climate Hyperspectral InfraRed Product (CHIRP)

Motivation

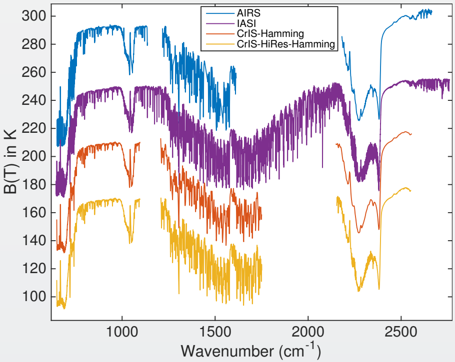
- Provide climate-level radiance time series spanning AIRS + CrIS, IASI
- User friendly by using a single spectral instrument line shape (ILS)
- A high-stability 25+ year long record of climate forcings and response
- Level 2 retrievals can use a common Forward Model (RTA) and channel selection for consistency

Three Products

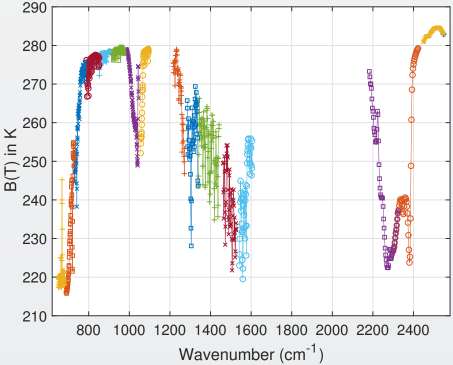
- CHIRP L1c: (radiances)
  - Nearly ready
  - Q/A is the hard part
- CHIRP L1c Gridded: (space/time gridded radiances)
  - Simple product
  - May subdivide averaged/binned radiances into (a) nearly clear (b) mixed clear and cloudy, and (c) high (cold) deep optical depth clouds
  - This subdivision will greatly enhance surface, lower tropospheric retrievals
- CHIRP Level 3: (geophysical anomalies)
  - Retrieve geophysical anomalies
  - Start with radiance anomalies derived from CHIRP L1c Gridded

Three Sensors Converted to Single Virtual Sensor

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).

CHIRP L1c

- Uses AIRS L1c and CrIS L1b (and IASI) as inputs
- Granule in, granule out
- Common insrument line shape (ILS), **allows us to correct for inter-instrument radiance offsets**
- CHIRP noise often lower than input noise, normalize to a common level?
- Signifiant Q/A effort: AIRS Q/A influences CrIS Q/A flags

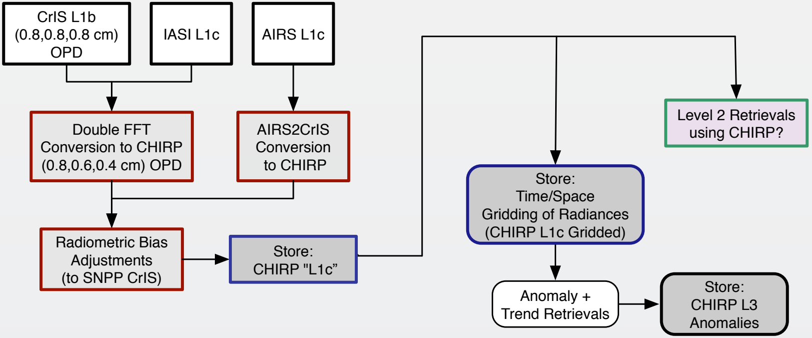
CHIRP L1c Gridded

- Likely most important long-term climate data record
- Simple gridding of CHIRP L1c
- 16 day bins (orbit repeat cycle)
- Nominal 1x1 degree grid?
- Gridded radiance noise included
- Radiometric offset correction for AIRS to match CrIS mean secant angle (0.2-0.3K correction)

CHIRP Level 3 (Gridded) Geophysical Anomalies

- Input is CHIRP L1c Gridded
- Create anomalies in radiance space before geophysical retrievals to enhance error traceability
- Approach minimizes sensitivity to a-priori estimates (i.e. use zero for T, H_2O, O_3 a-priori estimates)
- Minimze sampling biases due to clouds
- Designed for quick reprocessing, essential for climate products

CHIRP Processing Flow



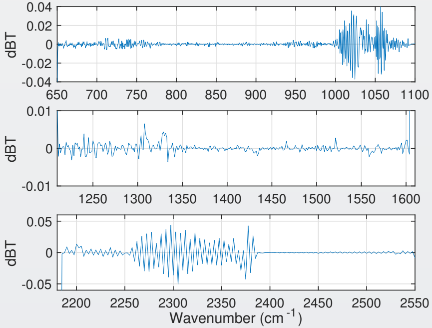
CHIRP: (Common or Climate) Hyperspectral InfraRed Product

- CrIS High-Res OPD = 0.8/0.8/0.8 cm
- CHIRP "OPD" = 0.8/0.6/0.4 cm (Allows AIRS conversion to CrIS)
- CHIRP MW/SW 75%/50% lower resolution than CrIS

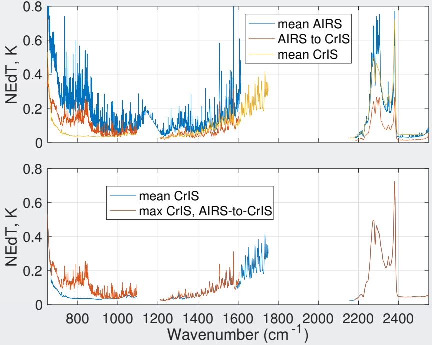
AIRS2CrIS Algorithm

- 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)



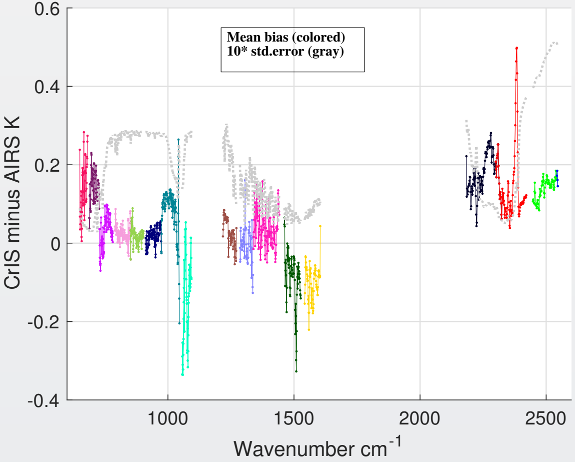
AIRS2CrIS Noise



Shortwave sounding region max noise dominated by CrIS

Radiometric Corrections Applied to AIRS

- CrIS-like ILS is CHIRP standard
- We convert AIRS to CrIS ILS, and apply inter-instrument radiometric offsets to create a seamless record



Anomaly and Trend Approach:

First: generate radiance anomalies $dBT(t)$.
Then perform geophysical anomaly retrievals.

Linear solution for trends with a-priori state = 0 given by,

$$dx(t) = \left(K^T S_\epsilon^{-1} K + R^{-1}\right)^{-1} \left(K^T S_\epsilon^{-1} dBT(t)\right)$$

- *dx(t)* are the atmospheric state vector anomalies
- *K* are the B(T) Jacobians
- S_ϵ is the observation error covariance matrix (noise)
- *R* combines empirical regularization (Tikonov L1-type) and the *a-priori* covariance-based terms

Sergio showed zonally averaged dx(t) samples yesterday

- Cloud parameter Jacobians may be derived from MERRA-2 (or ERA5)
- Or, if necessary retrievals of $x(t)$, at least for cloud top heights and amounts

Level 2 Retrievals using CHIRP

- CHIRP L1c could be input for the AIRS/CrIS Level 2 product
- Removes instrument bias differences
- Removes retrieval differences due to different RTAs
- Level 2 validation may be more straightfoward using this approach

Conclusions

- We hope to have CHIRP L1c algorithm ready in several months
  - File formats almost done
  - Q/A issues and noise normalization still being worked out
- CHIRP L1c Gridded will soon follow, relatively easy to develop
- CHIRP Level 3 geophysical anomalies will require further development
  - Hope to have CHIRP Level 3 mature in 1 year