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

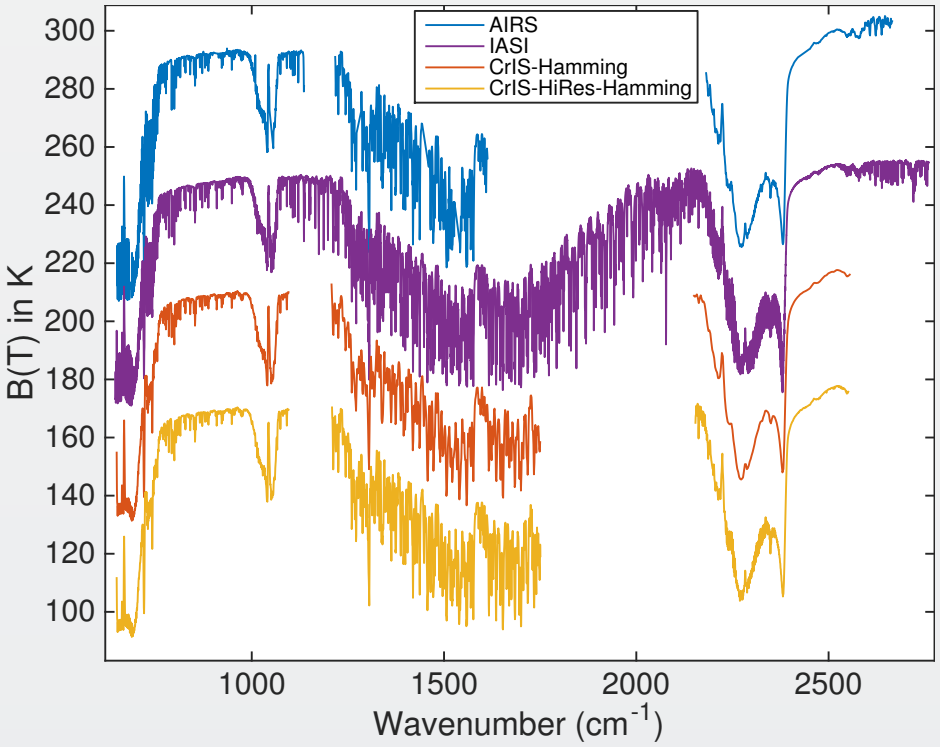
- Provide climate-level radiance time series spanning AIRS + CrIS, IASI
- User friendly by using a single spectral instrument line shape (ILS)
- A high-stability 25+ year long record of climate forcings and response
- Level 2 retrievals can use a common Forward Model (RTA) and channel selection for consistency

Three Products

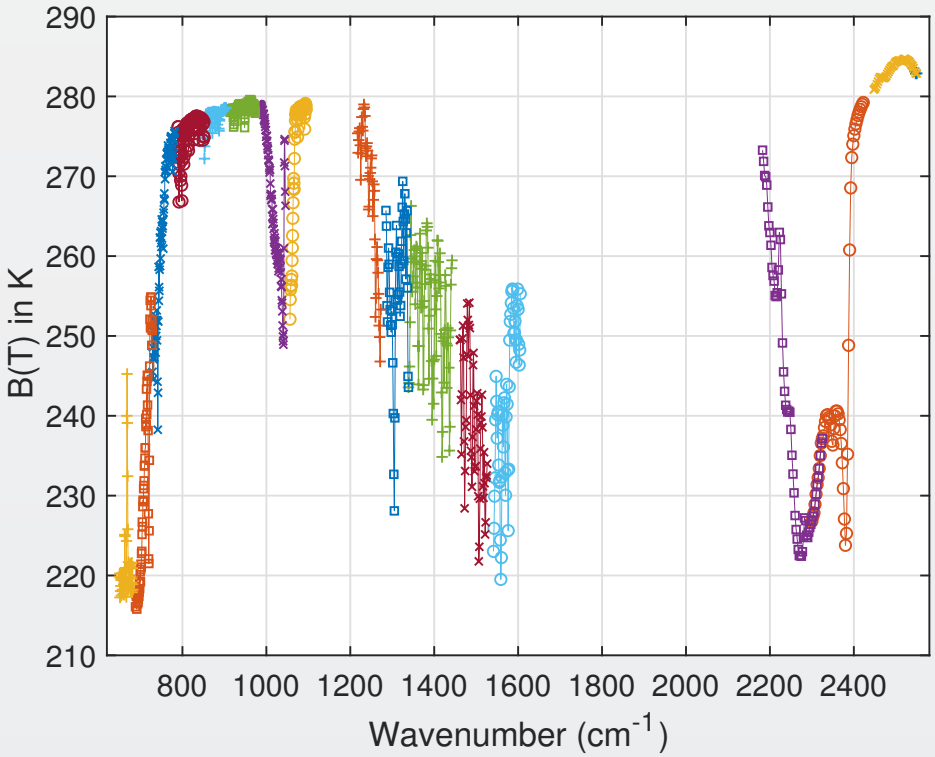
- CHIRP L1c: (radiances)
  - Nearly ready
  - Q/A is the hard part
- CHIRP L1c Gridded: (space/time gridded radiances)
  - Simple product
  - May subdivide averaged/binned radiances into (a) nearly clear (b) mixed clear and cloudy, and (c) high (cold) deep optical depth clouds
  - This subdivision will 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

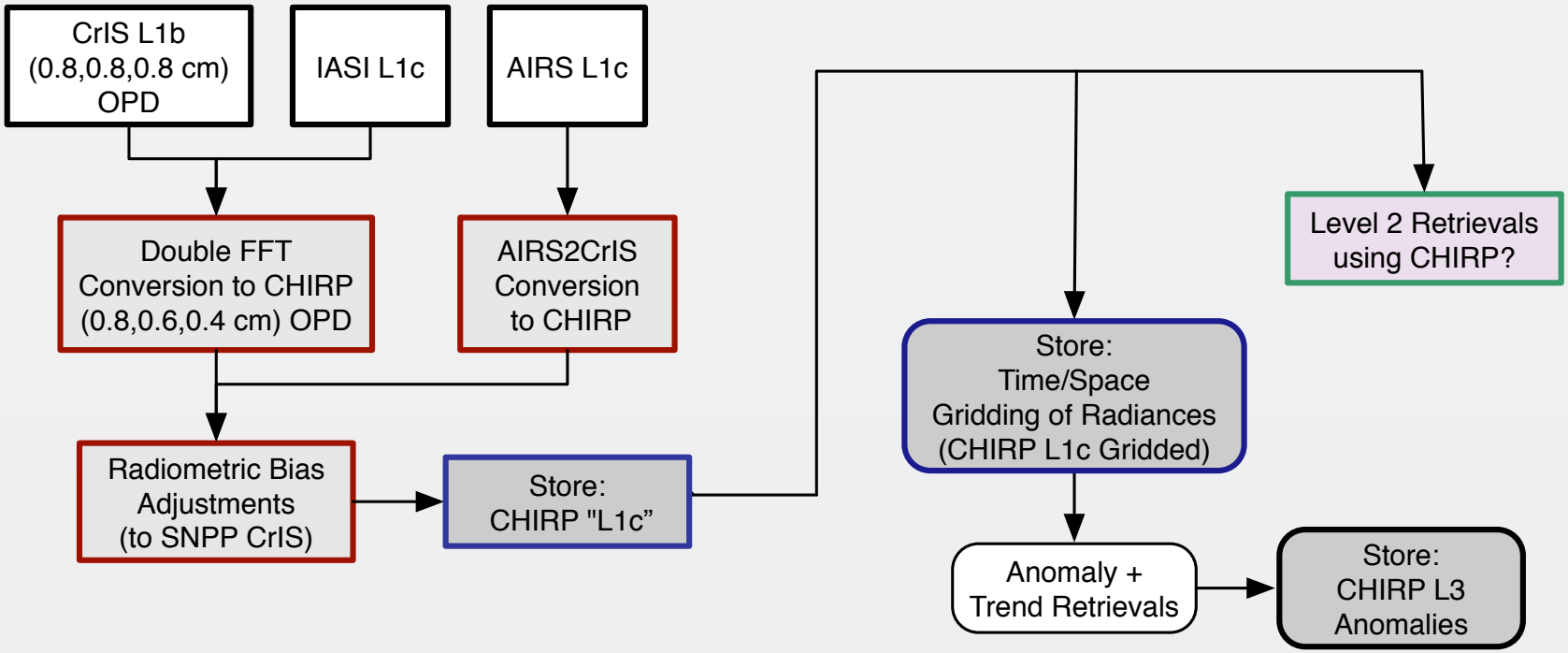
CHIRP L1c Gridded

- 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



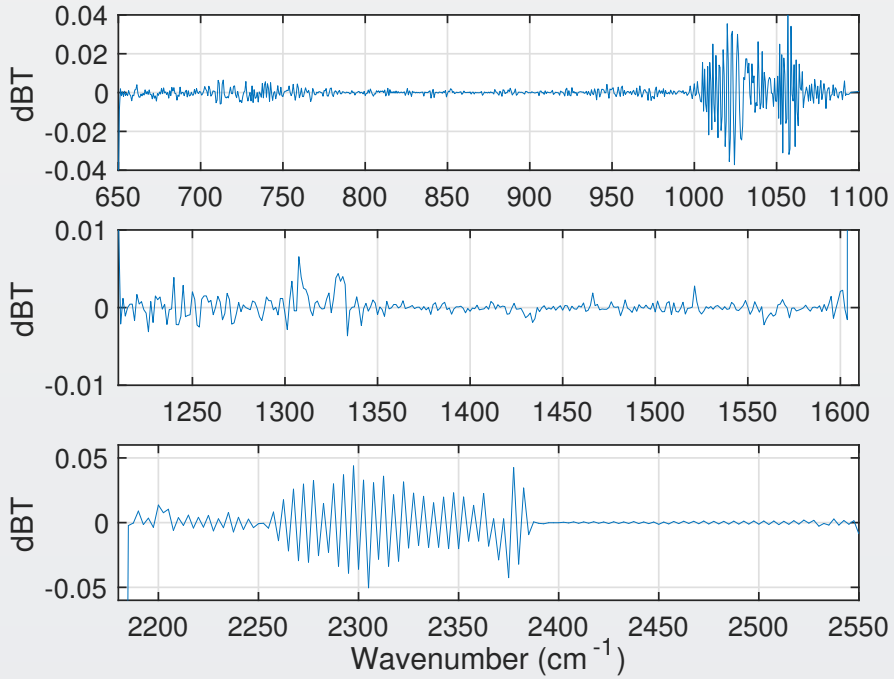
CHIRP: (Common or Climate) Hyperspectral InfraRed Product

- 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

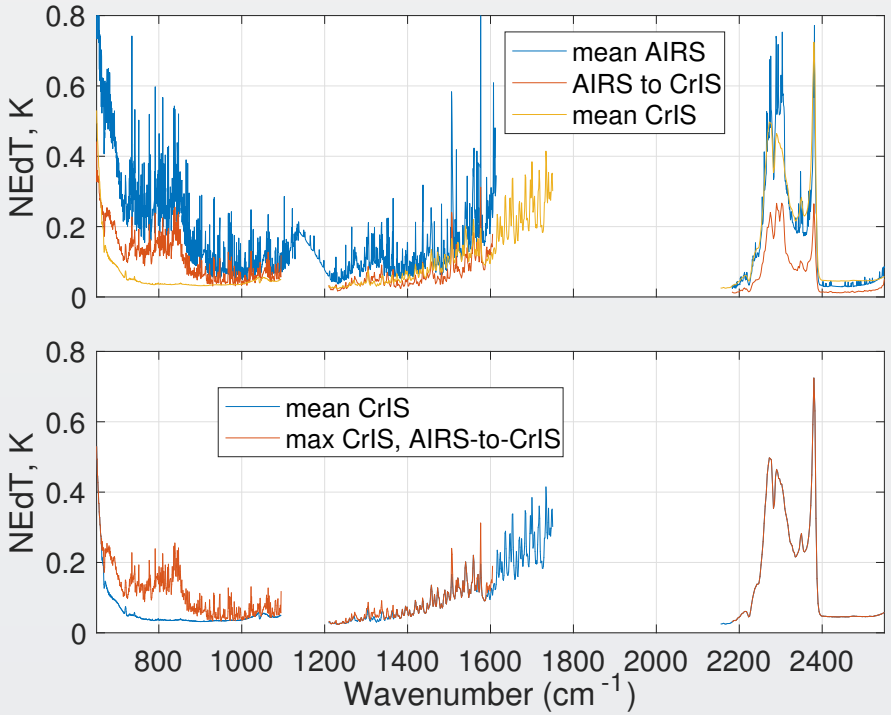
AIRS2CrIS Algorithm

- 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)

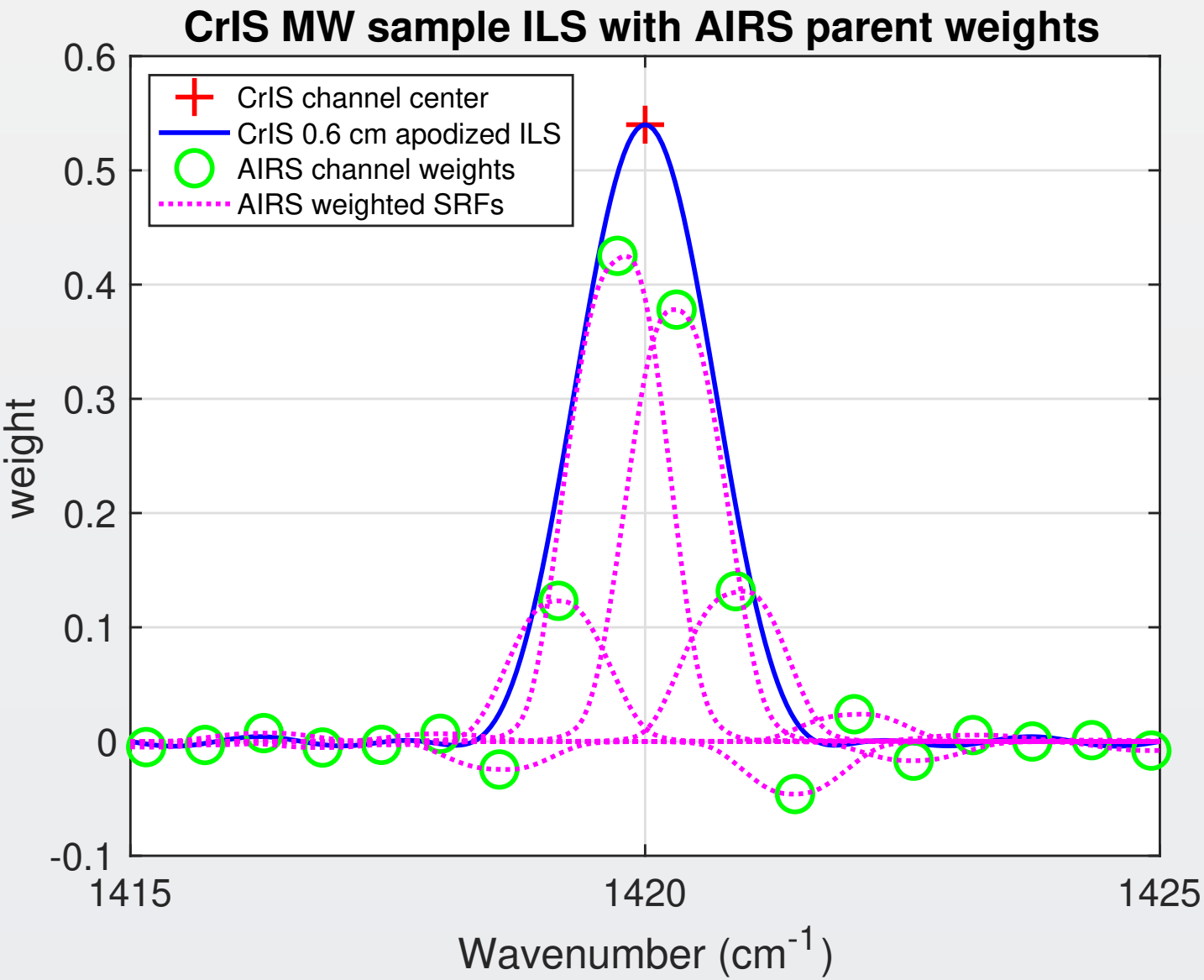


AIRS2CrIS Noise



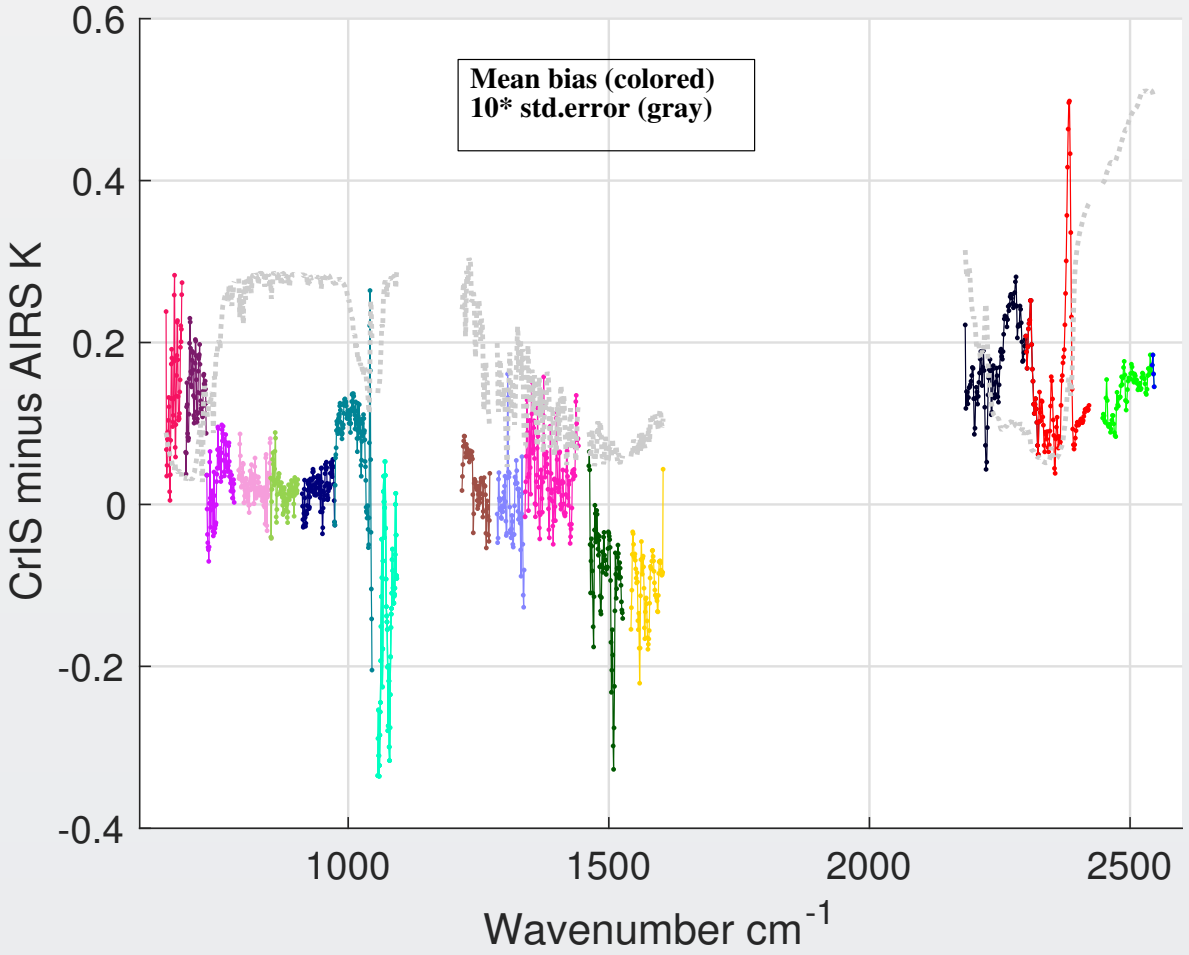
Shortwave sounding region max noise dominated by CrIS

Illustration of AIRS Conversion to CHIRP



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