A New Highly Stable Multi-Decade Satellite Climate Data Set Derived from Polar Hyperspectral Infrared Sensors.

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Overview

- The Purpose of this Presentation is to describe a new highly stable multi-decade global satellite based infra-red radiometric data set for use with climate studies.
- In very brief outline -
  - What it is.
  - How it is derived.
  - Some basic features and attributes.
  - Where it is.
  - Some examples of its application.

Motivation: Combine AIRS + CrIS + IASI for Long Time Series

- Create climate quality radiance record with common spectral scale.
- Combine current and planned missions to create 25+ year continuous record.
- We currently have 18+ year multi-instrument record (AIRS, CrIS(2), IASI(3)).
- For climate, the radiances are the “product” used by the scientific community.

Instrument Characteristics (AIRS vs CrIS vs IASI)

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

Solution: Climate Hyperspectral InfraRed Product CHIRP

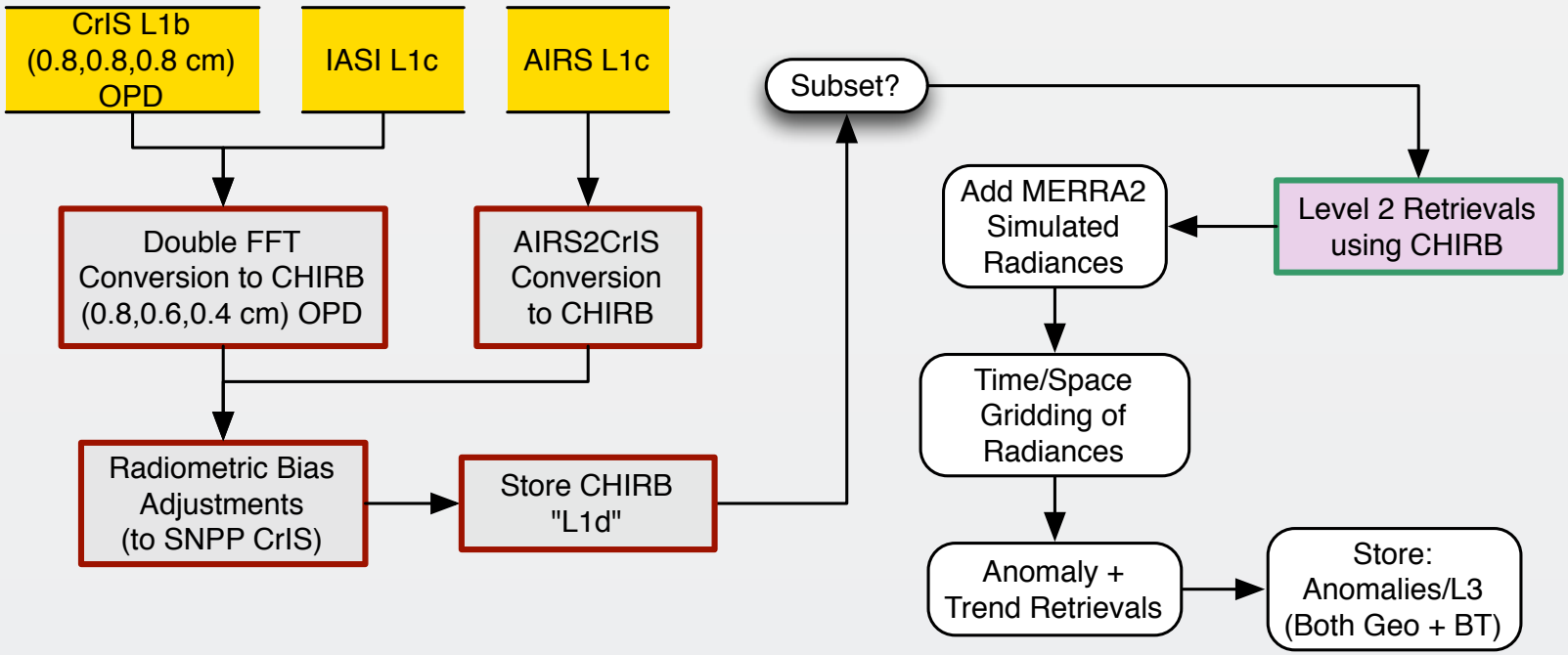
Continuity Requirements (that provide same observation sensitivities)

- Same SRFs and Center frequencies.
- Same Radiative Transfer Model (RTA).
- Same retrieval algorithm.
- Easily traceable uncertainties.

Approach:

- Produce Level 1b CHIRP radiances (global).
- Produce Level 3 climate-level gridded radiances.
- Geophysical Products - Level 3 T/Q anomalies and trends.
- Very fast algorithm.
- Minimize sensitivity to a-priori estimates.
- Remove artificial sampling biases and analyse in radiance space.

CHIRP: Data Flow



- OPD: Close to 0.8 / 0.6 /0.4 cm (With Spectral Spacing: 0.0625 / 0.0833 / 0.1250 cm -1)
- Ref. H. E. Motteler and L. L. Strow, "AIRS Deconvolution and the Translation of AIRS-to-CrIS Radiances With Applications for the IR Climate Record," in IEEE Transactions on Geoscience and Remote Sensing, vol. 57, no. 3, pp. 1793-1803, March 2019.

CHIRP Overview

- CHIRP derived from AIRS from Sep-2002 to Sep-2018, then to present from CrIS.
- The AIRS Level 1c radiances are corrected for radiometric and spectral drift and each detector assigned a measure of quality.
- CHIRP inherits the accuracy and stability of its parent. Much work undertaken to validate and quantify, including intercalibration and trending to equatorial SST and CO2.
- Radiance data records (heirarchical format) currently being implemented and installed at JPL in advance of going to the Goddard Distributed Active Archive Center (DAAC).

Anomaly and Trend Approach

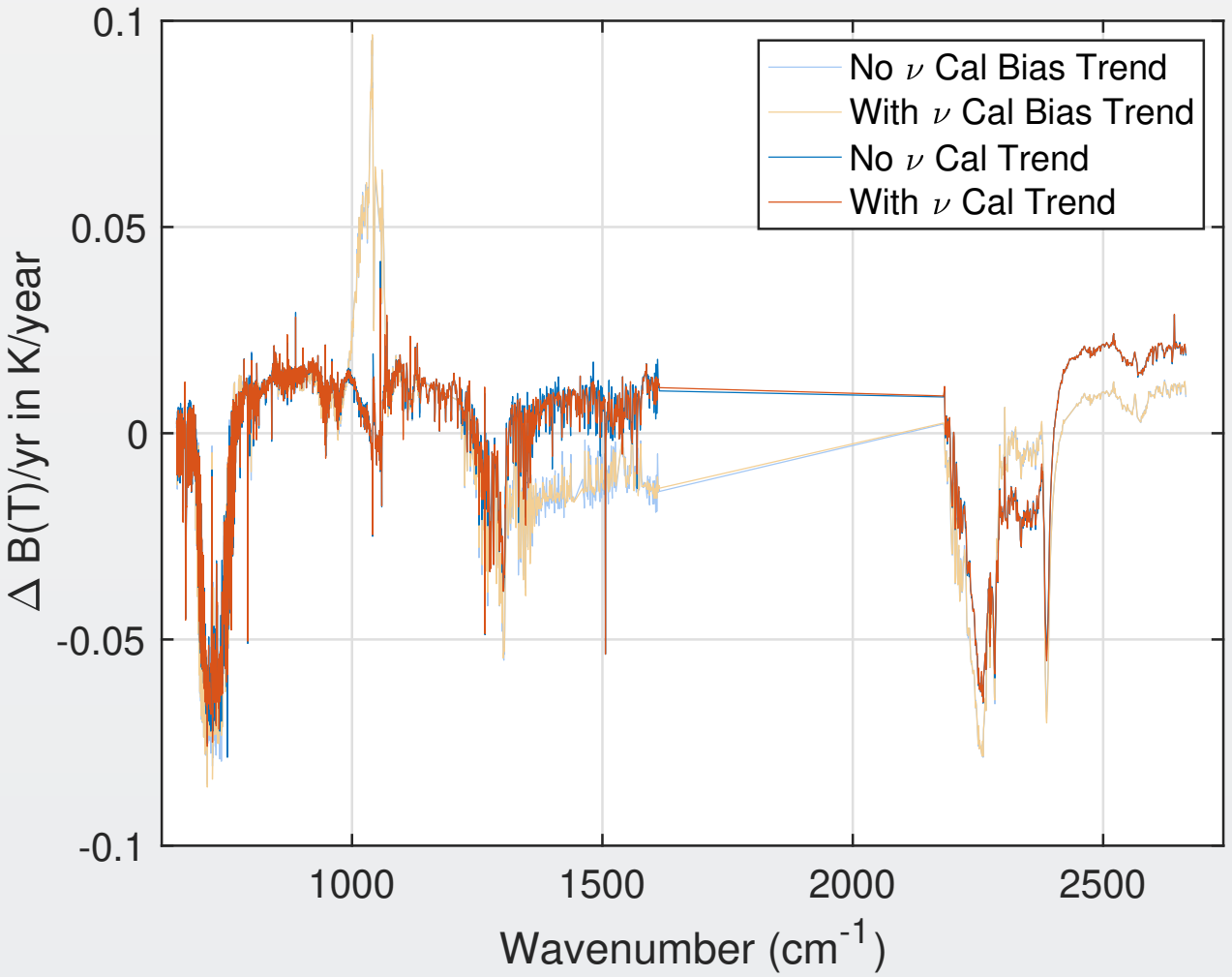
First: generate radiance anomalies $dBT(t)$.
Then perform geophysical anomaly retrievals.

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

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

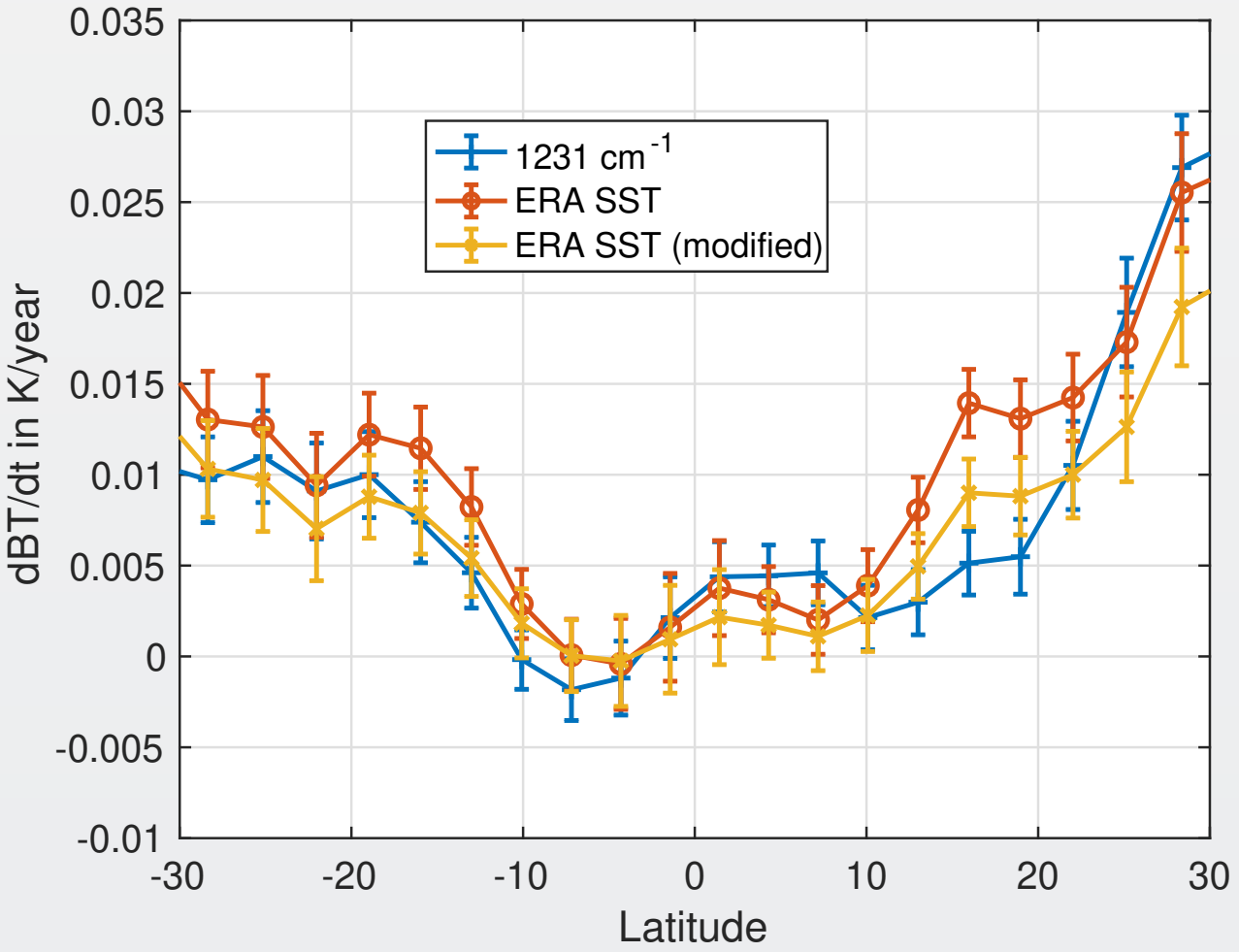
- *dx(t)* are the atmospheric state vector anomalies
- K are the B(T) Jacobians
- S_ϵ is the observation error covariance matrix (noise)
- R combines empirical regularization (Tikonov L1-type) and the *a-priori* covariance-based terms

Stability: Clear Ocean Trends



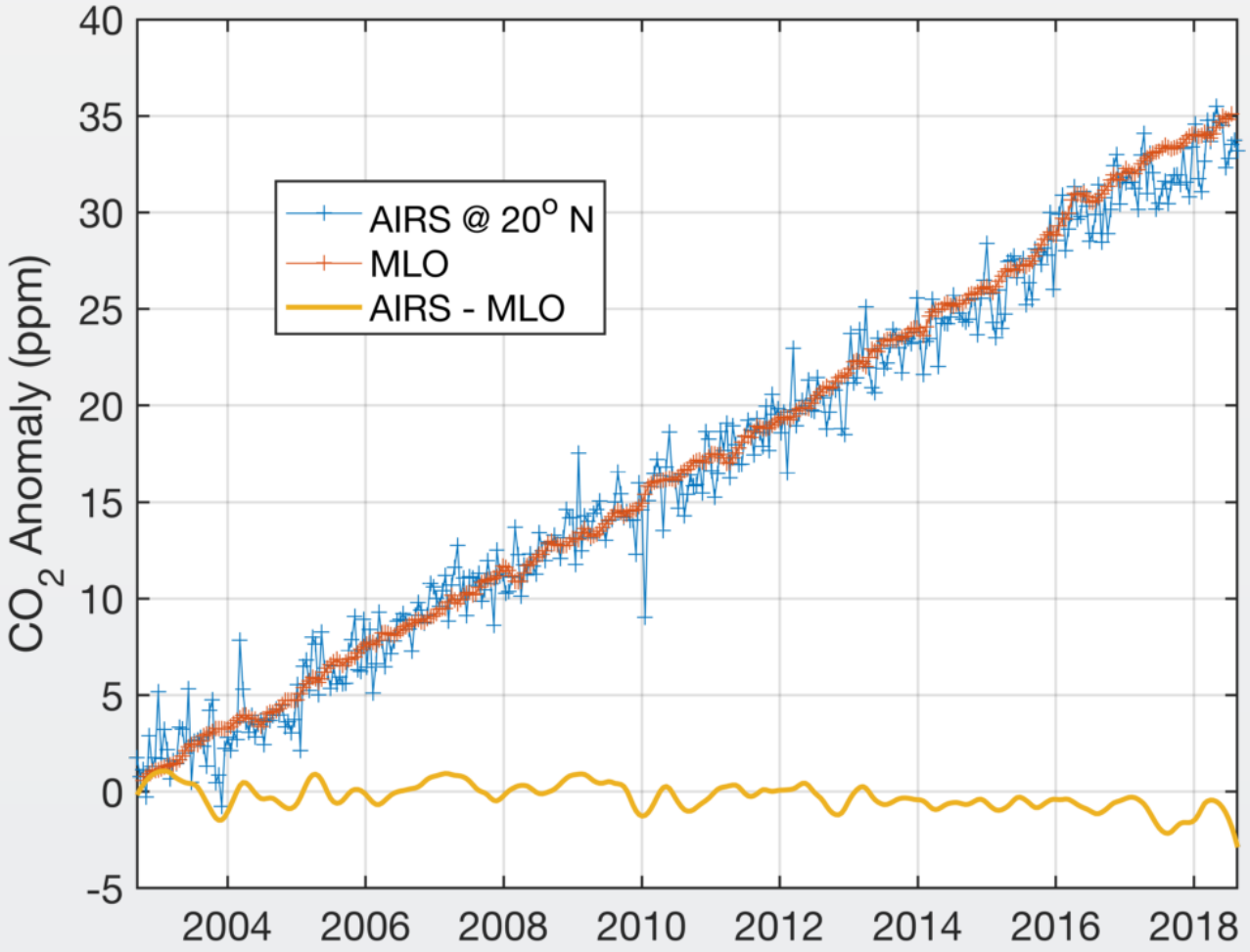
- Showing 16-year clear ocean observation BT trend & bias relative to SST.

Stability: 1231 cm-1 Trend vs ERA SST Trend



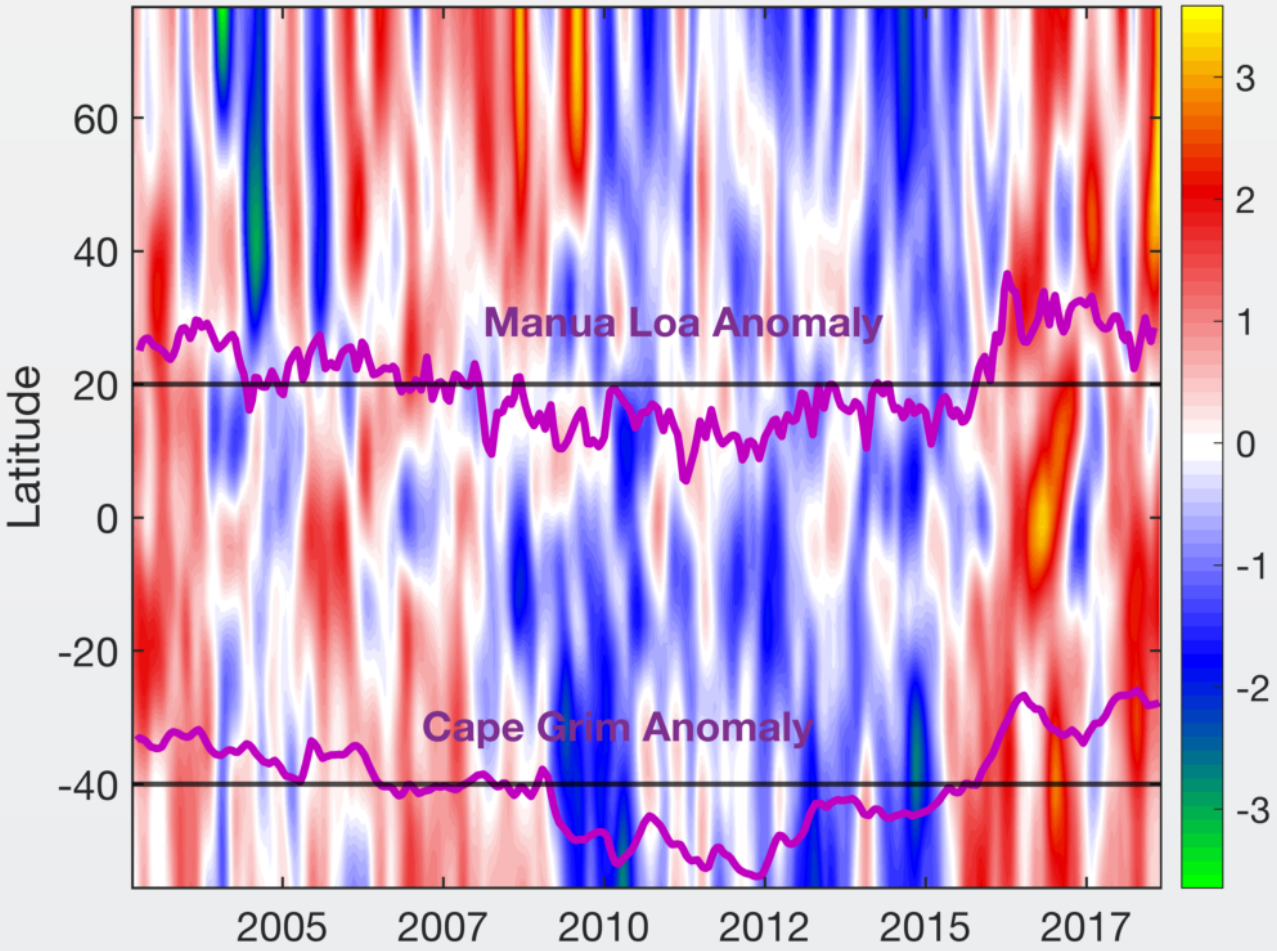
- ERA SST modification due to change in water vapour absorption. (confirmed with OISST).

Stability: Retrieved CO2 Anomaly (growth), at Muana Loa



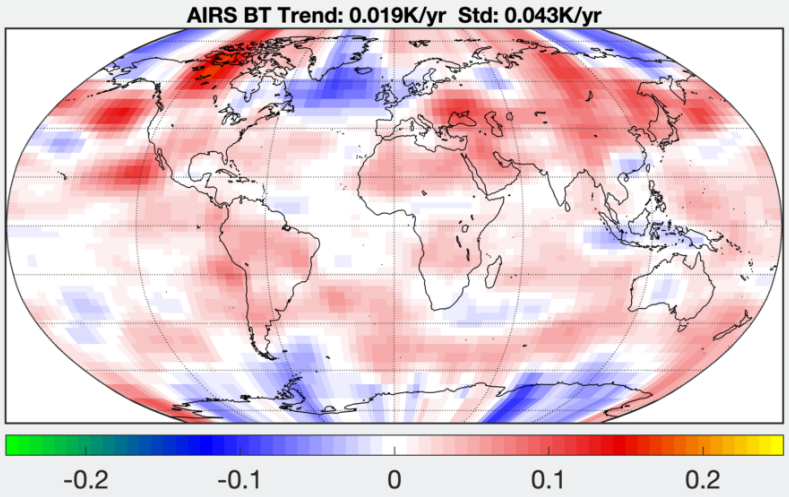
- Observations are zonal average centered on 20-deg North.

CO2 anomaly vs latitude (detrended).

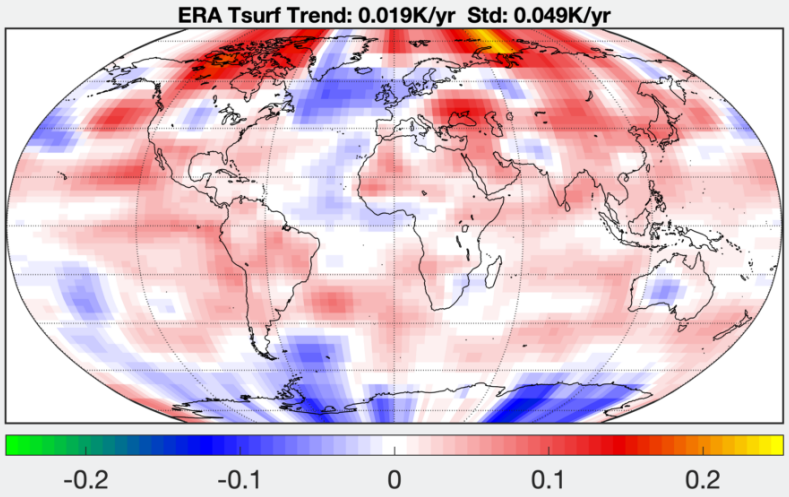


- The CO2 residual after detrend and de-seasoned.
- 40 equal area latitude band averages.

Mapping Example: Global Variability for 10% hot subset.



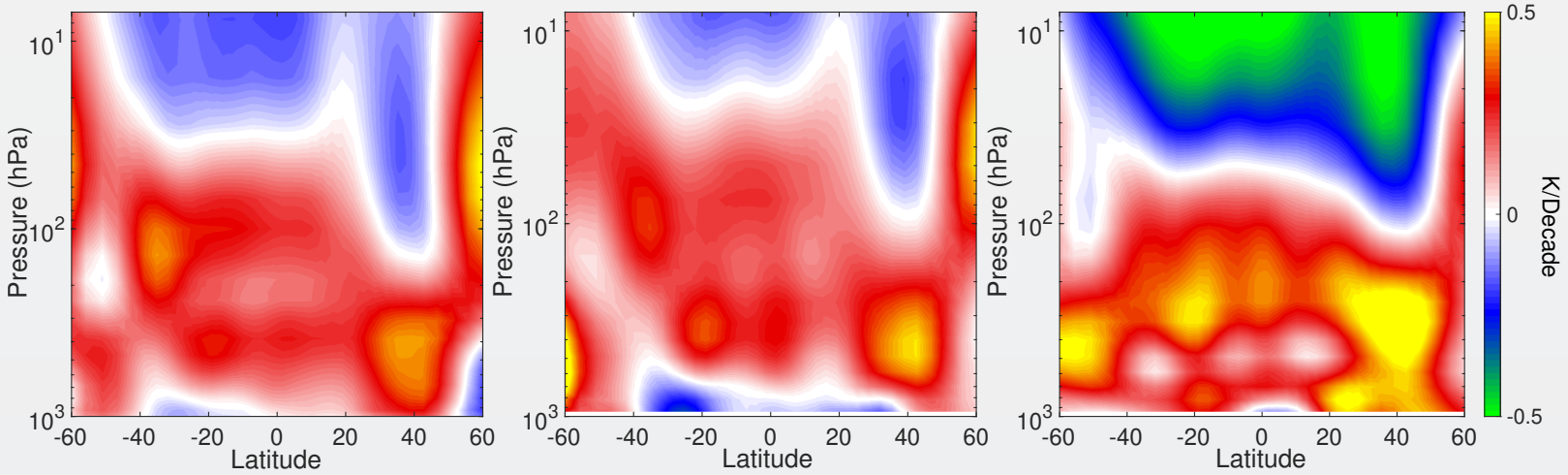
(a) AIRS Global trend: 0.019K/yearAIRS Global std: 0.043K/year



(b) ERA Global trend: 0.019K/yearERA Global std: 0.049K/year

- Quite similar, no cloud patterns?
- High cancellation of trends, but not to zero.
- Very simple, accuracy can be modeled.

Retrieval Example.



- Temperature profile trends for the period 2003-2018.
- Left: Derived directly from the ERA model temperature fields.
- Middle: Simulated retrievals of the ERA trends using our SARTA RTA.
- Right: Profile trends retrieved from the AIRS observed anomalies.

Conclusion - Future Work

- CHIRP Product defined, channel quality flags and attributes established.
- Implementation is in progress (UMBC to JPL to DAAC).
- CHIRP radiometric stablility evaluation largely assessed but will be on-going.
- Time-dependencies to be formally determined. Examples using parent AIRS radiances demonstrate stability.
- CHIRP gridded "L3" product being assessed.
- All scenes are paired with re-analysis (ERA, MERRA, OISST).
- Several types of gridding seem worthwhile (all sky, lat/lon equal area, subset) - Users fedback encouraged and welcome.
- OEM retrievals of T/Q zonal trends will continue with an emphasis on observation error co-variances and better all-sky cloudy jacobians. Examples using parent AIRS have been shown.