Climate Hyperspectral InfraRed Product (CHIRP): Radiometric Stability and Trends

AIRS Science Team Meeting

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

- Produce Level 1b CHIRP radiances for retrievals
- Produce Level 3 climate-level gridded CHIRP radiance products
- Goals
  - Minimize sensitivity to a-priori estimates, etc.
  - Remove artificial sampling biases
  - Perform as much analysis in radiance space for error traceability
- Geophysical Products
  - Level 3 T/Q anomalies and trends (and surface T?)

This approach is in principle very simple and quick. Allows frequency re-processing.

What's Hard:

- Dealing with clouds
- AIRS radiometric stability estimates (ie. how good?)

Overview: Two Products Proposed

(1) Multi-Instrument Hyperspectral Radiance Climate Time Series

- 1:30 Orbit: AIRS + CrIS, 9:30 Orbit: IASI
- Convert to common ILS to facilitate inter-instrument radiance calibration
- Produce time/space grids of radiance time series and anomalies for climate analysis

(2) Level 3 Geophysical Products

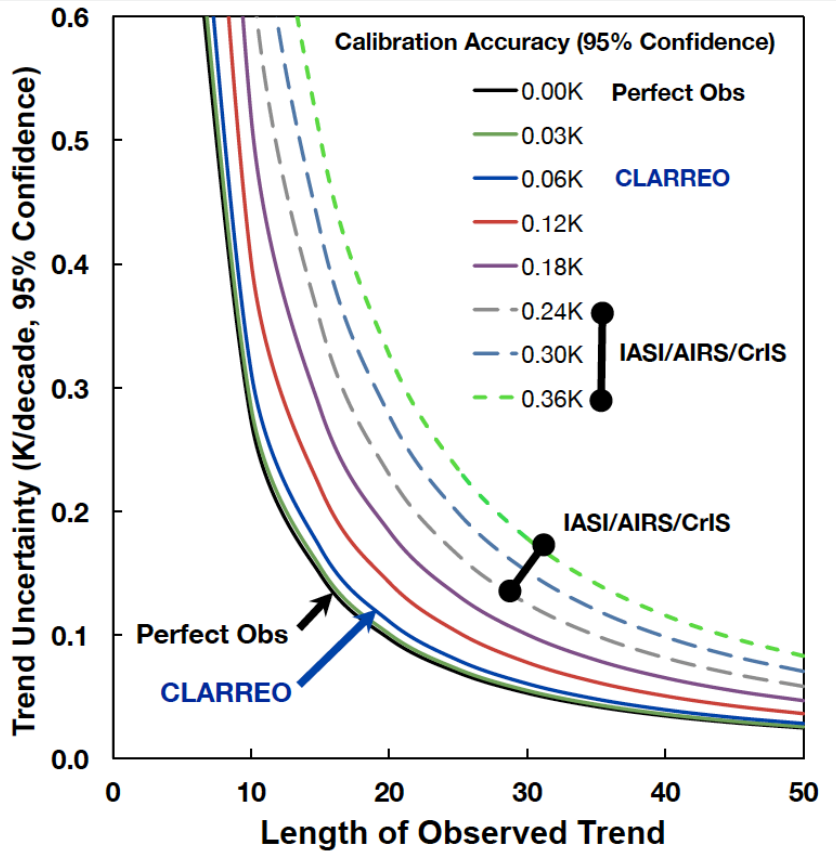
- Generate geophysical (T/Q, etc.) "Level 3" anomaly time series
- Trends will be a science product, not a DIS product

Validation/Comparisons

- AIRS/CrIS/IASI inter-comparisons
- Reanalysis: ERA+, MERRA-2
- Microwave
- Surface and SST climatologies
- GPS-RO (Leroy)

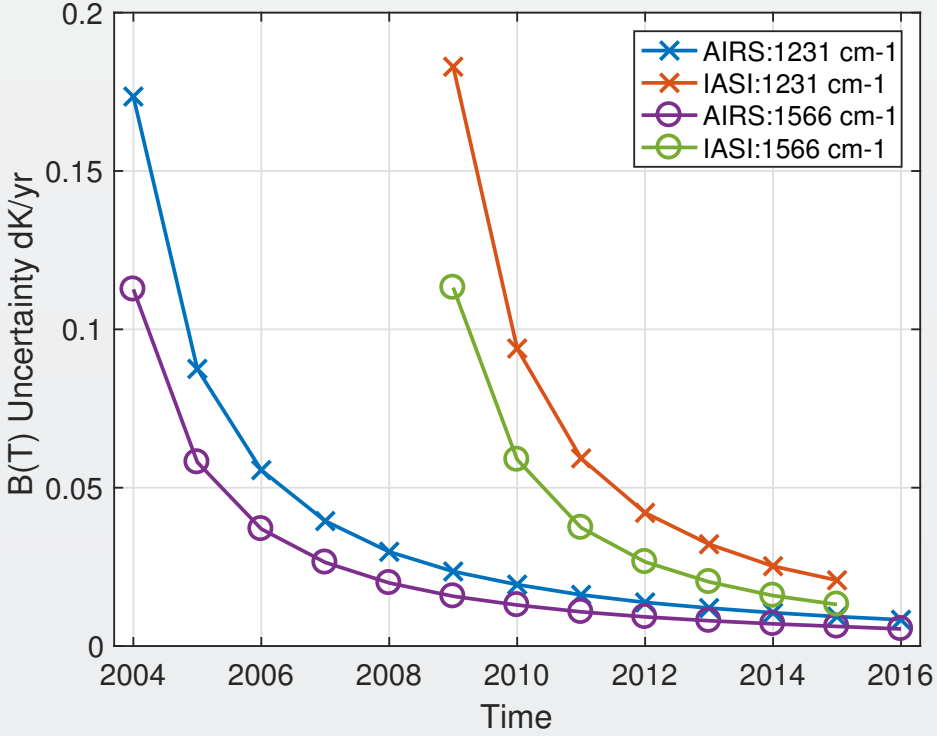
Time Series Length Nearing Climate Scales

CLARREO Schematic: Our Uncertainty?



AIRS, CrIS, IASI are *all* very stable
CLARREO has removed us from this figure!

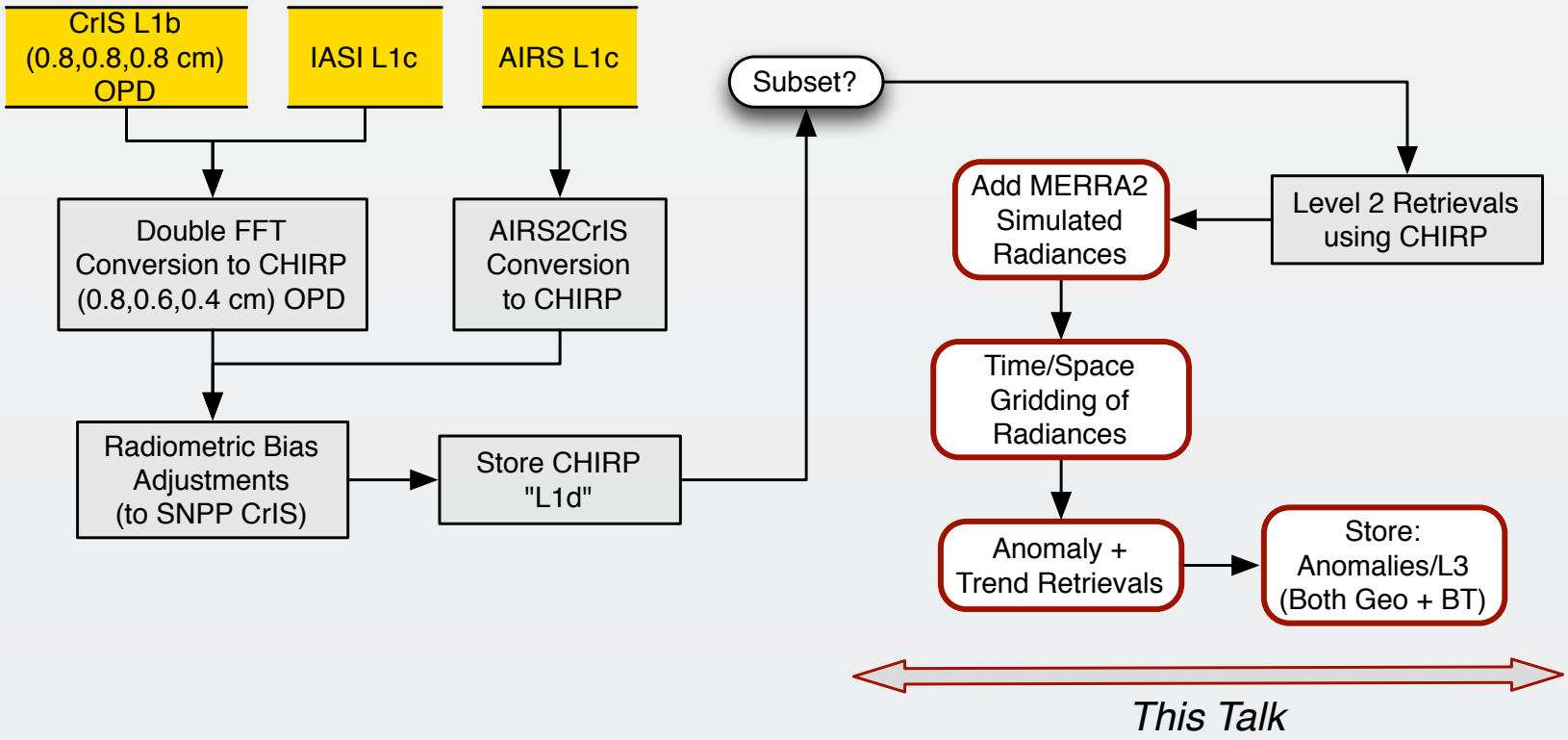
AIRS 14-Year global trends



These are 2-σ B(T) statistical uncertainties due to inter-annual variability.

Some channels, some latitudes not gaussian (strat sudden warmings, QBO, etc.)

CHIRB Processing Flow



CHIRP: (Common or Climate) Hyperspectral InfraRed Product

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

Anomaly and Trend Approach: (Result Shown Previously)

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

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

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

S_ϵ covariances represent inter-annual variability and instrument stability. They introduce significant constraints compared to L3 time derivatives, *still implementing*.

Jacobian state from standard all-sky retrievals or from re-analysis; high accuracy not needed.

This Talk

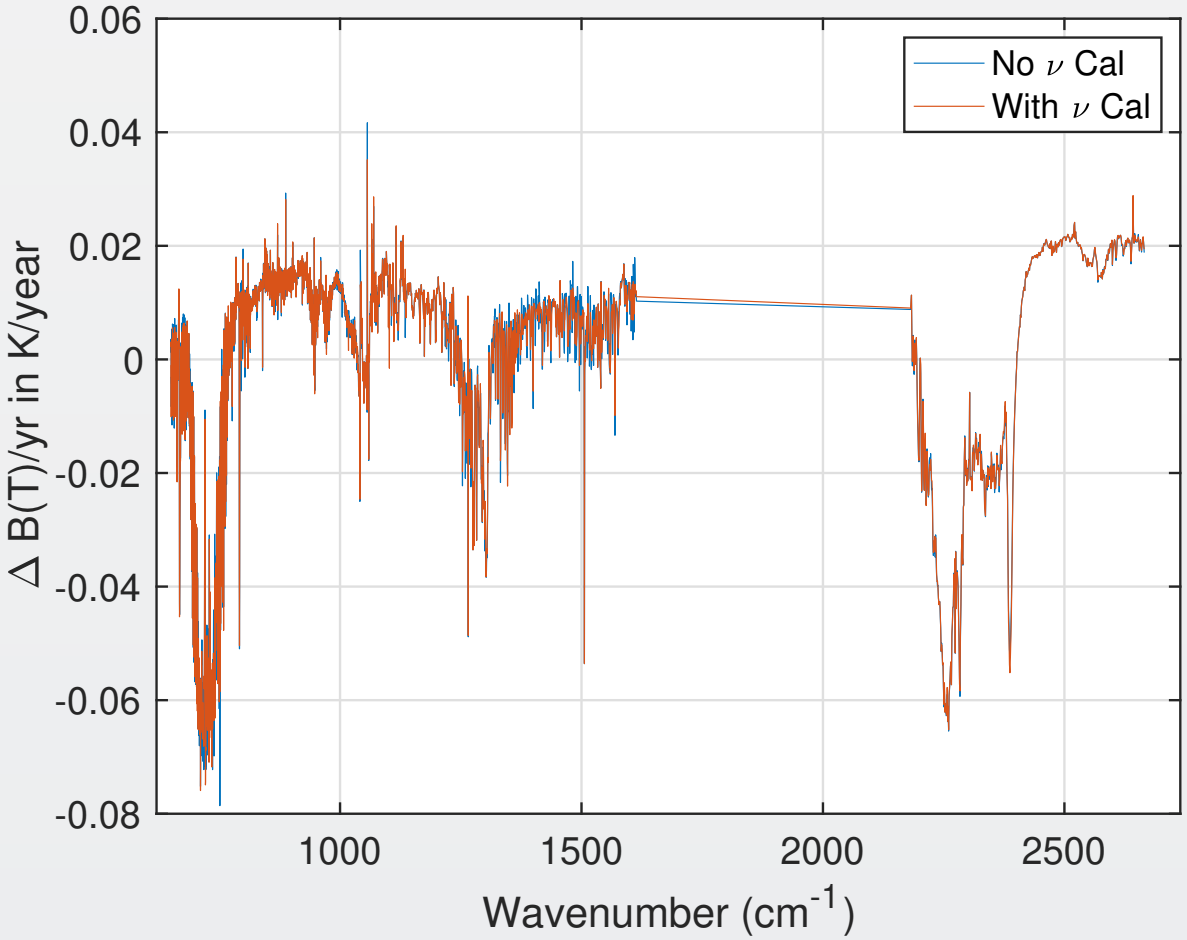
- Concentrate on 16 (or 15) year radiance trends
- AIRS Stability
- Cloud variability on 15 years, how to minmize

Cocentrate on global, zonal trends to emphasize instrument issues

Data Sets

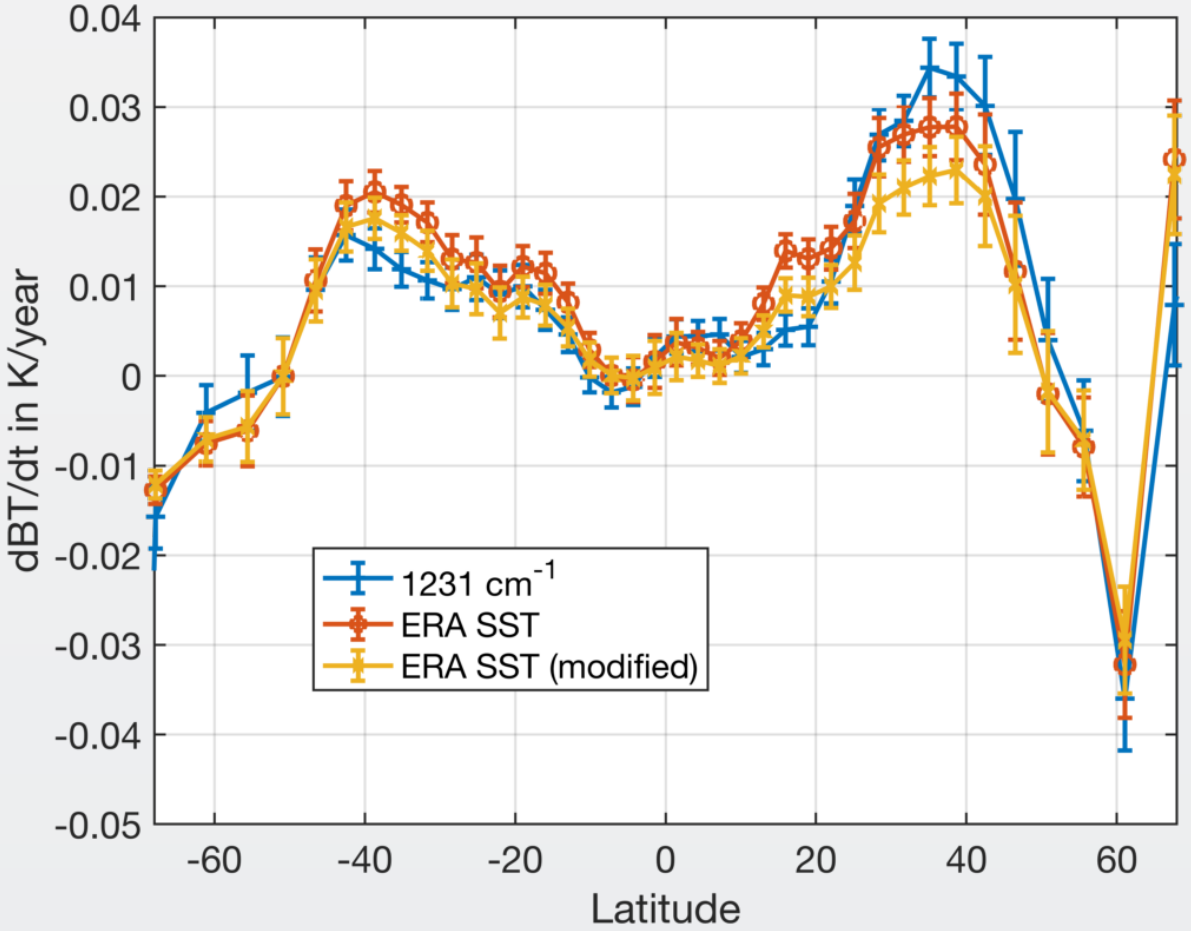
- Start with a ~1% random, area-weighted subset (for quick processing)
- Produce 40 area weighted zonal bins (all channels) for 5475 days
- Proudce 48 x 90 deg. area-weighted gridded trends (1 channel)
- All data is L1c (frequency calibrated)

Stability: Clear Ocean Trends



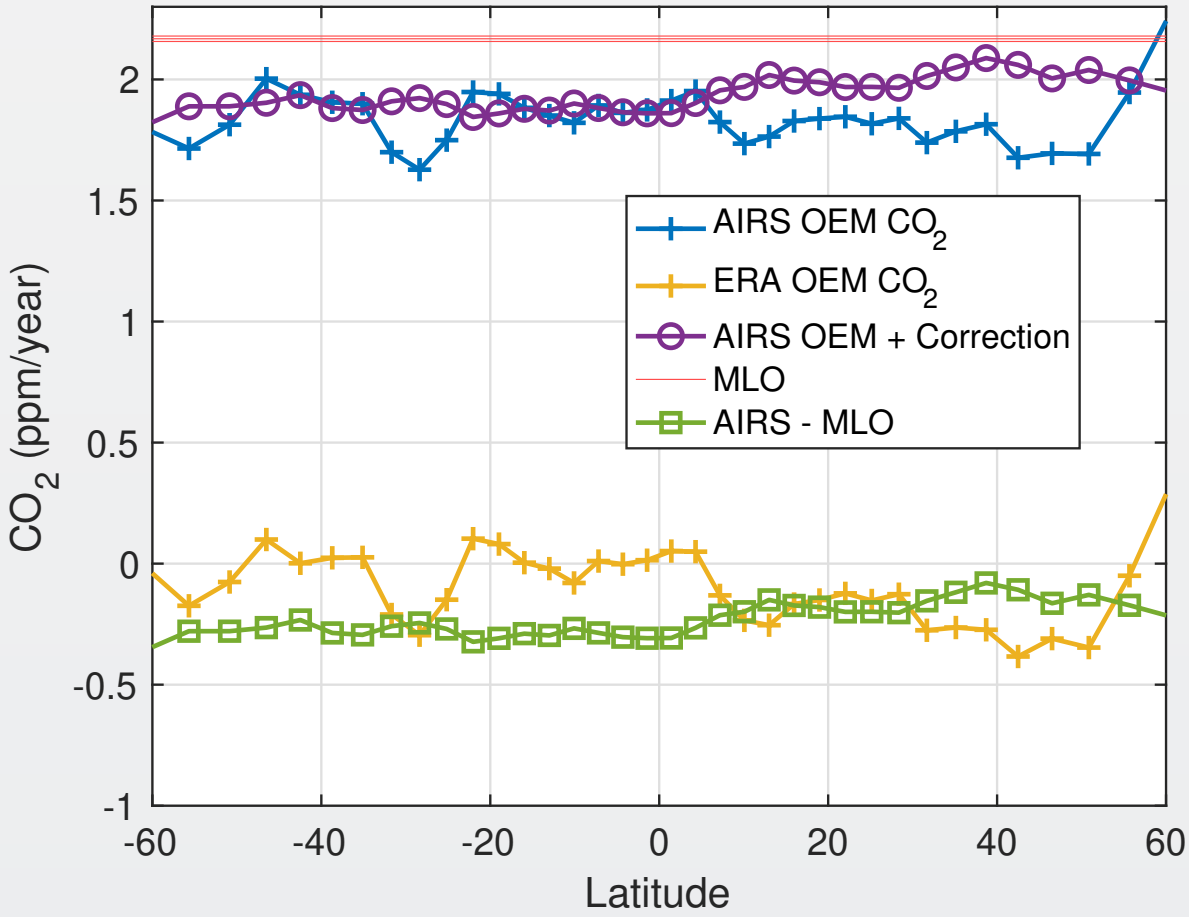
- This is AIRS 16-year clear ocean BT trend
- Shortwave has issues, not used for science trending
- Compare to ERA vs latitude for "good channels"
- Modify ERA SST to account for effect of water vapor on BT trends

Stability: AIRS 1231 cm^{-1} Trends vs ERA SST Trends



- ERA SST modification due to water vapor absorption
- These are quite accurate, use Aumann's "split-window" to correct
- AIRS trending hotter by ~0.003K/year
- Differences mostly 30-40 deg. lat??, look at time-dependence

Stability: OEM Retrieval of Clear Ocean CO_2 Trends vs MLO

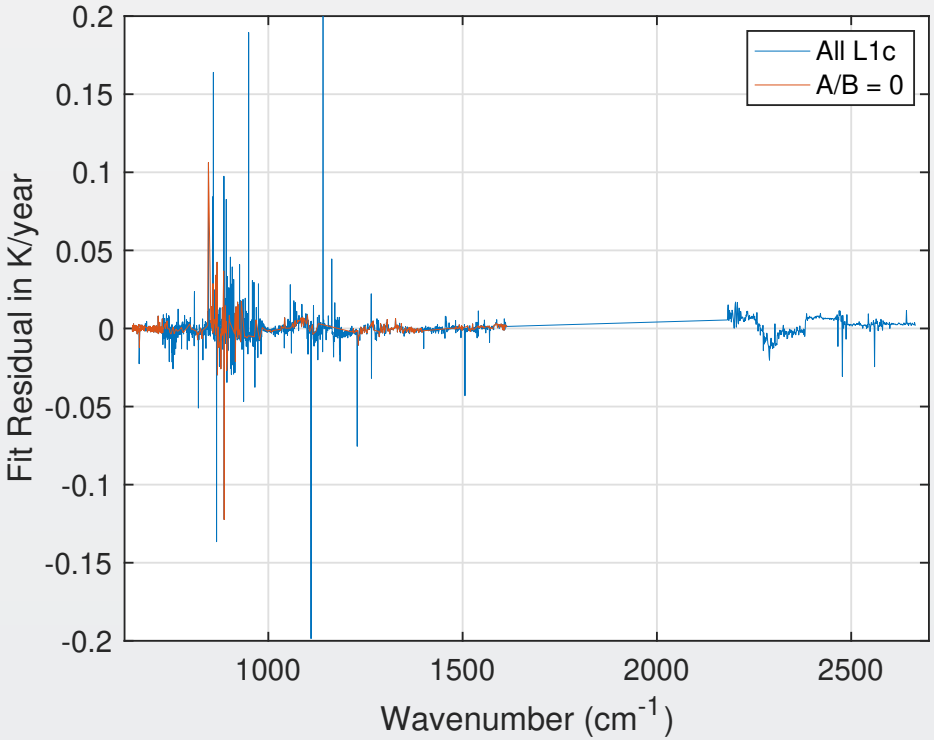


- OEM retrieval off due to co-linearity of CO_2 and T
- Determine OEM offset by retrieval CO_2 from ERA trend (no CO_2)
- Correct OEM CO_2 trend for this co-linearity
- Compare this to NOAA MLO; AIRS B(T) trend ~+0.003K/year

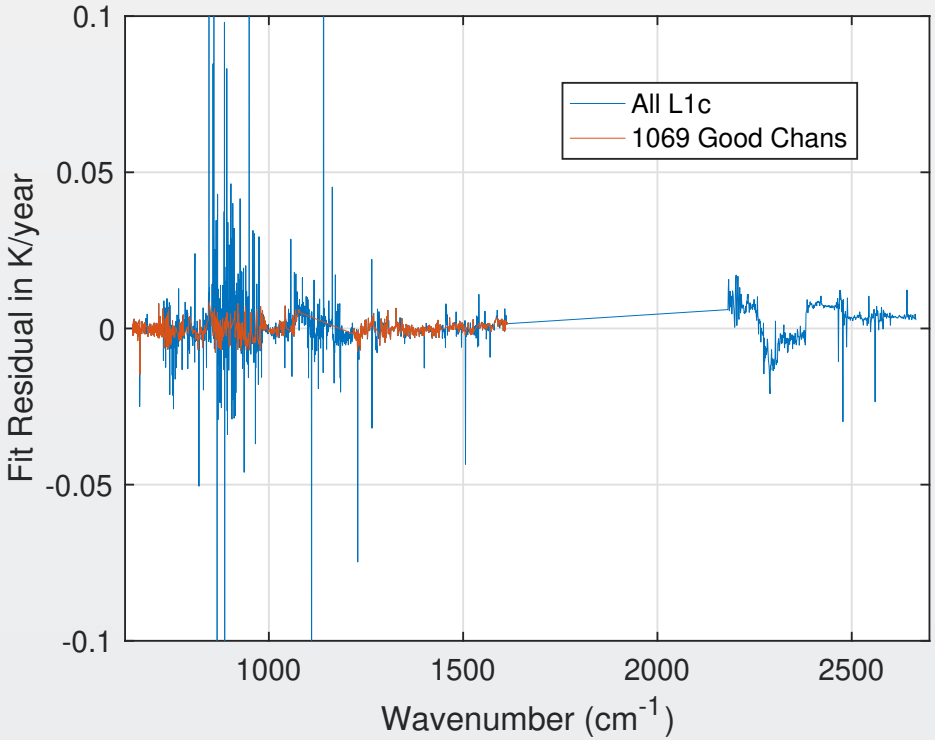
Climate Quality AIRS Channels

OEM retrieval fitting residual for clear-ocean trends

All L1c with A/B=0



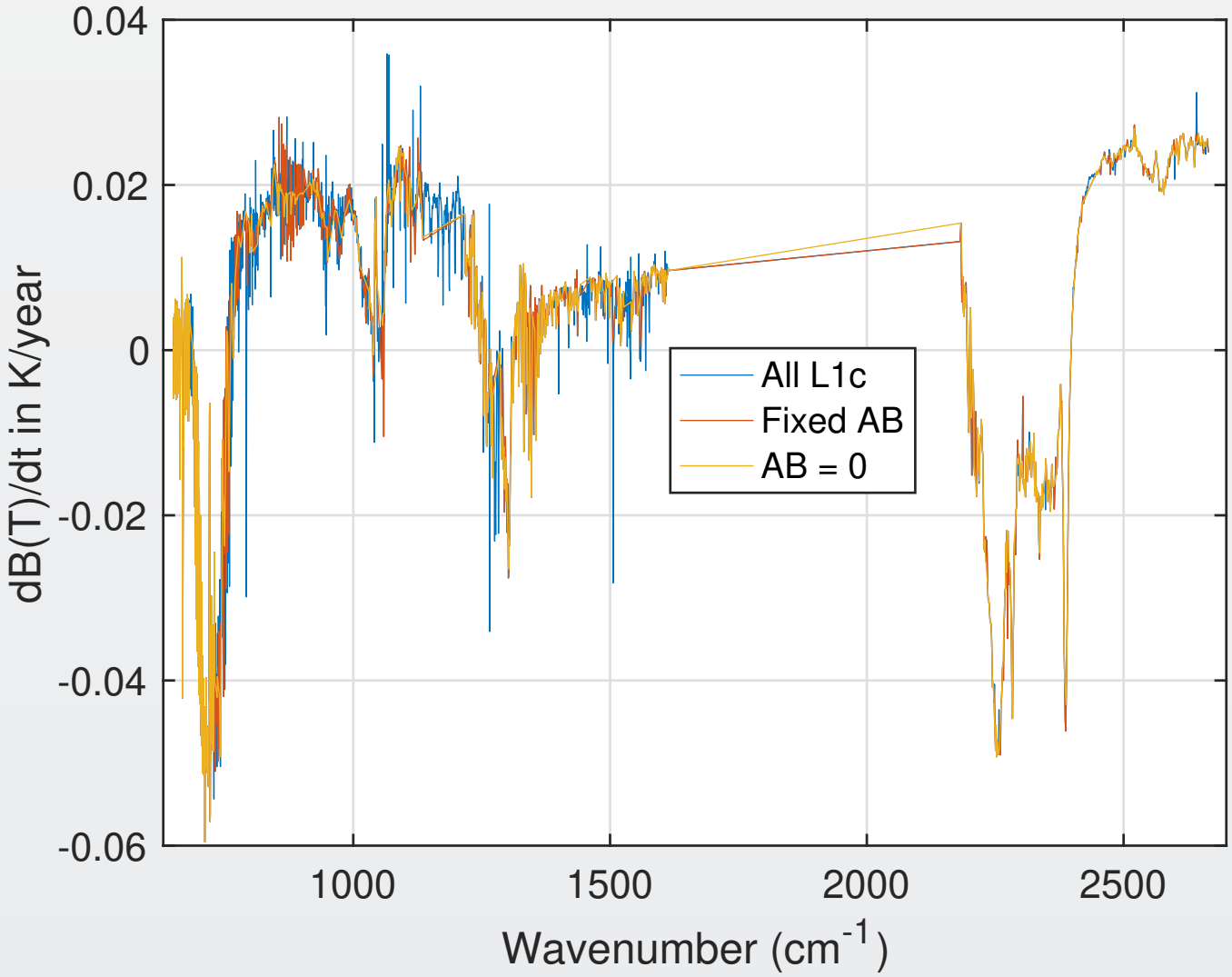
Further Trimming of A/B=0



About 1000 L1c channels good for trending

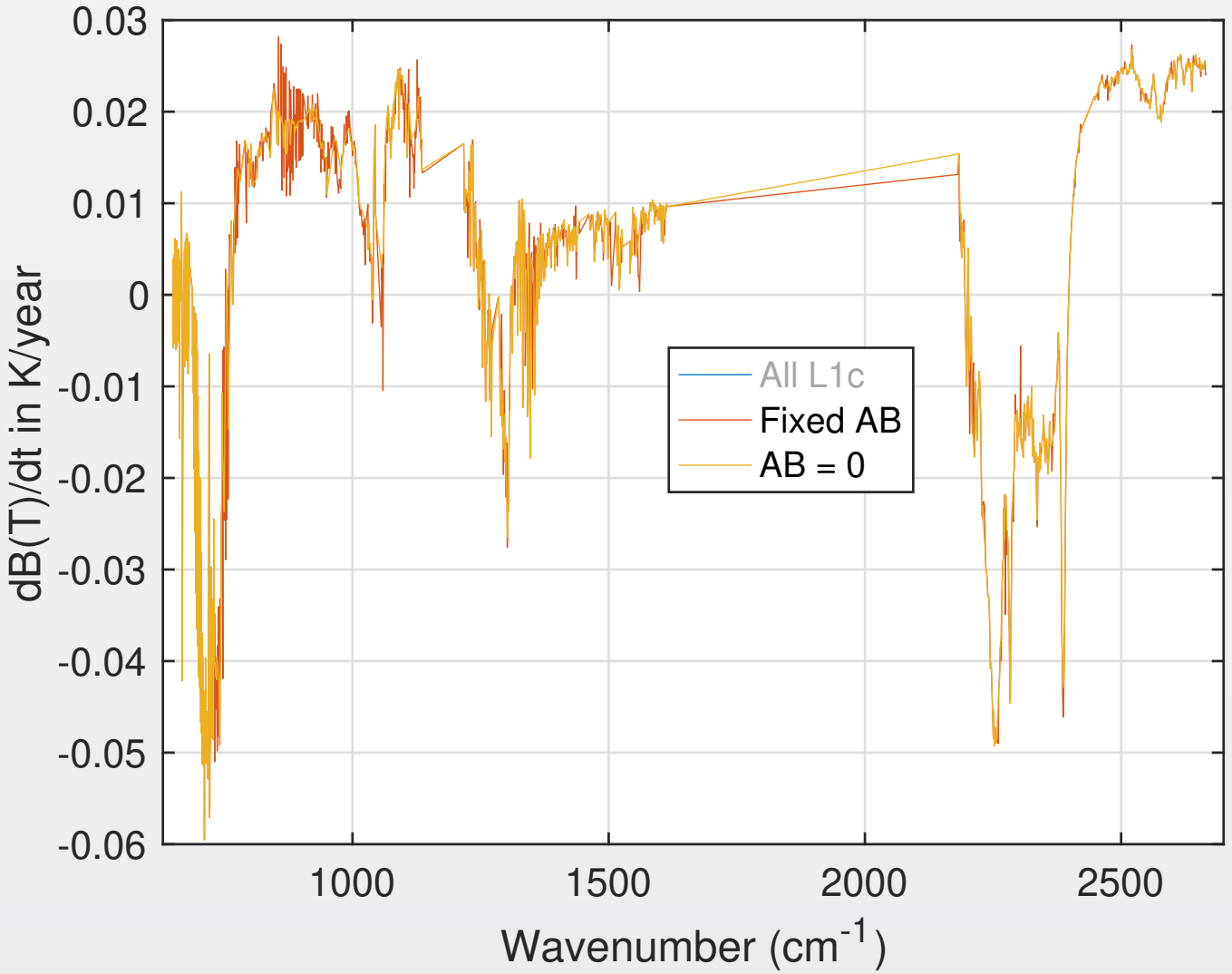
Global B(T) Trends: Descending Node

All L1c Channels:



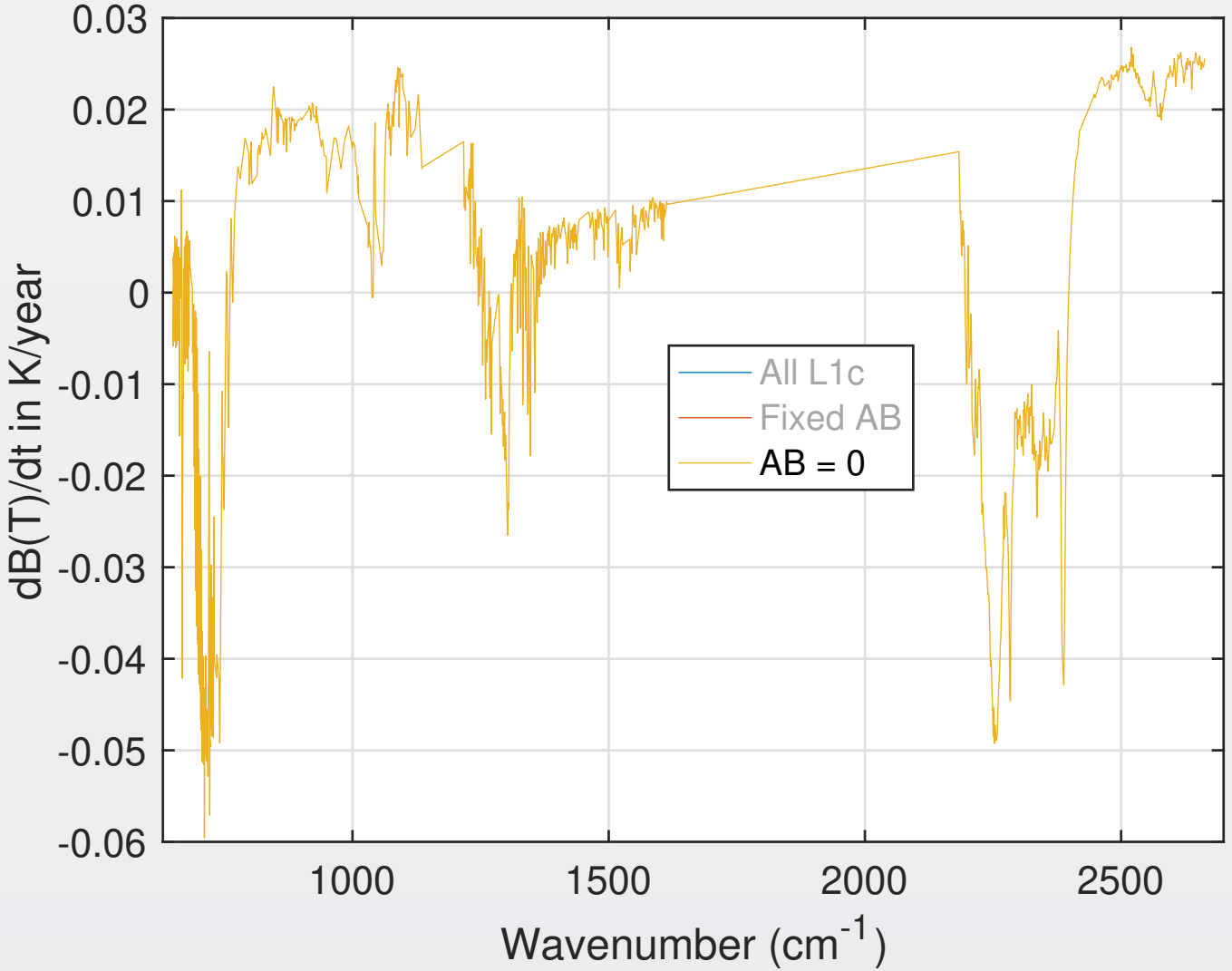
Global B(T) Trends: Descending Node

Now only A/B Fixed Channels:

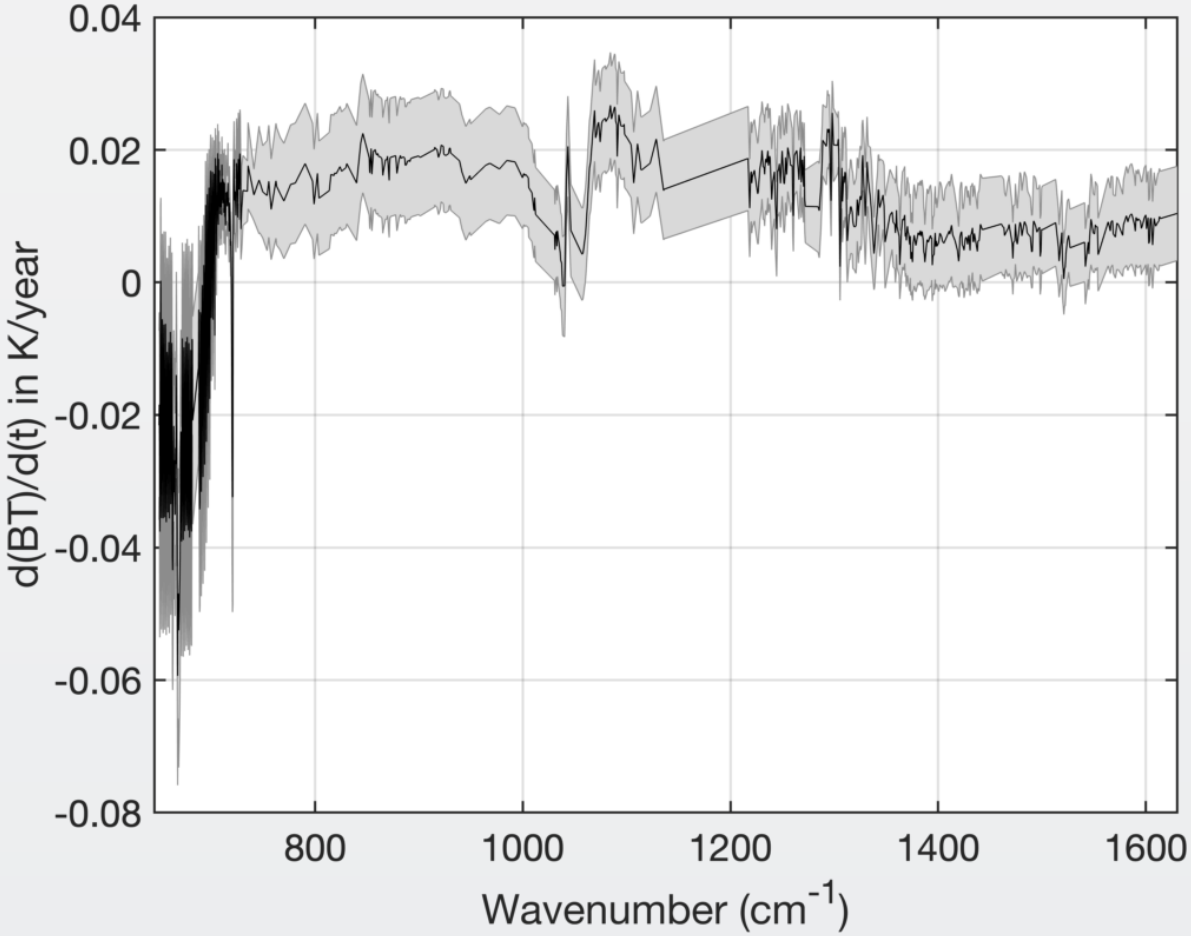


Global B(T) Trends: Descending Node

Now only A/B = 0 Channels (equally weighted)

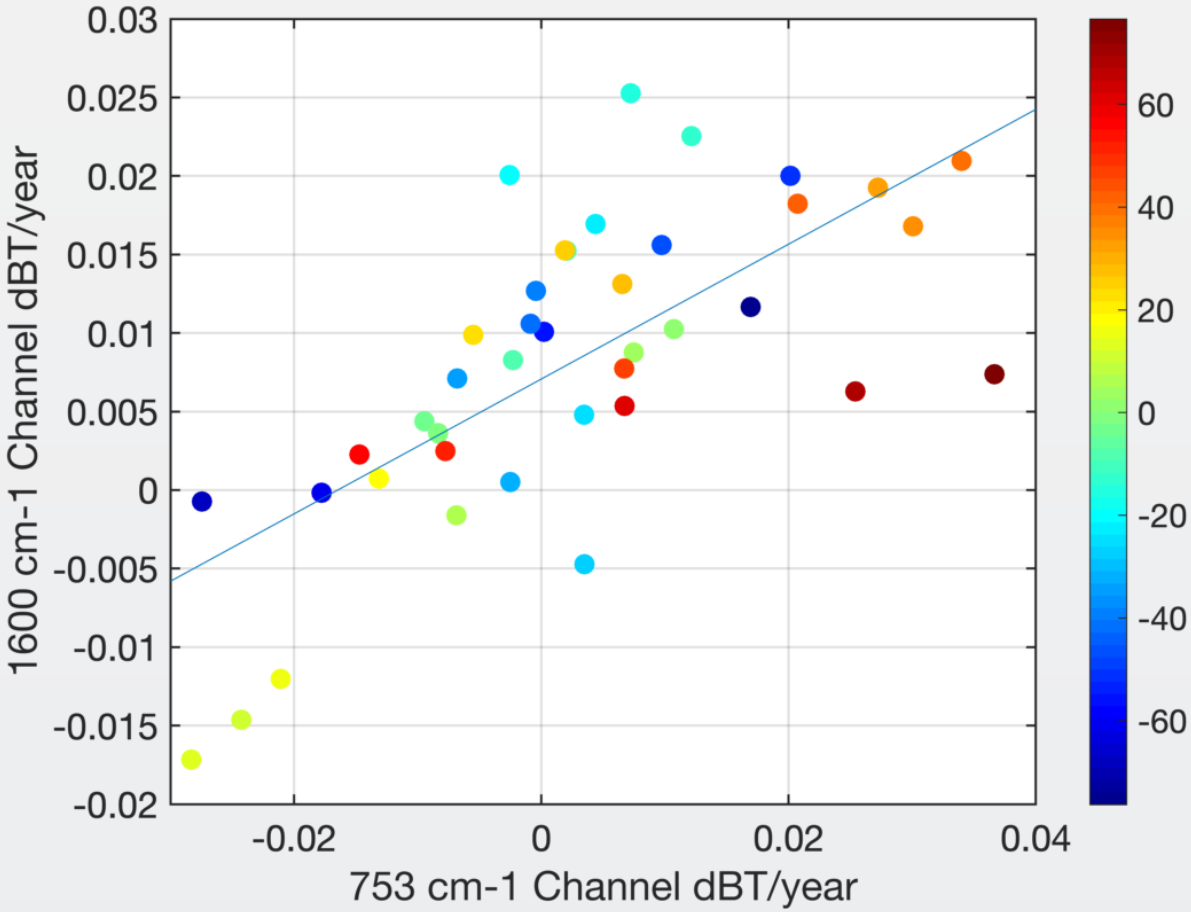


Global B(T) Trends w/ 2-σ Unc: CO_2 Removed using MLO



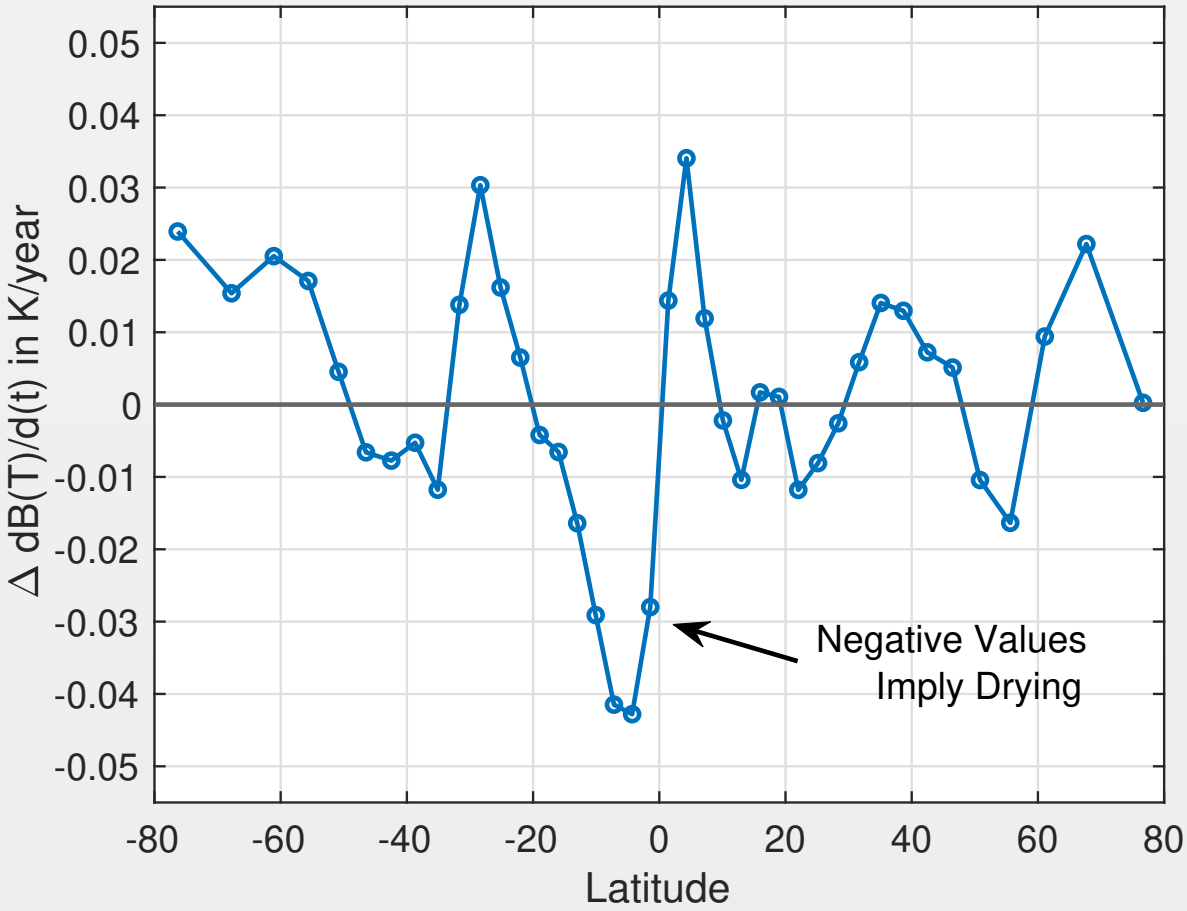
- CH_4 dominates MW (follows ESRL trends)
- H_2O B(T) trends smaller than T-channel trends
- *Window channel and tropospheric channel trends the same!*
- Stratospheric channels show cooling

Compare T-channel to WV-channel Trends (vs Latitude)



- Color is latitude: note "lime green"
- If relative humidity is constant, Δ BT = 0 for water channels
- Compare absolute and relative trends among these two channels
- Both approaches suggest ~+8%/K increase in specific humidity, *maybe* slightly lower relative humidity

How Does the T vs H_2O Trend Vary with Latitude?



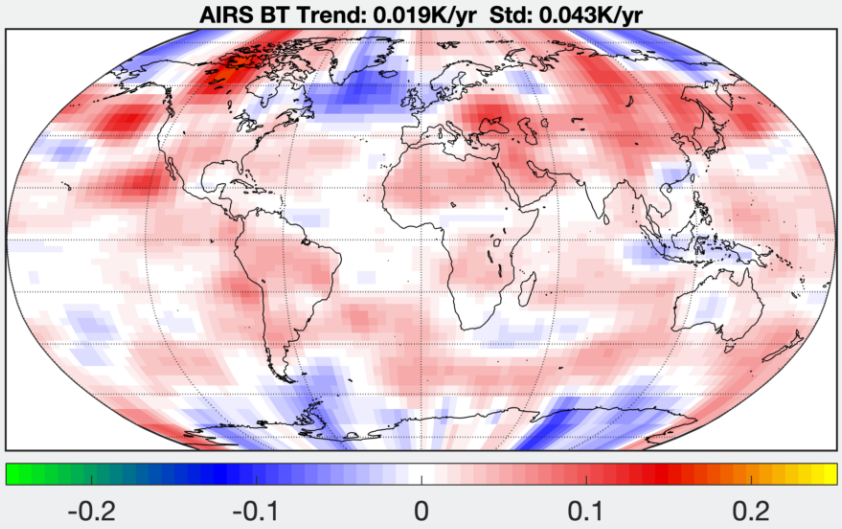
- Plotting latitude variability relative to the global mean ratio of $dBT_{T\ chan}$ vs $dBT_{Water\ chan}$
- Suggests relative drying in convective regions, moistening nearby
- These results largely independent of any calibration drifts
- These data are from "real?" climate trends, not ENSO-like proxies

Radiance Gridding: Minimize Cloud Variability

- Radiance gridding combines clear + cloudy scenes
- Clouds change slowly, but regional variability seen after 16 years
- Want simple approaches to evaluating gridded radiances trends
- Possible approach (suggested several years ago)
  - Grid not ony mean radiance but:
  - Grid by rough measure of "clear"
- Nominal approach
  - Generate radiane anomaly
  - Separate 10% hottest scenes in anomaly radiance, from colder (more cloudy) scenes.
  - Minimized cloud interferene for surface trending
- Crude test done here
  - Forget anomaly
  - Just trend 10% hottest scenes in yearly gridded bins
  - Just one channel, 917 cm^{-1}

15-Year Global Trends: 10% of Hottest Scenes (Desc node)

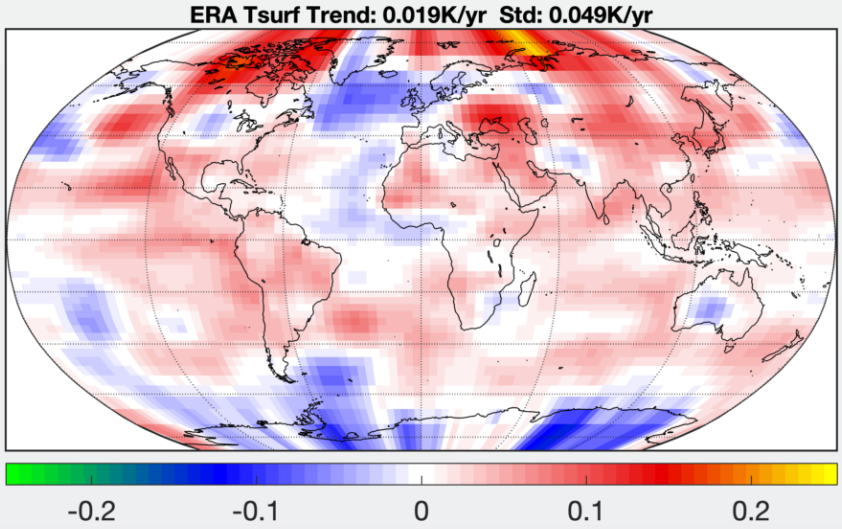
AIRS Trends (K/year)



AIRS Global trend: 0.019K/year

AIRS Global std: 0.043K/year

ERA Surface Trends for *these* Scenes



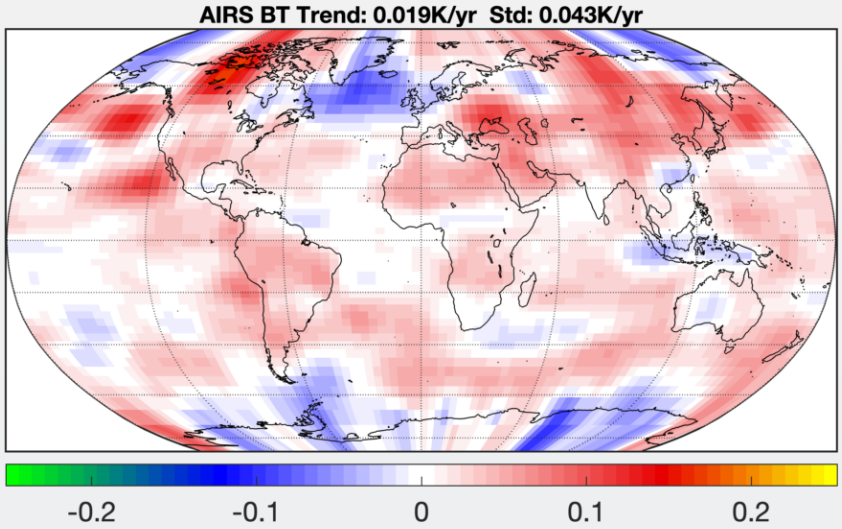
ERA Global trend: 0.019K/year

ERA Global std: 0.049K/year

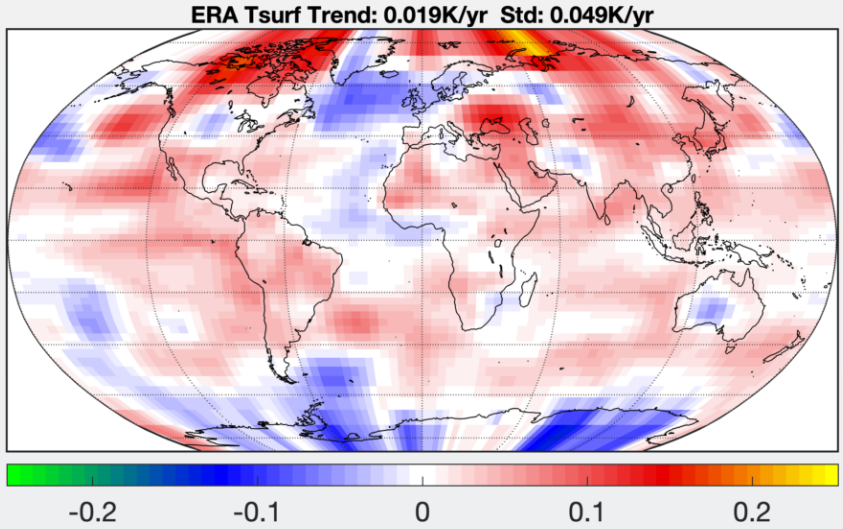
- Quite similar, no cloud patterns?
- High cancellation of trends, but not to zero
- Very simple, accuracy can be modeled

Compare Trends to Full ERA Sampling

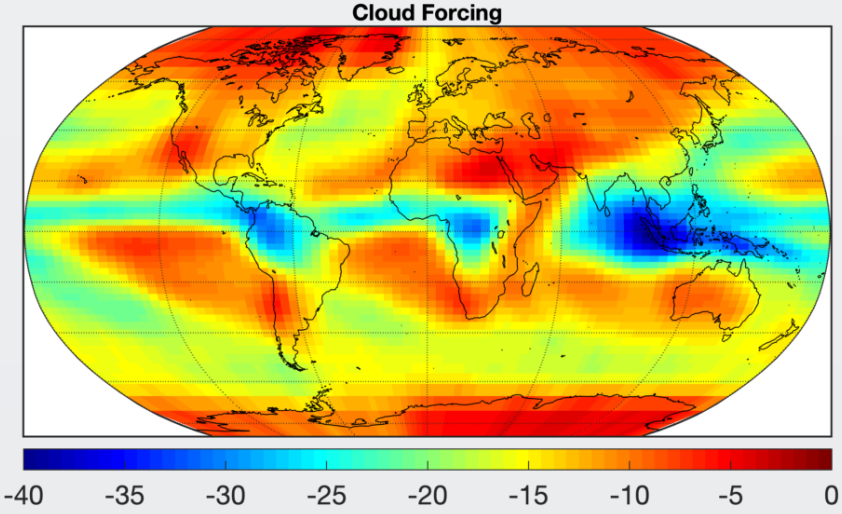
AIRS Trends (K/year)



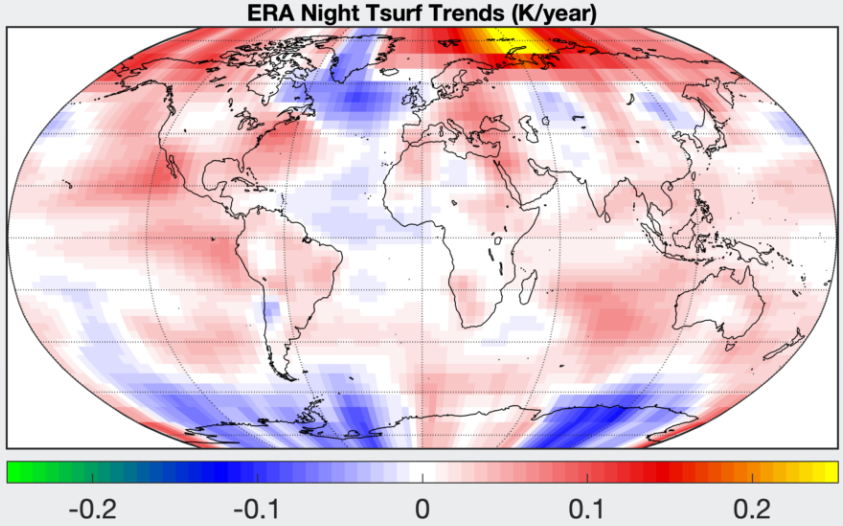
ERA Surface Trends for *these* Scenes



Cloud Forcing Patterns (K)

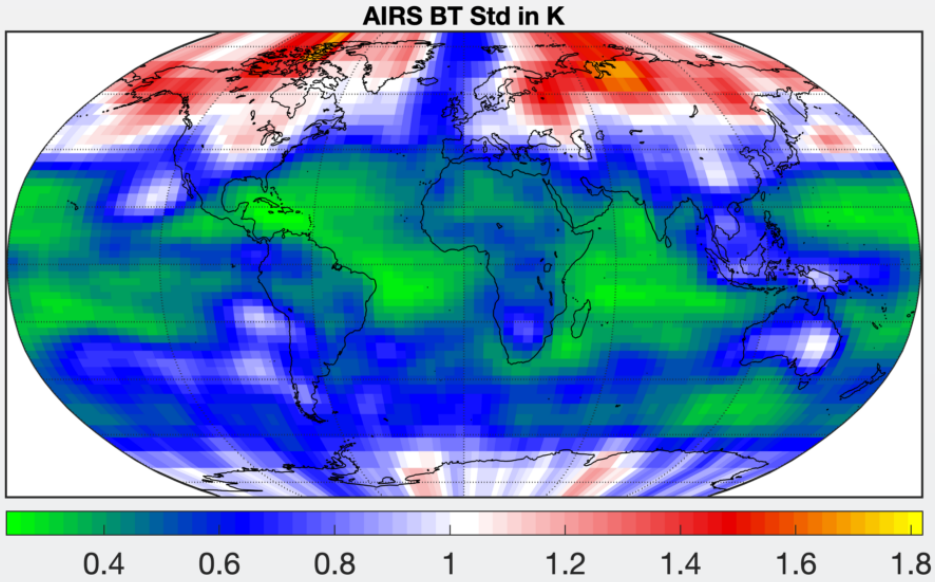


ERA Surface Trends (full Sampling)

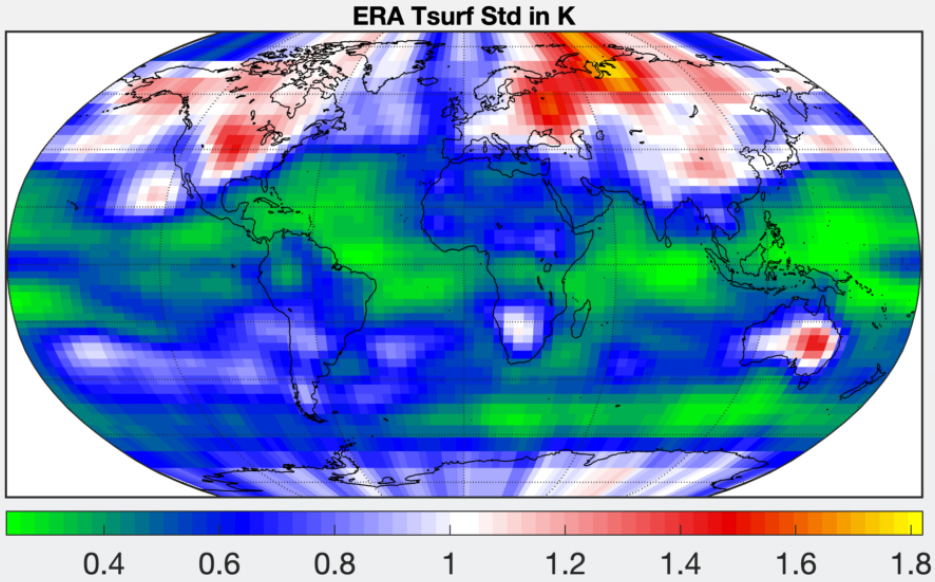


Global Variability for This 10% Hot Subset

AIRS Std (over time, in K)



ERA Std (over time, in K)



- Quite similar!
- No obvious cloud patterns?
- High North polar variability
- Just an example of what can be done without retrievals!

Conclusions

- Good progress in defining "good" channels for CHIRP
- CHIRP radiometric stablility evaluation on-going
  - Need to examine time-dependence more carefully
- CHIRP "L1c" product nearly ready for implementation (need AIRS L1c)
- CHIRP gridded "L3" product being assessed
  - Very valuable to have all scenes paired with re-analysis
  - Several type of gridding seem worthwhile (all sky, gridded by nominal % clear)
- OEM retrievals of T/Q zonal trends will continue with an emphasis on observation error co-variances and better all-sky cloudy jacobians