

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

AIRS Science Team Meeting

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# Calibration Requirements for Climate Science

- AIRS 17+ year record long enough to address key climate questions
- Stability of radiometric calibration is key
- AIRS sensitivity to CO<sub>2</sub>, SST, etc allows stringent tests of stability

## Climate Science Questions

*All require min ~0.1K/decade  
stability*

- Global Trending: T(z), H<sub>2</sub>O (z), T<sub>surf</sub>
- Water vapor feedback (Does relative humidity vary)
- Cloud feedback
- Trends in PBL cloud occurrence
- OLR anomalies separated by cause: T/H<sub>2</sub>O/cloud/surface, etc.

## Hyperspectral IR Advantages

- AIRS senses both climate forcings, and responses
- Clean separation of tropospheric vs stratospheric temperature trends (unlike microwave)
- Multiple long-term overlapping missions (AIRS, CrIS, IASI)
- AIRS, CrIS, IASI already agree to ~0.1-0.3K and can be merged to 0.03K or better.

Significant AIRS calibration drifts have **already** resulted publication of in-accurate data that were publized by NASA/GSFC and the media (Washington Post, Scientific American). *This talk suggests how to make AIRS an accurate instrument for climate science.*

# Weather versus Climate Research

## Weather Applications

- AIRS original focus was for NWP
- Both 1Dvar retrievals and data assimilation *require* bias removal
  - NWP: biases due to the instrument, RTA, model
  - Retrievals: biases due to the instrument and RTA
  - Bias removal is generally in the ~0.1-0.3K range
- Radiometric accuracy is important
  - But, below the nominal ~0.3K range we cannot differentiate instrument vs RTA errors.
  - Spectroscopy errors are at the 1-2% level, or 0.1-0.3K

## Climate Applications

- Anomalies are the main language of climate observations
- Although energy budget and fluxes are important, AIRS is not a major contributor
- For AIRS, radiometric stability is most fundamental calibration requirement

Hyperspectral IR instrument stability appears to be 1-2 orders of magnitude better than absolute accuracy. This is where we can shine, especially with a 17+ year record.

# Climate Product Characteristics

## Uncertainty Estimates

- If we provide something unique, validation will be difficult
- Internal product uncertainty estimates will be far more important than for weather applications
- Establishing uncertainties for products is a NASA ROSES requirement!

## Reproducibility

- Reproducibility of results is becoming increasingly important
- Difficult to achieve with our Level 2 approach
- For climate simpler algorithms with reproducible results would enhance our impact on the broader community

There is a long history of controversies in climate measurements (esp. microwave temperature trends). AIRS derived results will be heavily scrutinized, we need to be prepared for that to retain trust.

# AIRS Stability Calibration: An Approach

- External standards needed to establish stability
- CO<sub>2</sub> and possibly N<sub>2</sub>O and CH<sub>4</sub> can provide those standards
  - CO<sub>2</sub> is well mixed (on long time scales) and extremely well known
  - Establish AIRS stability by retrieving CO<sub>2</sub> anomalies (vs time)
- SST is the other well established climate record
  - Similarly, use retrieved SST anomalies to test AIRS stability
- Land surface temperatures are another possibility, although less reliable than SST but of great interest and heavily studied.

Essentially you need to perform climate-level retrievals to test the capabilities of your instrument.

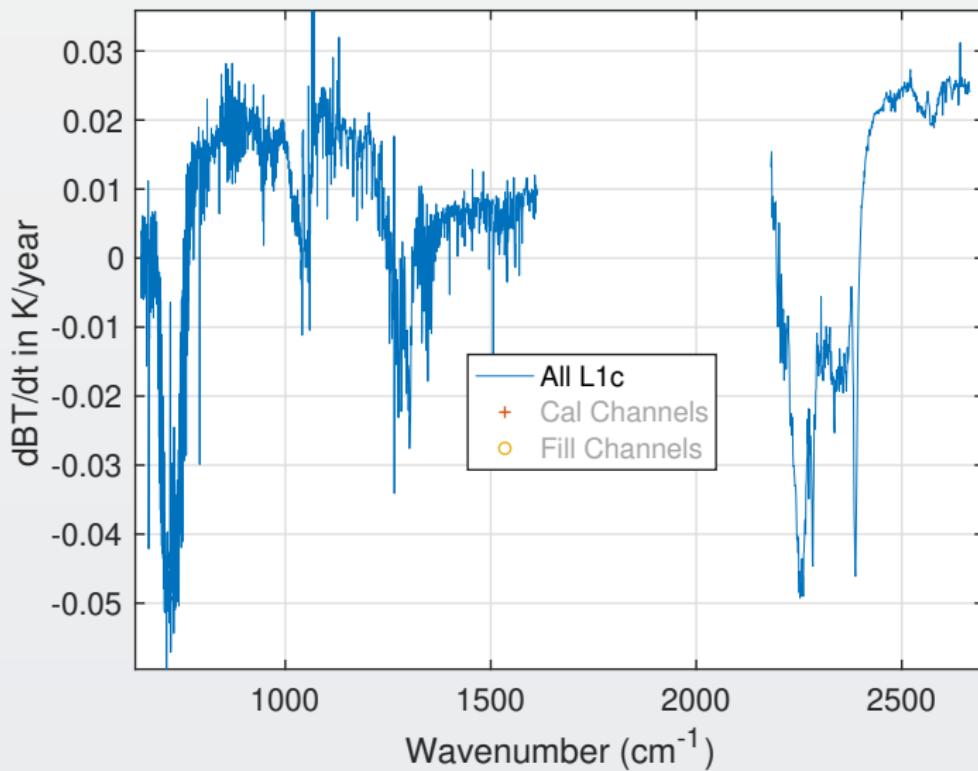
A key requirement is the need to reprocess the *full record* many times. NOT possible with Level 2 approach! Need fast alternatives that may also address issues of reproducibility.

# Characteristics of AIRs Long-Term Radiance Trends

- 1% random subset

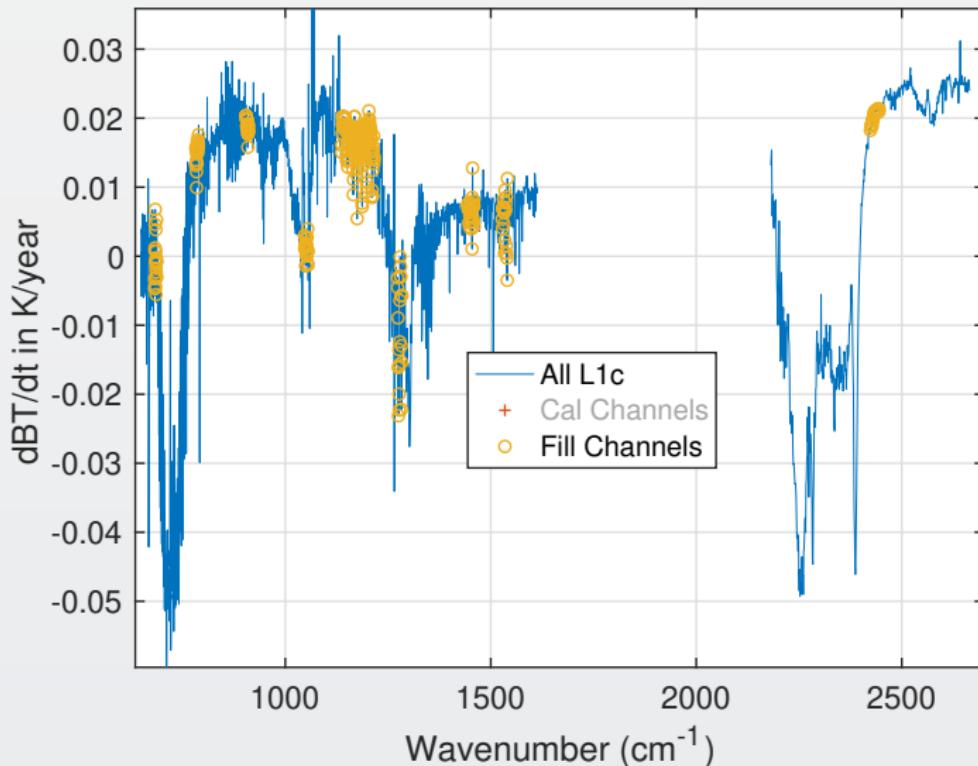
# AIRS Global 16-Year B(T) Trend

All channels (including fill)

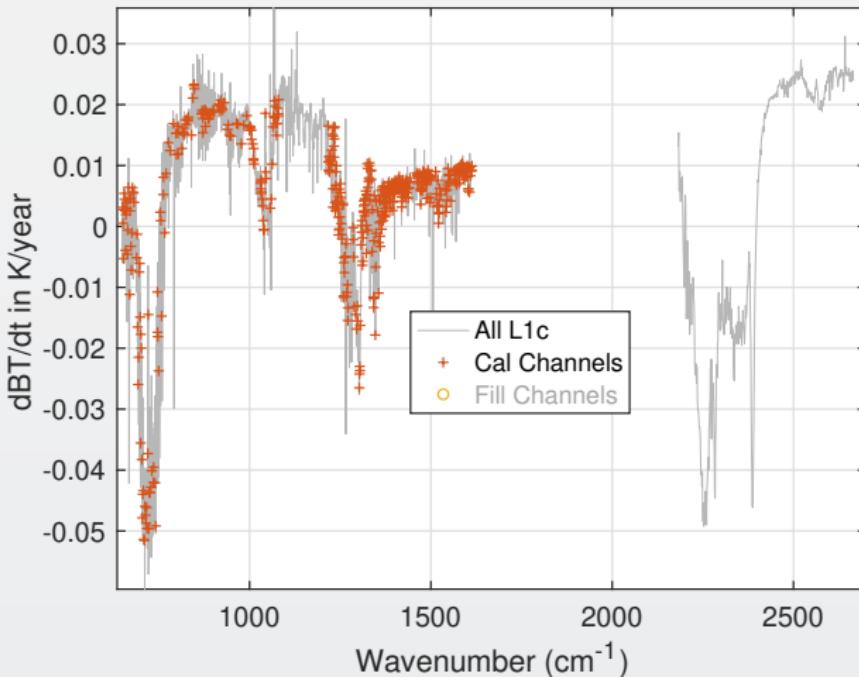


# AIRS Global 16-Year B(T) Trend

Fill channels marked

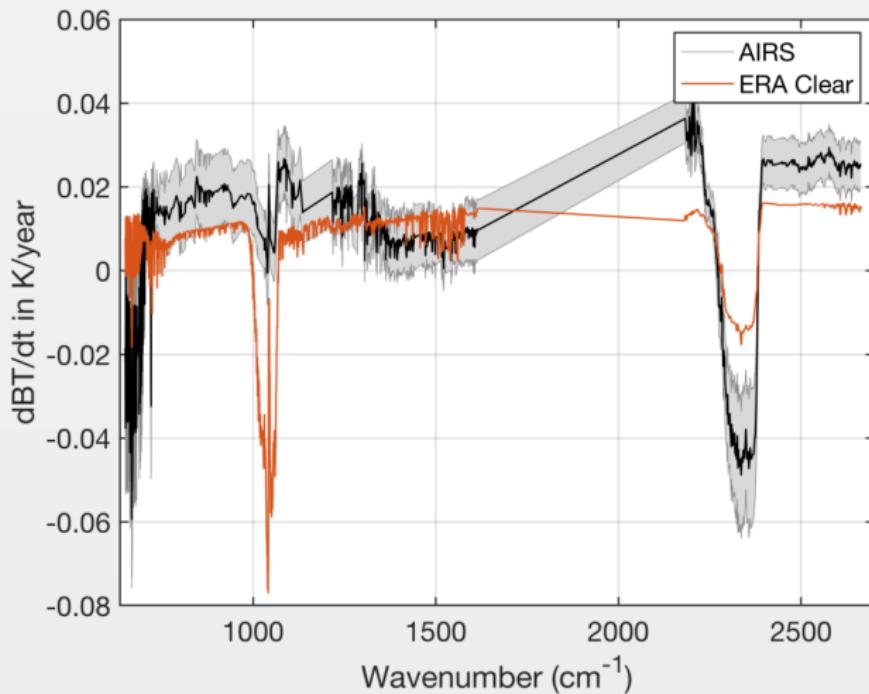


# AIRS Global 16-Year B(T) Trend



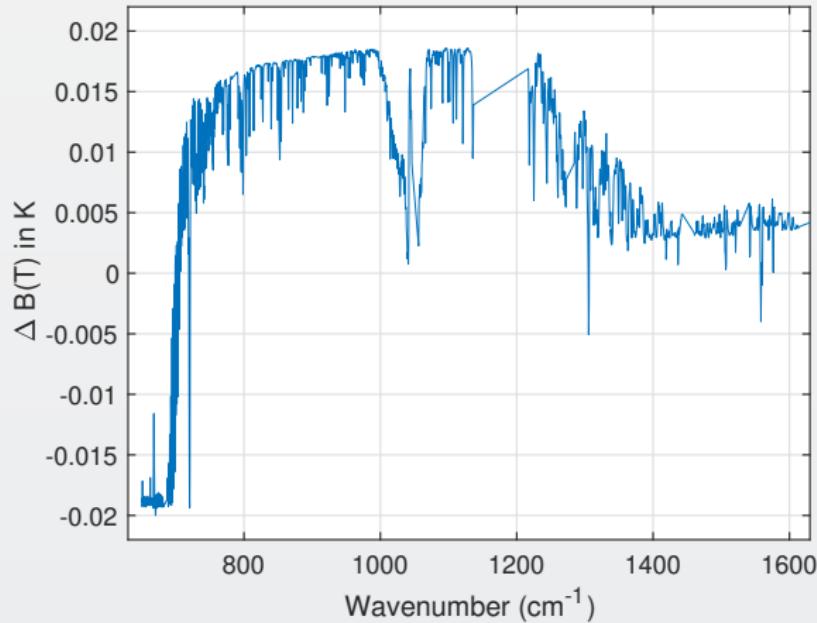
- Channels used for calibration testing marked.
- These channels have no A/B state changes, good S/N, small drift
- Note sparsity of CO<sub>2</sub> channels in tropospheric sounding region

# $\text{CO}_2$ and $\text{CH}_4$ Trends Removed, Fitted Chans Only



Uncertainty (gray) is geophysical (Std over latitudde).

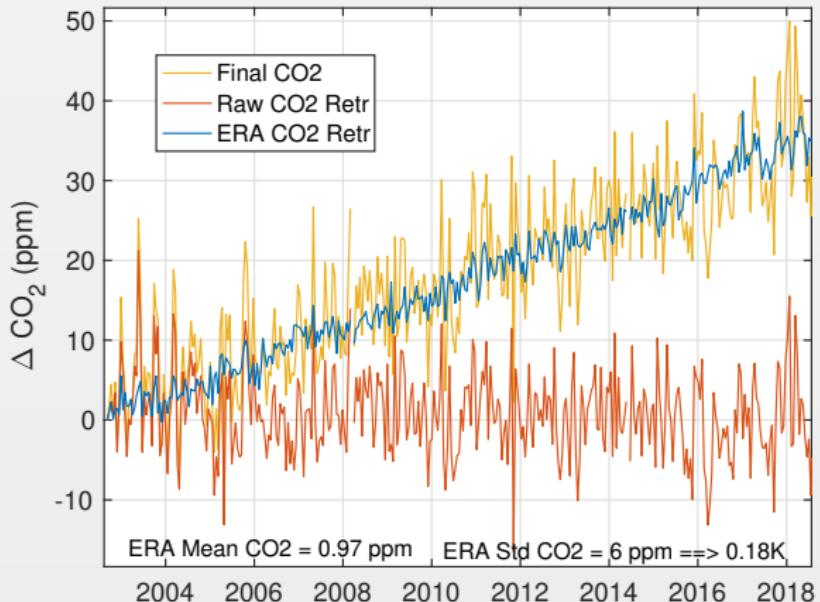
# BT Response to Constant Relative Humidity



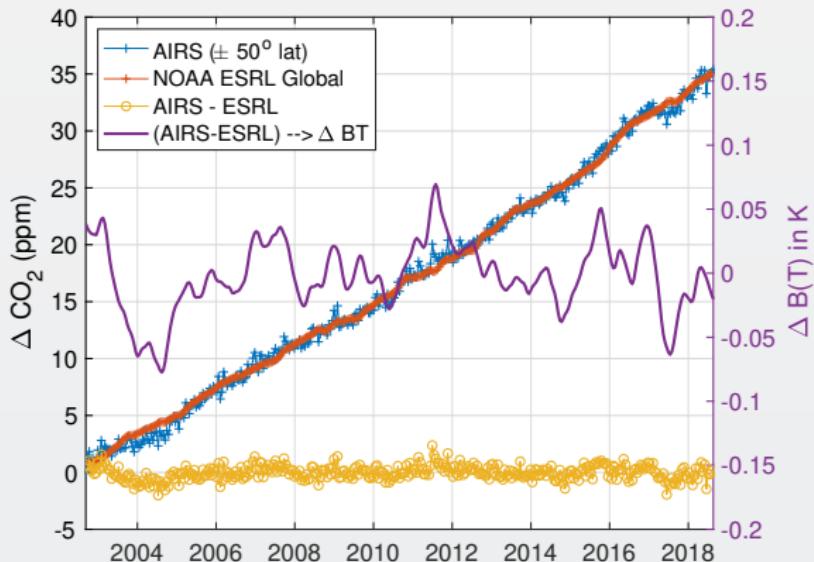
## Retrieval of CO<sub>2</sub>, N<sub>2</sub>O, CH<sub>4</sub> Anomalies

- oem approach
- data set

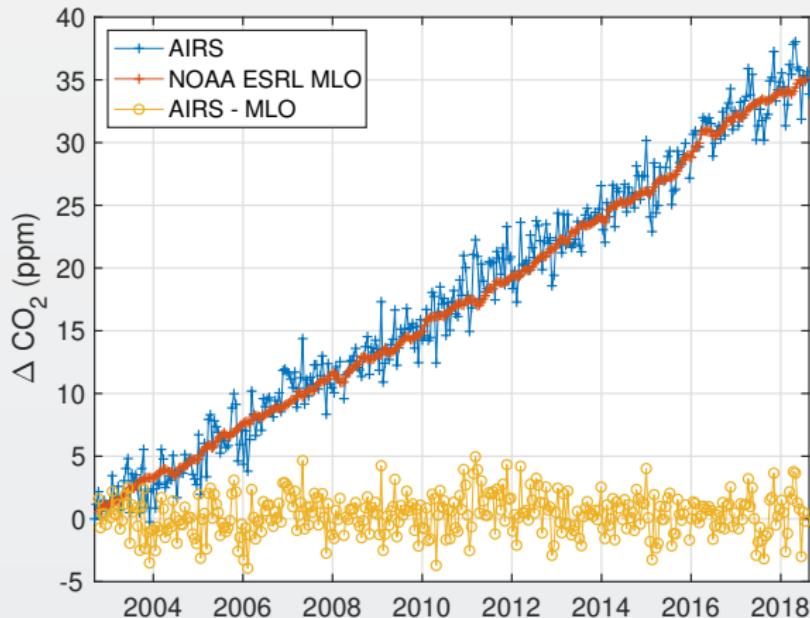
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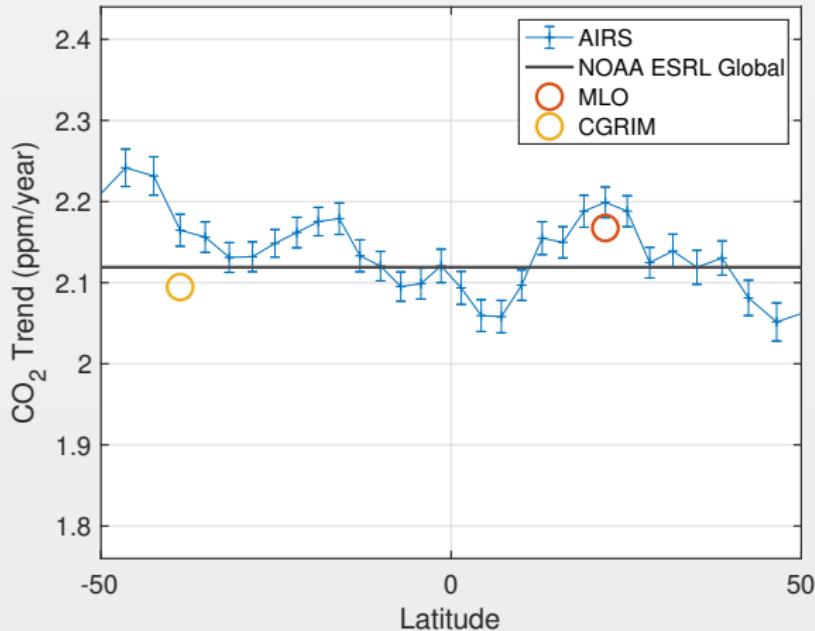
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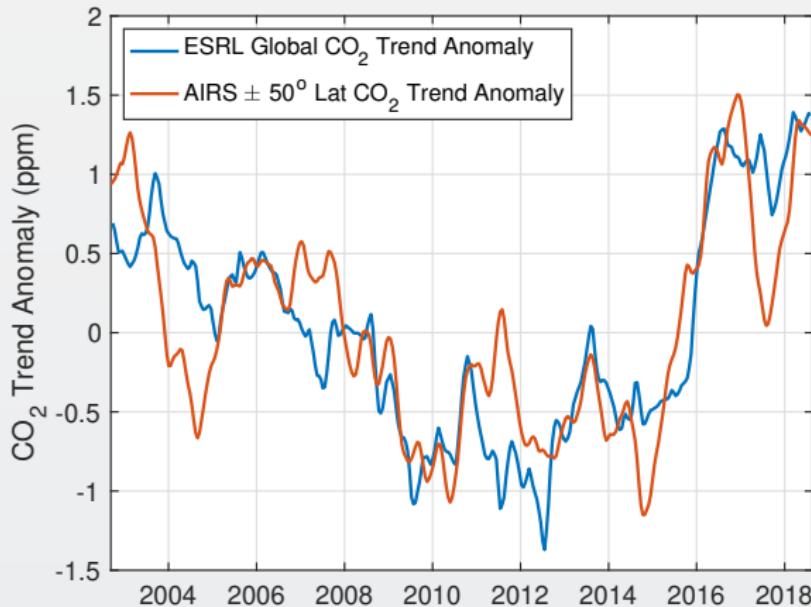
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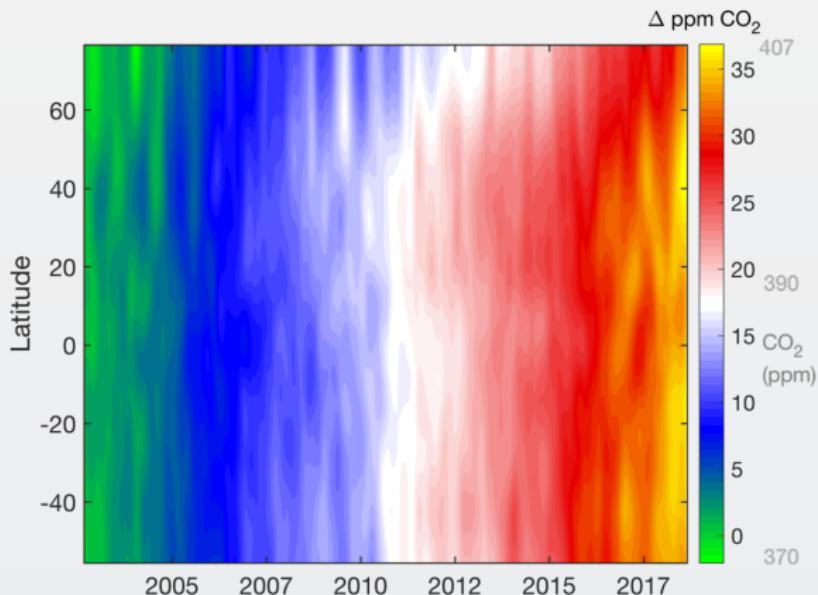
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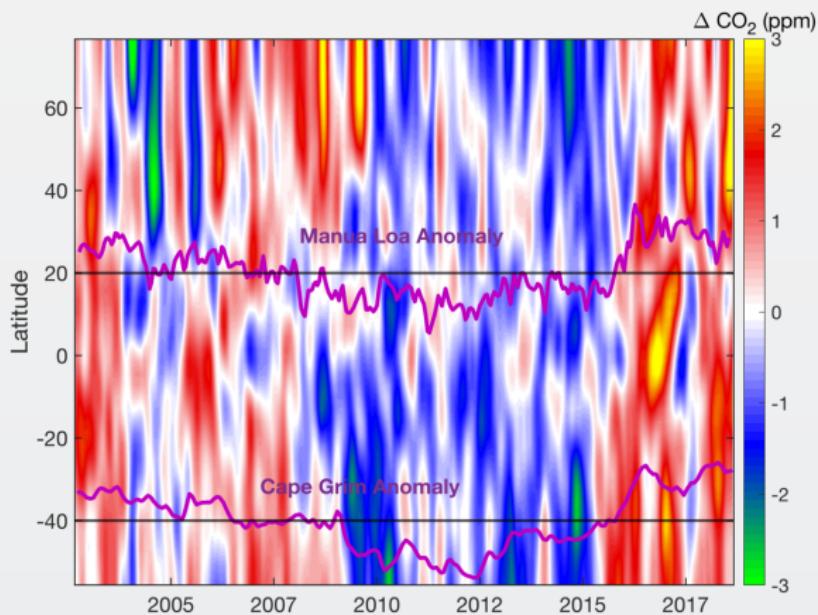
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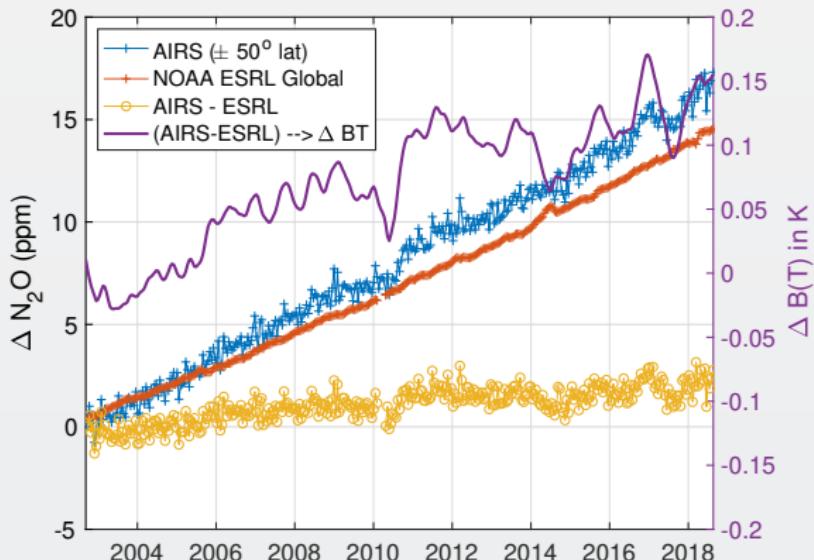
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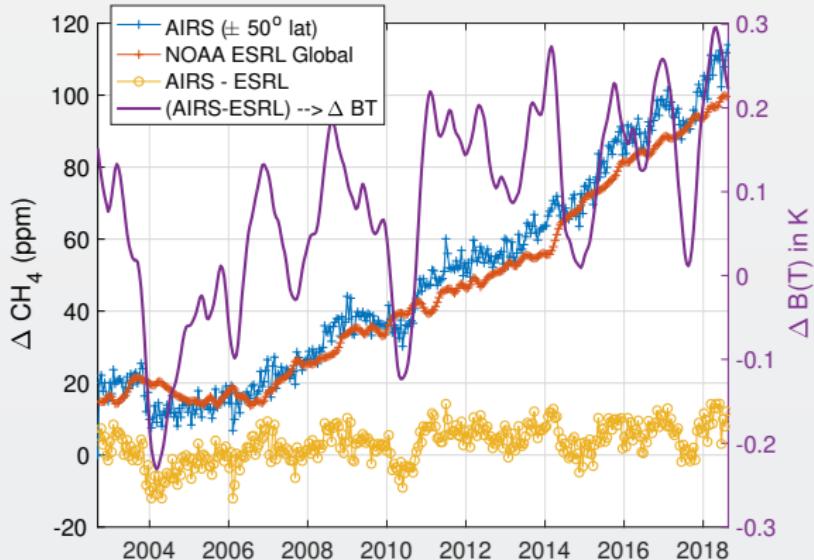
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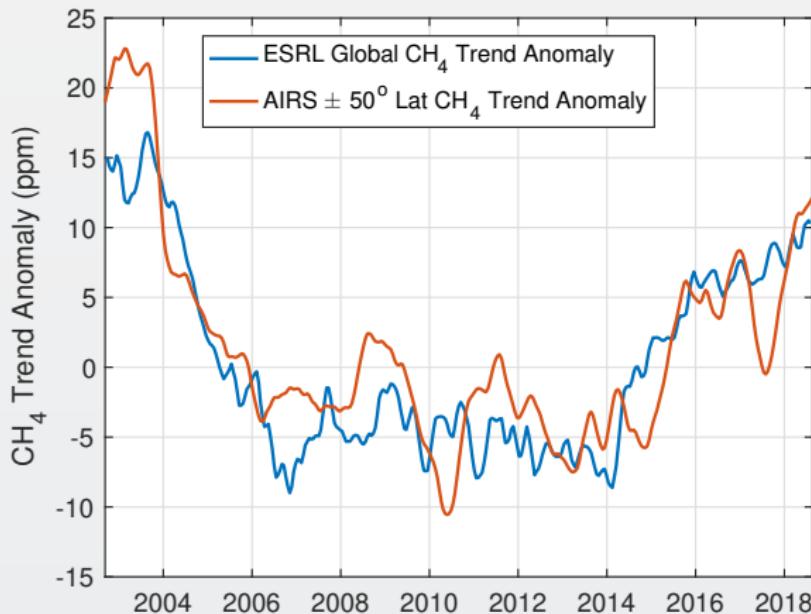
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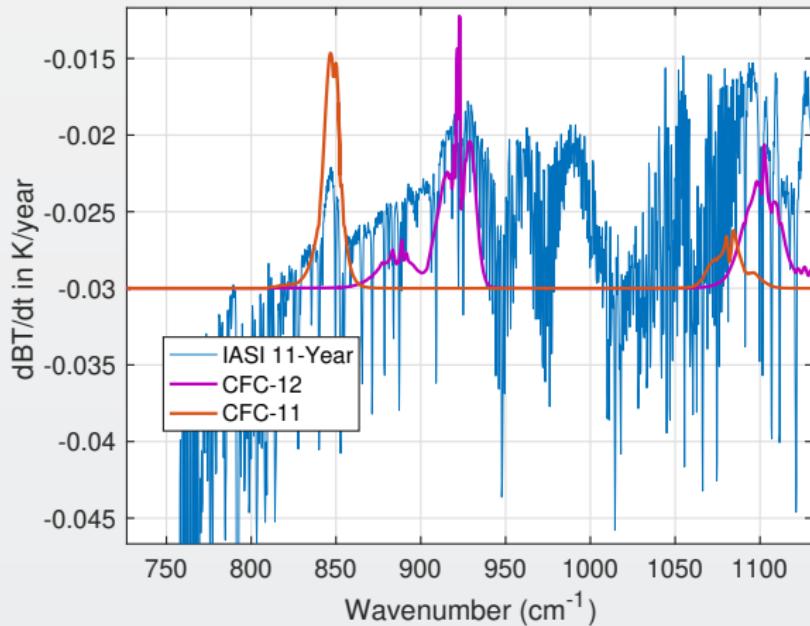
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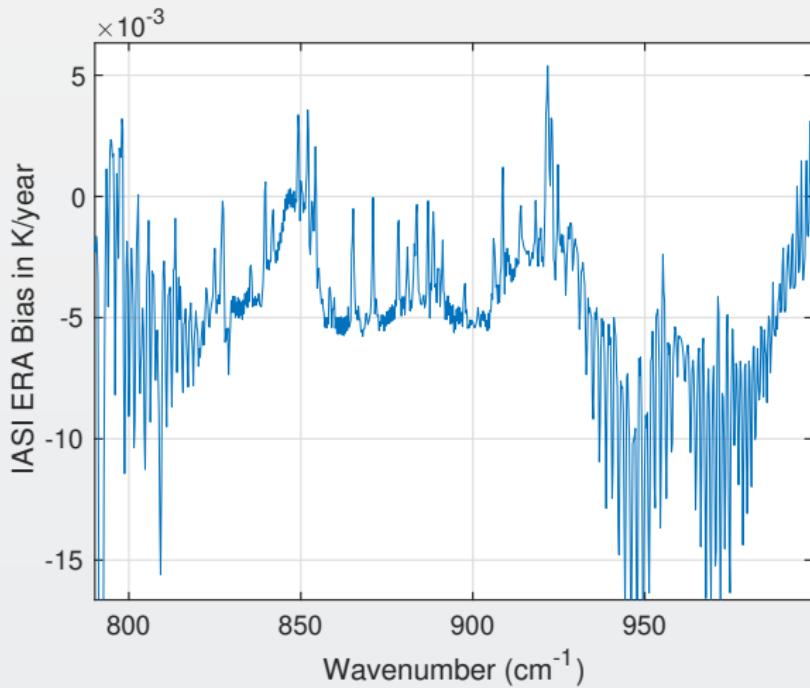
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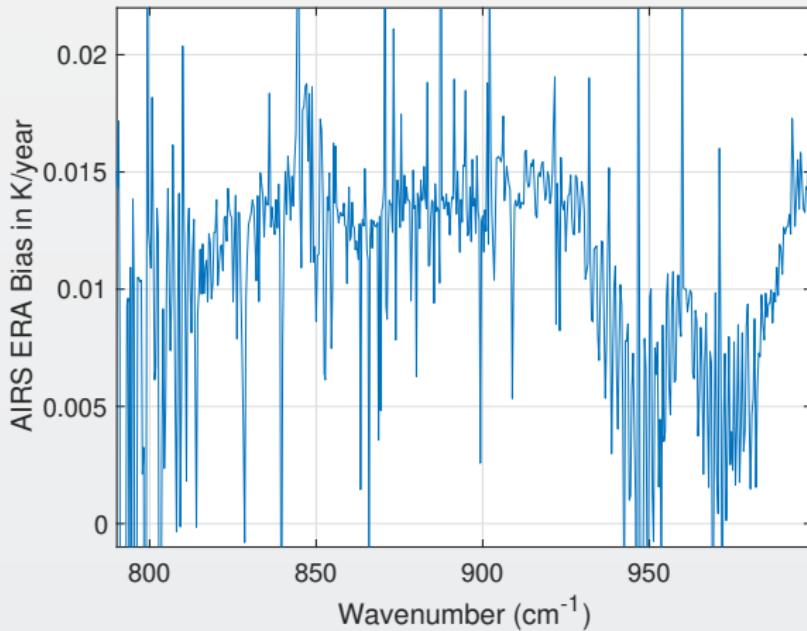
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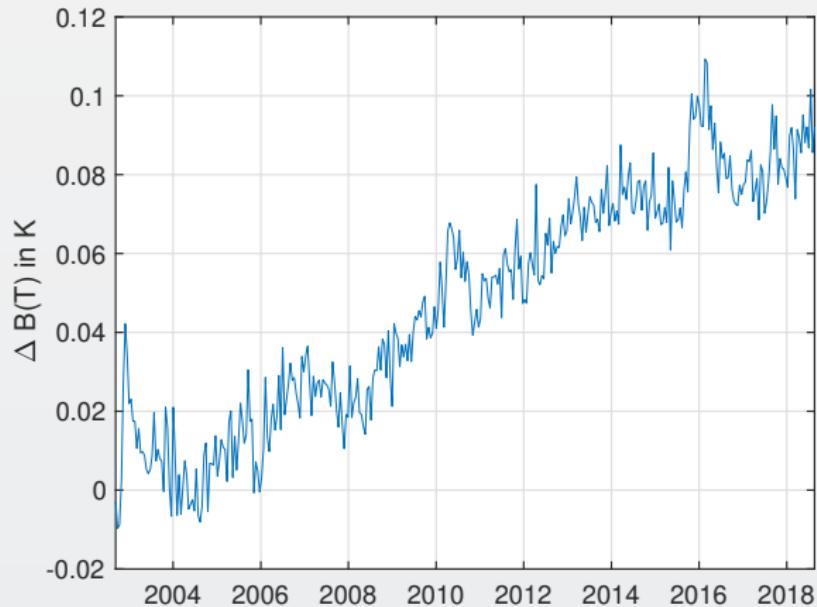


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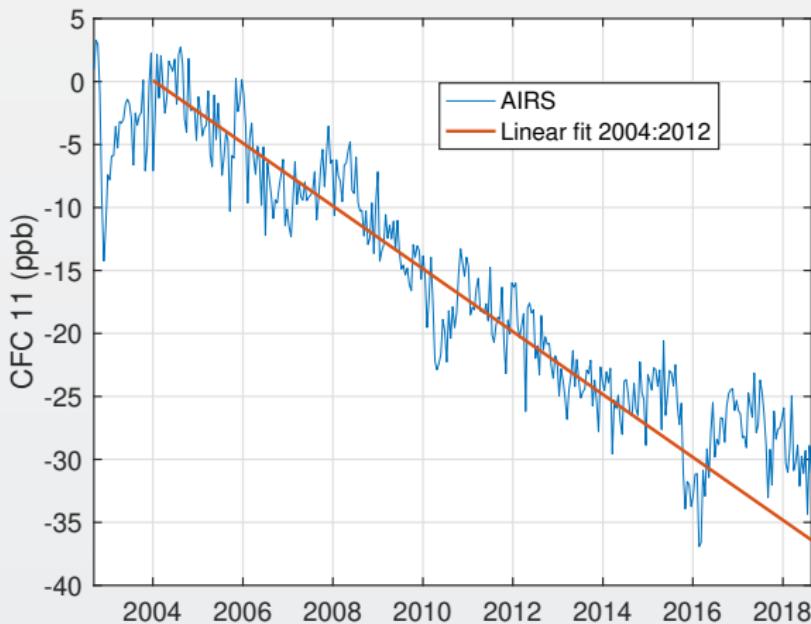


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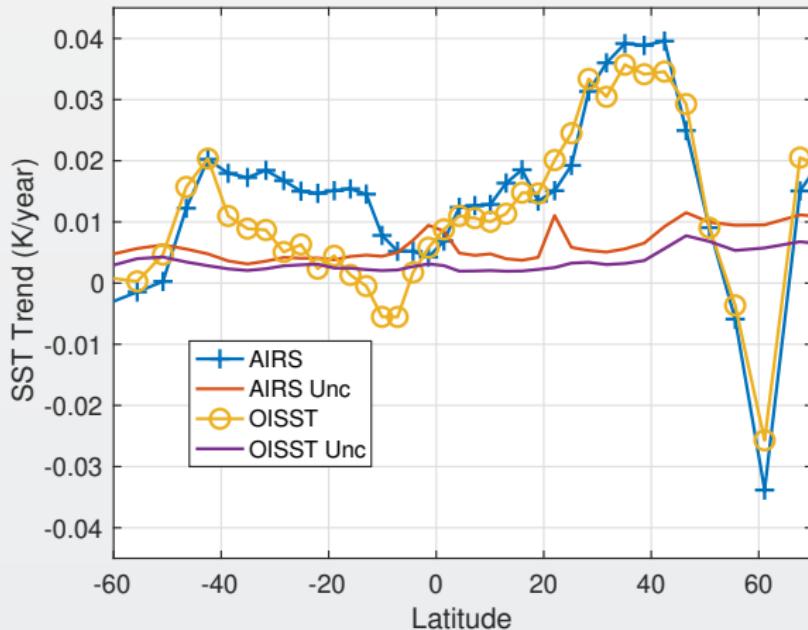




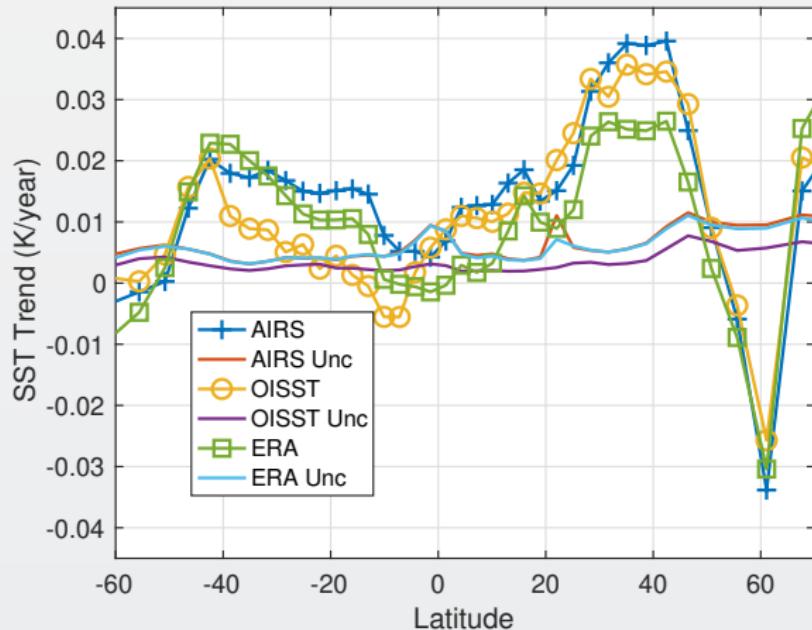
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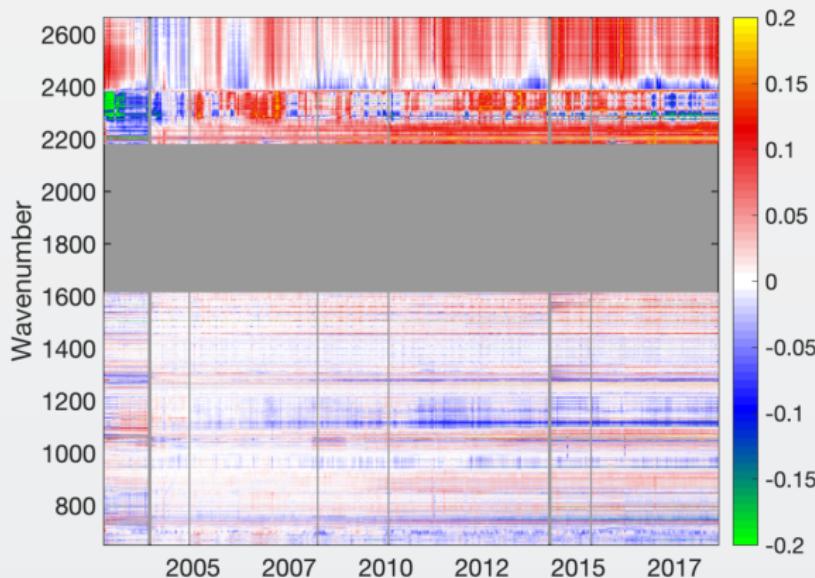
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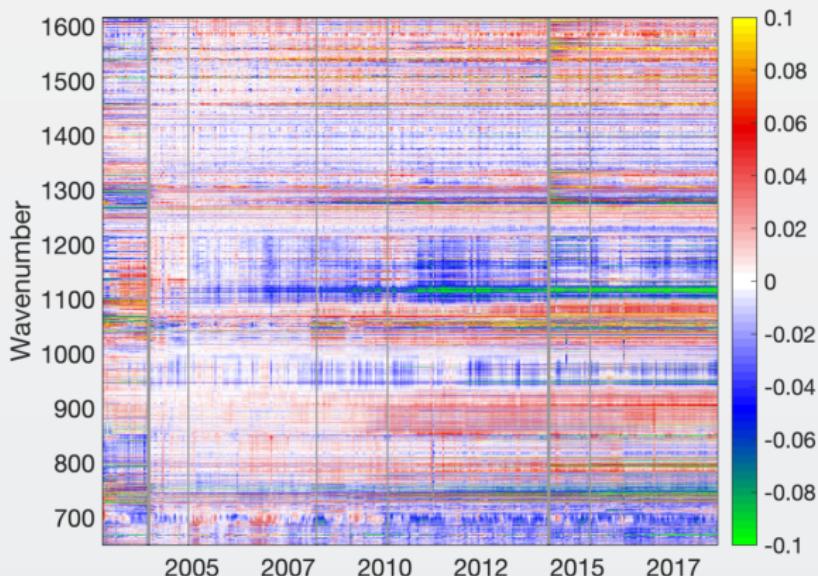
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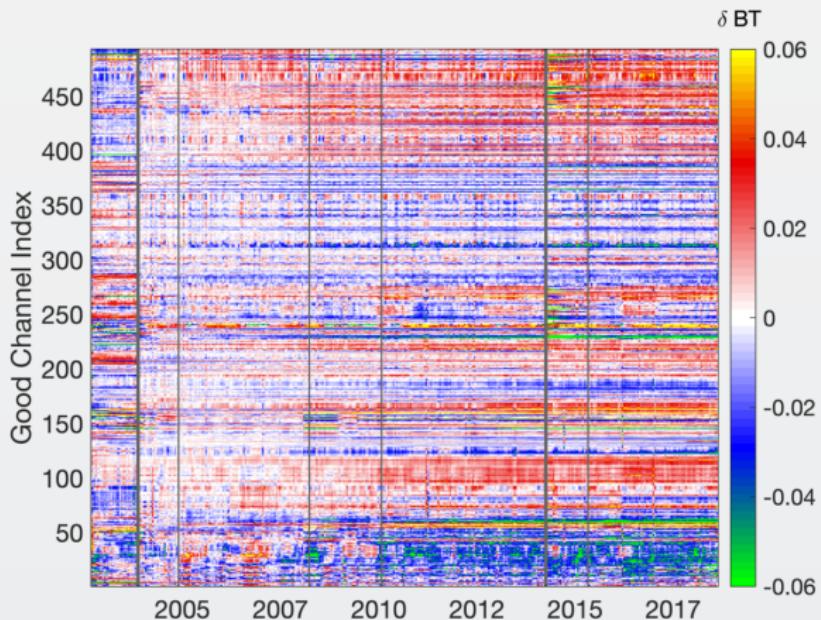
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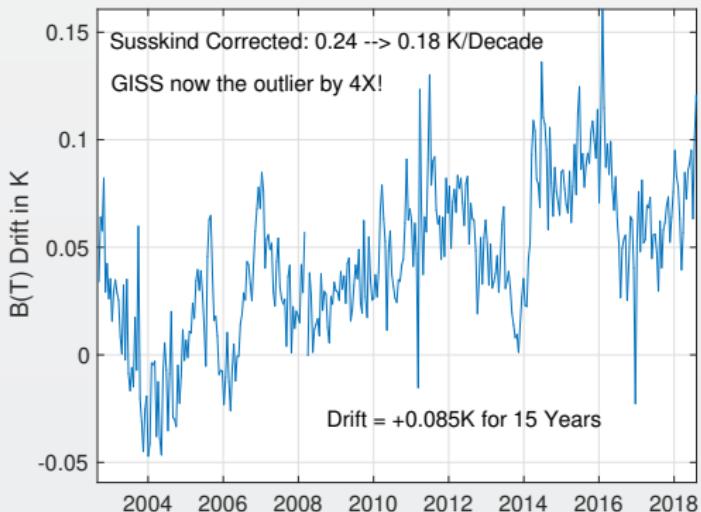
# Png/best\_co2\_anom\_resid\_no\_sw.png



# Png/best\_co2\_anomaly\_resid\_fit\_chans\_concat.png



# Pdf/bt\_drift\_from\_anom\_resid\_2613\_chan.pdf



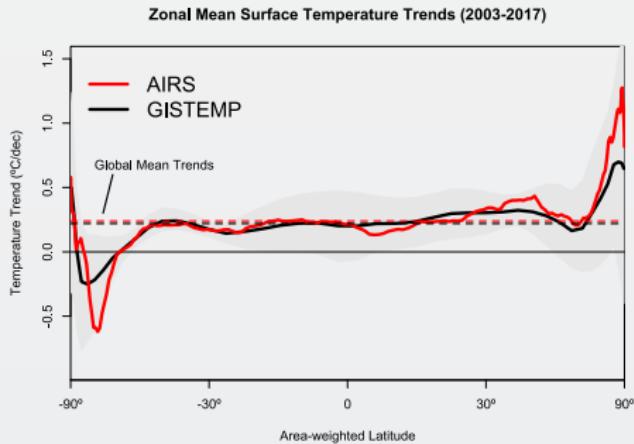
From Susskind et. al.

AIRS	$0.24 \pm 0.12$
AIRS Corrected	0.18
GISTEMP	$0.22 \pm 0.13$
HadCRUT4	$0.17 \pm 0.13$
C&W	$0.19 \pm 0.12$
ECMWF	$0.20 \pm 0.16$
UAH LT	0.18

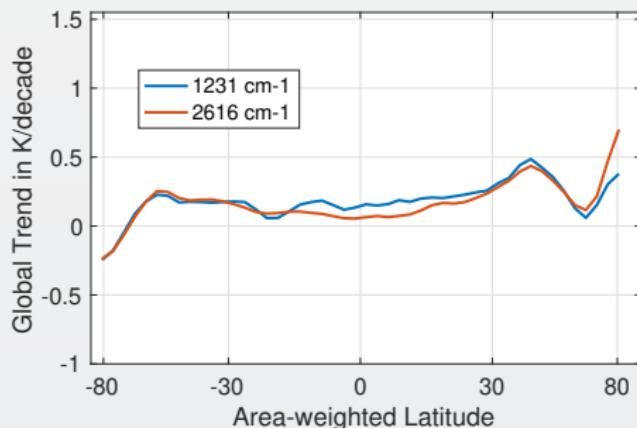
Shortwave drift correction reduces AIRS global temperature trend by 33% and bring AIRS into close agreement with HadCRUT4, C&W, and UAH LT, significantly worse agreement with GISTEMP.

# Latitude Dependence Surface Trends

Susskind 2019: SW



UMBC Trends: LW and SW



Global Means

GISS	Susskind	UMBC-1231	UMBC-2616	HadCRUT4
0.22	0.24	0.18	0.17	0.17

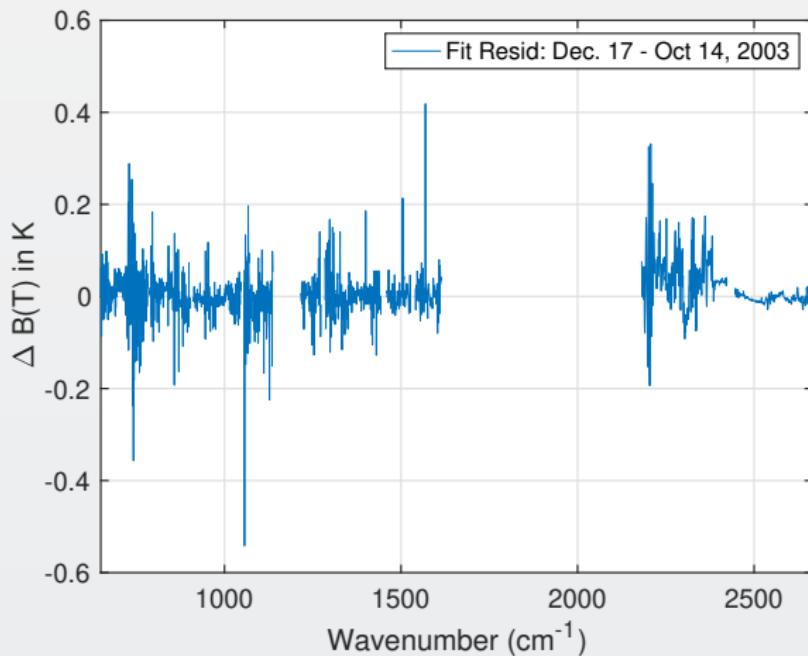
But, why isn't UMBC-2616 0.05K higher??

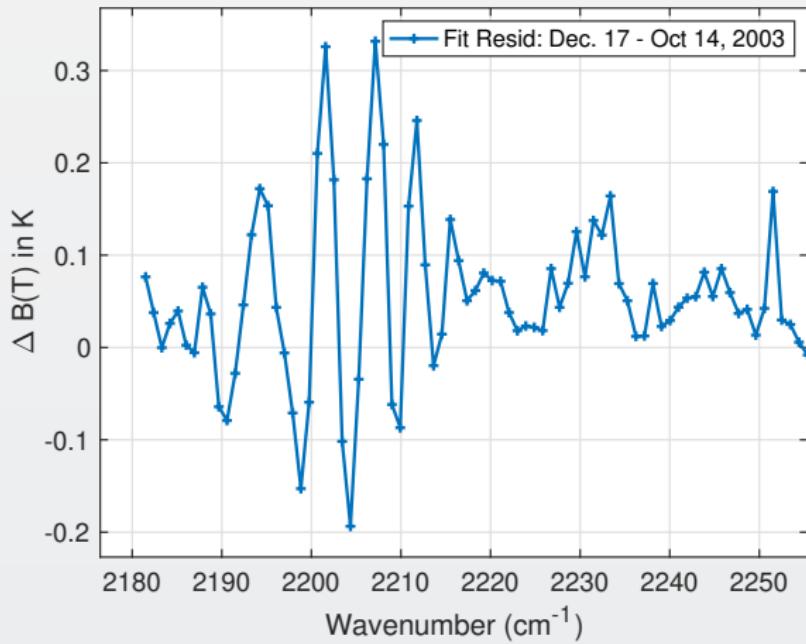
Note high/low Susskind values at poles not matched by UMBC

*Rough estimate for 2616 scene dependence: 0.06K/decade, Obs: 0.09K/decade*

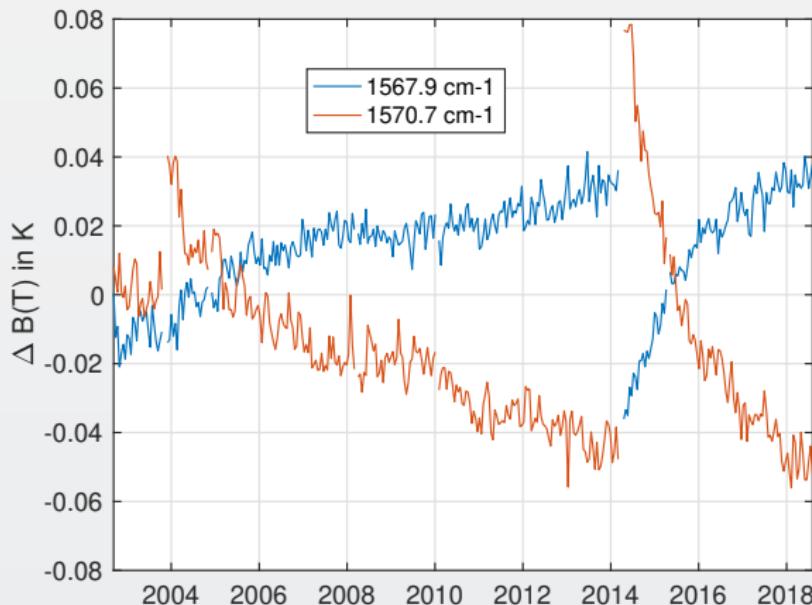
But what about the S. Pole??

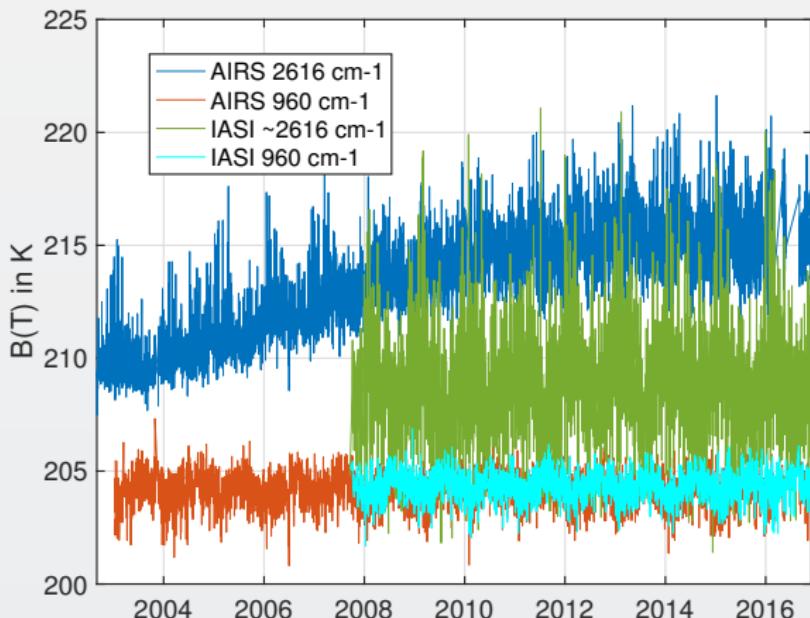
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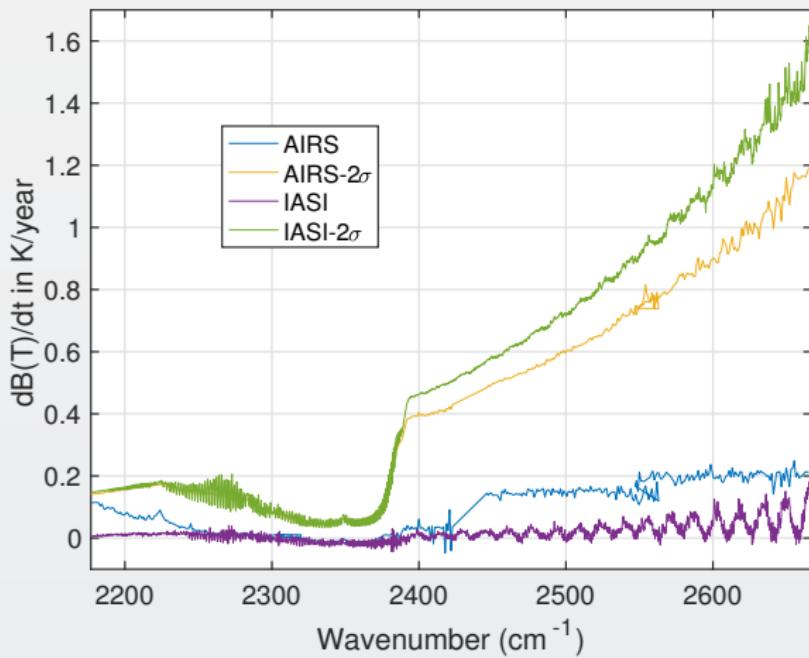


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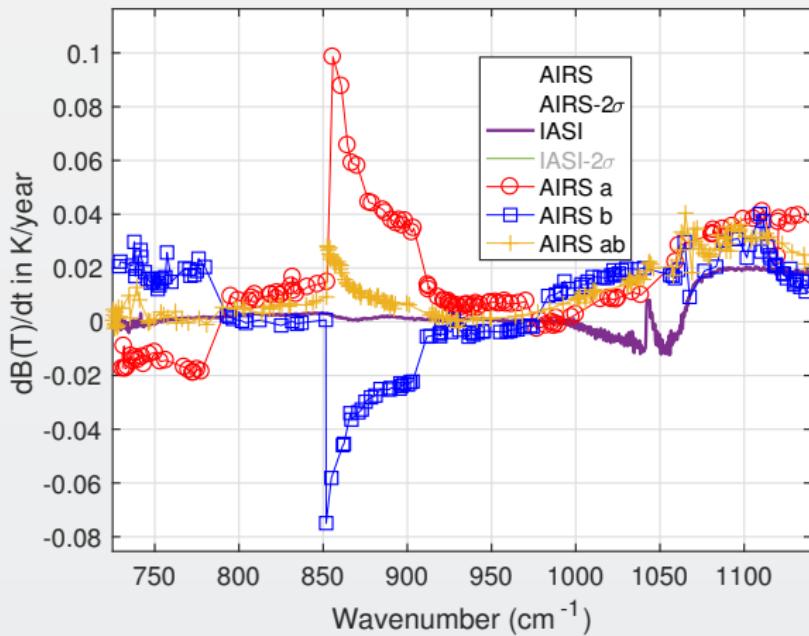




**Figure 1:** AIRS and IASI Dcc daily average temperatures versus time. The IASI curve for  $2616 \text{ cm}^{-1}$  is an average over 54 IASI channels.



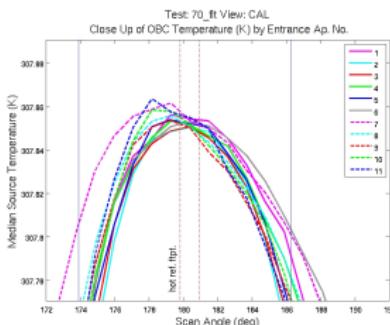
**Figure 2:** Same as Fig. where? with every two points in IASI averaged.



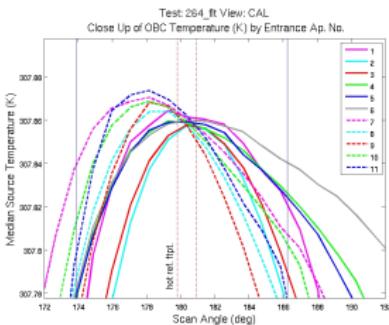
**Figure 3: Longwave DCC linear rate of change with AIRS A,B, AB channels identifications highlighted.**

## Profiles with Expanded Temperature Scale

Test 70, July 2002



Test 264, April 2014

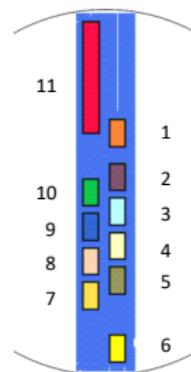


- Vertical blue lines define the limits of the normal calibration footprint
- Curvature within the limits probably indicate gradients within the OBC
- Some difference seen in the profiles, 2002 to 2014

# overroye\_map.pdf

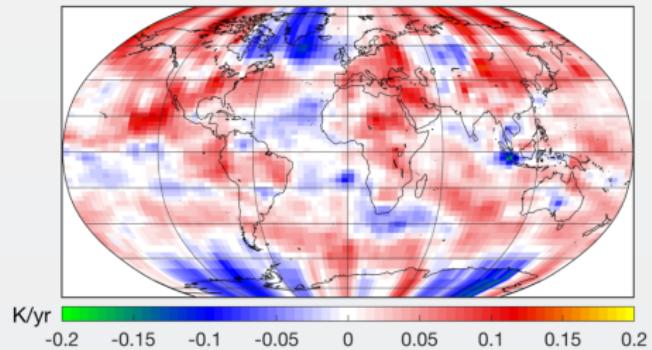
## C9 Test Differences (2002 - 2014) positions projected onto OBC Aperture

Aper.	Lt. Edge	Rt. Edge	Center	Width	
No.	(mm)	(mm)	(mm)	(mm)	Modules
Right col. of apertures (in order of height position on FPA):					
1	-0.008	0.045	0.018	0.052	M9, M10
2	0.018	0.039	0.029	0.024	M2a
3	0.013	0.029	0.021	0.016	M2b
4	0.000	0.084	0.039	0.084	M4c, M4d
5	0.000	0.050	0.026	0.050	M4a, M4b
6	NaN	0.039	NaN	NaN	M5, M6
Left column of apertures (in order of height position on FPA):					
11	-0.013	0.013	0.000	0.024	M11, M12
10	-0.024	0.018	-0.003	0.042	M3
9	NaN	0.005	NaN	NaN	M1b
8	NaN	0.005	NaN	NaN	M1a
7	NaN	0.052	NaN	NaN	M7, M8

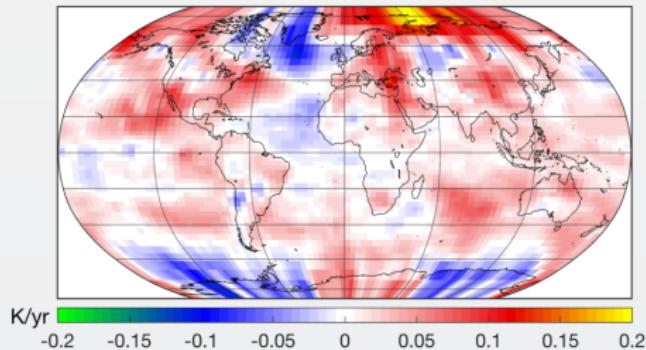


# Surface T Trends Using $1231\text{ cm}^{-1}$ Channel

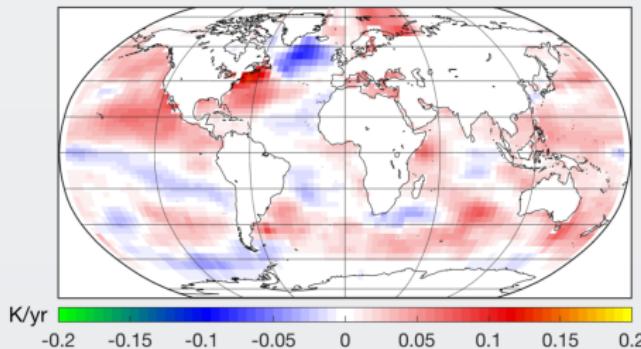
AIRS  $1231\text{ cm}^{-1}$



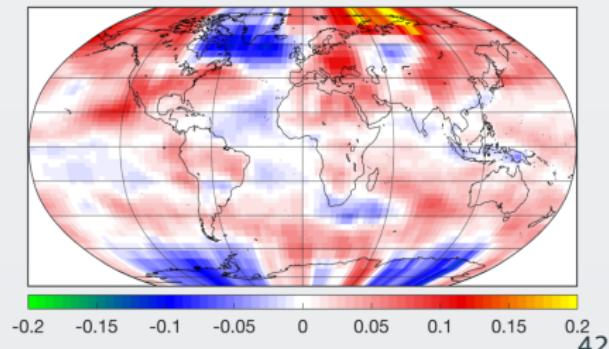
ERA



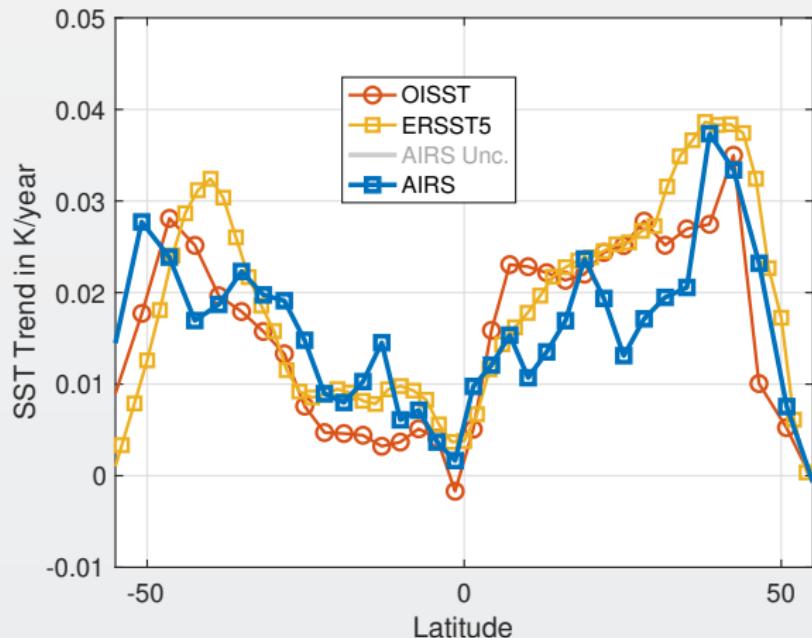
OISST



AIRS  $2616\text{ cm}^{-1}$

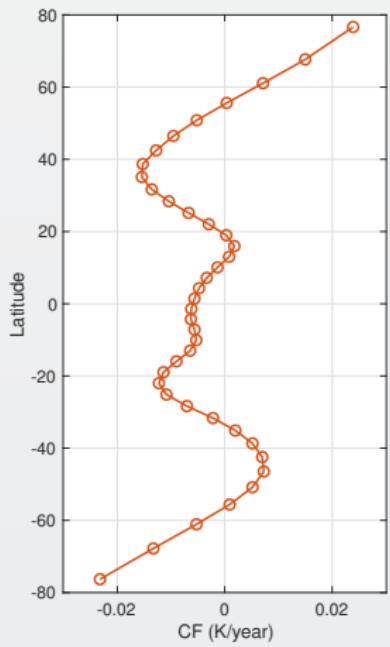


# Pdf/zonal\_sst\_trends\_12311\_vs\_oisst\_ersst5\_hottest\_per\_grid

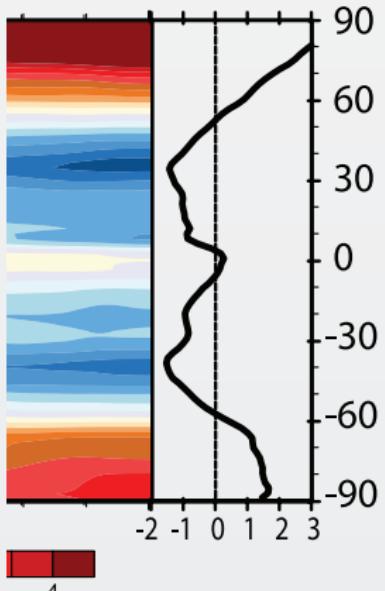


# Cloud Forcing Zonal Trends

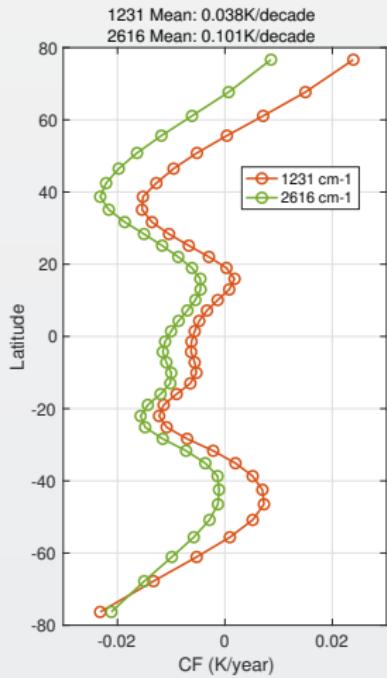
Some Small Title

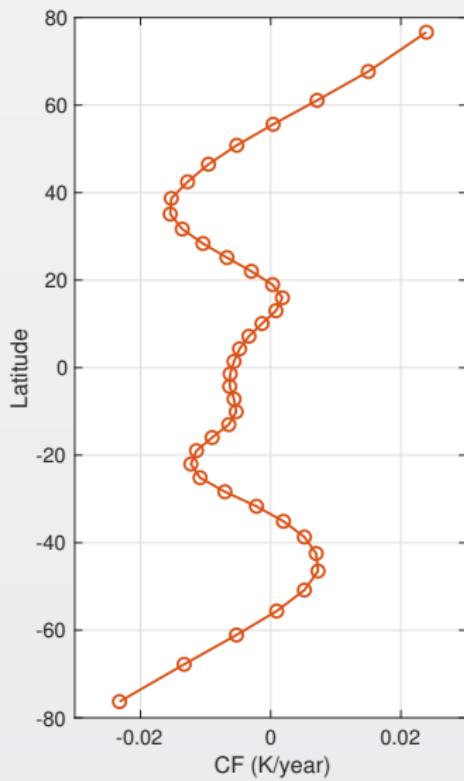


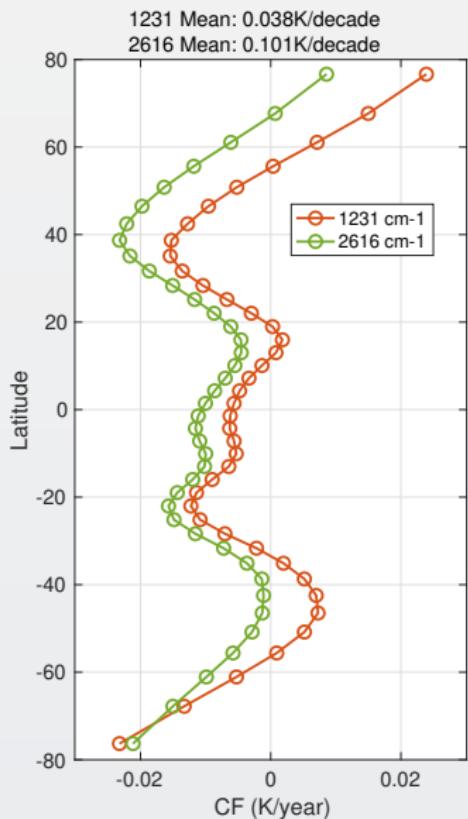
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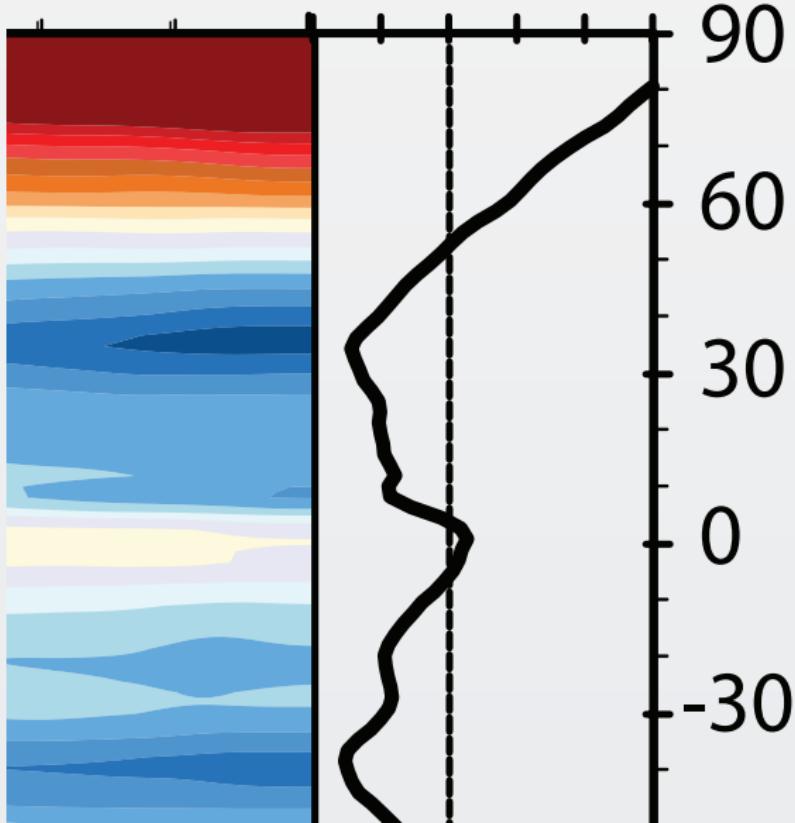


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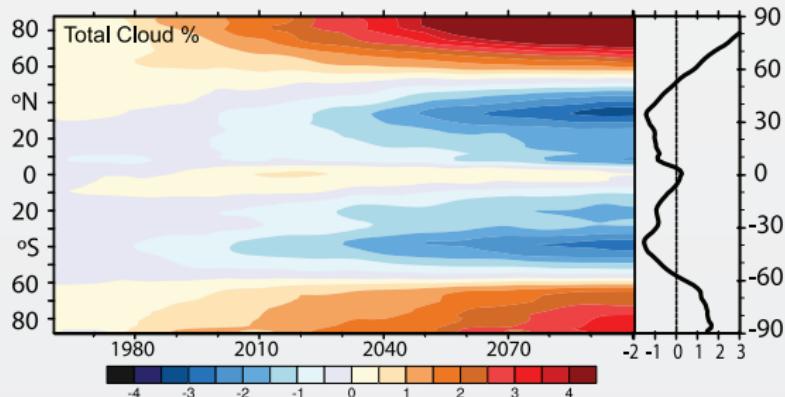




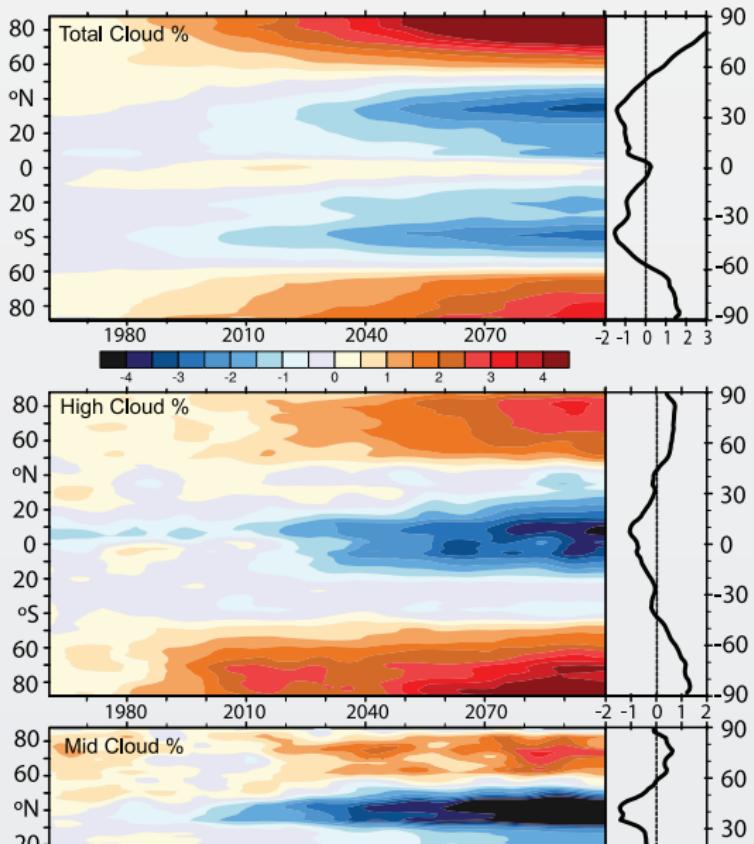




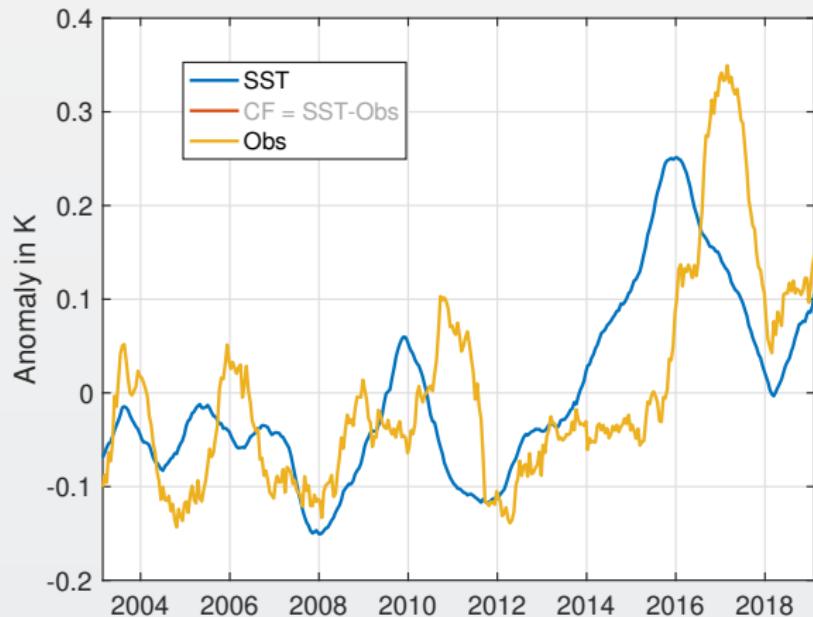
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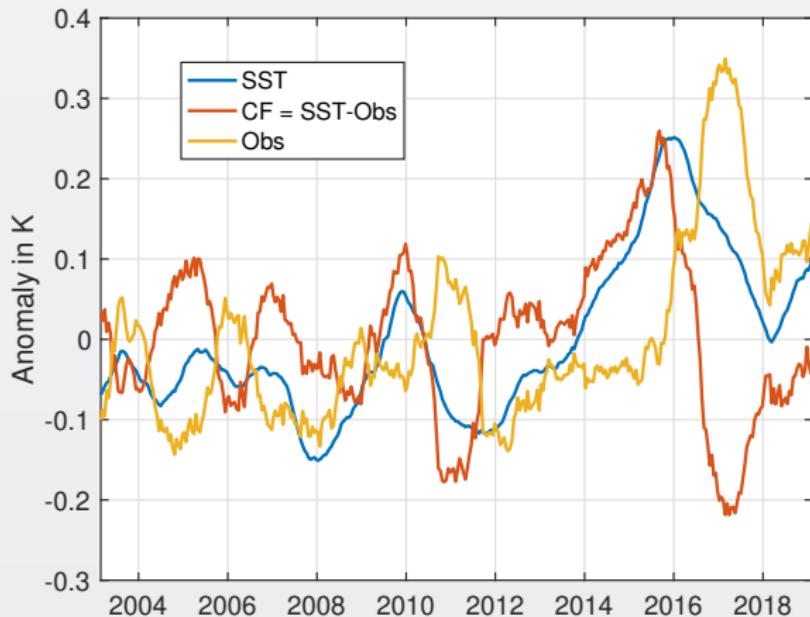
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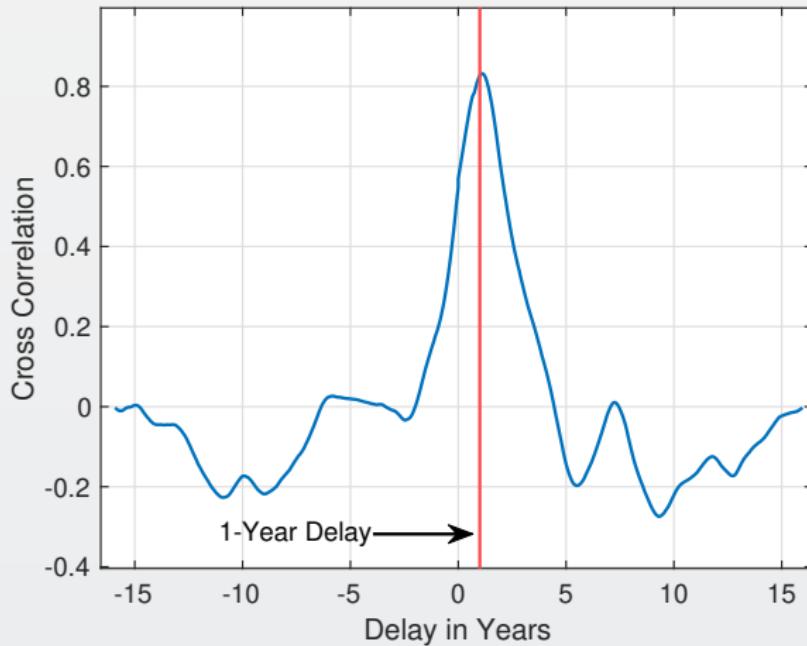
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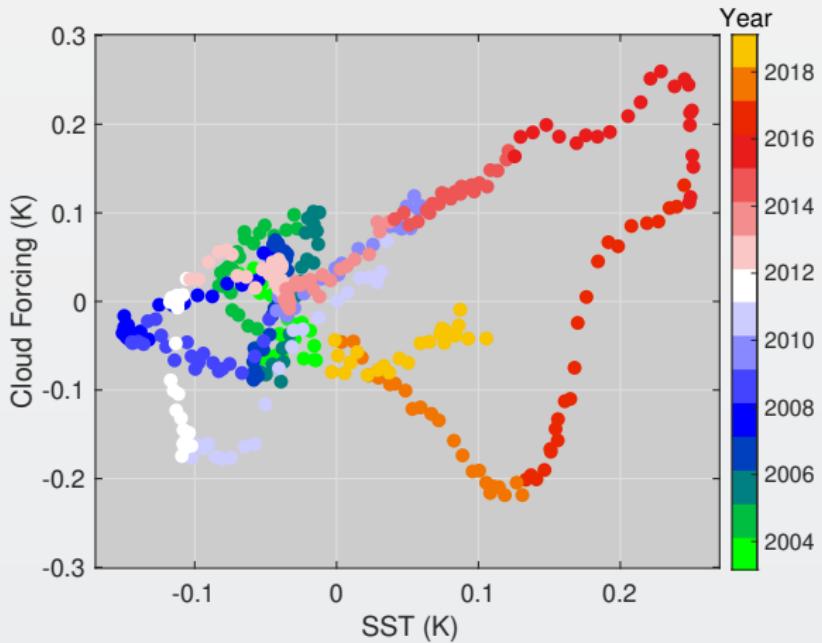
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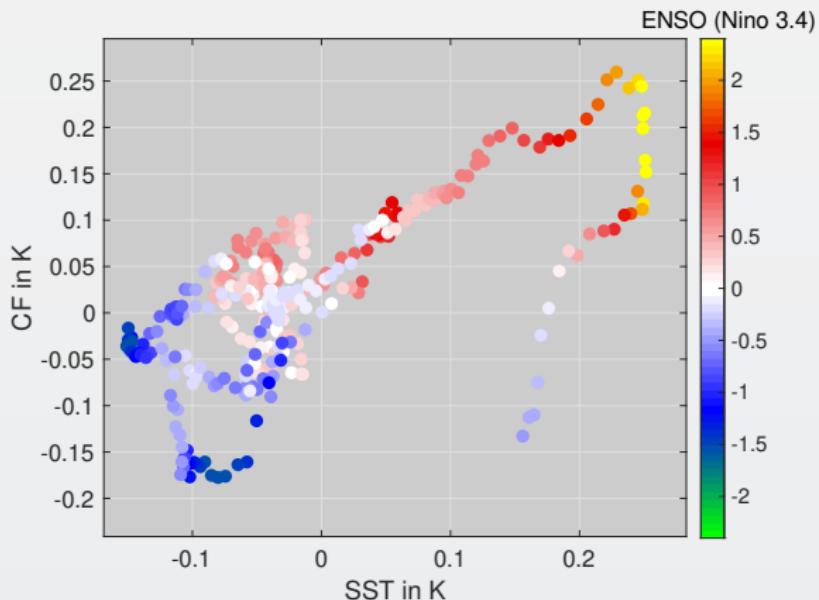
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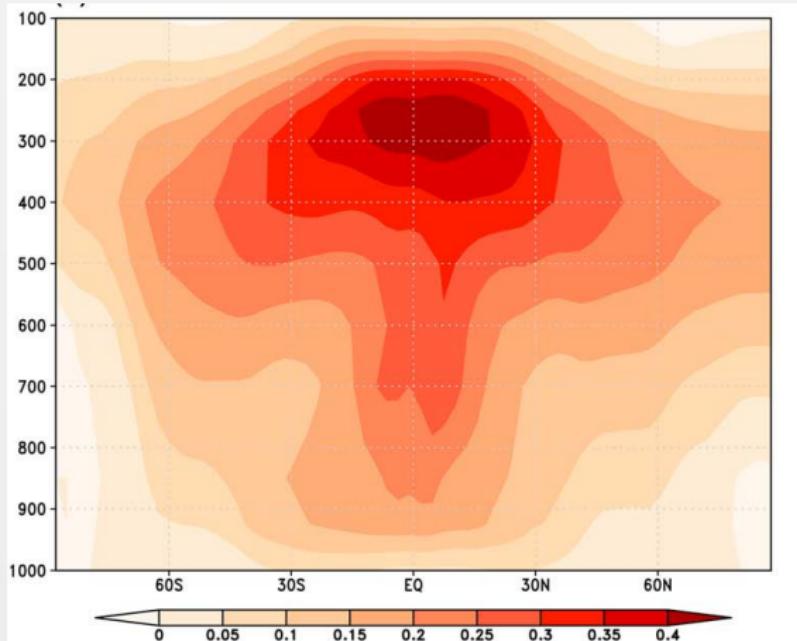
# Pdf(cf\_vs\_sst\_vs\_year\_2019.pdf



# Pdf(cf\_vs\_sst\_vs\_enso\_v2.pdf



# Pdf/lw\_h2o\_flux\_kernel.pdf



# Png/water\_chans\_1400to1600\_trend\_vs\_btobs\_2dhist\_global.

