AIRS Calibration for Climate Trend Studies: Status and Future

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_2, SST, etc allows stringent tests of stability

Climate Science Questions

All require min ~0.1K/decade stability

- Global Trending: T(z), H_2O (z), T_{surf}
- Water vapor feedback (Does relative humidity vary)
- Cloud feedback
- Trends in PBL cloud occurance
- OLR anomalies separated by cause: T/H_2O/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 aleady 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 applciations
- Establishing uncertainites for products is a NASA ROSES requirement!

Reproducibility

- Reproducibiity of results is becoming increasingly important
- Difficlt 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_2 and possibly N_2O and CH_4 can provide those standards
  - CO_2 is well mixed (on long time scales) and extremely well known
  - Establish AIRS stability by retrieving CO_2 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.

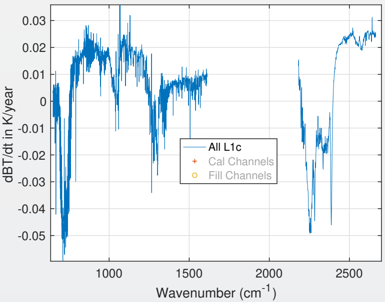
A *key* requirement is the need to reprocess the *full record* many times. NOT possible with Level 2 approach! Need fast alternatives that may also address issues of reproducibility.

Characteristics of AIRs Long-Term Radiance Trends

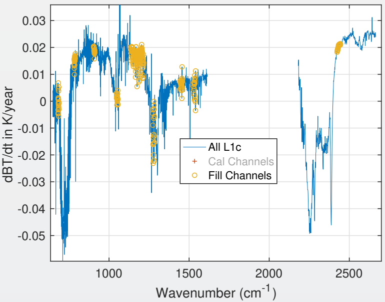
- 1% random subset

AIRS Global 16-Year B(T) Trend

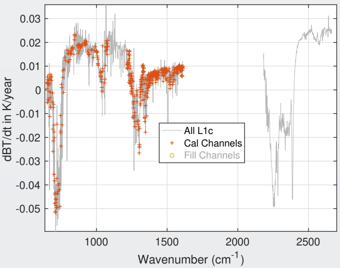
All channels (inc. fill)



Fill channels marked



Calibration channels



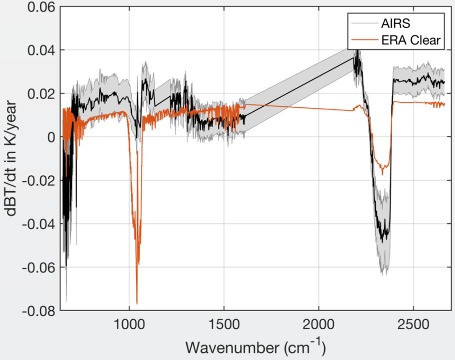
Channels used for calibration testing marked.

These channels have no A/B state changes, good S/N, small drift

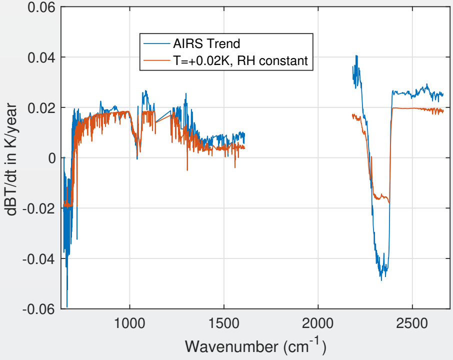
Note sparsity of CO_2 channels in tropospheric sounding region

CO_2 and CH_4 Trends Removed, Fitted Chans Only

AIRS + ERA



AIRS w/ 0.02K dT, RH constant



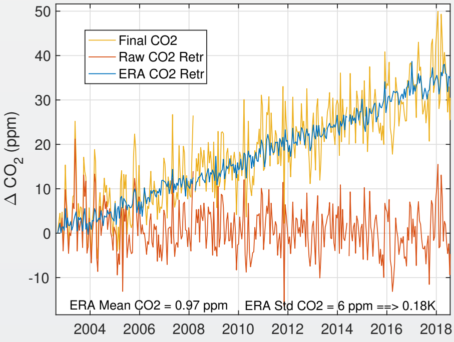
- Uncertainty (gray) is geophysical (Std over latitutde).
- RHS: Trop T(z) + 0.02K, Strat T(z) - 0.02K
- H_2O trend is close to constant RH. (Varies with latitude).
- Could suggest RH is a bit lower over time??
- Shortwave appears to have a positive drift

Retrieval of CO_2, N_2O, CH_4 Anomalies

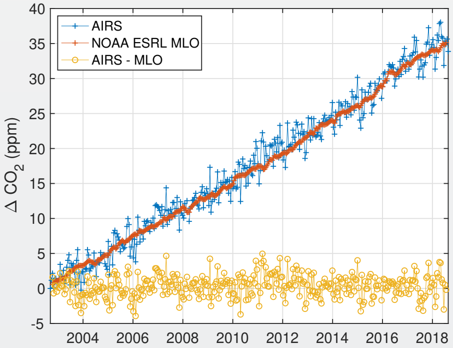
- oem approach
- data set
- kcarta vs sarta
- true noise, averaged over ~600 pts/16 days per 1/40 lat bins.
- 2ppm CO_2 a-priori covariance, with 2ppm slope a=prori, 5 ppm covariance almost as good
- jacobian (kernel) profiles from ERA, but we could fit for them,
- iterate: first remove jumps due to know events in fitting channels
- then evaluate channels not fitted, and include if warranted
- possible BB is stable
- relative channel errors are likely due to small thermal changes changing view of cold space, etc. a/b often different

CO_2 Anomaly Fit for MLO Latitude

Fitting Trick

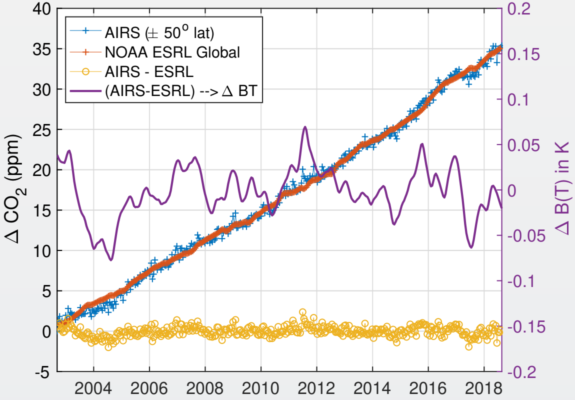


Fitted CO_2 Anomalies



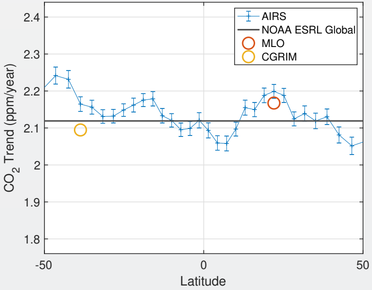
- ERA simulations done per footprint
- Fit ERA simulation for CO_2
- Removes co-linearity? and lowers "noise"

CO_2 Anomaly Converted to B(T) Trends

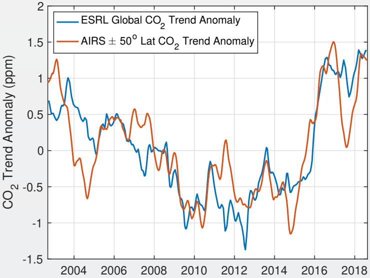


Other CO_2 Diagnostics

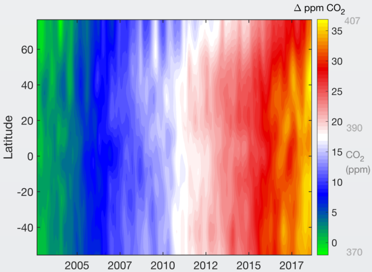
Growth Rates



Growth Rate Anomaly

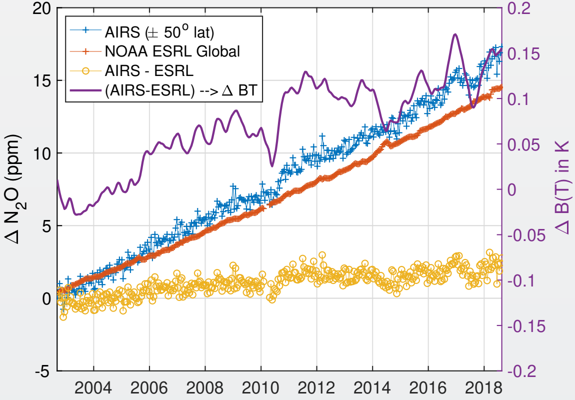


Zonal Anomalies



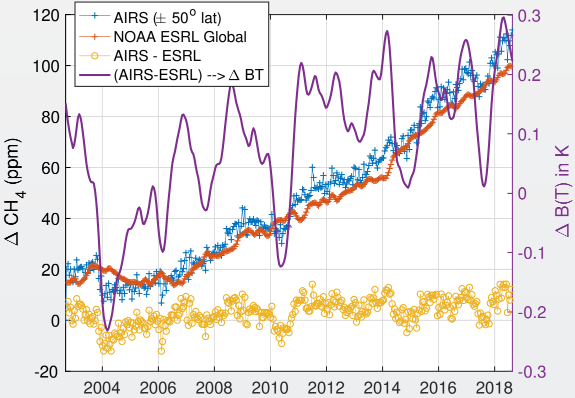
Growth rate anomaly accuracy very encouraging.

N_2O Retrieved Anomalies



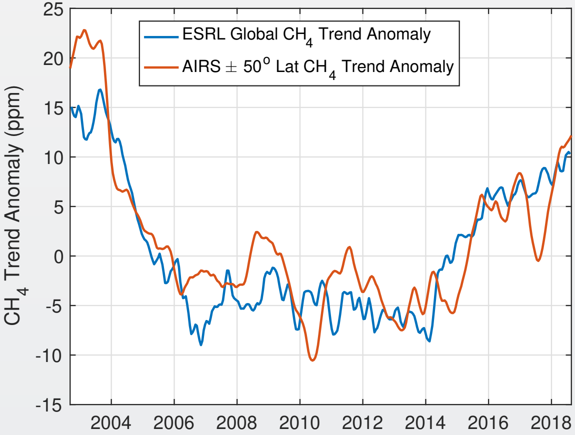
- This is what we are after
- Something a little before 2006?
- A jump due to the Jan. 2010 shutdown
- Stable otherwise
- Look at residuals of fits to understand guilty channels

CH_4 Retrieved Anomalies



- Is CH_4 well mixed enough for this analysis?
- Clearly an offset in Jan 2010 but it recovered (seen in spectral!)
- Clear Nov. 2003 B(T) shift

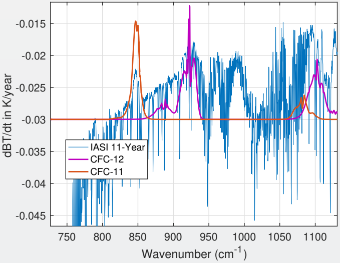
CH_4 Growth Rate Anomalies



- Very nice agreement with NOAA ESRL in-situ
- Shows drop-off in global CH_4 growth early in mission
- Then increasing growth starting in 2014

Unlike Retrievals We'd Like to Examine Many Channels

IASI: 11-Year Trend



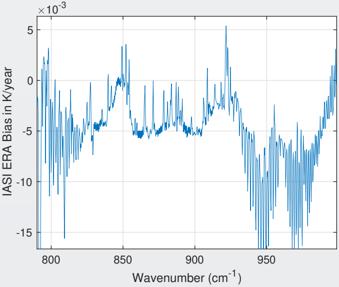
That means taking the CFC 11 and 12 into account.

Maybe 3 strong CFC 11 channels?

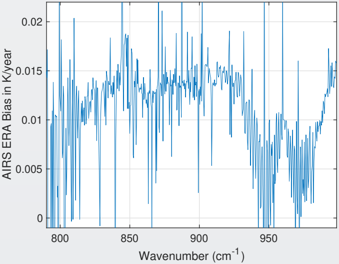
Maybe 3-5 strong CFC 12 channels?

But, need to remove effects in wings

IASI Trend Zoom

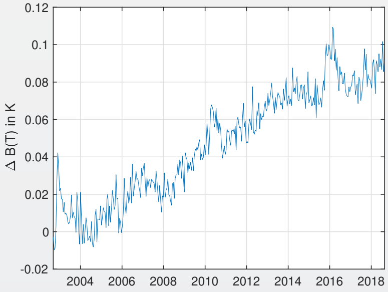


AIRS Trend Zoom

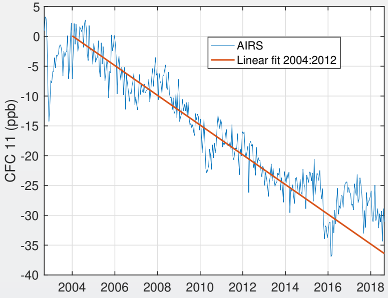


Fit to AIRS CFC-11 for Removal in Fit Residuals

CFC-11 B(T) Trend

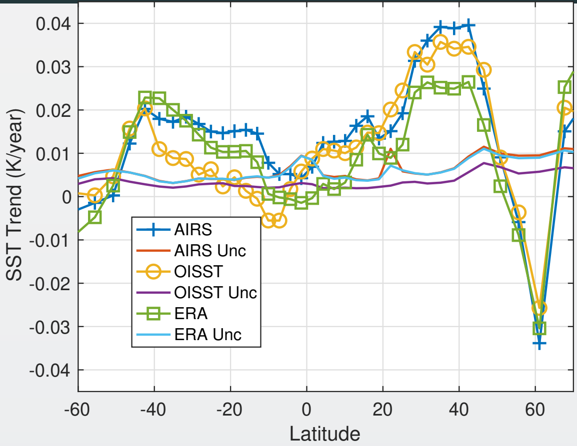


CFC ppb Trend



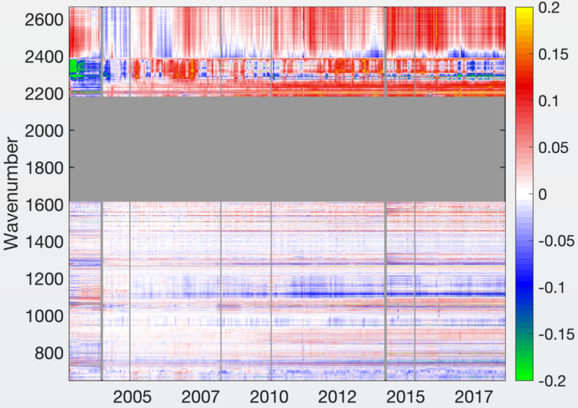
- Reasonably linear negative trend, as expected
- Values agree well with in-situ
- BUT, the trend appears to be decreasing!
- Also expected from in-situ: possible cause is Chinese production of CFC-11
- ENSO signals in time series: retrieval problem or something real?
- Clear problems due to Nov. 2003 AQUA shutdown

SST Retrieved from Anomaly Fits

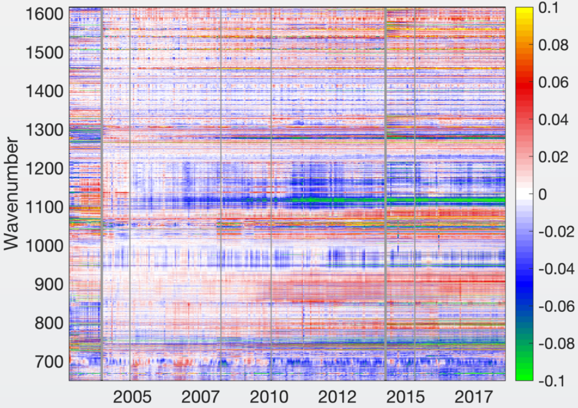


- OISST likely better? AIRS-OISST = +0.005 ± 0.007 K/year (tropics)
- ERA transitioned from RTG to OSTIA in Feb. 2009, we likely see that
- Differences very small and at limits of SST climatologies

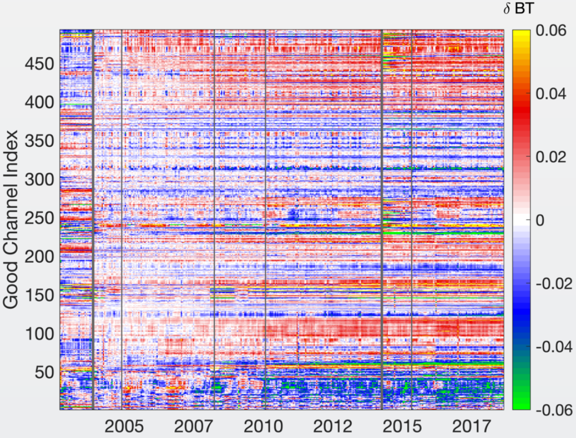
Png/best_co2_anom_resid.png



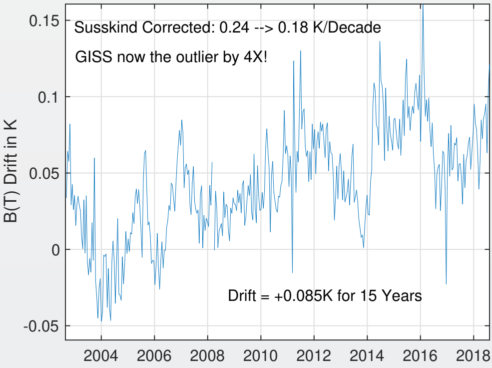
Png/best_co2_anom_resid_no_sw.png



Png/best_co2_anomaly_resid_fit_chans_concat.png



Pdf/bt_drift_from_anom_resid_2613_chan.pdf



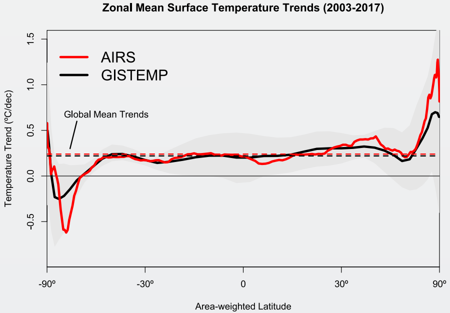
From Susskind et. al.

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

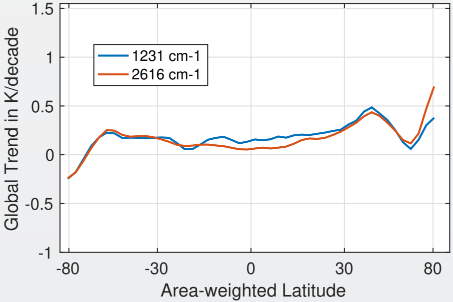
Shortwave drift correction reduces AIRS global temperature trend by 33% and bring AIRS into close agreement with HadCRUT4, C&W, and UAH LT, signficantly worse agreement with GISTEMP.

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

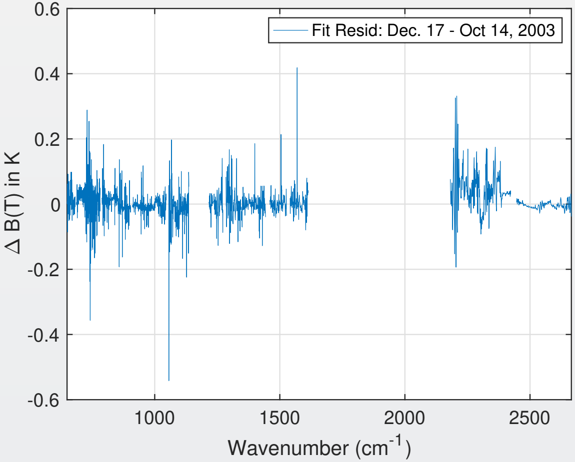
But, why isn't UMBC-2616 0.05K higher??

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

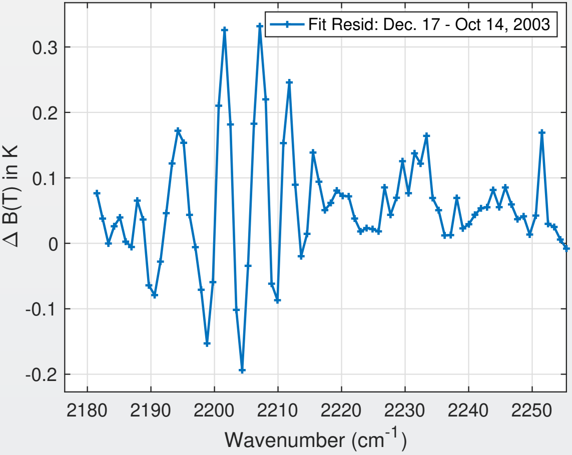
Rough estimate for 2616 scene dependence: 0.06K/decade, Obs: 0.09K/decade

But what about the S. Pole??

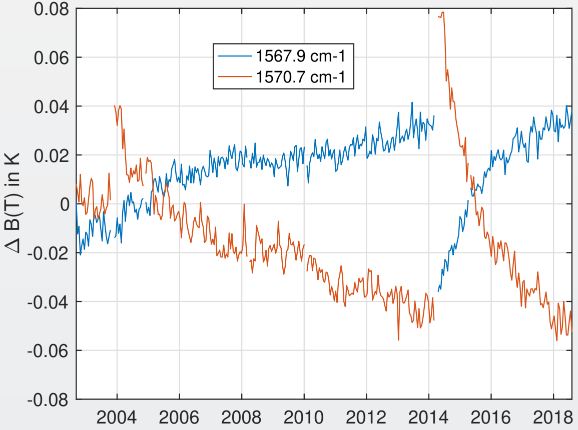
Pdf/resid_spectrum_dec17_minus_oct14_2003.pdf



Pdf/resid_spectrum_dec17_minus_oct14_2003_swzoom.pdf



Pdf/resid_1567_and_1570_cm01_dnu.pdf



DCC1

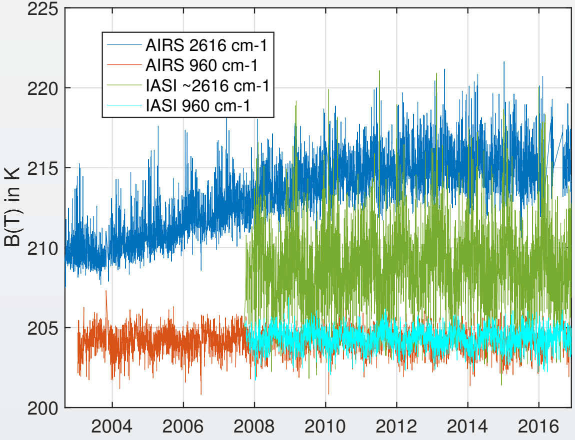


Figure 1: *AIRS and IASI Dcc daily average temperatures versus time. The IASI curve for 2616 cm^{-1} is an average over 54 IASI channels.*

DCC4

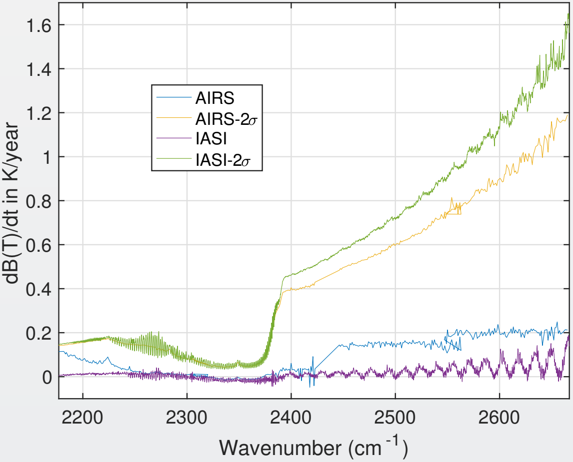


Figure 2: *Same as Fig. where? with every two points in IASI averaged.*

DCC6

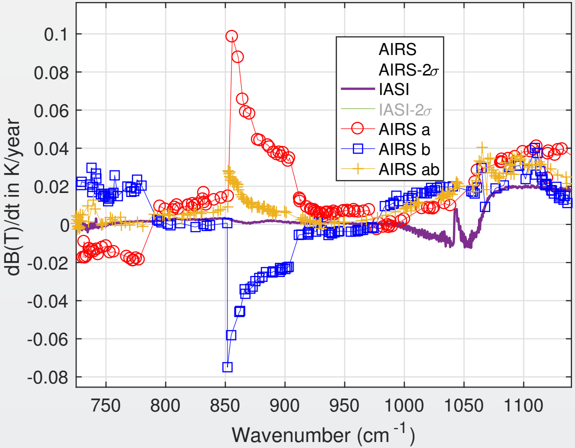
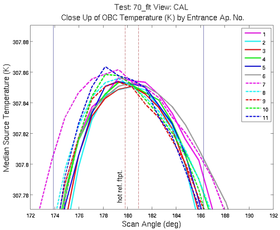


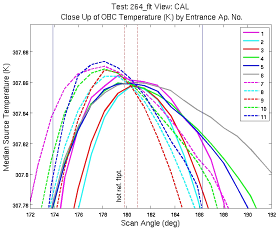
Figure 3: *Longwave DCC linear rate of change with AIRS A,B, AB channels identifications highlighted.*

Profiles with Expanded Temperature Scale

Test 70, July 2002



Test 264, April 2014

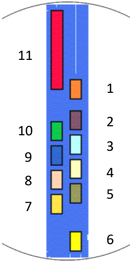


- Vertical blue lines define the limits of the normal calibration footprint
- Curvature within the limits probably indicate gradients within the OBC
- Some difference seen in the profiles, 2002 to 2014

overroye_map.pdf

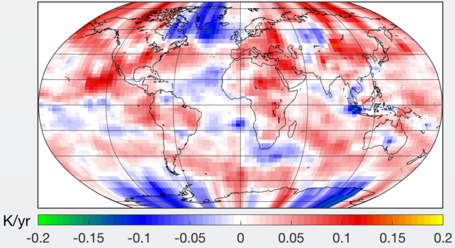
C9 Test Differences (2002 - 2014)
positions projected onto OBC Aperture

Aper. No.	Lt. Edge (mm)	Rt. Edge (mm)	Center (mm)	Width (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

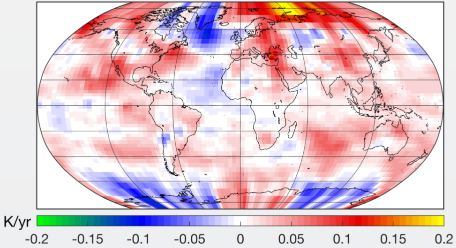


Surface T Trends Using 1231 cm^{-1} Channel

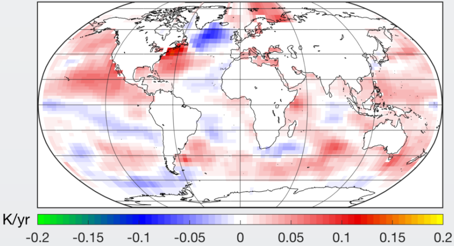
AIRS 1231 cm^{-1}



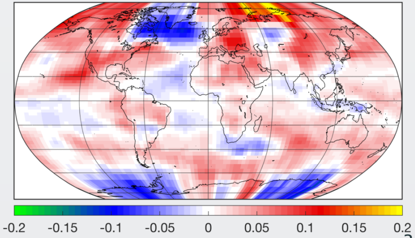
ERA



OISST



AIRS 2616 cm^{-1}



Pdf/zonal_sst_trends_12311_vs_oisst_ersst5_hottest_per_grid