Radiometric Calibration of AIRS and Possible contamination of Scan Mirror

By

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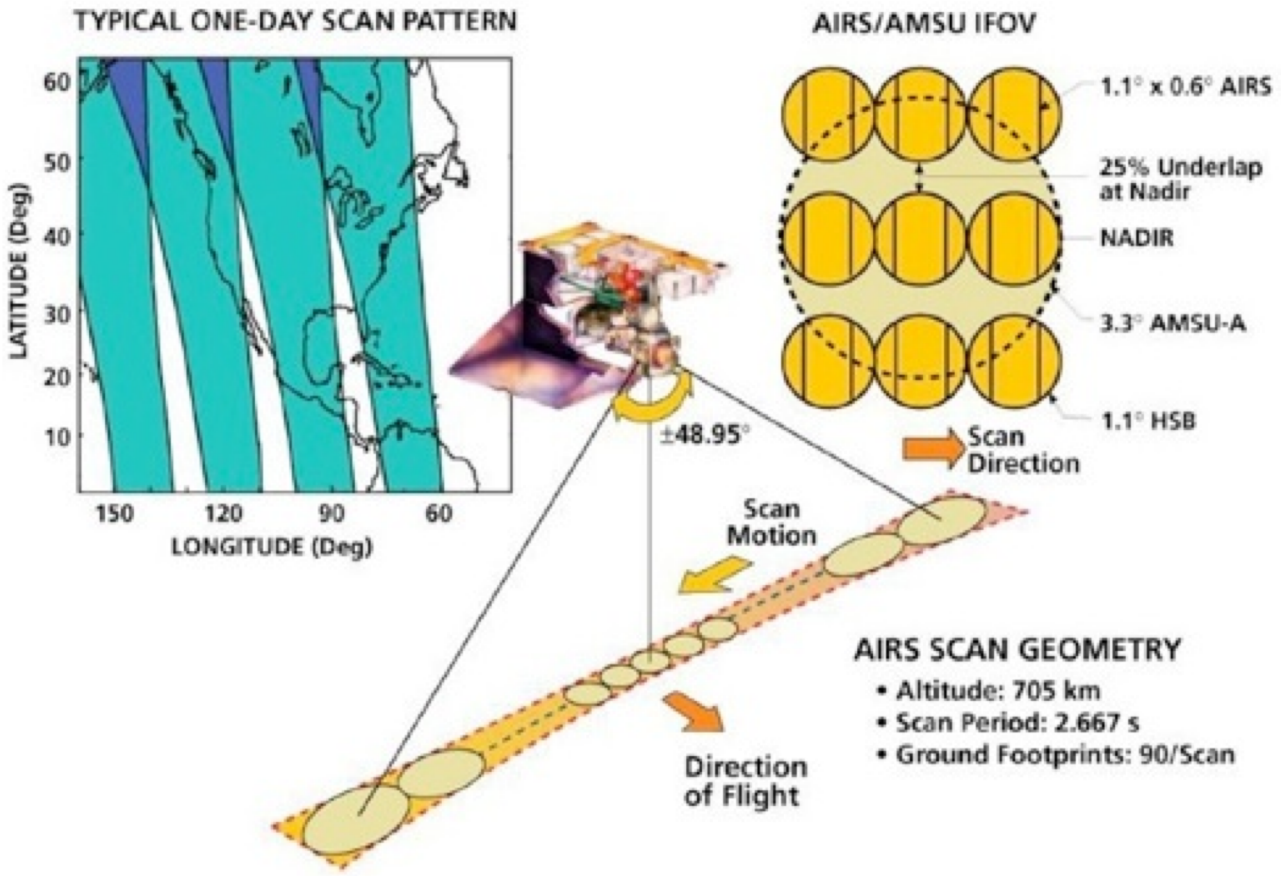
www.nasa.gov

The Atmospheric Infrared Sounder

- Launched May 2002
- 2378 channels measuring infrared energy from 3.7 to 15.4 microns
- Spatial resolution is ~ 13.5 km (nadir)
- Sounding has comparable vertical resolution to radiosondes
- Global measurements occur twice per day from the AQUA satellite
- Microwave instrument AMSU allows AIRS to measure temperature and water in cloudy scenes
- Cloudy temperature retrieval goal is 1K accuracy for 1 km vertical resolution

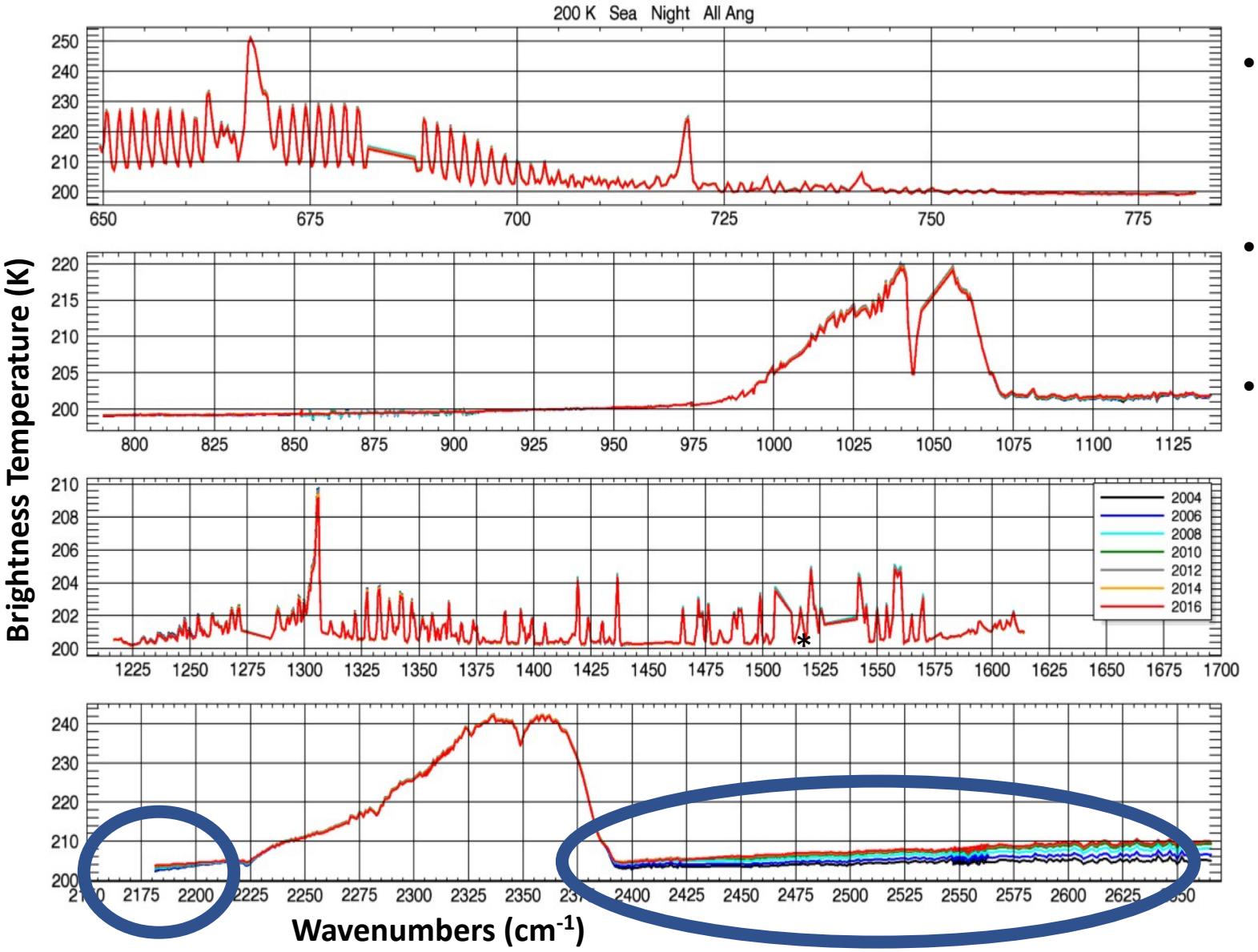
- **Use window channels (channels that see surface or cloud top)**
- **Look mostly at really cold scenes**



http://airs.jpl.nasa.gov/instrument/how_AIRS_works/

Agenda

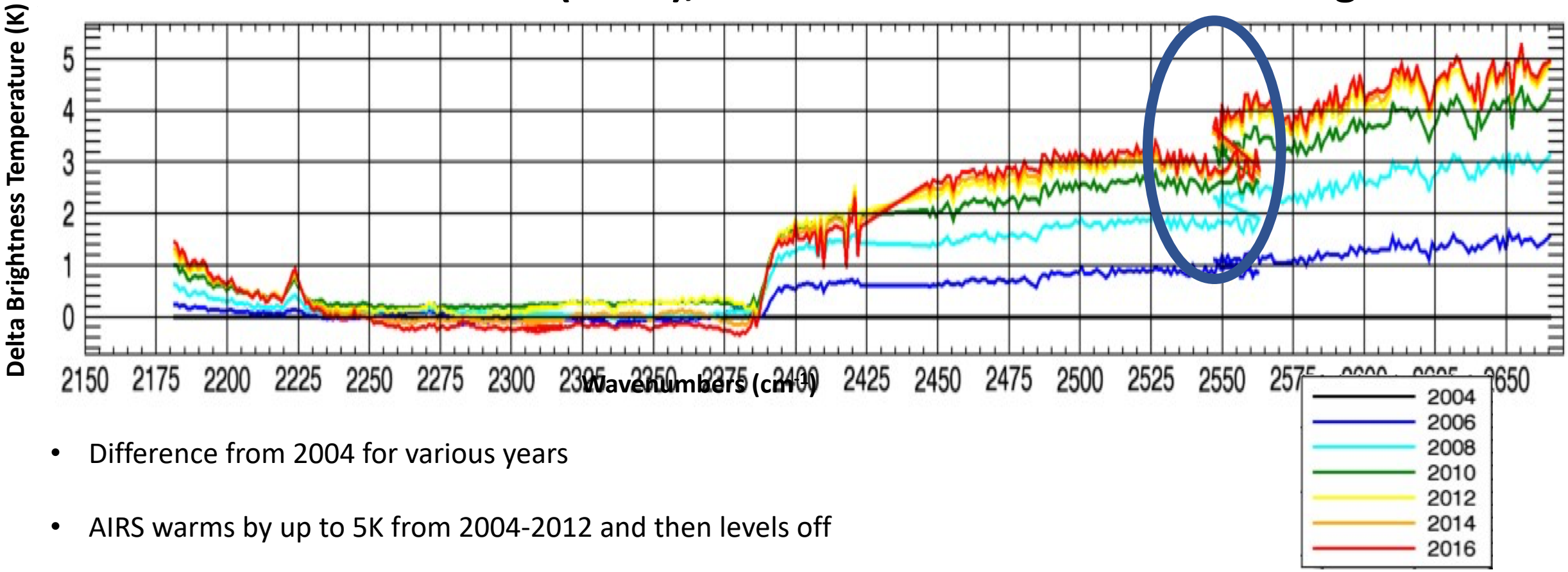
- AIRS shortwave channels see warming trends when viewing extremely cold scenes such as deep convective clouds (DCCs)
- The warming trends are not seen for scenes with little variability
- Warming trends only occur for part of the mission (2002-2012)
- We suspect signal from near field scenes due to contamination of scan mirror
- Regression between window channel residuals and near field pixels can model the warming trend



- This shows the mean of all spectra which are 200 +/- 1 K at 939 cm^{-1} for ever other year over the AIRS mission
- No >1 K trends are seen except in the shortwave band
- Here a trend is seen at both ends of the band but not in the stratospheric region 2225-2385 cm^{-1}

(From Manning 2017)

For extreme cold scenes (200K), AIRS shortwave show a warming trend



- Difference from 2004 for various years
- AIRS warms by up to 5K from 2004-2012 and then levels off
- Different trends are seen where different AIRS detector modules overlap near 2555 cm^{-1}

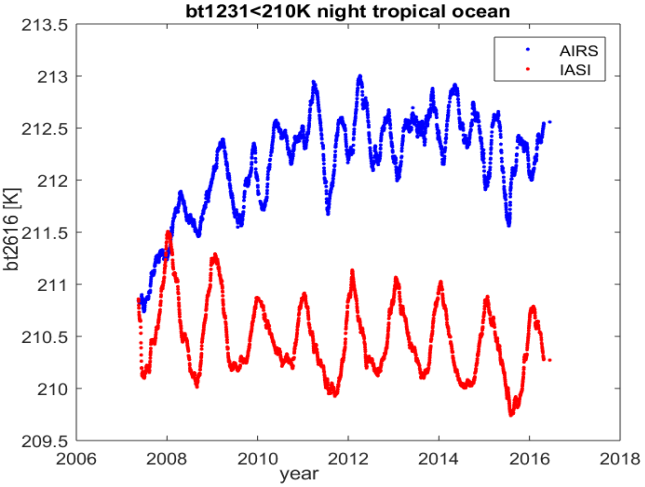
Warming trend of 1.5-5K in the shortwave at 200K occurred from 2004-2012

(From Manning 2017)

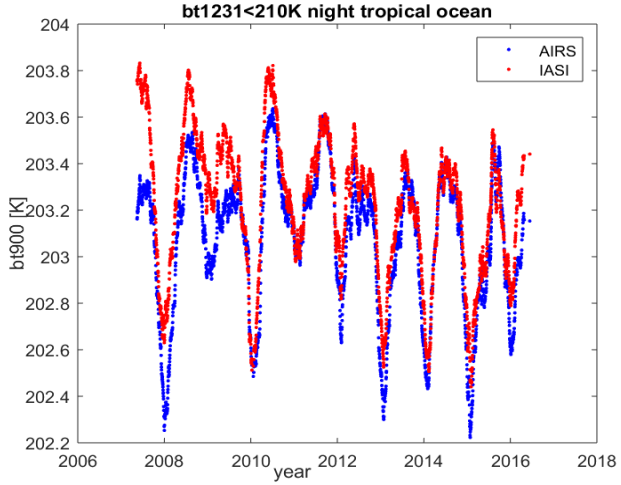
Tropical Ocean Nighttime Measurements: AIRS vs. IASI

All cases are for Bt1231<210K night tropical ocean

BT 2616



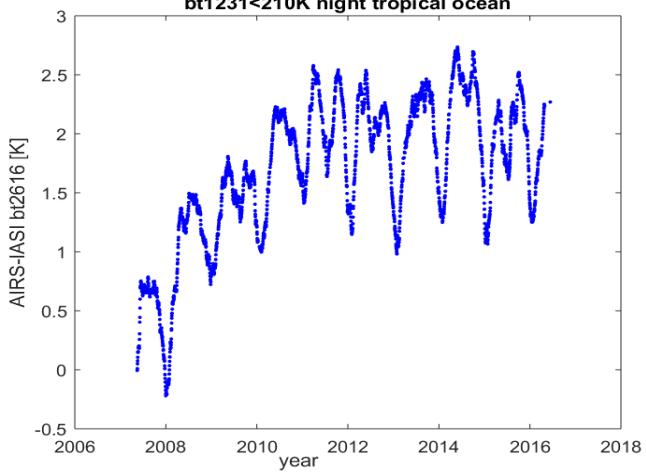
BT 900



- IASI 2616 is mean of 7 channels centered on 2616
- IASI has similar calibration data set to the ACDS
- Use Brightness Temperature at 1231 cm^{-1} to determine cold cases

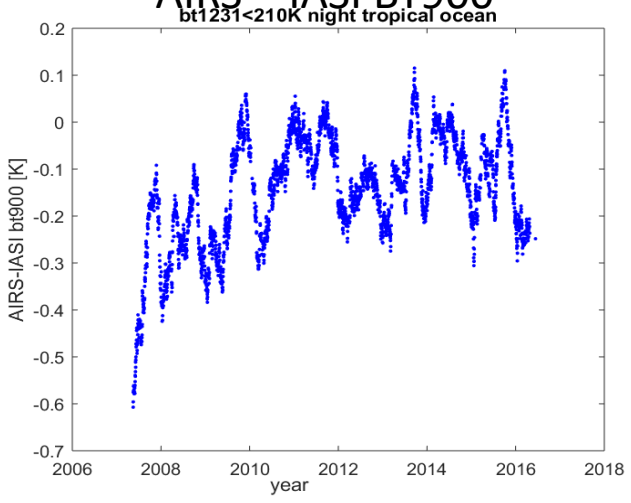
Differences ~ 2K

AIRS – IASI BT2616



Differences ~ -.2K

AIRS – IASI BT900

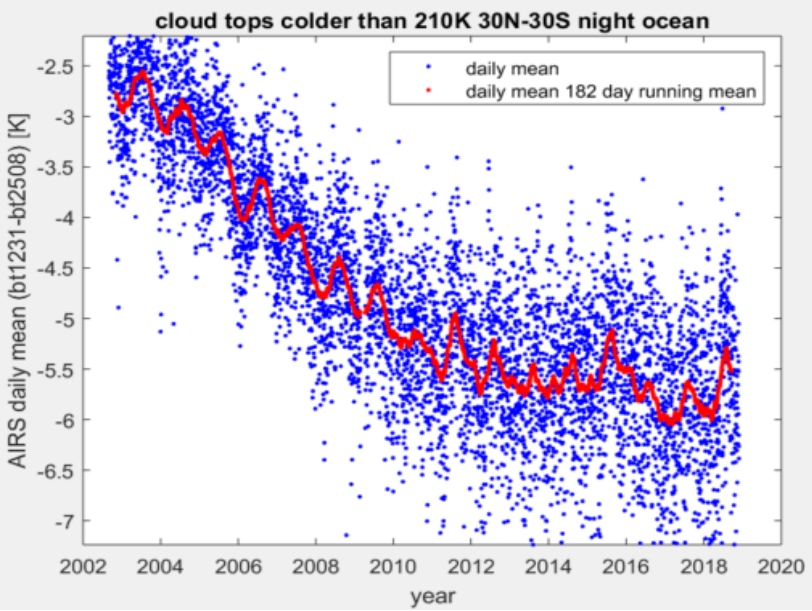


IASI doesn't observe same warming as AIRS at 2616 cm^{-1}

- AIRS brightness temperature at 2616 cm^{-1} is clearly warming
- IASI seems to cool during the same time period
- Over same time period IASI and AIRS are very similar at 900 cm^{-1}
- AIRS warming trends levels off around 2012

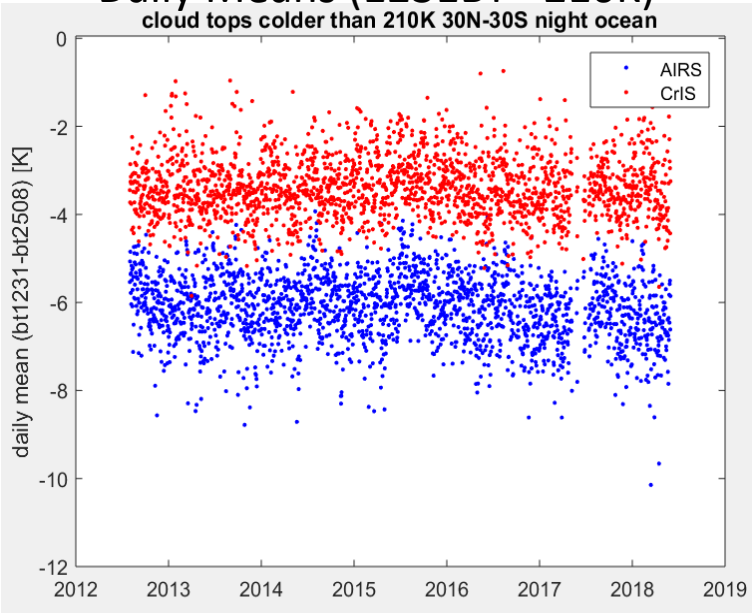
Tropical Ocean Nighttime Measurements: AIRS vs. CrIS

AIRS 1231 – 2508 BT difference



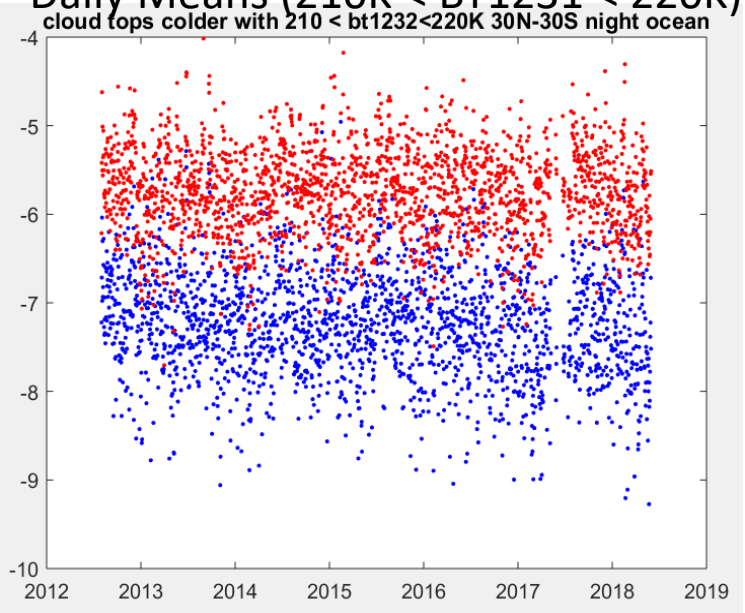
- AIRS daily means of cases < 210K in tropics at night
- Difference of 1231 – 2508 cm^{-1} brightness temperature decreases from -2.5 to -5.5K between 2002 to 2012

Daily Means (1231BT <210K)



- CrIS has similar calibration dataset to AIRS
- CrIS only has data for 2012-present
- Both are level with and offset

Daily Means (210K < BT1231 < 220K)

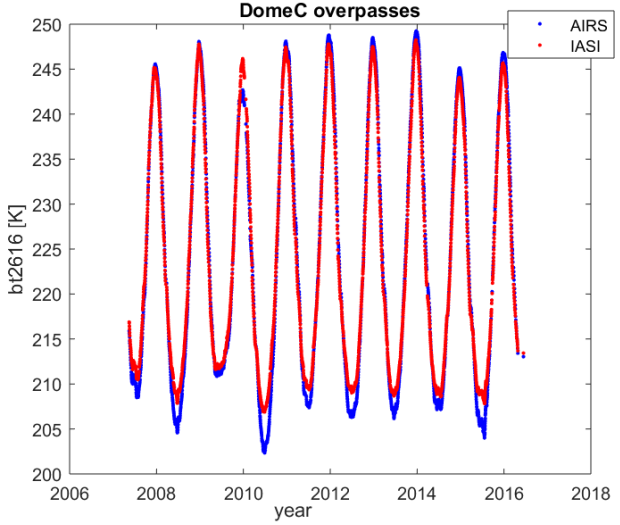


- Warmer scenes have more negative 1231-2508 cm^{-1} brightness temperature differences

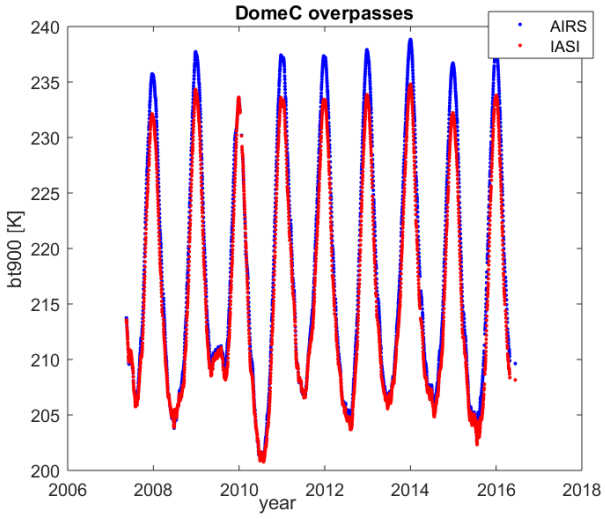
AIRS and CrIS see a constant difference between 1231 and 2508 cm^{-1} with an offset from one another

Dome C Measurements

BT 2616



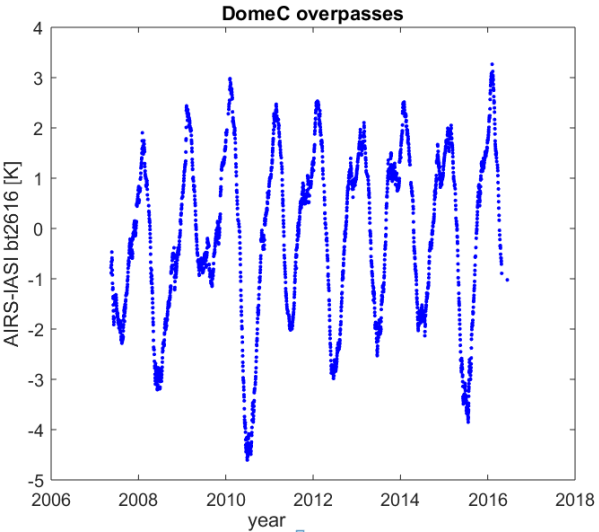
BT 900



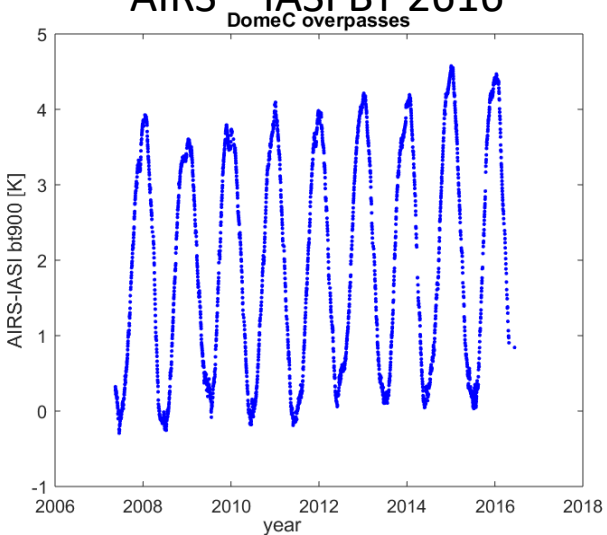
- Dome C is in Antarctica and one of the coldest places on earth ranging from -25 to -80 Celsius
- Spatially homogeneous and large frozen desert
- Daily means smoothed by 90 running mean

Shortwave warming trends not seen over large homogenous frozen desert

AIRS – IASI BT 2616

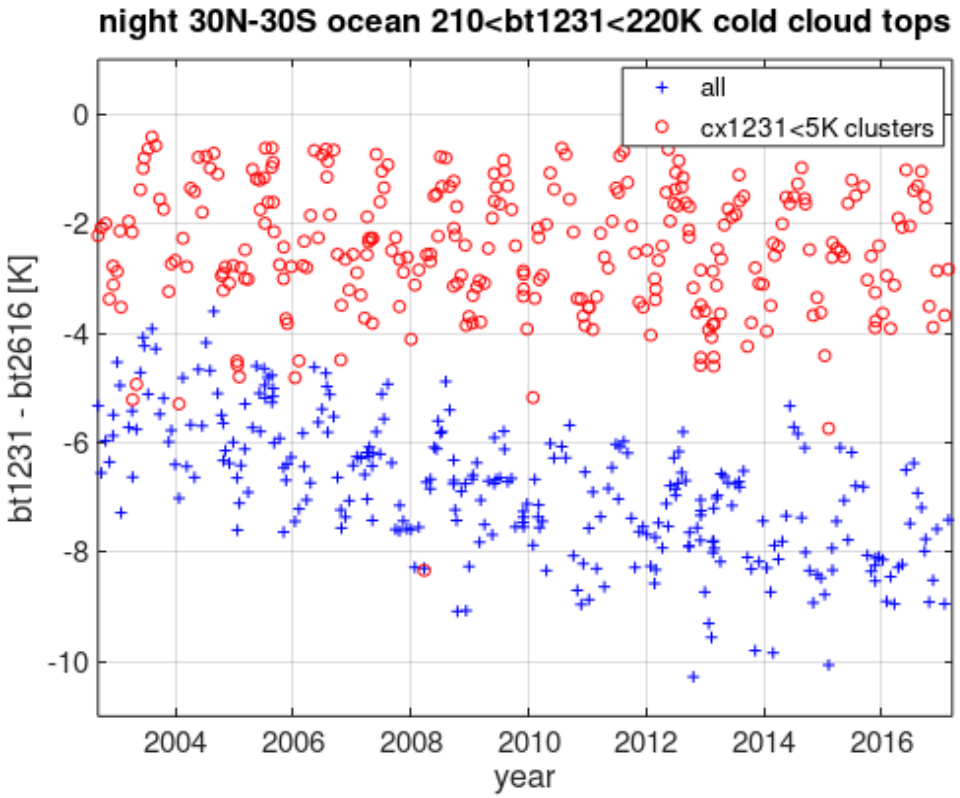


AIRS – IASI BT 2616



- Trend between AIRS and IASI at 2616 cm^{-1} is .02K/yr., much smaller then previous measurement including all cold scenes
- AIRS IASI difference at 900 cm^{-1} is around .11K/yr

AIRS Spatial Variability



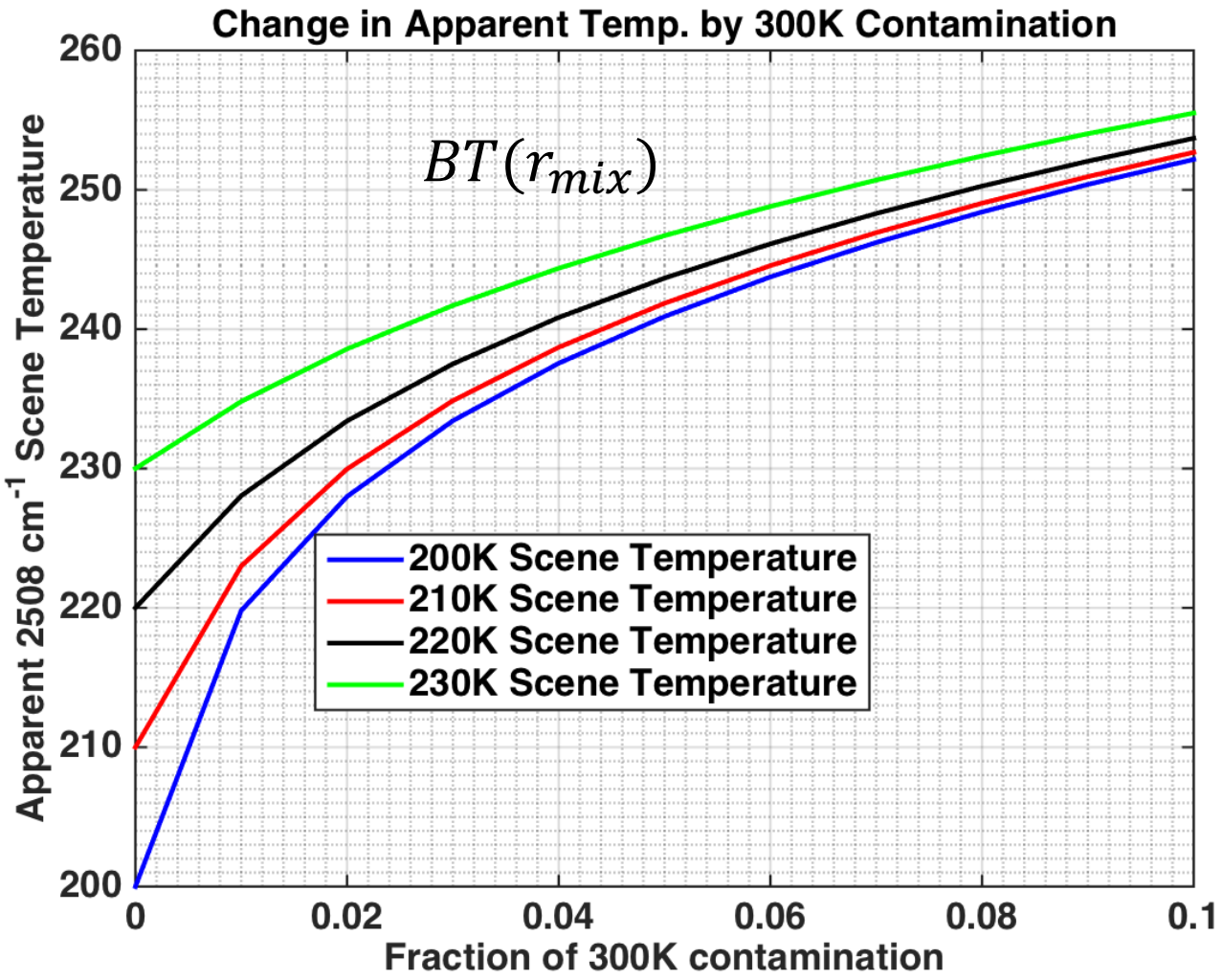
- Daily means of every 24th day between 2002 and present in ACDS
- Looked at clusters of 3x3 to determine variability
- Cx1231 < 5K means that the surrounding pixels must be within 5K of observation

- The cases with not filtering show 2616 cm^{-1} is warming relative to 1231 cm^{-1}
- Restricting variability shows that the 1231 – 2616 BT difference is around -2K and no trend

Summary

- **Shortwave observations are warming in AIRS from 2002-2012 (1-5K)**
- **Other instruments don't see a similar trend (i.e. not geophysical)**
- **Trends aren't present when adjacent footprints are near the same temperature as the observation footprint**

Hypothesis: Contaminants or microscopic imperfections around 4 micron in size were building up on the scan mirror, scattering light from nearby footprints



$$r_{mix} = (1 - X) * r_{cold} + X * r_{300}$$

$$X = Decimal\ Percent\ of\ mixing\ from\ 300K\ scene$$

- Simple model demonstrating warming observations due to scattered light from a nearby warm scene
- **Only takes small amounts of contamination to raise temperatures of cold scenes**

Scene Temp	Percent (%) req. for 5K increase
200K	~.2%
210K	~.4%
220K	~.6%
230K	~1%

Modeling the Near Field Response

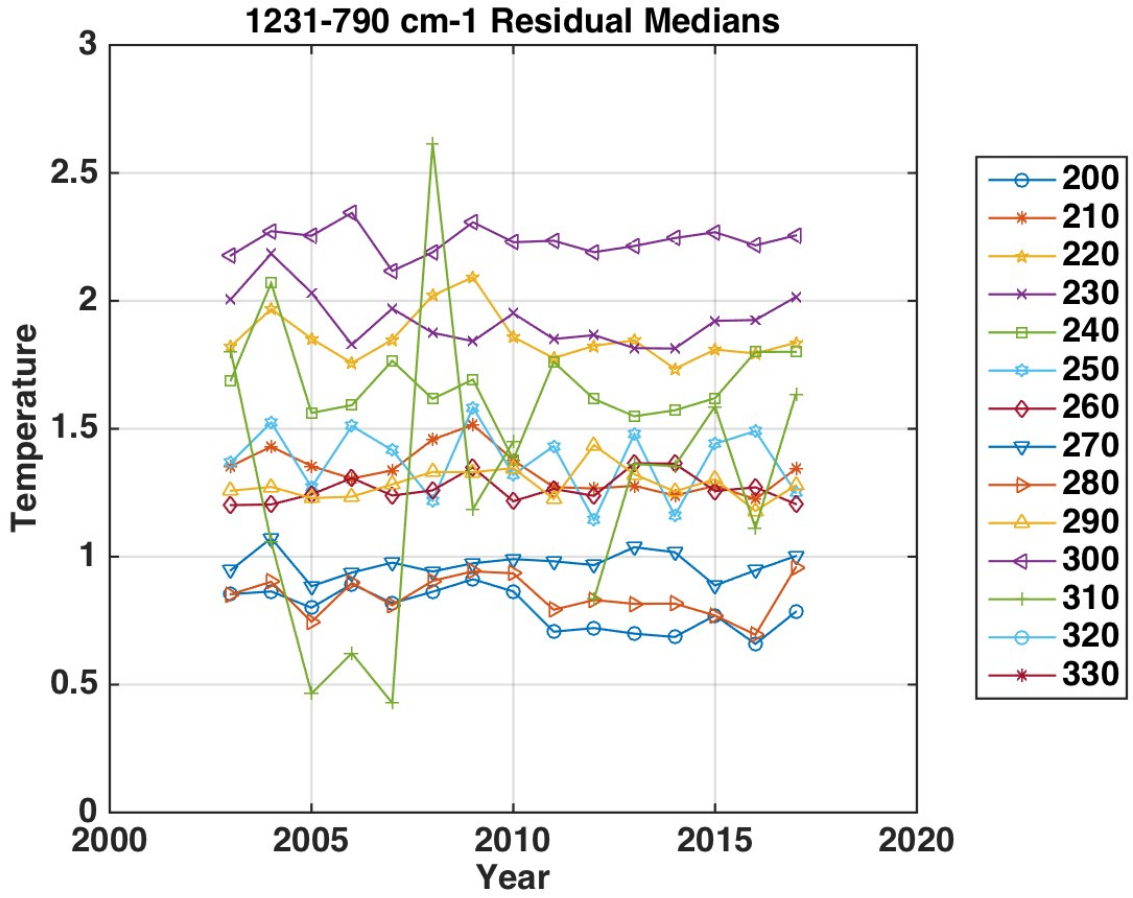
- All nighttime AIRS data for February from 65S to 65N was used
- **Longwave observations show difference of two window channels are constants in time and function of temperature**
- In general, any geophysical changes over time should affect channels nearly equally

1. Let r_2 be radiance at channel higher in wavenumber (lower wavelength)
2. Let r_1 be radiance from channel lower in wavenumber, converted to a brightness temperature, then converted to radiance at r_2's channel

Longwave observations demonstrate

$$r_2 - r_1 = C(temp)$$

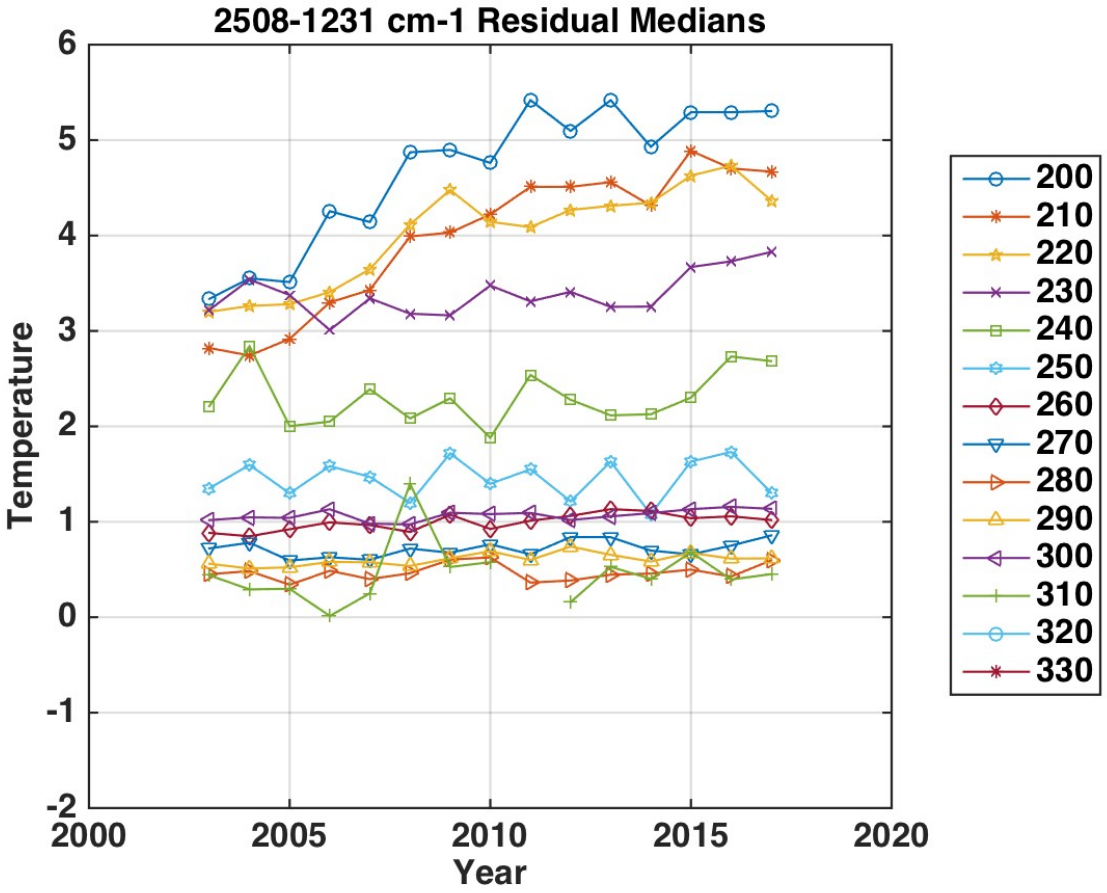
r_2: 1231 cm^{-1} r_1: rad(790)->BT(790)->rad(1231)



Modeling the Near Field Response

- Shortwave warming leads to trends in 200-230K bins
- Residuals are now a function in time

$$r_2 - r_1 = C(temp) + A(time)$$



- Assume A(time) is a weighted average of nearby radiances

$$r_2 - r_1 - C = \sum_{i=1}^{Pixel\ Number} a_i L_i$$

- We did a linear regression of 10 million points for every February from 2003 -2017 to calculate coefficients
- Two variables we control are C, the constant offset as a function of temperature, and the number of pixels assumed to be contributing to the NFR

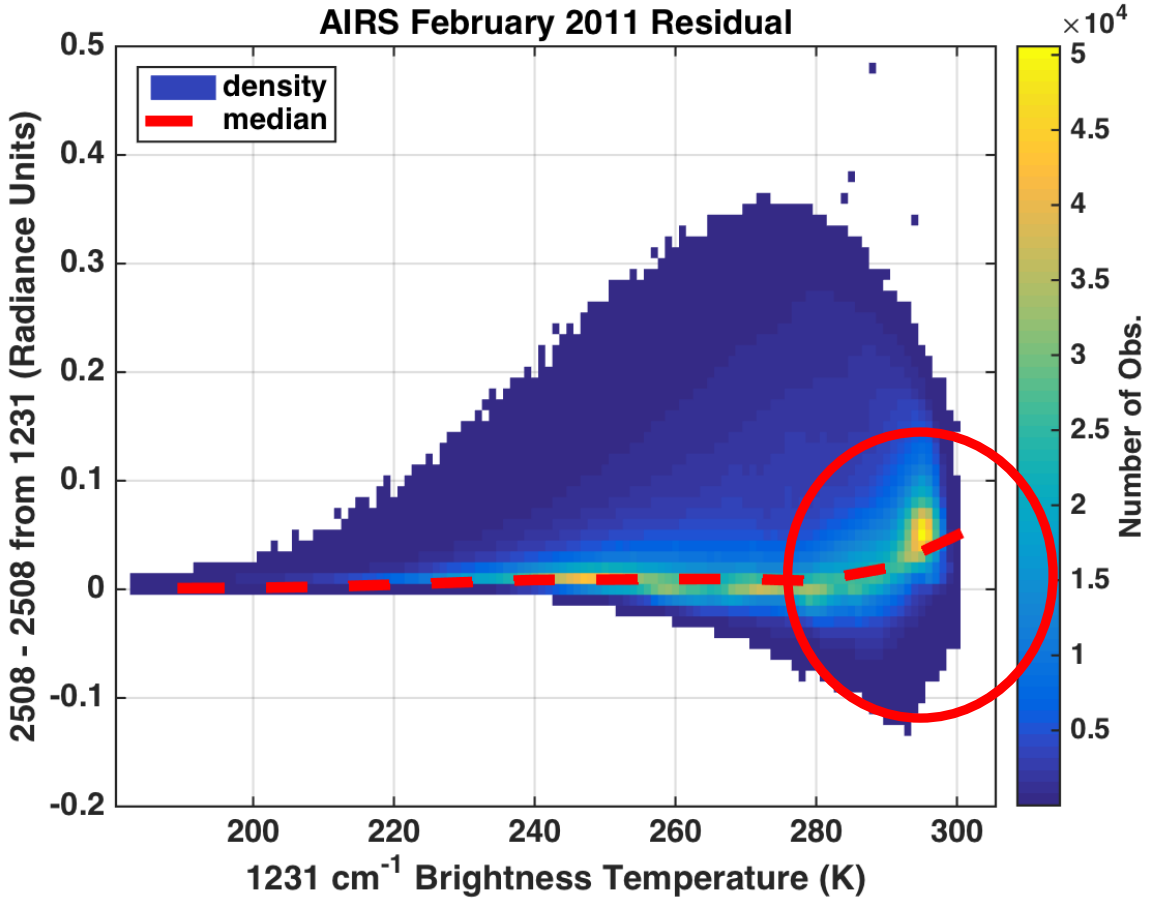
L_5 is what we are trying to measure

Example of 3x3 NFR
(Pixel Number = 9)

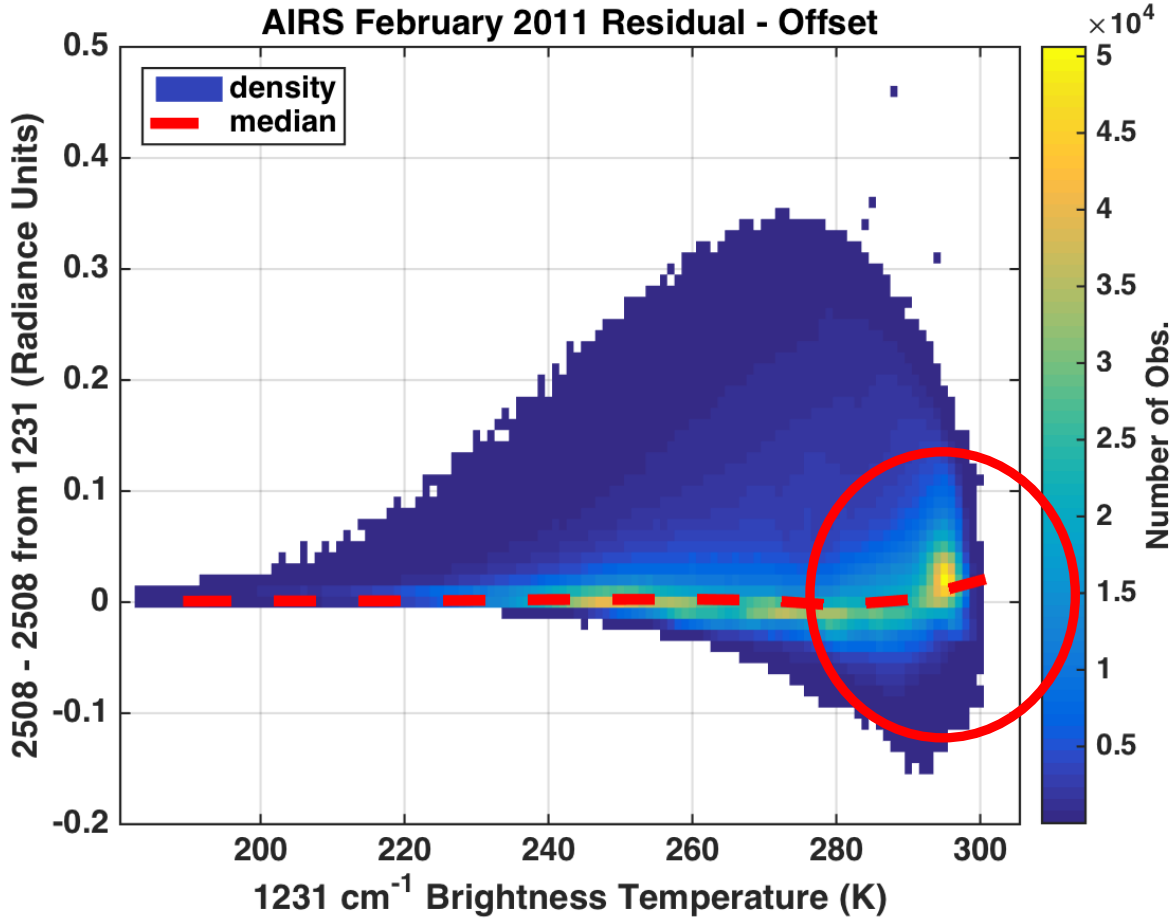
L_1	L_2	L_3
L_4	L_5	L_6
L_7	L_8	L_9

Estimating Constant offset for 2508 – 1231 cm^{-1}

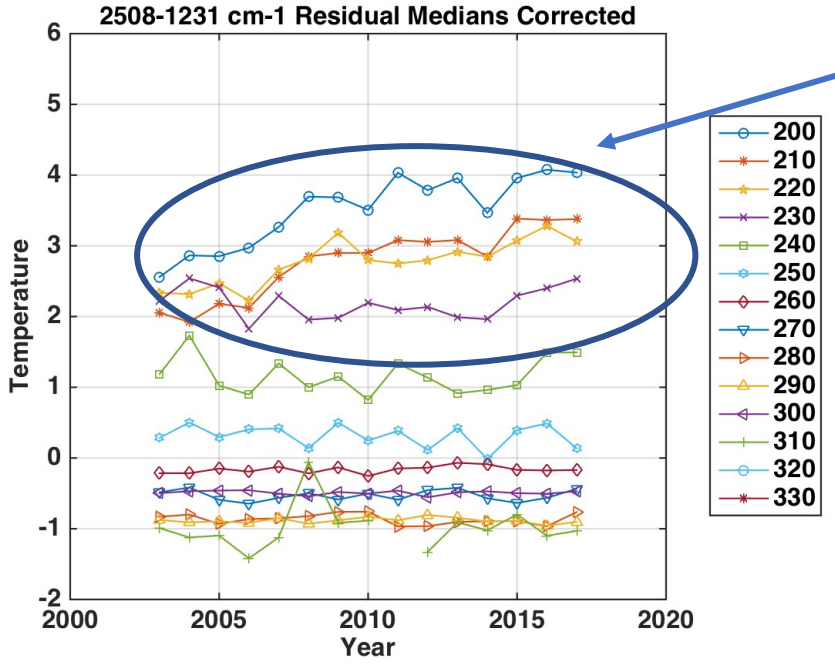
- Assume that year 1 is the best estimate of the constant offset between the two channels
- Calculate the median
- Estimate an empirical equation as a function of temperature to fit the median



- Remove the offset from the residuals

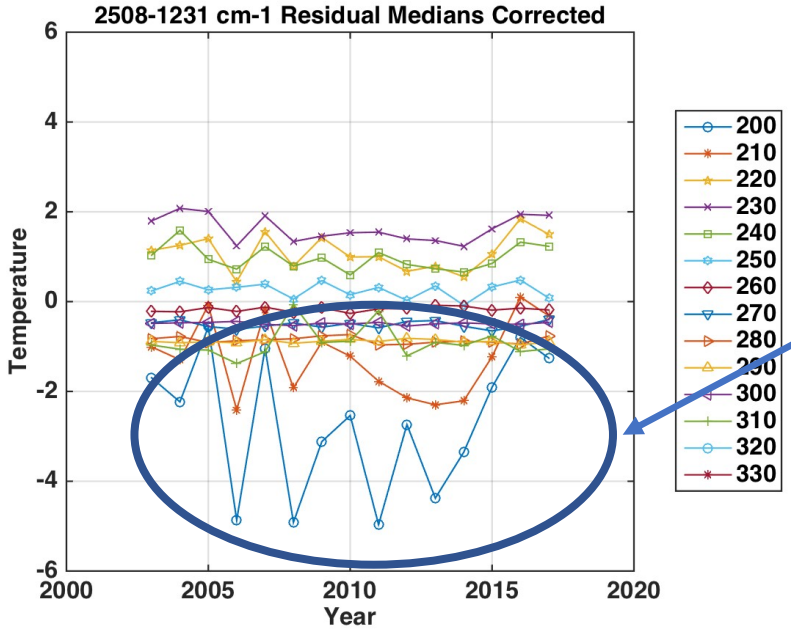


Size of Neighborhood



Still has trends

Near field scattering with 11x11 field contributions and < 180K scenes filtered out

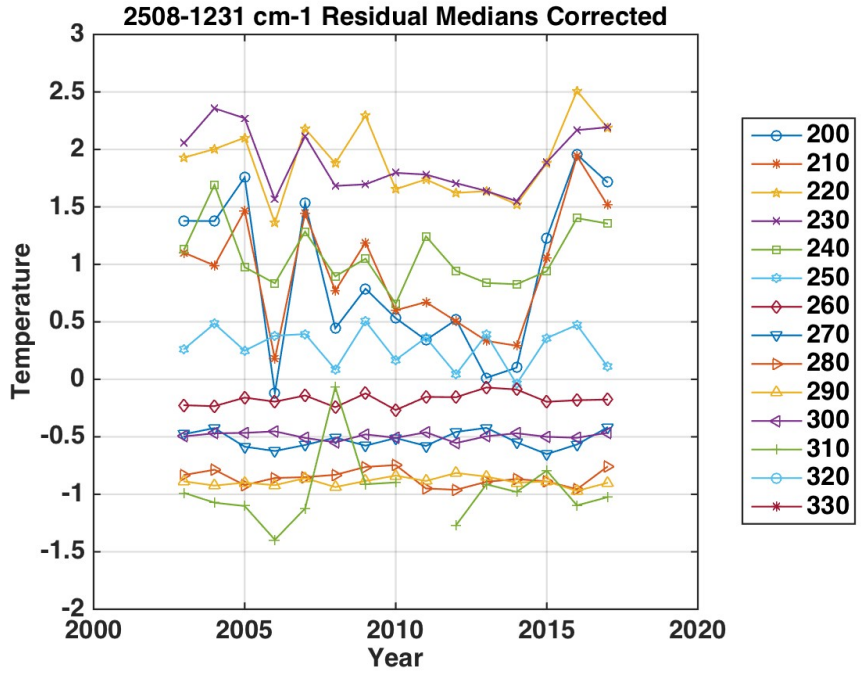


Near field scattering with 3x3 field contributions and < 180K scenes filtered out

Noisy results for cold scenes

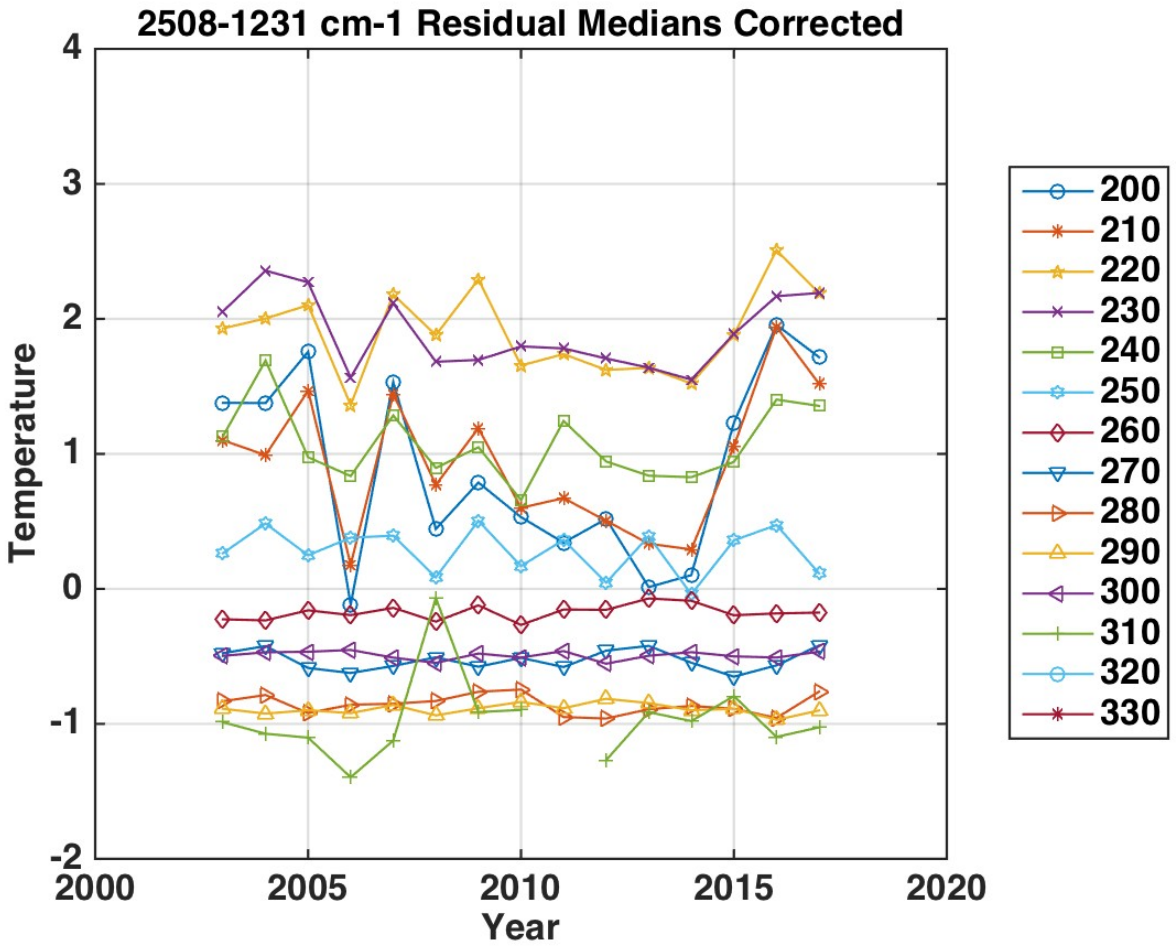
7x7 was the optimal number of parameters to fit residual trend

Near field scattering with 7x7 field contributions and < 180K scenes filtered out

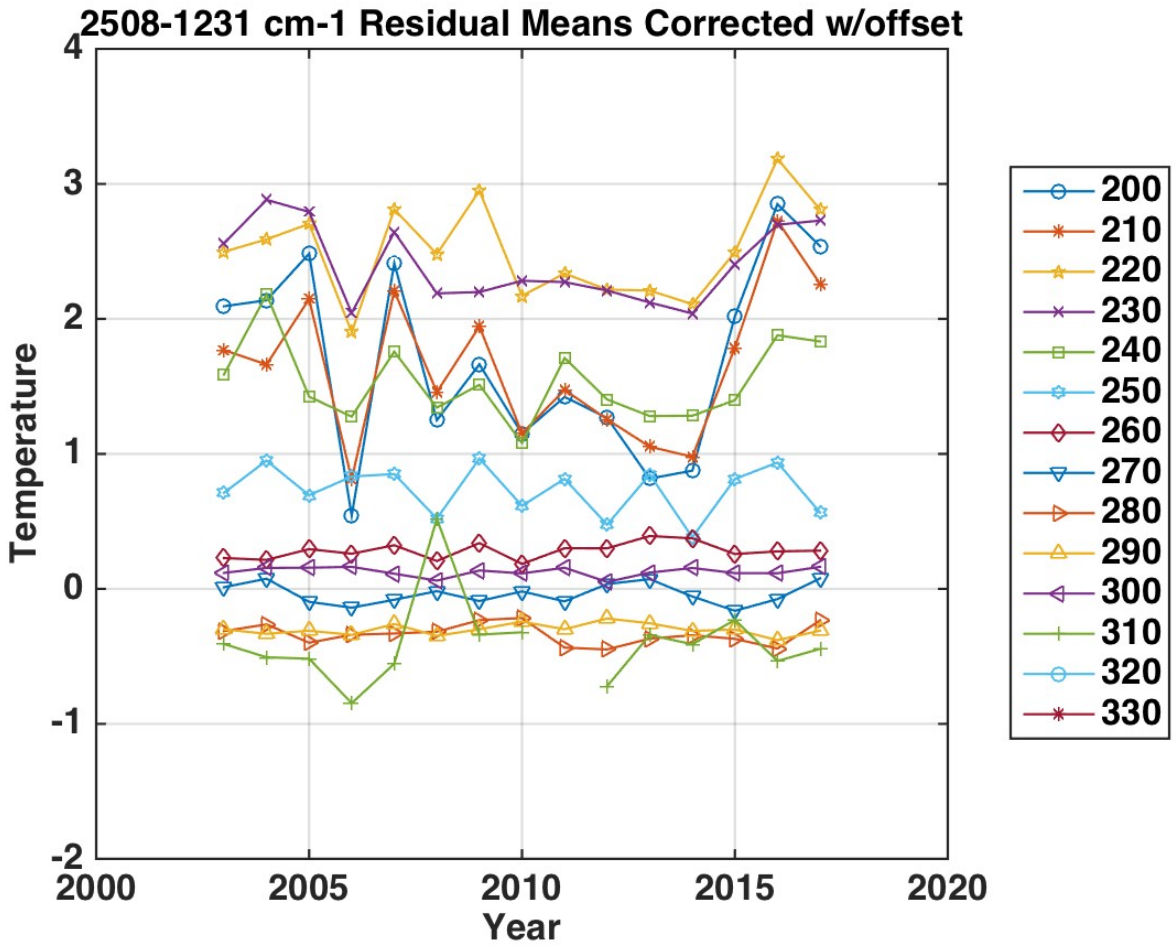


Removing the constant offset reduces negative residual medians for warmer scenes

Near field scattering with 7x7 field contributions and < 180K scenes filtered out, no offset added



Near field scattering with 7x7 field contributions and < 180K scenes filtered out, offset removed



- AIRS shortwave window channels warmed from 2002 -2012 relative to other window channels
- **We believe there was a time dependent contamination of the scan mirror**
- Trend doesn't appear to be geophysical, and wasn't seen in IASI
- Shortwave trends largely disappeared when neighboring footprints had similar measurements, such as over Dome C
- Regressing 2508 – 1231 cm^{-1} residuals against a 7x7 nearby field of observations removed warming trend at cold scene temperatures
- Regression technique may be over correcting the warmer scene temperatures
- Including a constant offset reduces the over correction for warm temperatures
- Future work includes further analysis on NFR correction equation, evaluation of appropriate constant, and weighted linear regression techniques
- **Be careful of instrument radiometry in non-uniform scenes, particularly when viewing cold scenes in the shortwave (this is true for any instrument!!!)**

Thank you for coming!