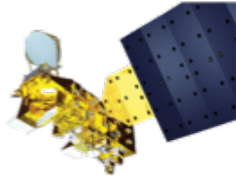

Hyperspectral Sounder Performance for Cold Scenes

Evan M. Manning

Hartmut H. Aumann

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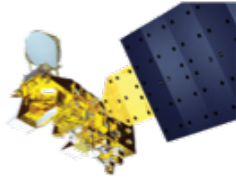

Intro – AIRS & CrIS

- AIRS and CrIS are hyperspectral infrared sounders in similar 1:30 PM sun-synchronous orbits.
- AIRS on EOS-Aqua has been flying since 2002.
- CrIS-1 on SNPP has been flying since 2012.
- More CrIS instruments will fly on JPSS-1, 2, 3 (NOAA-20, etc.) for decades to come.
- We need to characterize the instruments very carefully before we can make a merged record.

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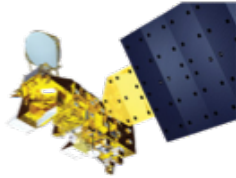

Intro- Cold scenes are important

- We investigate 200-K non-polar scenes here
  - These are the coldest scenes observed in large numbers.
  - They represent clouds near the tropopause that fill the field-of-view (FOV).
- These scenes are important to track:
  - Changes in the height of the tropopause
  - The frequency of severe storms
  - Polar change
- Cold scenes also impact cloud-clearing retrievals

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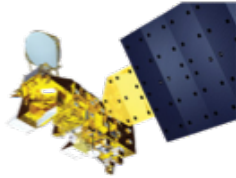

Intro- Cold scenes are useful

- 200K scenes are a valuable “stress test” for the evaluation of the calibration of AIRS and CrIS.
- For AIRS these regions are extremely cold scenes and the sensitivity to the accuracy and stability of the space view.
- For CrIS the extreme cold and hot scenes stress the linearity correction equally, since the instrument operates near 280K.
  - In addition, the self-emission of the instrument can essentially cancel the scene signal for certain conditions between 270 and 280K.

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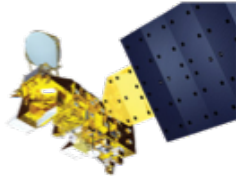

Intro- Cold scenes are misleading

- AIRS and CrIS are designed to be accurate to 0.1-0.2 K at nominal scene conditions.
- The shape of the Planck function means that small differences in radiance make a relatively large difference in Kelvins for cold temperatures.
- 1 K is a more reasonable target for 200 K scenes, and they generally achieve this.

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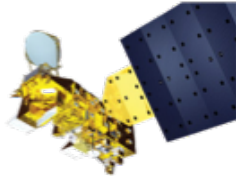

Intro – Read the paper

- This is very technical and there's a lot of material to cover.
- Read the paper in the SPIE proceedings

Hyperspectral sounder performance for cold scenes

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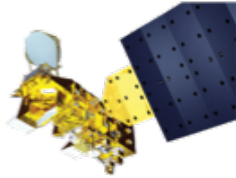

Axioms

1. Cold clouds have a basically flat spectrum
   - Except for regions of stratospheric emission
2. AIRS and CrIS should see the same stuff
   - Except the fine print
     - Different frequency coverage
     - Different spectral sampling -- AIRS is higher resolution
3. Left & right should look the same
4. Different years should look the same
5. Different CrIS FOVs should look the same
6. Day and night should look the same
   - Not really! But day minus night should look the same
   - Not shown

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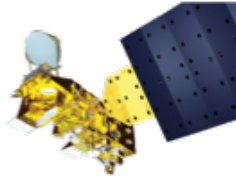

Worst case numbers

Band Name	Band Frequency range (cm^{-1})	Largest suspected artifact AIRS (K)	Largest suspected artifact CrIS (K)
Longwave	650 - 1150	0.7 (right/left, trend)	0.5 (FOV)
Midwave	1200 - 1700	0.1 (right/left)	0.2 (right/left)
Shortwave	2150 - 2670	5.0 (trend)	0.7 (FOV)

- At 200 K!

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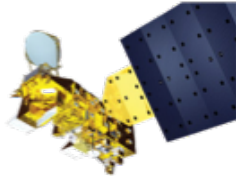

What are we looking at?

- For each category, we select only scenes where BT at 939 cm^{-1} is 200 +/-1 K
- These are very cold cloudy scenes
  - clouds near the tropopause occupy nearly the full FOV
  - Flat except for stratospheric emission & daytime shortwave reflected solar
- AIRS data is v5 with problem channels removed
- CrIS data is the normal spectral resolution IDPS public product, apodized
- Details in the paper

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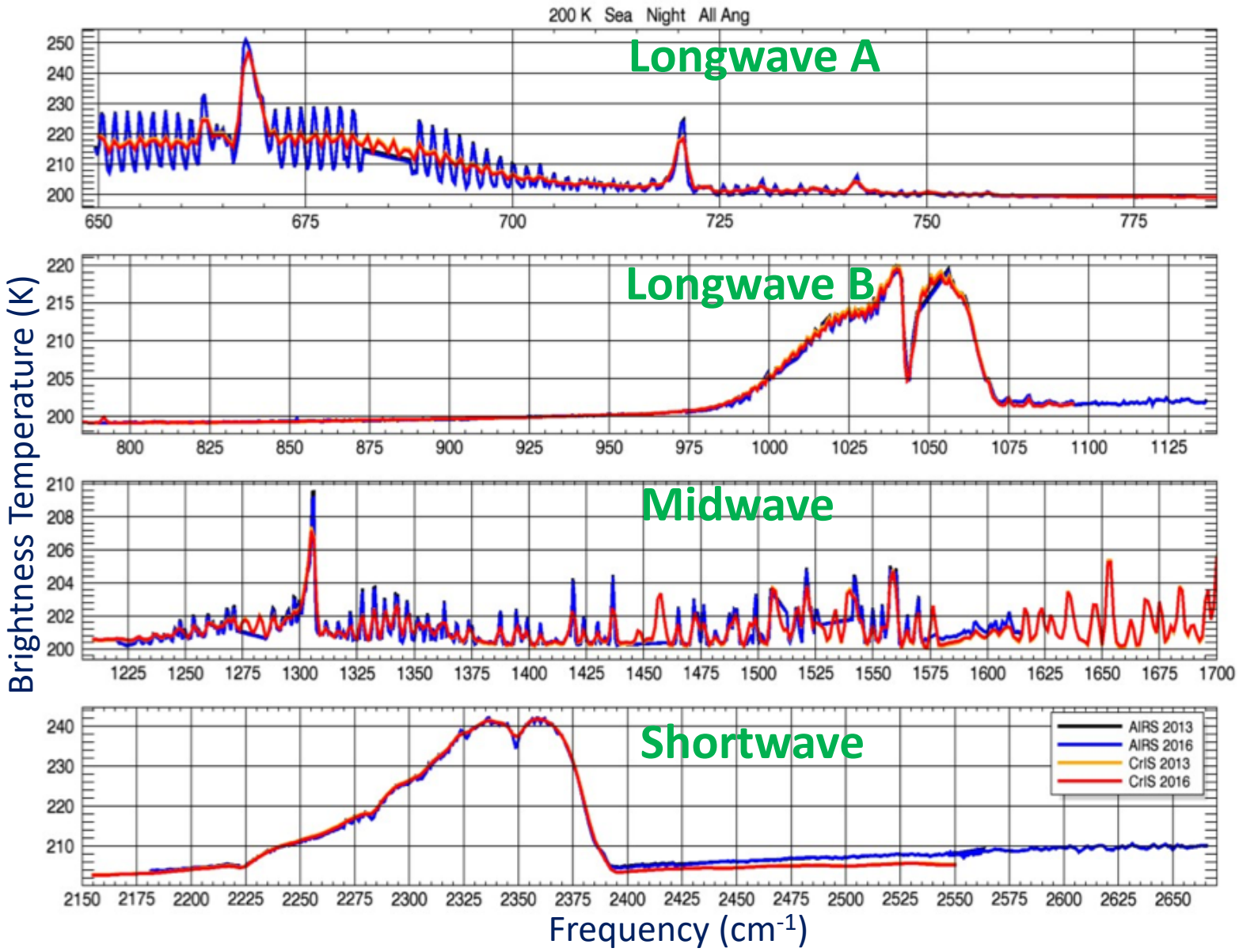
200 K spectrum

- These spectra are broken up by band
  - With longwave further broken at 785 cm^{-1}
- Axiom 1: Cold clouds have a basically flat spectrum
  - The spectra are flat at 200 K except for stratospheric emission from CO_2, O_3, CH_4, H_2O.
- Axiom 2: AIRS and CrIS should see the same stuff
  - Almost all visible differences are from differences in instrument specs: resolution & coverage.
  - But in the shortwave…



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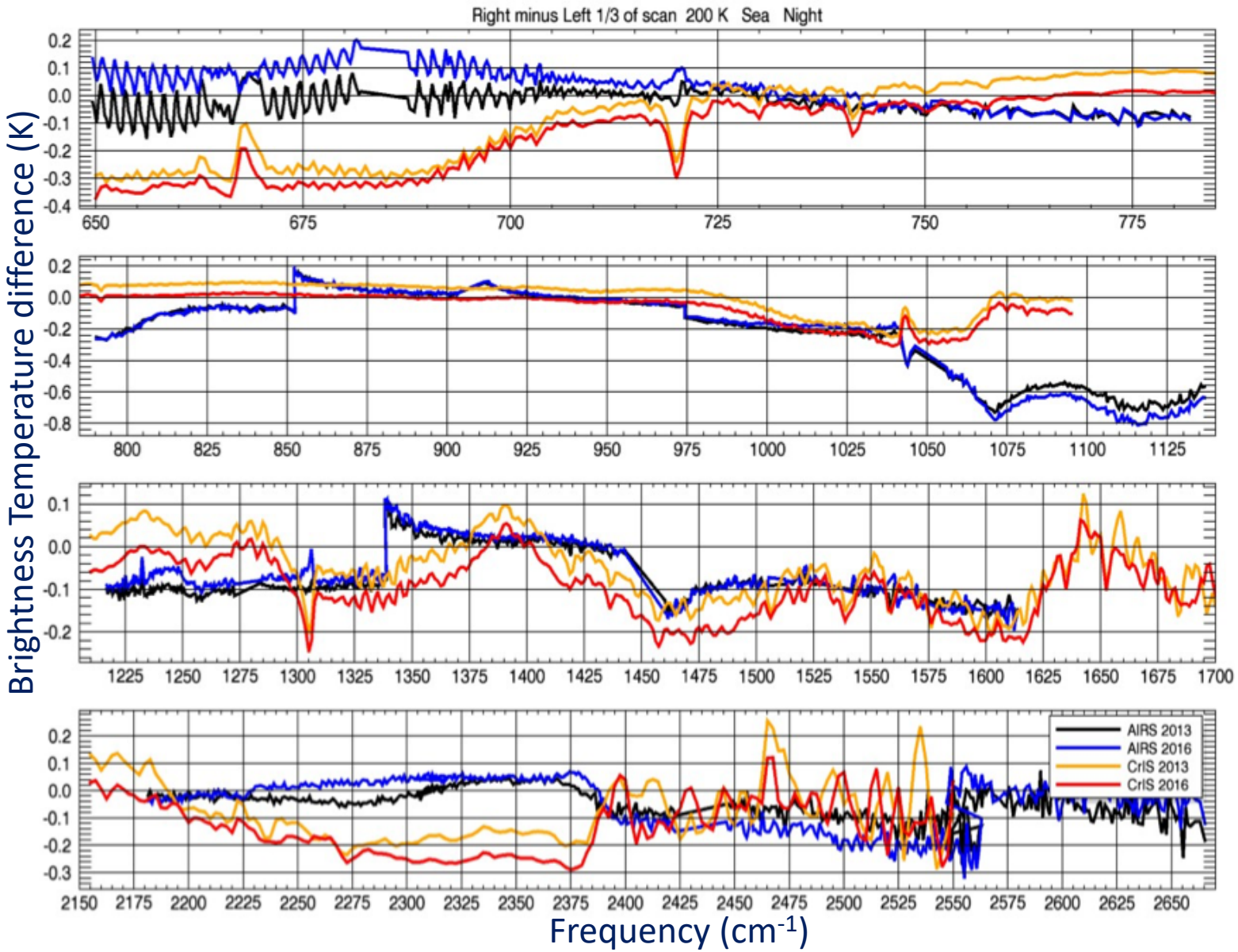
Right/Left

- Axiom 3: right & left should look the same.
  - So right minus left should be about zero. And it is.
- AIRS shows significant left-right bias in the 1070-1135 cm^{-1} region.
- AIRS has discontinuities at boundaries between detector modules, including 852, 905, 975, 1070, 1340, 1450, and 2555 cm^{-1}, and has some curvature within the modules.
- CrIS has some wavy structure 1220-1700 cm^{-1} with a period of ~125 cm^{-1} and an amplitude of ~0.15 K.
- Both instruments show temperature dependence in right-left bias.



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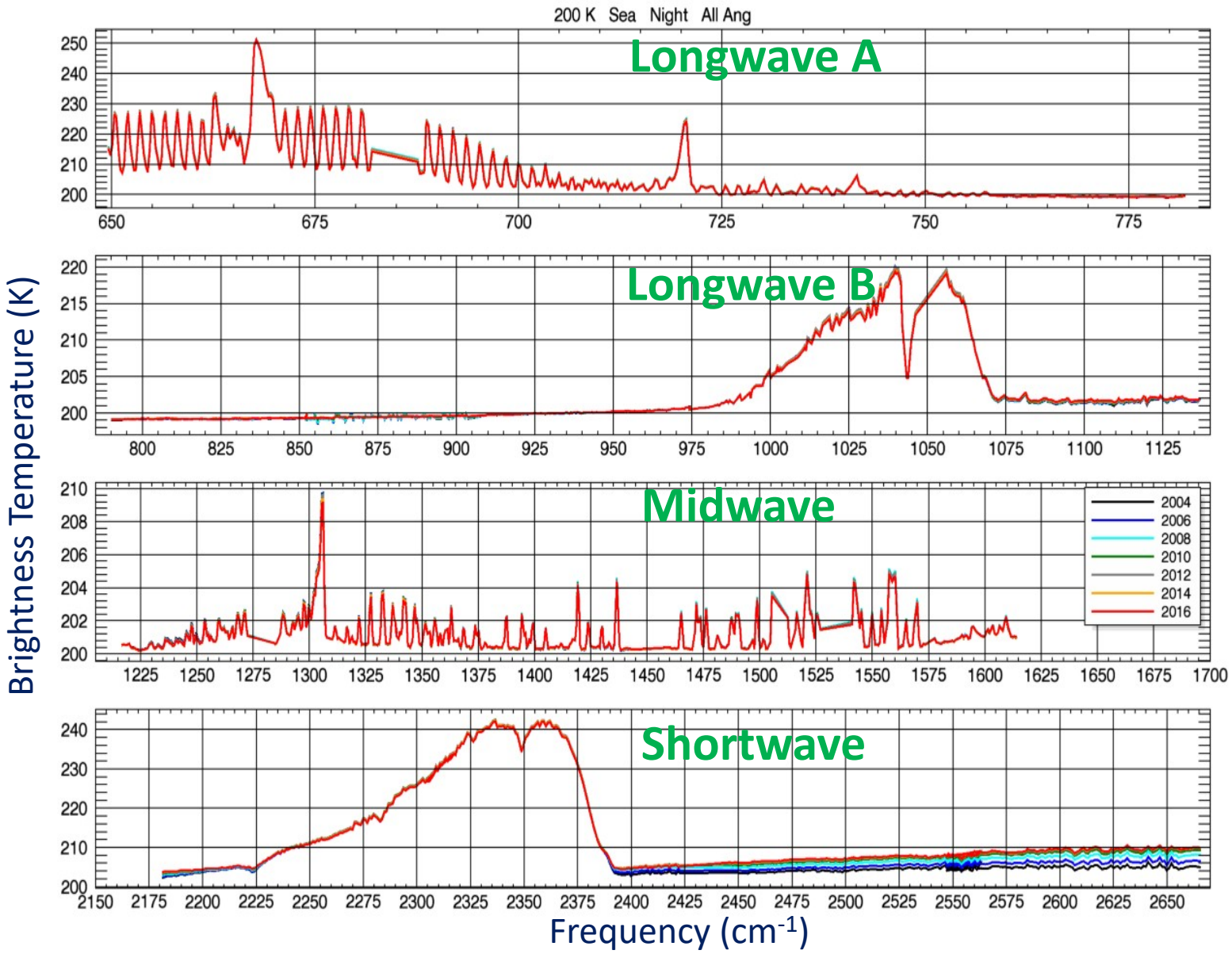
AIRS Trends 1

- Axiom 4: different years should look the same.
  - Can't test with CrIS data yet.
- Showing annual averages for even years 2004-2016
- There's a clear trend in the shortwave region and more subtle changes



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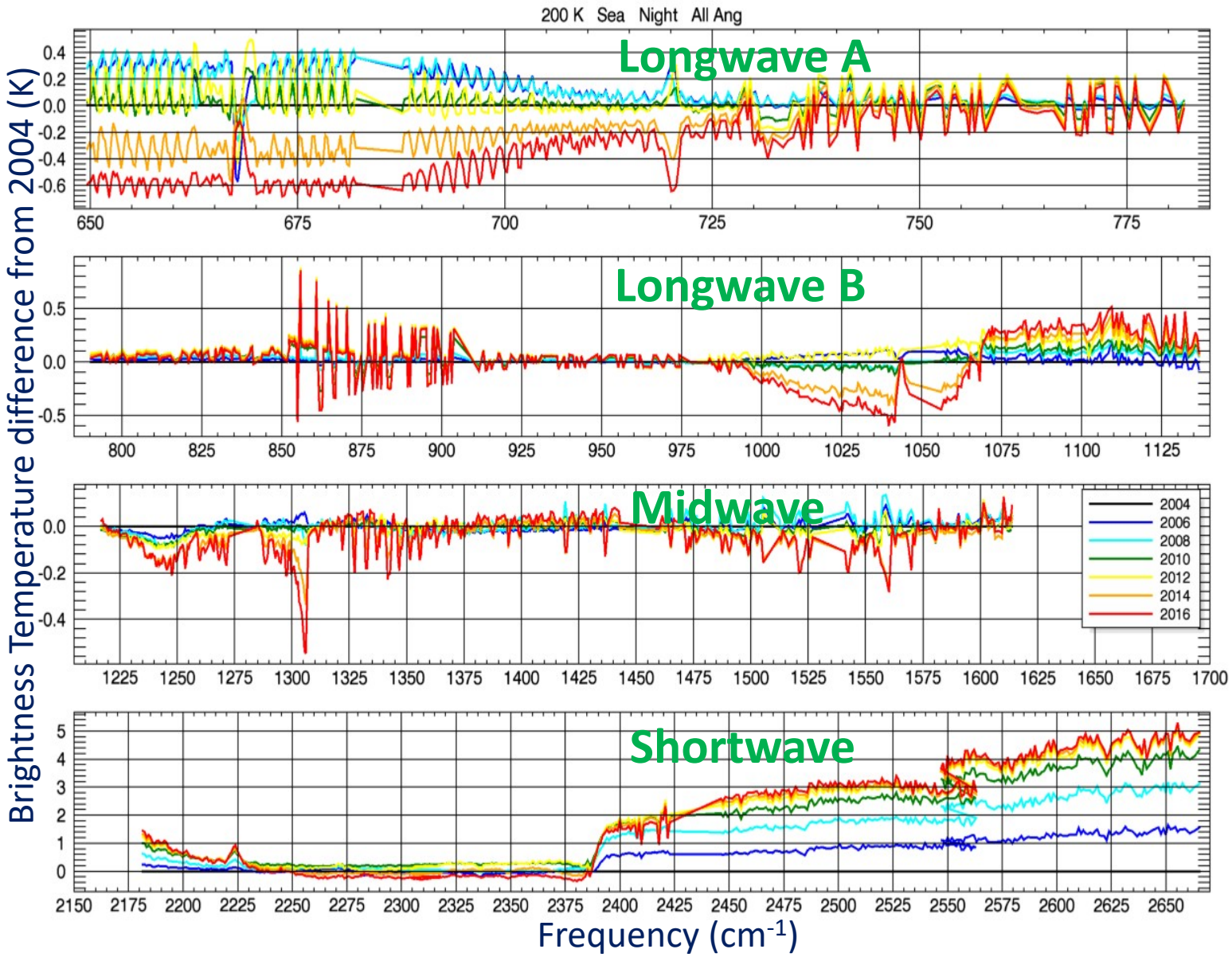
AIRS Trends 2

- The same data as the previous image but now shown as difference from a 2004 baseline.
- The stratospheric interannual differences are real
- A/B detector differences up to +/- 0.6 K are very obvious but are actually decreasing
- Shortwave trend is up to 5 K.
- There's also a trend up to 0.3 K ~1100 cm^{-1}.



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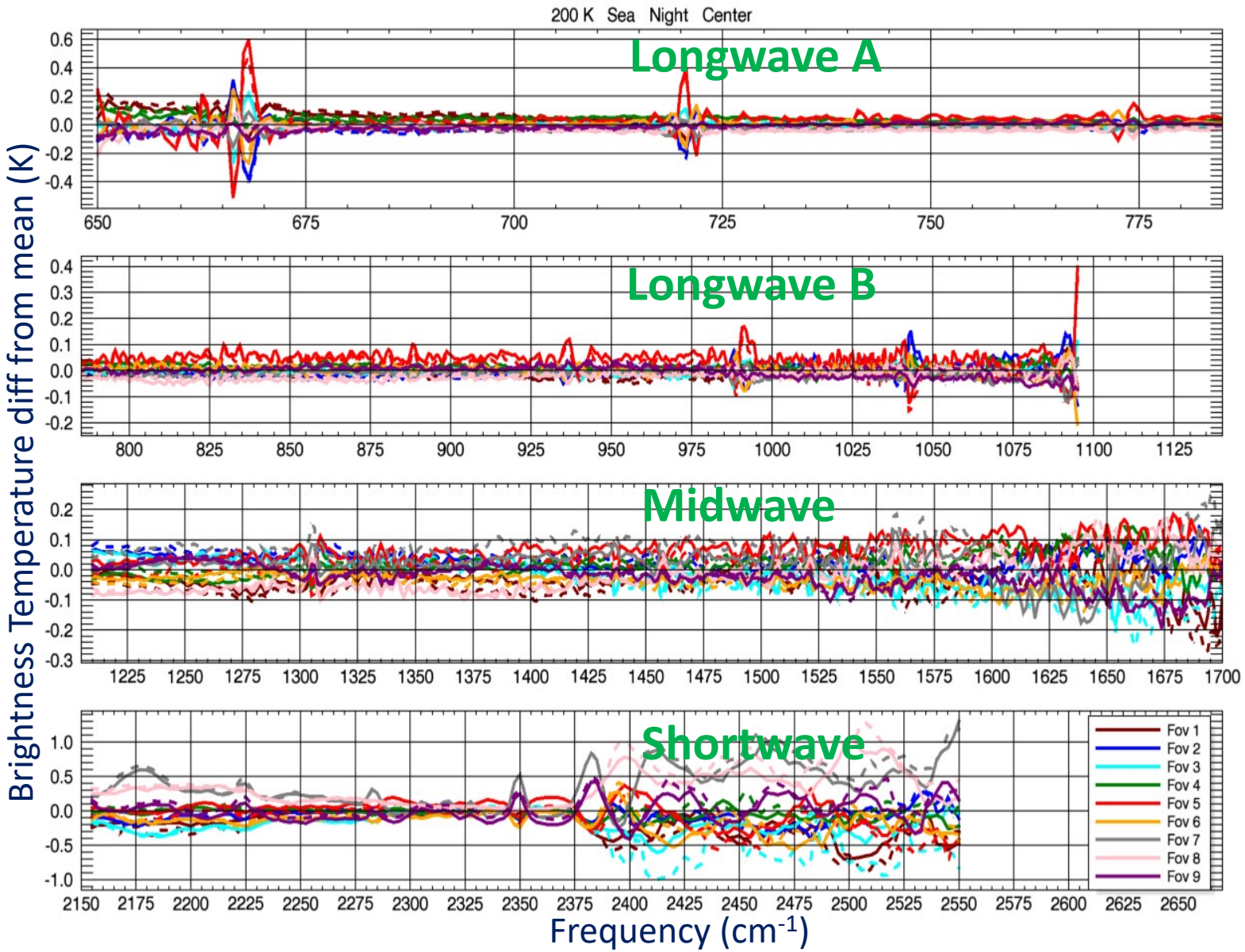
CrIS FOVs

- Axiom 5: different CrIS FOVs should look the same.
  - All 9 FOVs are plotted as differences from the mean
  - Solid lines for 2016; dotted for 2013.
- FOV 5 (red) is a known outlier in the longwave.
  - It misbehaves at spectral features near 668, 720, and 1043 cm^{-1}
  - But also at 775 & 990 cm^{-1} and the band end at 1095 cm^{-1}.
- There are biases among the bands.



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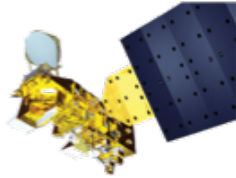

Those numbers again

- Worst-case artifacts at 200 K

Band Name	Band Frequency range (cm^{-1})	Largest suspected artifact AIRS (K)	Largest suspected artifact CrIS (K)
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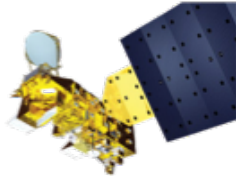

Conclusions

- We have a new tool to probe hyperspectral IR sounder instrument artifacts.
- We found some. (But: 200 K!)
- Both instrument teams are working on improvements.

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