JET PROPULSION LABORATORY

INTEROFFICE MEMORANDUM
AIRS ADF #930
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To: Distribution

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Subject: AIRS In-Flight Near Field Response and Observed Shortwave Drift

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1. INTRODUCTION

In April of 2018, George Aumann described in a memo an apparent time dependent bias between two window channels in AIRS at 2616 cm^{-1} and 2508 cm^{-1} relative to window channels at 1231 cm^{-1} (Aumann, 2018). The bias is mostly apparent when viewing Deep Convective Clouds (DCC's) and is not present when viewing Dome C. George's analysis shows a trend in the difference between 1231 cm^{-1} the 2508 cm^{-1} starting at -4K for scenes at 250K reaching <-10K at 295K. The trend seems highest for warm scene temperatures. George speculates that the scatter could be increasing on the instrument scan mirror that could be causing changes in the far field response.

In this report we revisit the trend in the two channels and include comparison with a window channel at 790 cm-1. We then explore the possibility of the observed trend being caused by changes in the instrument spatial response function over time. The theory is that if the instrument is viewing more of its surrounds in one channel relative to the other, it would reduce the correlation between the two channels and potentially result in biases that are dependent on scene temperature. The results show that the trend between channels in AIRS at 2508.1 cm^{-1} and 1231.3 cm^{-1} does indeed exist, but not to the degree seen in prior analyses. Attempting to correct the spatial response function between the two channels reduces the trend, but introduces noise and is not yet effective. All work is performed on the AIRS Version 5 Level 1B and we recommend we repeat the analysis with the new radiances from Version 7k.

2. METHODOLOGY

2.1 Nominal Radiance Difference

The radiance difference between two window channels can give us insight into the stability of the AIRS instrument. To the degree the two channels have similar vertical weighting functions and atmospheric absorption, they should retrieve the same scene temperature. For a given scene temperature, the radiances will be different for the two channels. The expected brightness temperature difference between two channels corrected for the Plank function difference can be written as

$$\Delta T_{ij} = \frac{L_{\lambda 2} - P(T(L_{\lambda 1}), \lambda_2)}{\frac{\partial L}{\partial T}_{\lambda_2}}$$

Where

ΔT_{ij} = Temperature difference between channels at λ_2 and λ_1 (K)
$L_{\lambda 1,\lambda 2}$ = Level 1B Radiance for channels at λ_2 and λ_1 (W/m^2-sr-um)
P = Planck Blackbody Distribution Function (W/m^2-sr-um)

2.2 Spatial Response

To test the hypothesis that the instrument spatial response is changing, we perform a linear regression on the contribution of signal from the surrounding region on the center pixel.

$$\Delta L = L_{\lambda 2,i,j} - P\left(T\left(L_{\lambda 1,i,j}\right), \lambda_2\right) = a_{00} L_{\lambda 2} + \sum_{\substack{n=i-5:5 \\ m=j-5:5 \\ n\neq 0, m\neq 0}} a_{ij} L_{\lambda 2,n,m}$$

Figure 1 shows the different configurations explored. Figure 1a, 1b, and 1c show 10 circular zones, 30 circular zones and 11x11 individual footprints (zones) considered respectively. The equation above is for the 11x11 circular zones. We first explored the 10 circular zones as an integrated contribution from each ring. The response showed a slight uptick in the outermost ring (Figure 1d). This prompted us to explore more rings. We saw again the same response for the outermost ring (Figure 1e). It appears as though the regression gives a larger contribution from the outermost ring, perhaps to account for uncorrelated residual errors. Since no response was seen beyond the first 3-4 pixels from the center we decided to examine an 11x11 region or 5 pixels around the center in all directions. Figure 1f shows the response of the center cross of samples (scan and track individually labeled). These initial figures also showed a potential change in the response between 2003 and 2017.

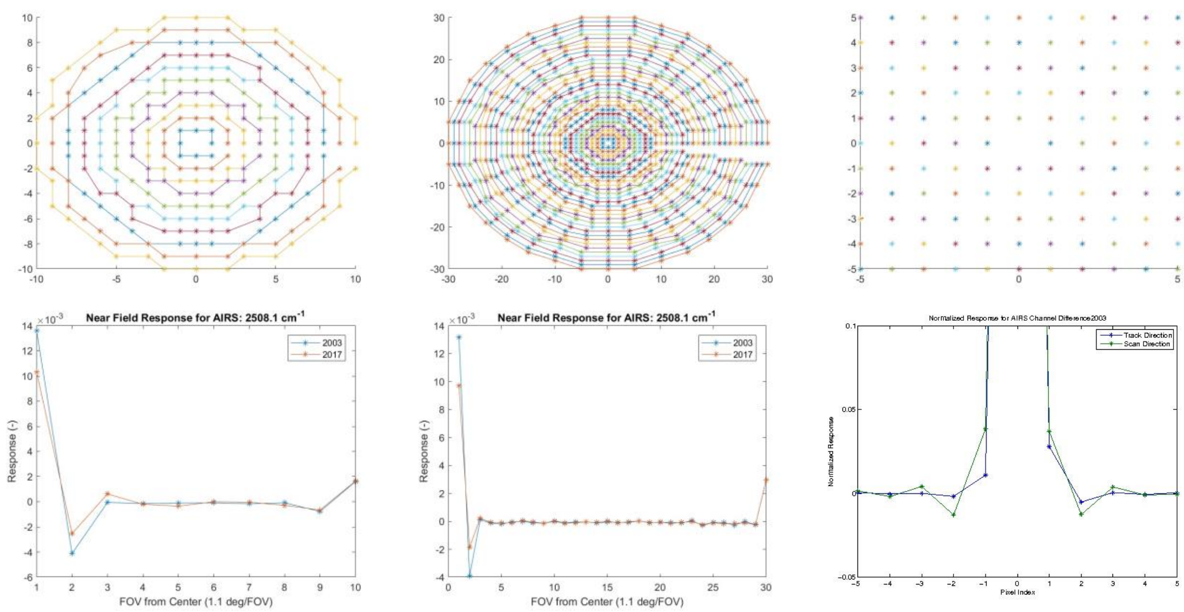

Figure 1a (top left): 10 circular zones, 1b (top center): 30 circular zones, 1c (top right): 11x11 individual footprints, 1d (lower left) response of 10 circular zones, 1e (lower center): resonse of 30 circular zones, 1f (lower right): response of center cross of 11x11 zones.

3. TEST DATA

For the analysis, Evan Manning provided AIRS Version 5 L1B radiances for the night side of the orbit for the full month of January for years 2003-2017. A total of 15 files were provided. Each file included an array with 360,000 scans x 90 footprints x 3 spectral channels. An array was made corresponding to the linear regression equation above with the LHS corresponding to the difference between the Planck corrected radiances of the two channels of the center footprint and on the RHS the sum of the center pixel and contribution from the surrounding pixels. Not all center footprints are analyzed due to a constraint imposed that every center pixel evaluated include the full contribution from all zones or footprints in the region. There was plenty of data to achieve 10,000,000 samples for the linear regression for each of the 15 years analyzed.

4. RESULTS

Figure 2 shows the amplitude of the retrieved coefficients vs field angle in the scan (left) and track (right) directions of the central cross of pixels. We see very little variation in the near field but a larger variation in the central response between the two channels.

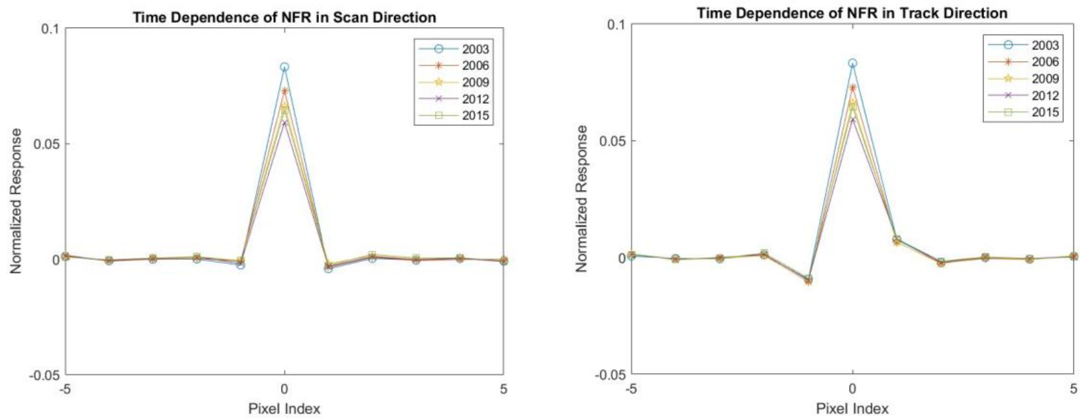

Figure 2. Retrieved Near Field Response for AIRS in the scan (left) and track (right) direction. Although y-axis says "normalized", the response is not normalized, but the value of the coefficient is plotted. We see the peak response of channel 2508 is reduced over the years compared to 1231 $cm^{-1.}$ Not much change is observed in the near field.

The difference in signal between 1231 cm^{-1} and 790 cm^{-1} is plotted in Figure 3 for multiple scene temperatures. Again, we correct the radiances based on the Planck function and the temperature difference is the radiance difference divided by the gradient in the Planck function at the specified scene temperature. We see a residual bias as a function of temperature, but there does not appear to be a significant trend in the radiances between the two channels, but further analysis is required. The fact there is no significant trend indicates that 1231 cm^{-1} is a good reference channel for comparing to 2508 cm^{-1} to detect trends.

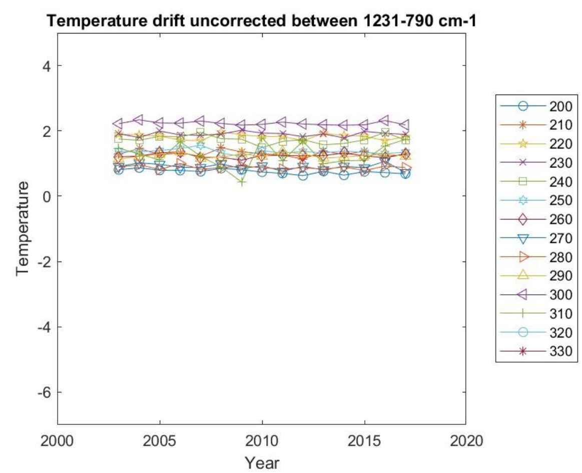

Figure 3. Difference in scene temperature between 1231 and 790 cm^{-1}. Difference is temperature dependent but stable

Figure 4 (left) shows the difference in Planck corrected radiance vs time between 2508 cm^{-1} and 1231 cm^{-1} between the central pixels. In this dataset we see a significant trend at cold scene temperatures. The trend is about 2K at the coldest scene temperature, much smaller than observed by George using DCC's.

Figure 4(right) shows the difference between 2508 and 1231 cm^{-1} but with a correction applied. The correction is to subtract the sum of the contribution of the surrounding pixels as derived through the regression.

$$\Delta L' = L_{\lambda 2,i,j} - P\left(T\left(L_{\lambda 1,i,j}\right), \lambda_2\right) - \sum_{\substack{n=i-5:5 \\ m=j-5:5 \\ n\neq 0, m\neq 0}} a_{ij} L_{\lambda 2,n,m}$$

This difference should be zero if the Planck corrected radiance difference between the two channels is due entirely to the contribution of the region surrounding the 2508 cm^{-1} channel. As evidenced by the Figure, the result of the correction is to over-correct the signal difference. This would indicate that either the process of solving for the near field response is in error or that the trend is due to some other phenomenon.

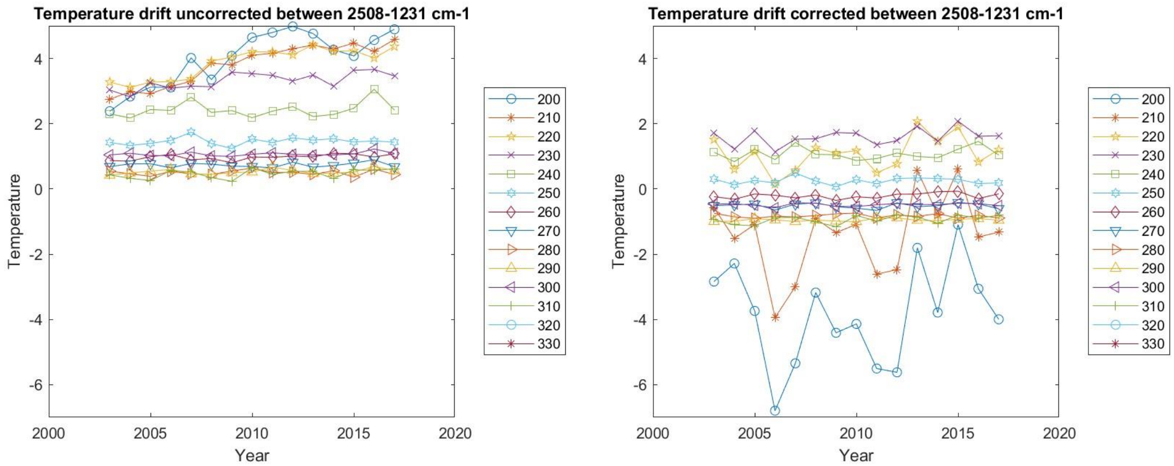

Figure 4. Change in the central response between 2508 cm^{-1} and 1231 cm^{-1} vs time. (Left). Uncorrected, (Right) Corrected. Correction does not perform well at cold scene temperatures

SUMMARY AND CONCLUSIONS

Comparing Planck corrected radiances between channels 1231 cm^{-1} and 790 cm^{-1} shows no real trend. We then use channel 1231 cm^{-1} to compare to 2508 cm^{-1} and see a difference that increases with time and is more significant at cold scene temperatures. Using a regression method to derive a time dependent near field response, we were able to apply a correction to the radiance difference. The correction tends to over-correct the error. This indicates that either the methodology was inadequate or some other factor is responsible for the trend. Evan suggests we regress on fewer spatial samples, for example the 8 pixels surrounding the center pixel instead of 11 x 11, and/or we average over more footprints. Both suggestions should be examined in the next iteration. Another explanation is that the phenomenon is not due to a change in near field response, but a change in the instrument polarization. We will repeat the calculation of the difference between the two channel pairs with Version 7k radiances. The V7k radiances have a time dependent polarization correction that may impact the computed difference at cold scene temperatures (Pagano, 2018).

It should also be considered that the polarization and spatial response are not independent. Cross-axis scans obtained pre-flight were shown to be highly polarization sensitive. This means that a change in polarization may be accompanied by a change in the spatial response. The polarization effect is more likely to affect the radiometry than the spatial response, however and would behave as we see with a bigger impact at cold scene temperatures.

REFERENCES

[1] Aumann, H.H., “The large warming trend in 2616 cm-1 and 2508 cm-1 when viewing cold clouds”, ADF 928, 2018

[2] Pagano, T. S.; “Revised radiometric calibration coefficients for AIRS: V7j”, ADF 925, 2018