Stratified radiometric means for the evaluation of AIRS and CrIS

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ABSTRACT

There are now five hyperspectral infrared sounders in orbit (AIRS, two CrIS instruments, two IASI instruments). A long-term record spanning these instruments and continuing forward with future instruments holds great promise for the study of weather and climate. This long-term record must separate the effects of instrument artifacts and weather variability. We introduce the "StratRad" stratified radiance means product, containing means of groups of spectra for AIRS on Aqua and CrIS on SNPP. We show how this product can be used both to illuminate instrument artifacts and to study common observations of weather patterns at an accuracy of better than 0.1 K. Radiances are stratified by latitude, longitude, day/night, land/sea, and observation angle.

Keywords: AIRS, CrIS, CrIMSS, hyperspectral sounding

1. INTRODUCTION

There are now two Cross-track Infrared Sounder (CrIS)[1] instruments in orbit, with several more launches scheduled. Together these CrISs will provide a multi-decade climate record starting in 2012. The Atmospheric Infrared Sounder (AIRS)[2] provides similar hyperspectral infrared radiance data starting in 2002, but with a very different instrument architecture – AIRS is a grating spectrometer; CrIS is an interferometer. To maximize the utility of this heterogenous record, we must characterize the artifacts -- the differences among the radiance products from the different instruments -- and provide detailed information to users. We focus on the substantial overlapping data between AIRS (2002-present) and the first CrIS instrument launched on the Suomi National Polar-orbiting Partnership (SNPP) platform (2012 to present; full spectral resolution 2015 to present).

To produce this instrument characterization efficiently, it is important to process the data down to a much smaller "summary" while preserving the most important characteristics. We propose one way to do this and show AIRS and SNPP-CrIS results characterizing select instrument anomalies with this method. In addition, we show a matching climate signal from the AIRS and SNPP-CrIS instruments with this approach.

1.1 Input data

AIRS spectra come from Level-1B version 5 available from the GES DISC DAAC at http://disc.gsfc.nasa.gov/datacollection/AIRIBRAD_005.html. This is a stable product – the AIRS calibration still uses the coefficients and equations developed during the pre-launch calibration. The summary product uses all valid observations. No quality screening is applied beyond the need for valid location information and available calibrated radiances and the need for the instrument "state" to be set to 0, indicating that the instrument was collecting science data.

CrIS data used here is from the first flight instrument, on SNPP. For SNPP-CrIS we used the Full Spectral Resolution (FSR) NASA V2 calibration. https://doi.org/10.5067/9NPOTPIPLMAW. CrIS spectra are screened for quality by requiring that all 3 bands' quality flags ({`rad_lw_qc, rad_mw_qc, rad_sw_qc`}) are set to 0 ("best quality"). CrIS spectra are Hamming apodized as part of production of the StratRad product.

1.2 StratRad data product formulation

We wish to make a summary radiance product that preserves important differences among subpopulations of spectra while reducing overall volume by orders of magnitude. To do this we first segment ("stratify") the data into non-overlapping categories using the selected criteria and then take a mean of each channel over all observed spectra in each category.

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The data is divided into:

1. 18 10-degree latitude bins
2. 18 20-degree longitude bins
3. 10 9-FOV (Field-of-View) scan angle bins
4. 2 bins for Day vs Night
5. 2 bins for Land vs Sea

The 10-degree latitude binning is most essential. It separates the Earth into latitude bands with different climate so they sample instrument behavior over different domains. Because of the sun-synchronous polar orbits of these platforms, latitude binning plus day/night separation gives good sampling of effects linked to the orbital cycle of solar illumination of the spacecraft and the observed scene.

Together with latitude binning, 20-degree longitude binning splits the world into 18x18 regions, suitable for visualizing on a coarse map. This allows us to focus on regions where specific effects manifest. For many of the studies shown below the longitude bins essentially act as 18 independent data points in each latitude bin, allowing clear assessment of variability in the data.

The 10 bins in scan angle are important for assessing effects linked to the scanning of the instrument. There could be glints or blocking of the optical path at specific scan angles. Polarization changes the relative response of the instruments at different scan angles. For investigation of polarization we generally plot the difference between spectra in the left & right 1/3 of the scan[3], but the additional bins allow finer-grained studies when indicated.

Day vs. night is separated at 90 degrees solar zenith angle. It separates the different parts of the instrument orbit and also different geophysical conditions based on time of day. It is most important for the shortwave band, where reflected solar light complicates daytime analyses.

Land vs. sea separation treats all scenes with less than 1% of land as “sea” and all others as “land”. The “sea” category gives a sample of cases with known surface emissivity, while “land” gives more extreme hot and cold cases, which can help resolve temperature-dependent effects more clearly. Most analyses mix land and sea for global coverage with the most data possible.

1.3 Data volume reduction

Each monthly AIRS StratRad file is only about 75 MB, a tiny fraction of 400 GB for the Level-1B that went into it. These files are easy to transport and to manipulate, but still give valuable insight into instrument and climate behavior.

1.4 Using the data

For each month, for each instrument, data is collected into a single StratRad file with 18 x 18 x 10 x 2 x 2 = 12,960 bins. For any given analysis these are subsetted or averaged over the various dimensions. For example, Figure 1 shows 3 AIRS spectra for January 2018:

1) Global mean spectrum
2) Mean of daytime tropical (+/- 30 degrees) land spectra
3) Mean of nighttime North Pole (70-90 degrees N) spectra

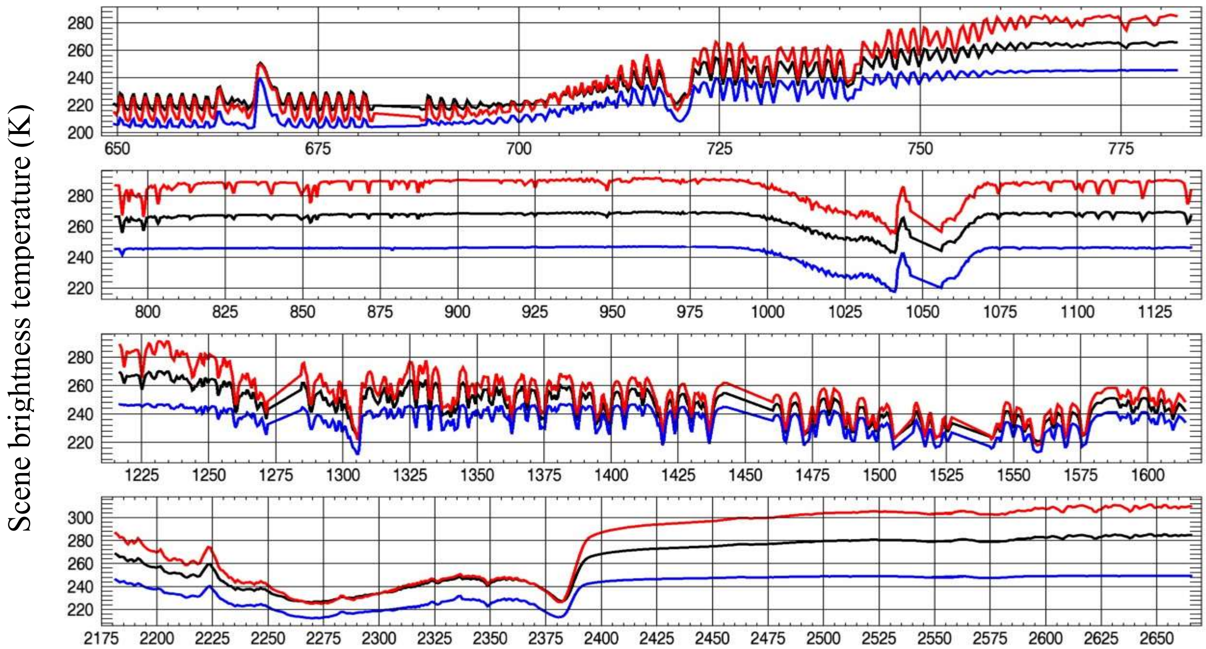


Figure 1. Mean AIRS spectra for January 2018. X axis is wavenumbers (cm^{-1}).

In addition to the categories internal to each monthly StratRad file, these other dimensions are important when doing instrument artifact or climate/weather analyses with this data:

1) Instrument. These files are currently being produced experimentally for AIRS and SNPP-CrIS. JPSS1-CrIS will be added as NASA V2 L1B becomes available for it. IASI may be supported also, though its different orbit complicates comparisons.
2) Product version. In addition to AIRS V5 Level-1B, these files can be produced for newer versions of Level-1B in development. They can even be reprocessed to simulate the effects of different calibration algorithms much more quickly than reprocessing full months of data. For CrIS we can compare version 1 vs version 2 data and we can compare data sets produced at different spectral resolutions.
3) Seasonality. Comparison of monthly files lets us see how climate features and artifacts move over the course of a year. Different patterns are seen if the artifacts are linked to Earth-based zonal weather patterns or solar illumination of the spacecraft. Seasonal cycles are also very important for climate studies.
4) Long-term trends. AIRS now has a 16-year record, which allows us to trace even very small trends. Since calibration traceability was established before launch, these studies are critical to evaluating the long-term accuracy of the instrument.

2. SAMPLE ANALYSIS VISUALIZATIONS

When we use this highly-dimensional data we can decide how to treat each dimension. For example, we can treat latitude as a free dimension, or we can make a global mean over all latitudes, or we can use it to subset only one band, like the tropics. Here are some examples.

2.1 Global brightness temperature maps

Maps are a powerful visual tool, allowing quick identification of correspondences with the areas of various geophysical and orbital effects. Figure 2 shows a simple AIRS brightness temperature (BT) map for daytime in the window channel at 1231 cm^{-1}. It shows expected coarse structure with hotter BTs in the tropics, especially deserts. Variability in window BT within the tropics is associated with amount and type of cloud cover more than with surface temperature.

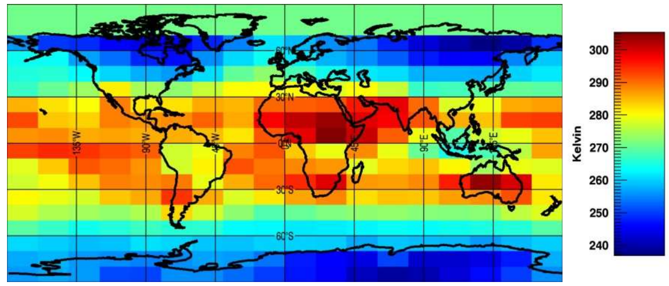


Figure 2. AIRS BT map daytime January 2018 1231 cm^{-1}

There is green filler in the northern-most two rows of Figure 2 because there is no data in January with the sun above the horizon for 70-90 degrees north latitude.

Each map is dynamically scaled from blue at the coldest BT to red at the hottest to emphasize spatial patterns.

2.2 Differences as a function of scene brightness temperature

Artifacts can vary strongly with scene BT, so this is the most important dependence to document. BT is not a dimension in the StratRad product, but we can easily find the BT for any subset for any channel. To make Figure 3 we took data from the January 2018 monthly file for the AIRS instrument. Data was averaged over the land/sea and angle dimensions. The day/night dimension was used to separate the data into two sets. Each lat/lon box was treated as an independent data point and the mean BT was calculated for each of the two selected channels. The smaller stars in figure 3 represent this data directly as a scatter plot of the BT difference between the two channels (dBT) as a function of the BT on one of the channels.

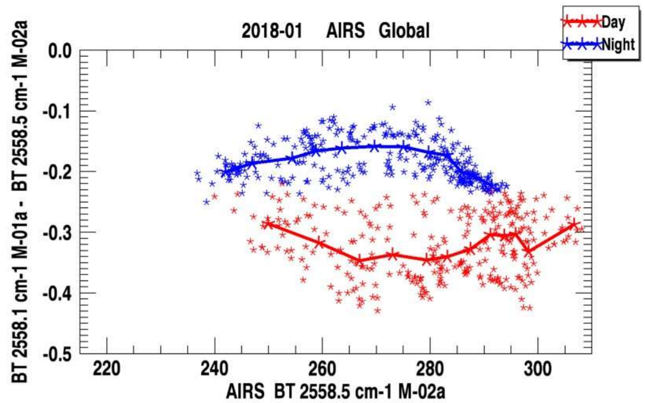


Figure 3. AIRS BT2558 overlap channel difference for January 2018 as a function of scene BT. Units are Kelvin for both axes.

In addition, to provide a visual summary, we sort the data by BT on the channel used as the X axis and divide it into quantiles. For each quantile we calculate the mean of BT and dBT. The larger, connected stars represent these means. This summary is used to combine such sets into more complex visualizations.

2.3 Inter-instrument comparisons

For some AIRS channel pairs it is useful to compare to CrIS. CrIS and AIRS will show the same differences between corresponding pairs if, for example, the main differences between the pairs come from different cloud emissivity at the different wavenumbers. But if the differences come from an instrument problem then the AIRS and CrIS patterns will be very different.

Figure 4 shows the BT difference for matched pairs of channels for AIRS and CrIS. The AIRS differences are bright red and blue with stars while CrIS is in darker colors with circles. In this case the AIRS data show much more structure and higher magnitudes, indicating a probable AIRS problem.

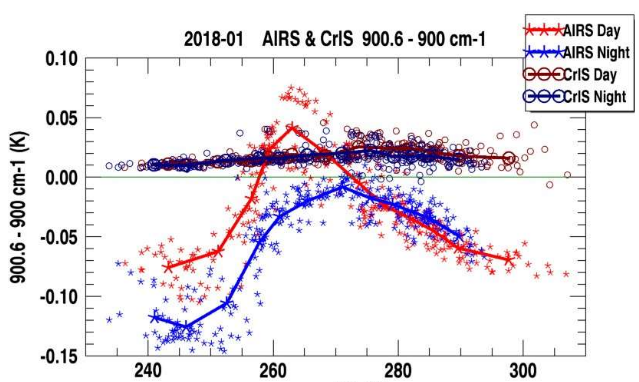


Figure 4. AIRS 900 cm^{-1} A/B channel pair BT differences with the BT differences for the corresponding CrIS pair

2.4 Trends of differences as a function of scene BT

Some artifacts are related to changes in the AIRS instrument over its 16 years of operations. Visualizing channel differences for different years shows how large these effects are and when they happened. These visualizations take the quantile data (section 2.2) from different years and combine it, now using a red-to-green-to-blue color gradient to distinguish the data from different years. We make separate plots for day and night.

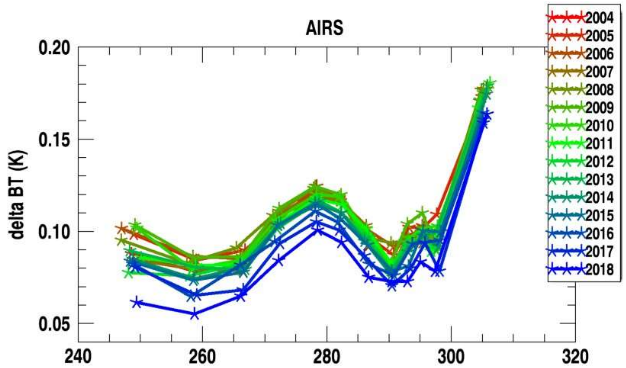


Figure 5. Scene dBT between equivalent channels on different detector modules at 2554 cm^{-1} for 15 years of AIRS January day.

Figure 5 shows the dBT as a function of scene BT for a pair of AIRS channels with nearly the same wavenumbers but on different detector modules. For this case we see that the difference between these channels is fairly constant over the years plotted, but it may be getting increasingly negative in the most recent (bluest) years.

We also make similar plots of the twelve months in a year to see the seasonal cycle of these differences.

2.5 Differences as a function of orbital phase

AIRS and CrIS are on platforms with similar sun-synchronous polar orbits. This orbit gives a periodicity to certain classes of instrument artifacts. Figure 6 shows this cycle.

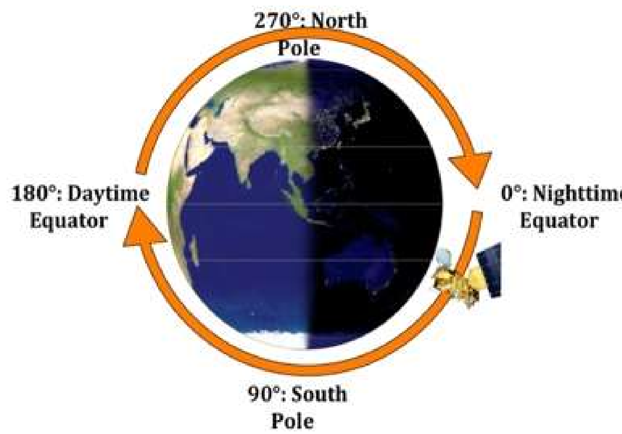


Figure 6. Polar orbit cycle

To investigate effects related to the orbit, we treat latitude and day/night as a single continuous free variable "orbit phase" start at zero degrees at the nighttime southbound equator crossing, hitting 90 degrees near the south pole, and then increasing through the northbound daytime stretch before heading south again near the north pole.

For the next figures we again combine all angles and land/sea data and treat each lat/lon box as a sample. But now the orbit phase is the independent variable.

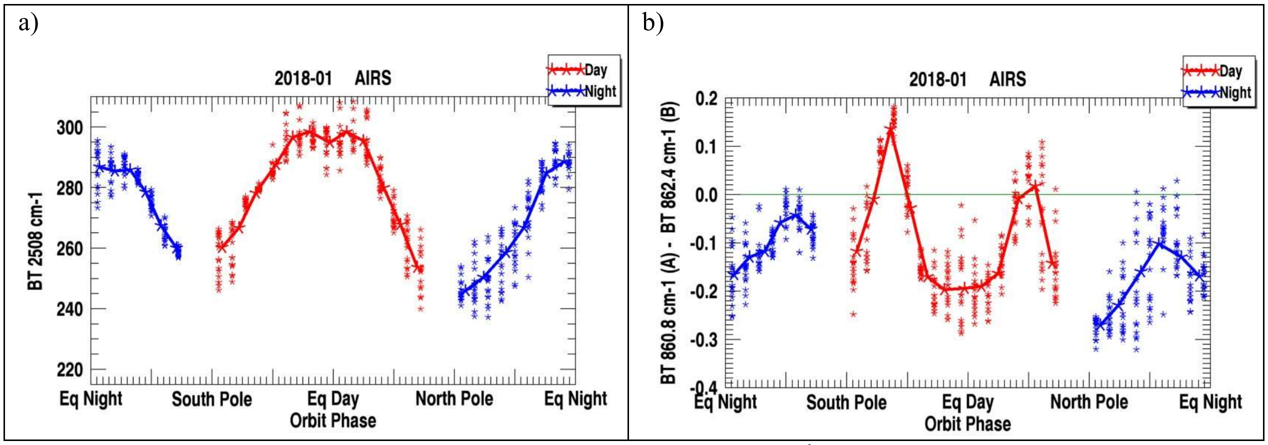


Figure 7. Orbital cycle. (a) BT for an AIRS shortwave window channel at 2508 cm^{-1}. (b) dBT for a pair of AIRS channels in module M-08, where anomalous differences are seen between channels using the A and B redundant detector sides.

Figure 7a shows scene BT at 2508 cm^{-1} as a function of orbital phase for January 2018. Generally, scenes are warmest near the equator and coldest at the poles, particularly whichever pole is in winter. Day is warmer than night, especially over land and for shortwave channels, which are somewhat sensitive to reflected solar light. Figure 7b shows a BT difference for an A/B pair of AIRS channels near 860 cm^{-1} with nearly equivalent sensitivity. We see a bias of about 0.15 K with peaks in the daytime north and south mid-latitudes and significant scatter.

3. SAMPLE ANALYSIS CASES

For each artifact it will be important to show the magnitude of the issue and also how it varies as a function of region, scene BT, scene uniformity, day/night, region, view angle, etc. This information can be used most crudely to characterize the uncertainty of the products, but it can also guide users as to which channels or scenes to avoid and may eventually form the basis for calibration updates or off-line empirical adjustments.

The StratRad product architecture and some of the same analyses can also provide interesting insight into climate phenomena. We show an example where, without any instrument adjustments, a clear climate signal appears similar in AIRS and CrIS data.

Many effects are best visualized by using the brightness temperature difference between a pair of channels, usually channels which should be nearly equivalent.

3.1 AIRS Module 8 (M8) A/B

AIRS has redundant A and B detectors for most channels. In most cases the two detectors are used together for a sqrt(2) decrease in noise, but where one side is bad the other is be used alone. Small differences have been observed between the channels in A-only and B-only configuration, with A+B channels in between. The differences are clearest in AIRS Module M-08, spanning ~850-900 cm^{-1}. M-08's spectral region is composed mostly of "window" channels, sensitive mostly to clouds and the Earth's surface, not atmospheric absorption by H_2O, CO_2, O_3 or other gases. There is a contribution from the water vapor continuum in this region, which must be taken into account.

For this comparison we use two pairs of window channels near each end of AIRS Module 8. Because the two channels in each pair are both window channels and the difference in wavenumbers is minimal, they would be expected to give nearly identical results.

The AIRS channels used near the 900 cm^{-1} end of M-08 are 900.3 cm^{-1} (B-only) and 900.7 cm^{-1} (A-only). CrIS channels at 900.0 and 900.625 cm^{-1} are used as a reference. At the 860 cm^{-1} end of M-08 the effect is about twice as large. AIRS channels at 860.8 cm^{-1} (A) and 862.4 cm^{-1} (B) are matched with CrIS channels at 860.625 and 862.5 cm^{-1}.

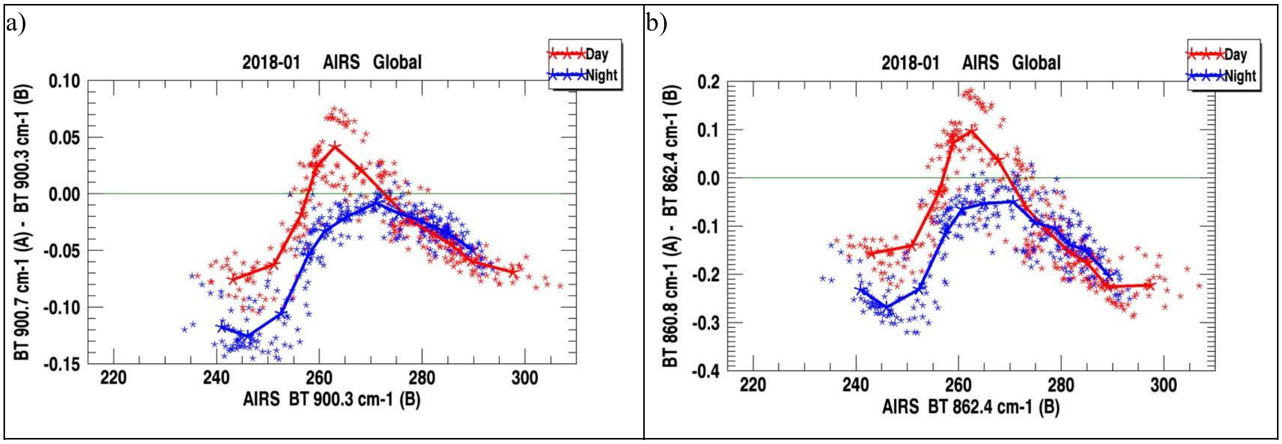


Figure 8. dBT as a function of scene BT for two AIRS Module 8 A/B pairs. (a) 900.7 – 900.3 (b) 860.8 – 862.4

Figure 8 shows BT differences (A-B) (Kelvin) for the 900 and 860 cm^{-1} pairs as a function of scene BT for January 2018. The patterns are nearly indistinguishable, though the 860 cm^{-1} pair has about double the magnitude: a range of about 0.4 K. We conclude that the same effect is seen throughout M-08. The remainder of the discussion here uses the 860 cm^{-1} channel pair because the greater magnitude gives a clearer signal.

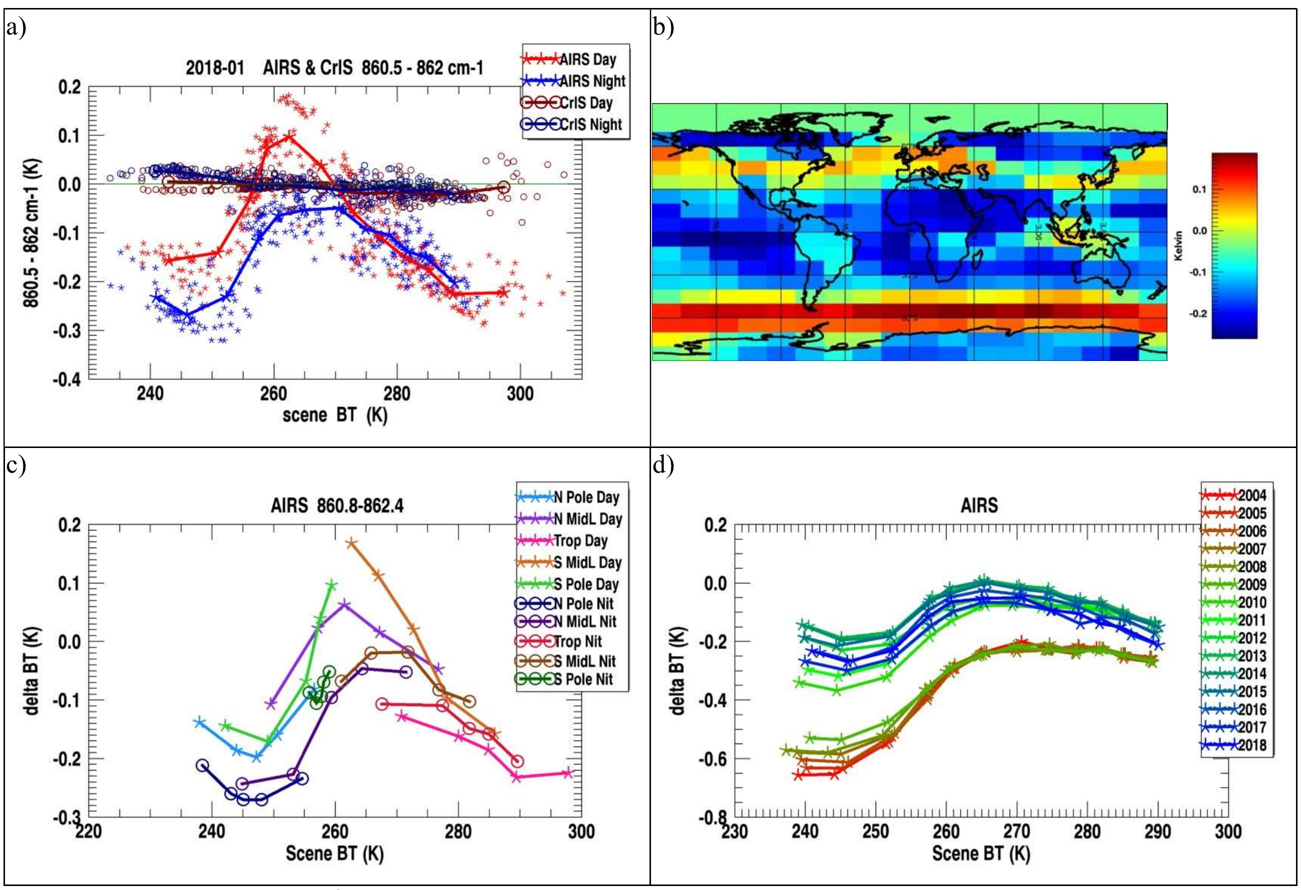


Figure 9. AIRS Module 8 860 cm^{-1} A/B channel pair. (a) comparison with CrIS as a function of scene BT For January 2018. (b) Map of (AIRS-CrIS) (860-862) double difference for January 2018 daytime. (c) dBT for January 2018 broken out by zone and day/night. (d) January night dBT changes over 15 years.

Figure 9a shows CrIS data (circles and darker lines) with the AIRS data. Because the CrIS lines are nearly flat, we conclude that the patterns in the AIRS data are not related to different sensitivity to water vapor or different cloud or surface emissivity between 860 and 862 cm^{-1}. The AIRS differences must be some sort of AIRS instrument artifact.

Figure 9b maps the double difference of AIRS-CrIS for 860-862 cm^{-1} channel BTs for January 2018 day. This is the difference of ($BT860_{AIRS}$ – $BT862_{AIRS}$) – ($BT860_{CrIS}$ – $BT862_{CrIS}$). Subtracting the CrIS difference removes the small geophysical variation, leaving only AIRS instrument artifacts. There's a prominent feature near 55 S latitude. This might be related to the climate conditions here, such as well illuminated ice & polar clouds, or could be an artifact related to the orbital position. Perhaps stray light can enter the instrument because of how it is oriented at this point in the orbit.

Figure 9c is like Figure 8b but broken down by latitude zones in addition to day/night.

Figure 9d shows night data for January of each year of the AIRS mission. A clear transition happened during 2008, with the magnitude of the difference decreasing about 2x at the cold end, much less for warm scenes. This could indicate that the problem is with the cold space views or perhaps is a small additional signal for Earth views, which is relatively unimportant as the scene signal gets larger for hot scenes.

A final clue about AIRS Module 8 comes from Figure 10. The top row of Figure 10 shows the differences between the AIRS A-side and B-side channels compared to their CrIS references as a function of orbital phase and seasonal pattern. There's a different color for each month.

A striking pattern is seen. Near the equator, the differences don't vary much with season and generally resemble the pattern seen for channels with their peak of sensitivity in the troposphere, including window channels. The second row of Figure 10 shows the BT for one such window channel: 2508 cm^{-1}. This image is flipped to make the similarities between the tropical regions of the first two rows visually clearer.

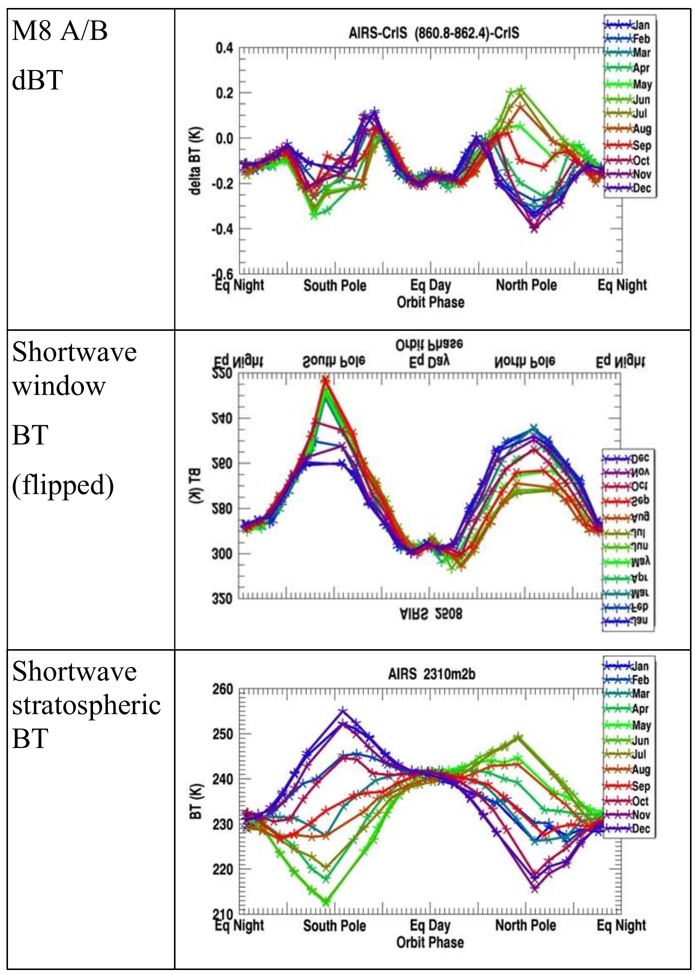


Figure 10. BT patterns as a function of orbital phase for 2017, colored by month.

In the polar regions, especially the north, there is a strong seasonal swing in M8 A/B dBT. This matches the behavior of stratospheric-sensitive channels. The third row of Figure 10 shows BT for a sample stratospheric channel: 2310 cm^{-1}, with a peak sensitivity near 20 hPa. This stratospheric BT matches the M-08 dBT pattern well for the north polar region, but has a bigger seasonal pattern at the south pole than is seen in M-08. Probably other channels sensitive to different parts of the stratosphere would be more similar to M-08 dBT.

This suggests that a small broadband light leak could be responsible for the differences between M-08 A and B channels. Each detector is supposed to be sensitive only to a narrow range of wavenumbers through a combination of:

- Grating dispersion
- Two bandpass filters
- Detector sensitivity

But it is still possible that a small amount of light from a different band reaches the detectors and affects the reported radiance. To create the observed A/B differences, more of this light would have to hit one side, perhaps because of a gap on one side of the filter holder or a problem with one area of the filter. Because the differences is seen at night as well as day, it would be a leak of upwelling radiances from Earth, not direct solar light on the instrument.

3.2 Shortwave

Over the AIRS mission, the brightness temperature observed in the shortwave band has drifted relative to the other bands (up to 5 K at 2616 cm^{-1} at 200 K) for isolated very cold clouds embedded in warm regions[4]. The current StratRad product does not isolate these scenes but its global coverage and multilayered stratification supports a variety of analyses that may help our understanding of the shortwave band more generally.

We compare the AIRS channel at 2508.1 cm^{-1} with the corresponding CrIS channel 2508.125 cm^{-1}. To include seasonal effects, we look at data for July 2017 and January 2018.

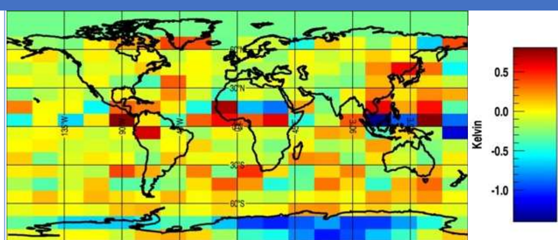
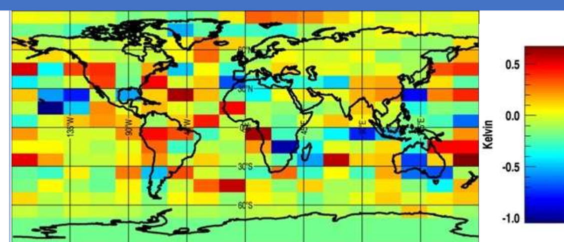
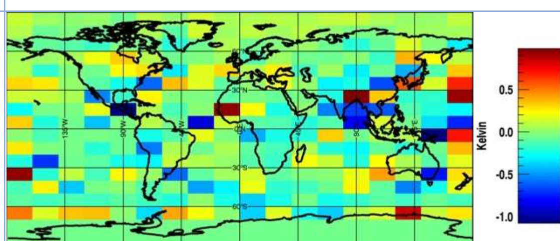
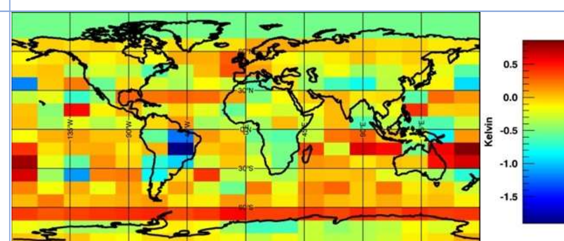
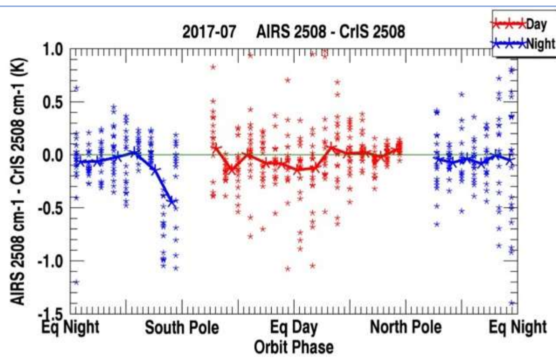
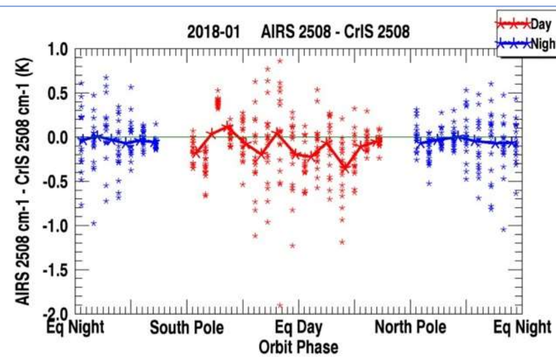
	July 2017	**January 2018**
Night Map		
Day Map		
BT diff by orbital phase		

Figure 11. Shortwave comparison: BT2508 AIRS-CrIS for July 2017 and January 2018

Figure 11 shows the difference between the AIRS and CrIS versions of BT2508. The first row shows maps of this difference for night cases. Most variation looks random – just the result of sampling differences, where in some cases AIRS happened to see warmer spectra than CrIS in a given area over the course of this month, and in other cases CrIS was warmer. The one clear coherent area of difference is nighttime July in east Antarctica. This is a very cold area in austral winter, <~ 220 K, and AIRS is significantly colder here.

The second row of maps shows the same for day. The striking feature here is a stripe in the band from 60-70 south latitude where AIRS is warmer.

The third row shows the BT difference as a function of orbital phase. This is where we can see the magnitude of the effects most clearly. July night Antarctic winter, the difference in the affected area is variable up to 1 K. January 60-70 S the difference is about 0.4 K and very consistent.

The instrument difference for the coldest Antarctic scenes may be attributed to a linearity problem with one instrument. Perhaps CrIS can't respond to such cold scenes, or perhaps AIRS overdoes it. It could also be a problem with contamination of the cold reference space views.

The stripe at 60-70 south latitude in daytime summer looks like it happens at a particular point in the sunlit part of the orbits, so it could be a place where sunlight bounces off of the ice and into the space or earth view port of an instrument.

3.3 Cloud optical properties

In addition to instrument artifacts, the StratRad product can support analyses in the weather/climate domain. Selected comparisons should show that AIRS and CrIS observe the same weather/climate signals, showing the way to eventual merged records.

The difference in BT across the 11-micron band is indicative of cloud thermodynamic phase (ice or liquid particles) and particle size[5,6]. AIRS channels at 830.5 and 961.1 cm^{-1} span this band. For CrIS we use 830.625 and 961.25 cm^{-1}.

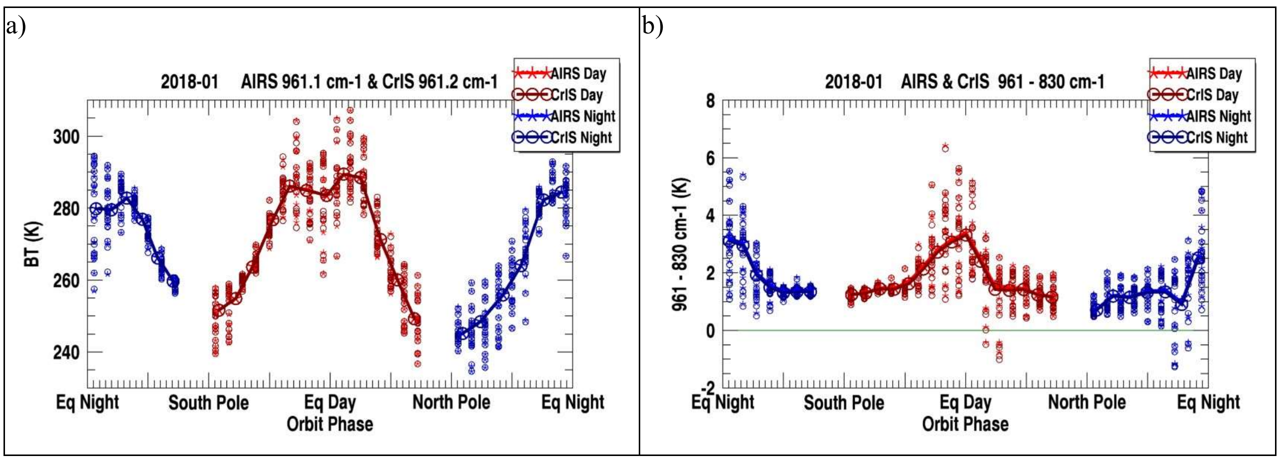


Figure 12. AIRS and CrIS 11-micron band by orbital phase. (a) BT at 961 cm^{-1} (BT961). (b) BT961 – BT830.

Figure 12a shows the background BT structure for the 11-micron band for January 2018 as a function of orbital phase. It's hottest near the equator for day and night, but the cycle is not highly peaked because clouds at the equator "hide" the surface temperature. Figure 12b shows the difference BT961-BT830 peaking pretty sharply near the equator where there are the most ice clouds, but it also shows a great degree of variability. Figure 13 is a map of AIRS daytime BT961-BT830 with black circles around the locations of two tropical ocean areas with similar mean BT but very different BT961-BT830. We look more closely at the spectra from these regions

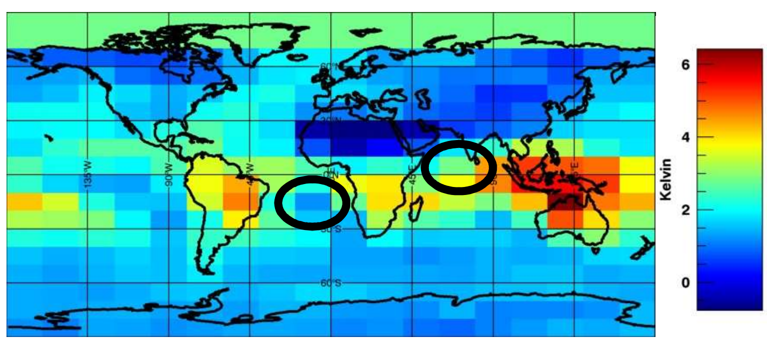


Figure 13. Map showing AIRS daytime BT961-BT830 for January 2018 daytime. Black circles show focus areas.

below. For these figures all spectra are differences from BT961 to make the shapes clearer. Without this normalization, random biases from different sampling would dominate.

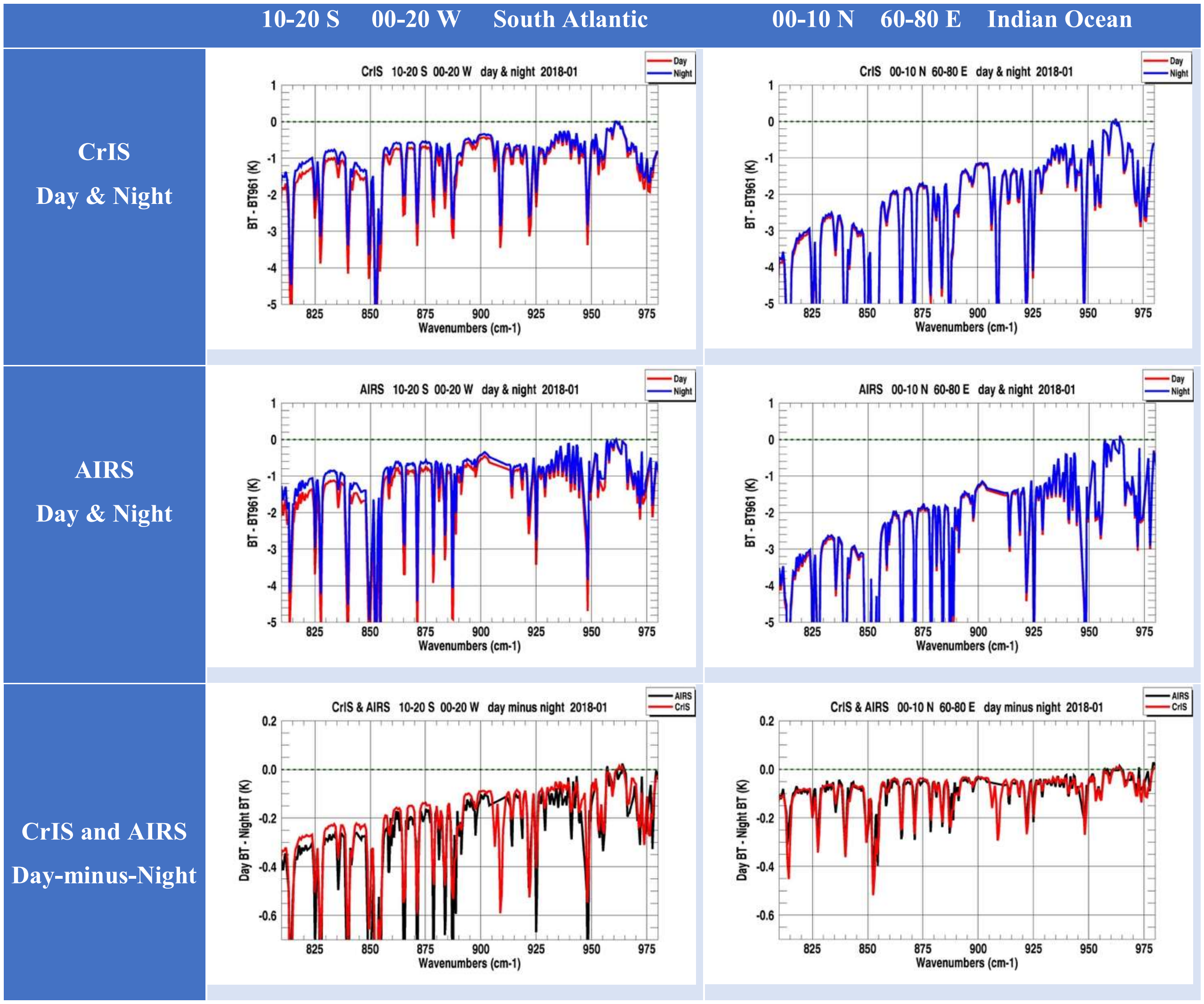


Figure 14. AIRS and CrIS spectral segment 810-980 cm^{-1} for focus geographic regions.

We see in Figure 14 that AIRS and CrIS produce very similar spectra, and that we would draw the same conclusions from the two instruments.

In the South Atlantic we see a relatively flat spectrum (dBT ~1 K) for both day and night, probably indicating mostly liquid clouds. In contrast, the Indian ocean case has a much steeper slope (dBT ~3 K), indicating ice clouds. Interestingly, the South Atlantic case has a relatively large slope in the difference between day and night. This probably shows a strong diurnal cycle in clouds here, with more ice clouds in day than night.

4. STATISTICAL CONSIDERATIONS

One important strength of these summary files is noise reduction so that even small artifacts can be documented. This noise reduction works very well for instrument noise, where the ~7000 spectra per bin give an 80x noise reduction: from <~ 0.3 K to <~ 0.004 K. But the ~7000 spectra in each bin represent observations from only about 30 orbital passes, so "weather noise" from different scene conditions is still an issue. Clouds can easily change scenes by 20 K, so even with a sqrt(30) reduction there can be 4 K of randomness. Further grouping of bins, for example over a full longitude band, over multiple months, and/or over all angles, can reduce this effect.

5. CONCLUSIONS

We have illustrated some of the benefits of the StratRad approach. The investigations in sections 3.1 and 3.2 contain important clues that might lead to full understanding and perhaps correction of instrument anomalies. But just the material here is enough to help users know, for example, when and where to use AIRS M-08 channels with caution, and to avoid both AIRS and CrIS shortwave for November and December near 60 degrees South.

Table 1 is a brief summary of what is shown here, and a sample of the type of information that can eventually be provided for many more effects with this approach.

Table 1. AIRS or CrIS Artifacts documented in this paper

Artifact	Max magnitude	Wavenumber range (cm^{-1})	Temperature dependence	Orbital dependence	Seasonal dependence	Long-term change	Suspected cause
AIRS M-08 A/B diffs	0.6 K	850-910	Larger at cold BT	strong	Strong at poles	~0.4 K around 2008	broadband upwelling light leak
Shortwave cold Antarctic	1 K	2000-2600?	Only BT < 230 K	N/A	Only detected austral winter	No	Linearity
Shortwave latitude stripe	1 K	2000-2600?	Unknown	Very local	Strong	Unknown	Solar light leak

There are a number of ways to decrease the data volume for analysis of trends and bias. This can be done with Level-1B or Level-2 data. The Level-2 data are often treated as a true representation of geophysical state. But at the high precision needed for climate change instrument effects can interfere with detection of geophysical trends. The Level-1B data are closer to the instruments, but have high variability dominated by cloud effects, so geophysical effects interfere with understanding of the instruments. By averaging large amounts of data while retaining important groupings, we are able to focus on either instrument artifacts or climate signals. In the long run, when instrument artifacts are well characterized, the focus can shift to true geophysical effects.

6. FURTHER WORK

This product is suitable for instrument monitoring. A new set of monthly files will be produced each month and the new set of visualizations will be reviewed.

The StratRad product will be used to evaluate candidate calibration modifications for the upcoming AIRS version 7 release, including the proposed V7k[7]. By retroactively backing out the old V5 calibration and applying V7 to the StratRad product we will have the benefit of large amounts of V7 data without a large processing campaign. We can then check V5 and V7 for agreement of channel pairs and for agreement with CrIS.

The next version of the StratRad product will be separated by ascending vs descending instead of day vs night, for better phase coverage near the poles.

Variants of the StratRad product will be needed to characterize some artifacts fully, and also for climate work. Longitude is the least important of the current dimensions, so we plan to make products which replace longitude with binning on:

- Scene homogeneity
- Fine-grained scan angle
- Cloud amount and thermodynamic phase; perhaps even cloud height, cloud overlap, and cloud microphysics
- FOV number and sweep direction (CrIS only)

Versions of the product should also be produced with AIRS Level-1C and eventually with AIRS resampled to CrIS SRFs.

This methodology can also be applied to IASI, to microwave sounders, and to AIRS's Visible/Near-Infrared channels. With modifications it could also include imager data. This will support more cross-comparisons.

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