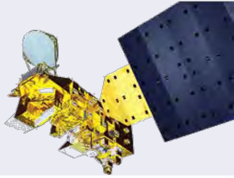

Principle Component Analysis of AIRS and CrIS Spectra

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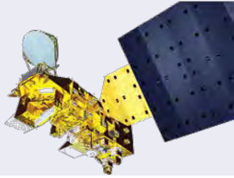
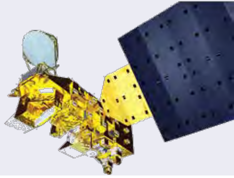
SPIE San Diego,
August 10, 2015



Outline

- Motivation
- Principle Component Analysis (PCA)
- Results using PCA with synthetic Eigen Vectors (EV) with AIRS and CrIS
- Summary and Conclusions

A seamless continuation of AIRS data with CrIS requires radiance agreement at the better than 100 mK level



100 mK is the equivalent of 10 years of global warming. Discontinuities at this level create unacceptable artifacts for climate data analysis.

AIRS has produced data since 2002, but the AIRS climate data record will eventually end.
The climate data record established with AIRS is intended to be continued by CrIS with data starting in 2012.

AIRS and CrIS are in polar orbit with 1:30 AM ascending node, have similar specifications and measurement objectives, but the orbits inclination and altitude differ.

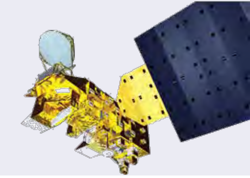
The most direct and maybe the only credible way of establishing a seamless transition from AIRS to CrIS is with the direct comparison of radiances.

There are cases where nearly the same spot on the globe(within a few km) is observed almost at the same time (within a few minutes) within 3 degrees of nadir by AIRS and CrIS. These Simultaneous Nadir Overpasses (SNO) allow pairwise comparisons of AIRS and CrIS. More on this in the next talk.

Approximately every 3 days the sub-spacecraft tracks of Aqua and NPP are parallel within 1 degree in longitude, but trail each other by several minutes. None of the data pass the SNO requirements. For these data we can compare the images of PC reconstruction residuals for AIRS and CrIS.

Our focus is on PC reconstruction residuals.

PC Analysis allows comparison between observed and expected spectra



Eigen Vectors (EV) define a rotation matrix.

**We can derive the EV from a representative set of observed spectra.
This produces empirical EV. This technique is used for regression retrievals.
This requires no knowledge of the RTA or understanding of the instrument.**

**We can derive EV from a representative set of simulated spectra.
This produces synthetic EV. The simulated spectra represent what we expect the spectra to look like based on RTA and our understanding of the instruments.**

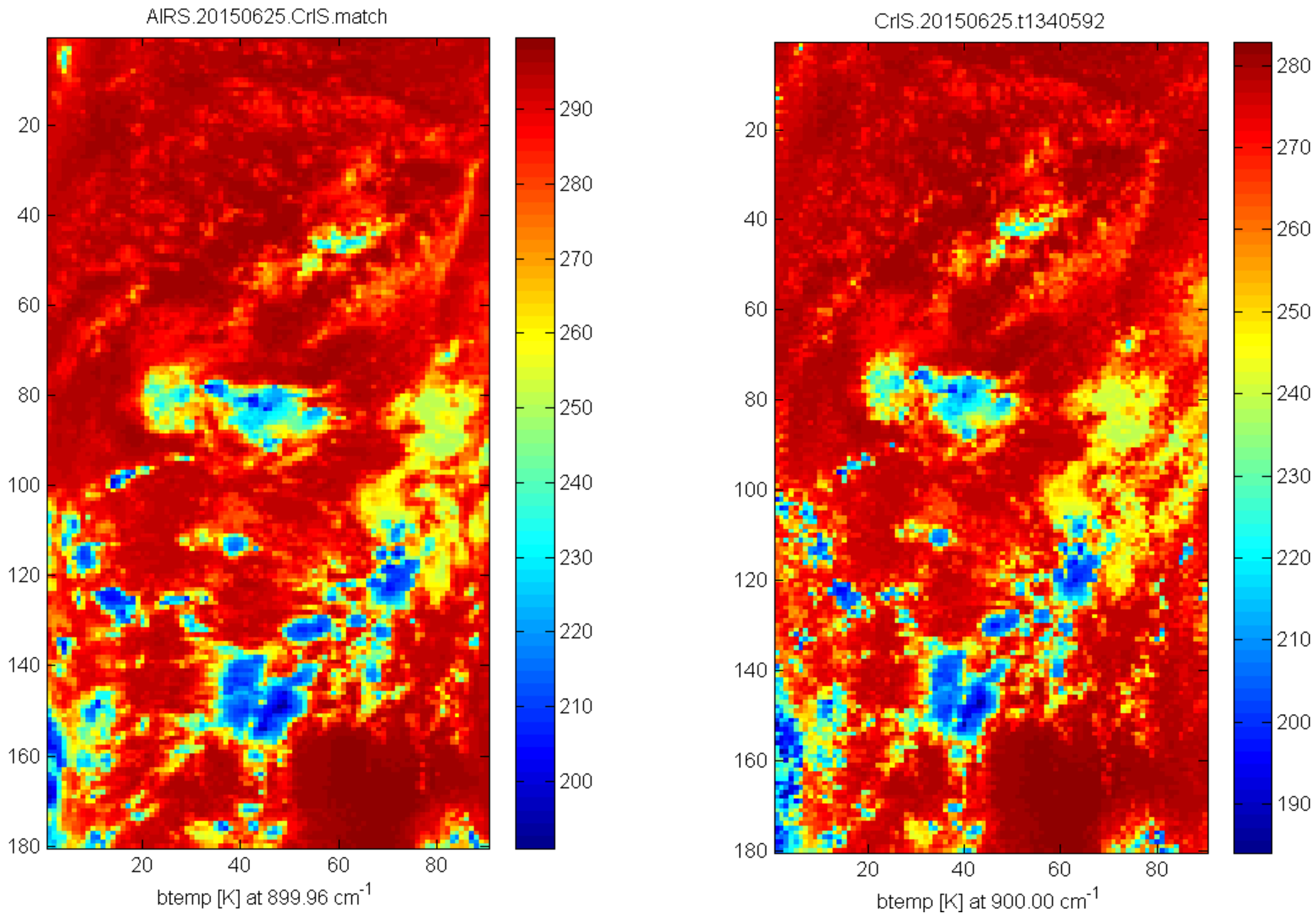
**We illustrate this with AIRS and CrIS spectra from one data granule
(8 minutes of data 16200 spectra) from the tropical western Pacific Ocean
on 6/25/2015.**

For AIRS we show results only for the 2243 (of 2378) AIRS channels with nedt250<1K.

For CrIS we use hamming apodized, CCAST calibrated, full resolution data with 2211 channels . All CrIS data passed the quality control thresholds established by the CrIS calibration team .

This example is for 8 minutes of data from the night W. Tropical Pacific.

On a scale from 190 to 300K AIRS and CrIS agree perfectly.



There is a lateral shift of 5 footprints of the 90 cross-track footprints between AIRS and CrIS.

The RTM used to generate the AIRS and CrIS simulated spectra and the geophysical training sets have to be identical.

We selected a globally representative training set of 8000 geophysical conditions using the 60 level ERA (ECMWF) prescription for T(p), q(p) and liquid_water(q) and ice state(q).

For each od these conditions UMBC calculated a spectrum with extremely high resolution with line-by-line code using hitran2012 and scattering code. These spectra were convolved with the CrIS SRF and the AIRS SRF and resampled on the AIRS and CrIS spectral grids. The resulting spectra were used to create synthetic EigenVectors.

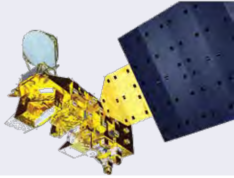
The first 200 EV were used to reconstruct real AIRS and CrIS data and evaluate the residual = (observed-PC.reconstructed)

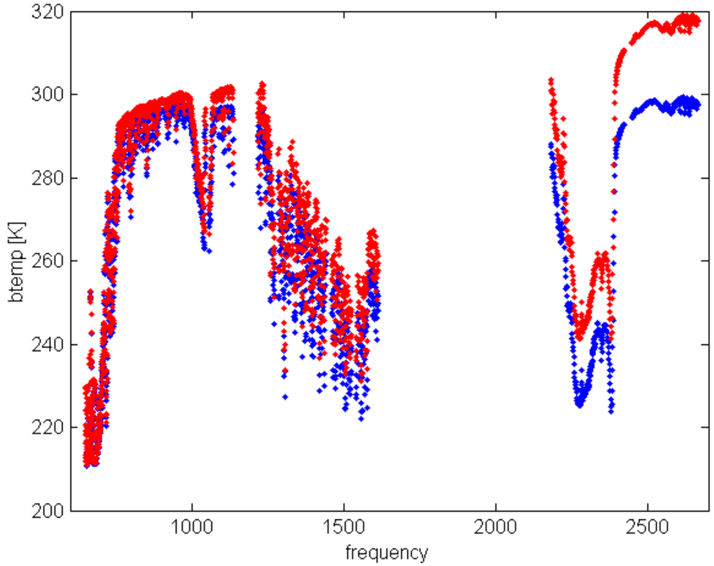
If our understanding of the instruments is perfect, we will see zero mean residuals with standard deviation equal to the instrument noise.

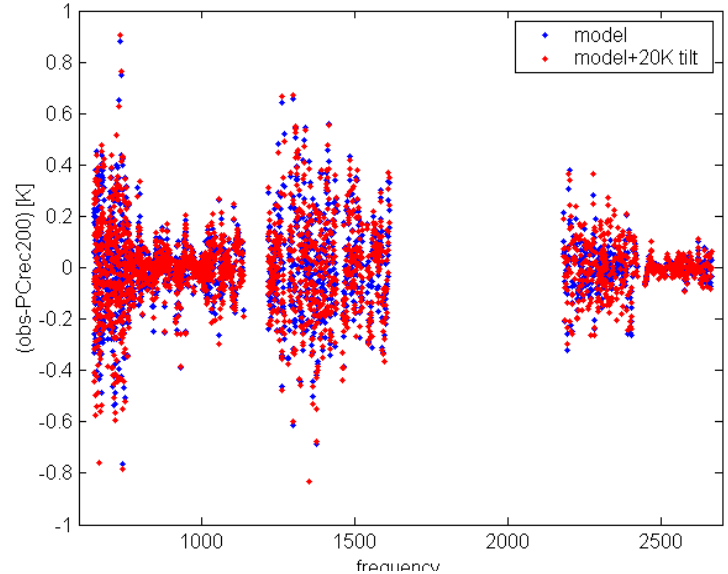
If our understanding of the calculation of cloudy radiances is imperfect, than the imperfections will show up as similar residuals in both AIRS and CrIS.

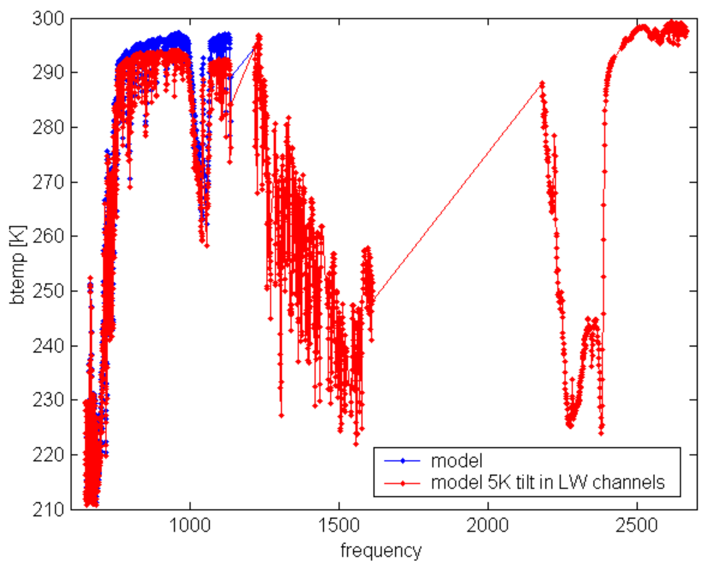
Residuals unique to AIRS or CrIS are due to a lack of understanding of either or both instruments.

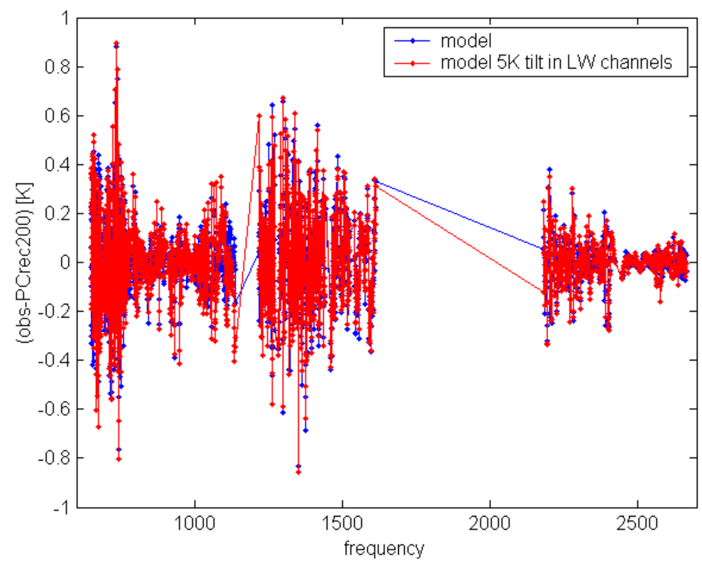
PC reconstruction is insensitive to spectrally correlated radiometric shifts which mimic clouds











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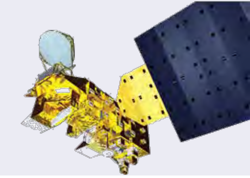
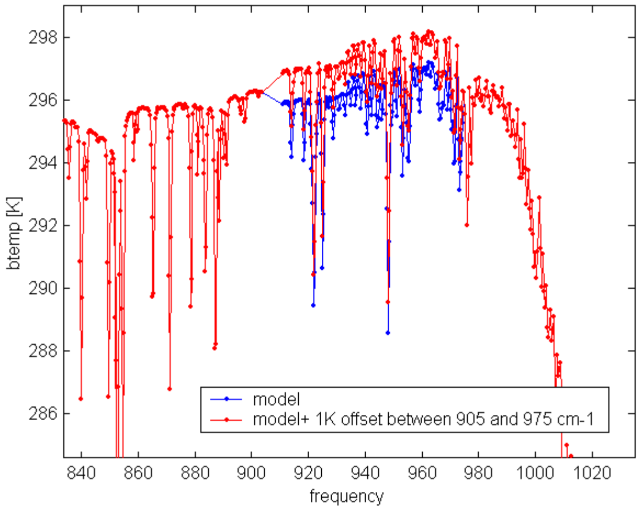
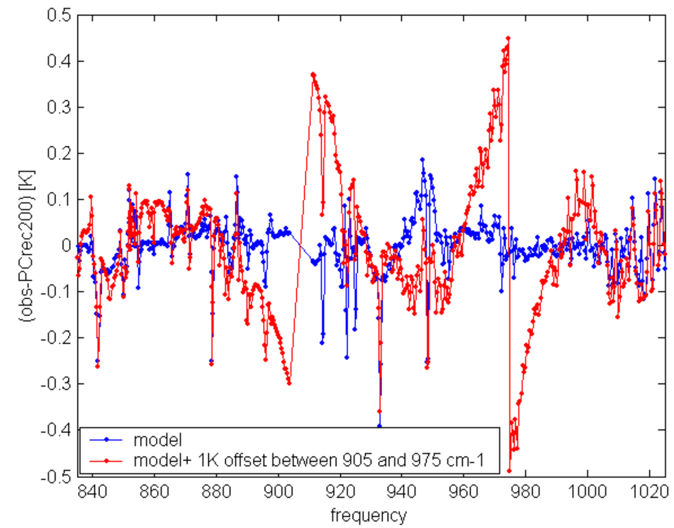
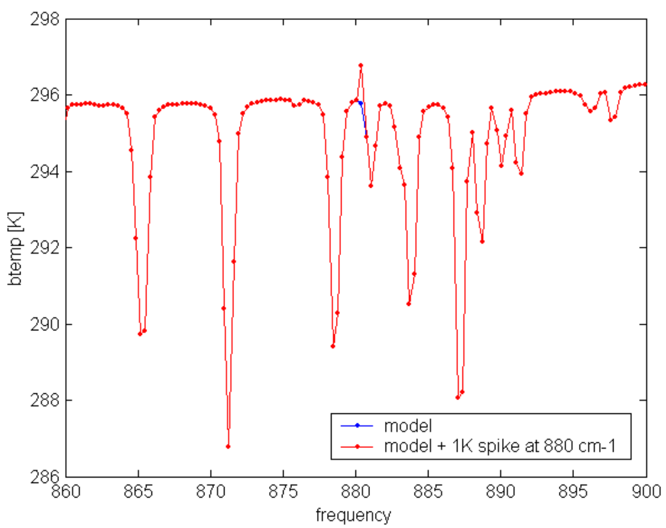
Atmospheric Infrared Sounder

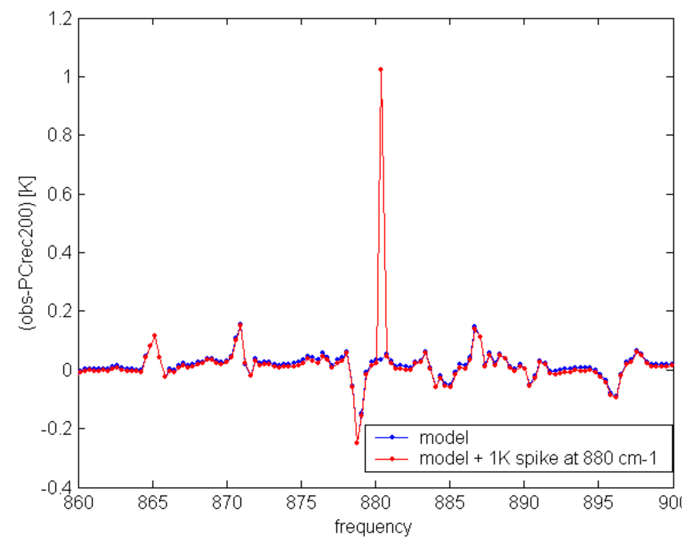


PC reconstruction is very sensitive to shifts between detector modules, shifts between spectral bands, single channel spikes and spectroscopy error

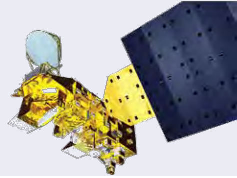


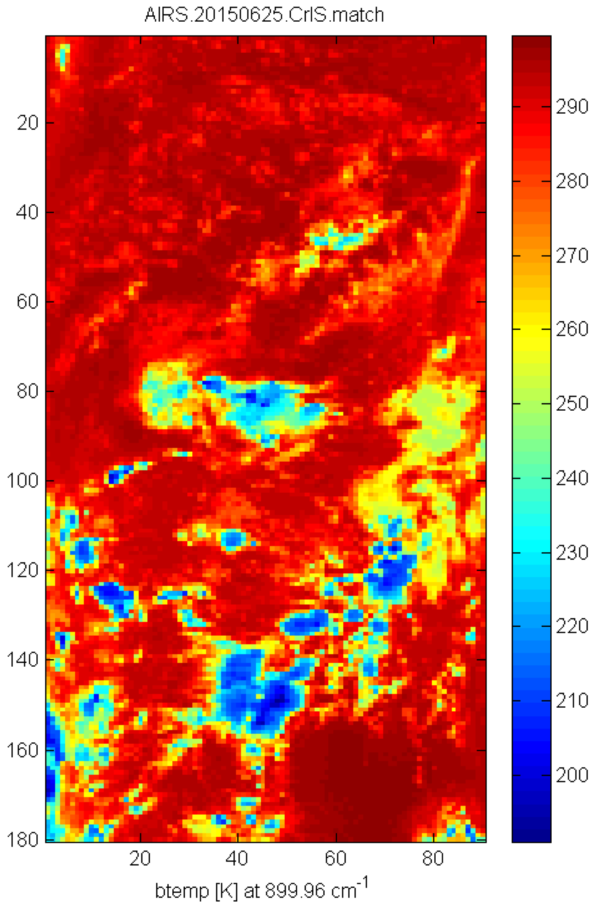


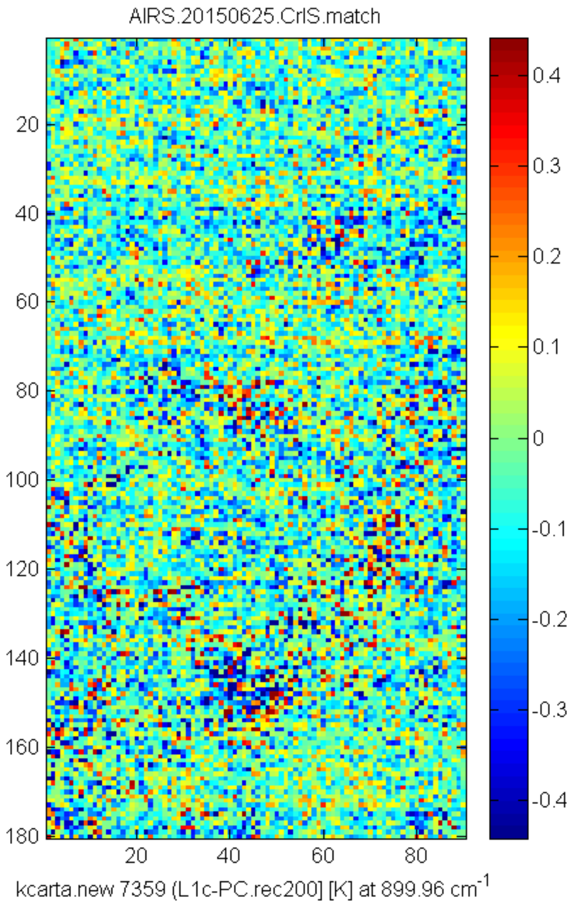




For a good channel the residuals averaged over the data granule are close to zero, the standard deviation is close to the detector noise equivalent radiance. Clouds produce outliers at the 1 K level.

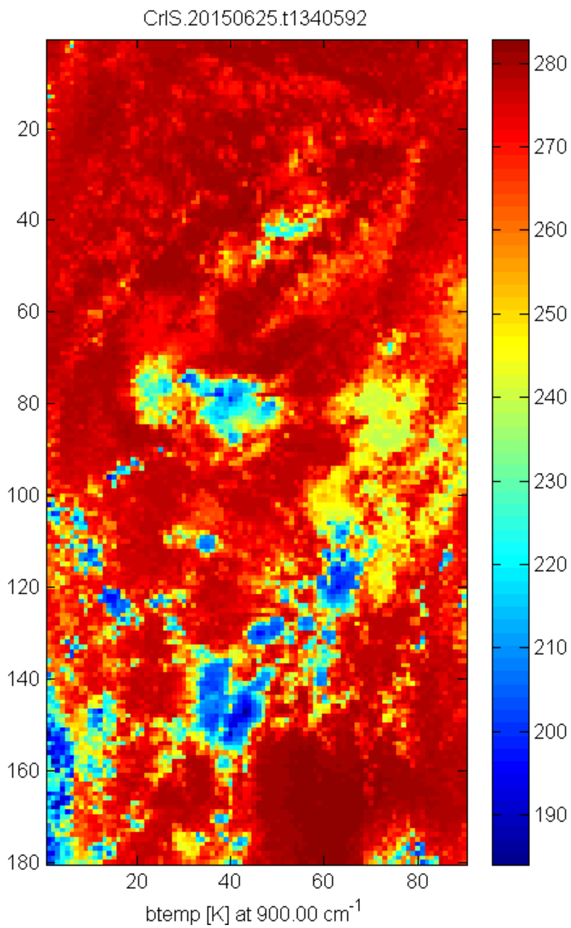


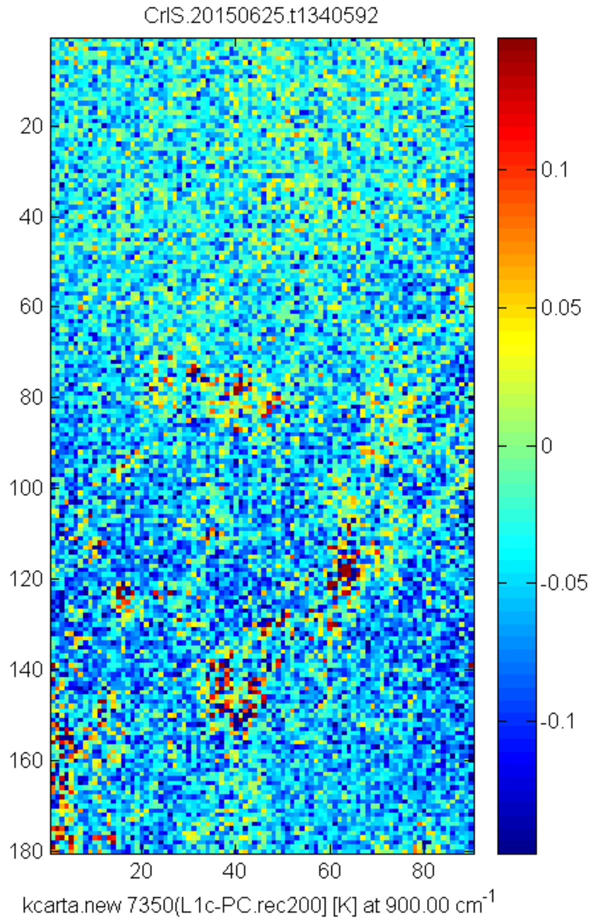




The AIRS 900 cm-1 channel has nedt250=0.19 K
The residual mean=-0.05 K, stdeviation=0.16 K range [-1.28K...+0.84K]

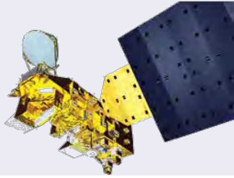
The CrIS residuals for the 900 cm-1 channel are less noisy than AIRS, but there is similar cloud print-through.



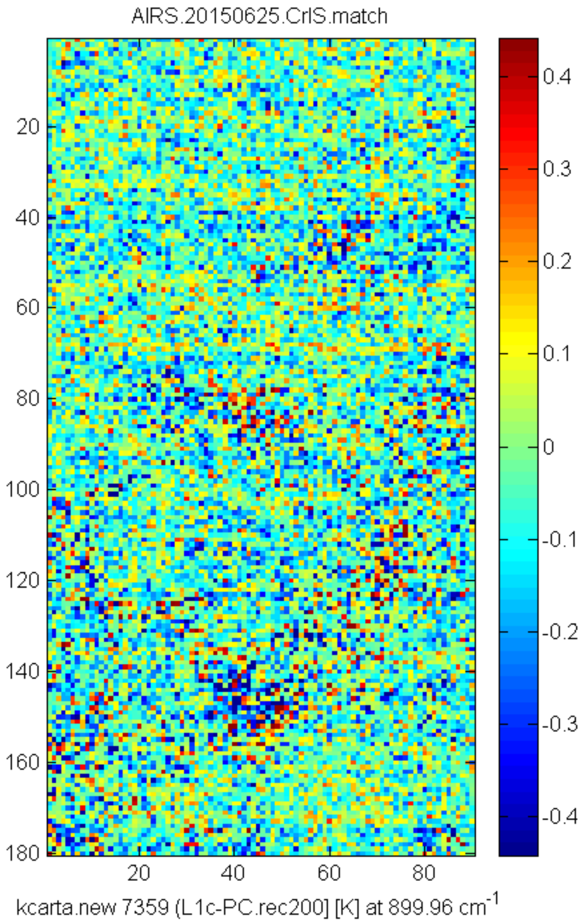


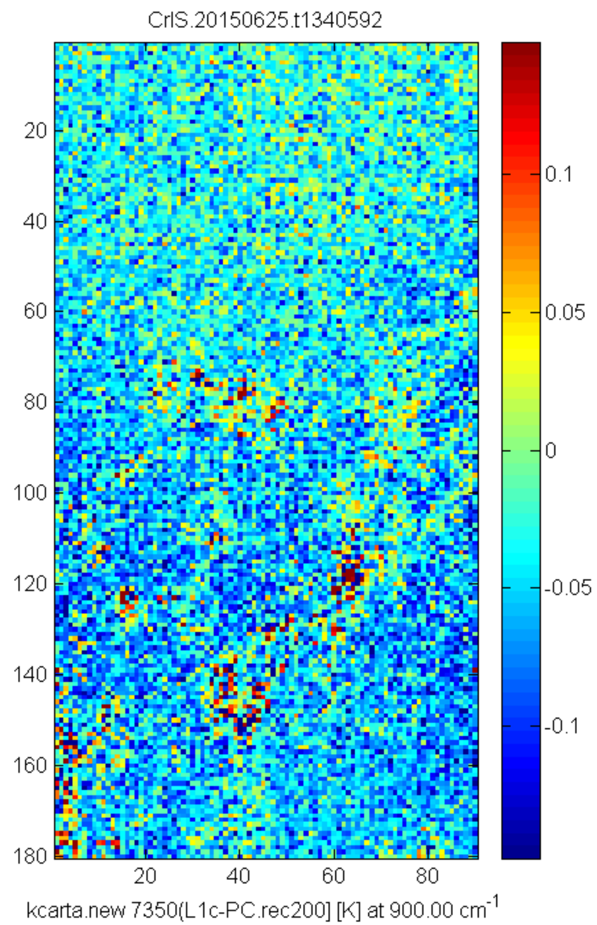
The CrIS 900 cm-1 channel has nedt250=0.03 K

The residual mean=-0.05 K, stdev=0.05 K range [-0.46K...+0.44K]



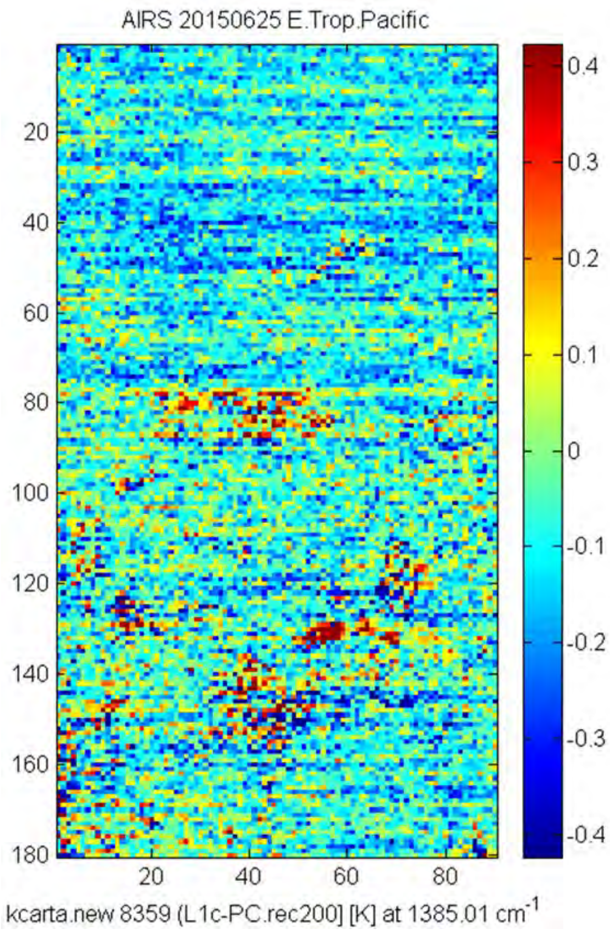
The comparison of AIRS and CrIS residuals at different spectral frequencies provide insight at the better than 50 mK level.

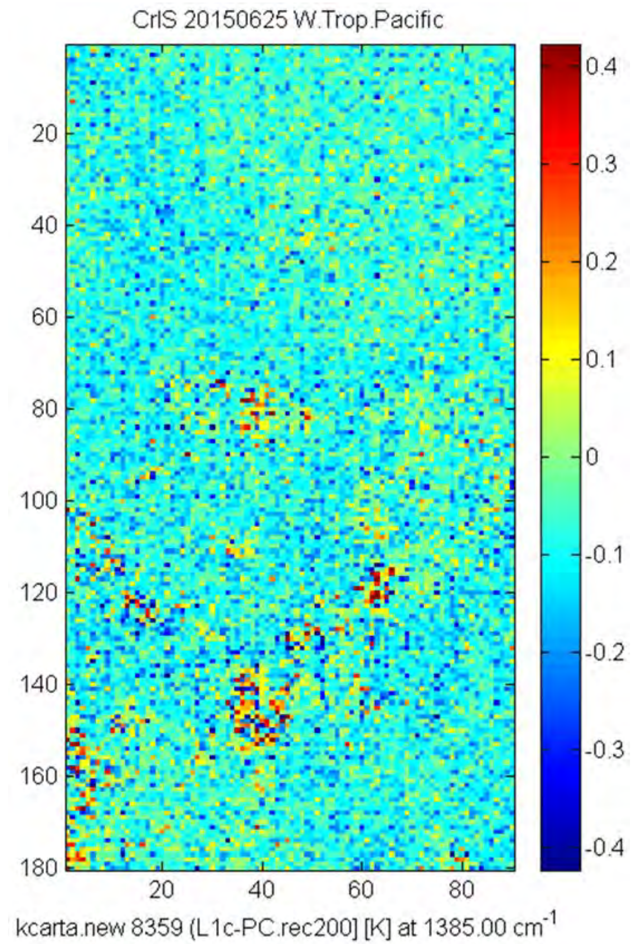




The AIRS residual image at any frequency is created with on physical detector.
The CrIS residual image at any frequency is created by a 3x3 detector array.

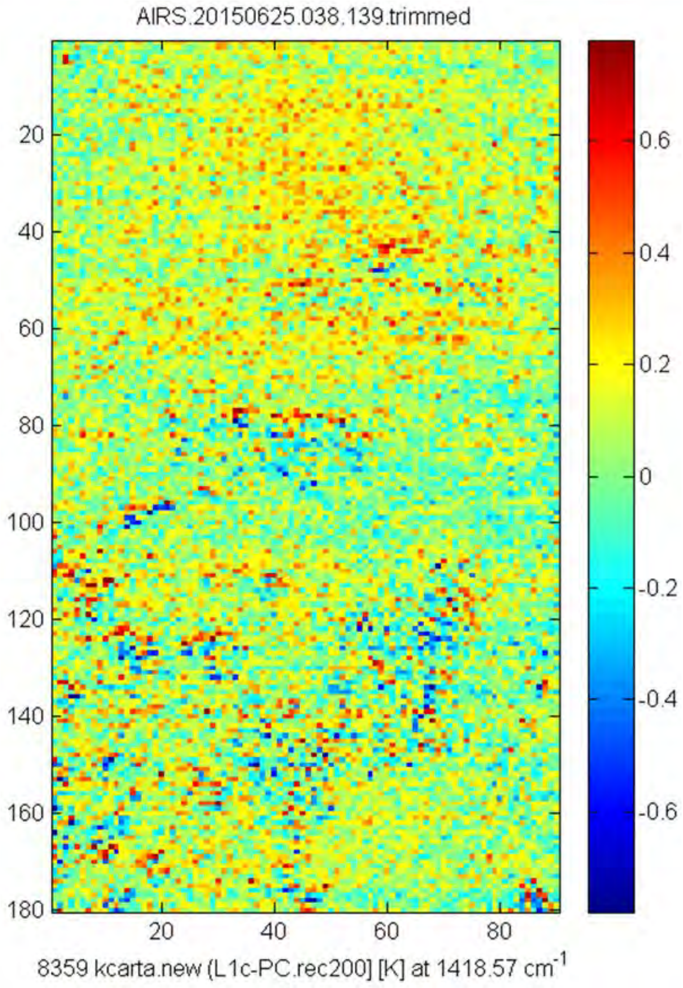
Some AIRS channels show stripes
CrIS residuals speckle patterns

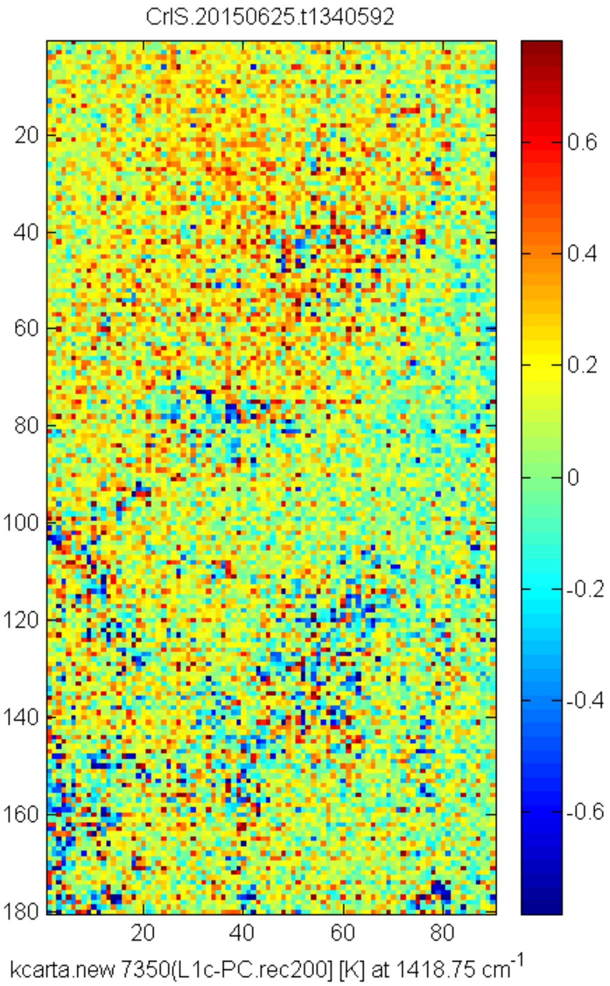




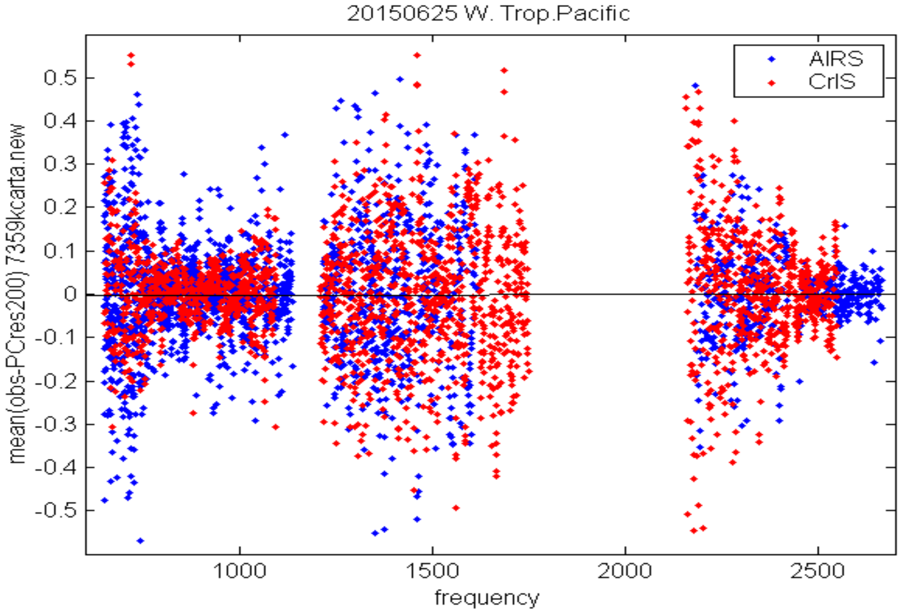
Stripes are related to a single detector non-Gaussian noise
Speckle is related to detector-to-detector non-uniformities

Some CrIS channels show pattern noise where the corresponding AIRS residuals are relatively clean





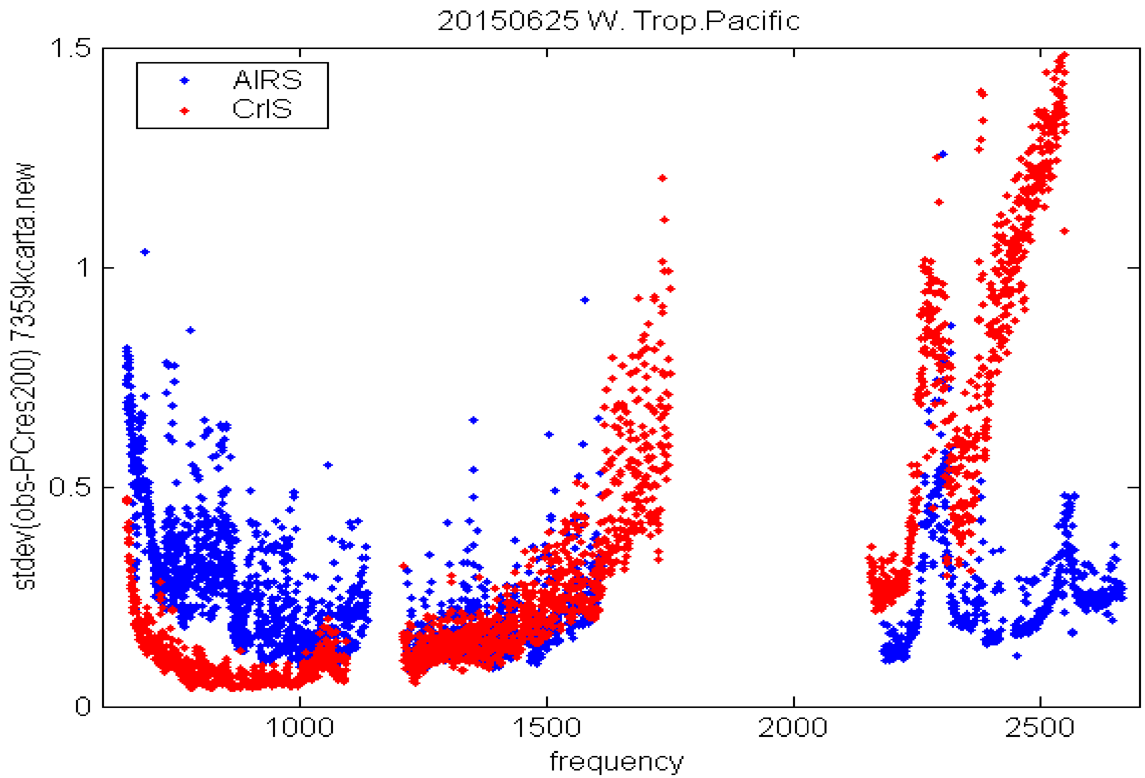
The residual mean and standard deviation evaluated for the data granule are Gaussian characterizations of noise.



The mean reconstruction residual from AIRS and CrIS has similar character. This means that kcarta with clouds has systematic errors are large as 0.5K

The granule standard deviation of the AIRS and CrIS residuals mimics the instrument noise.

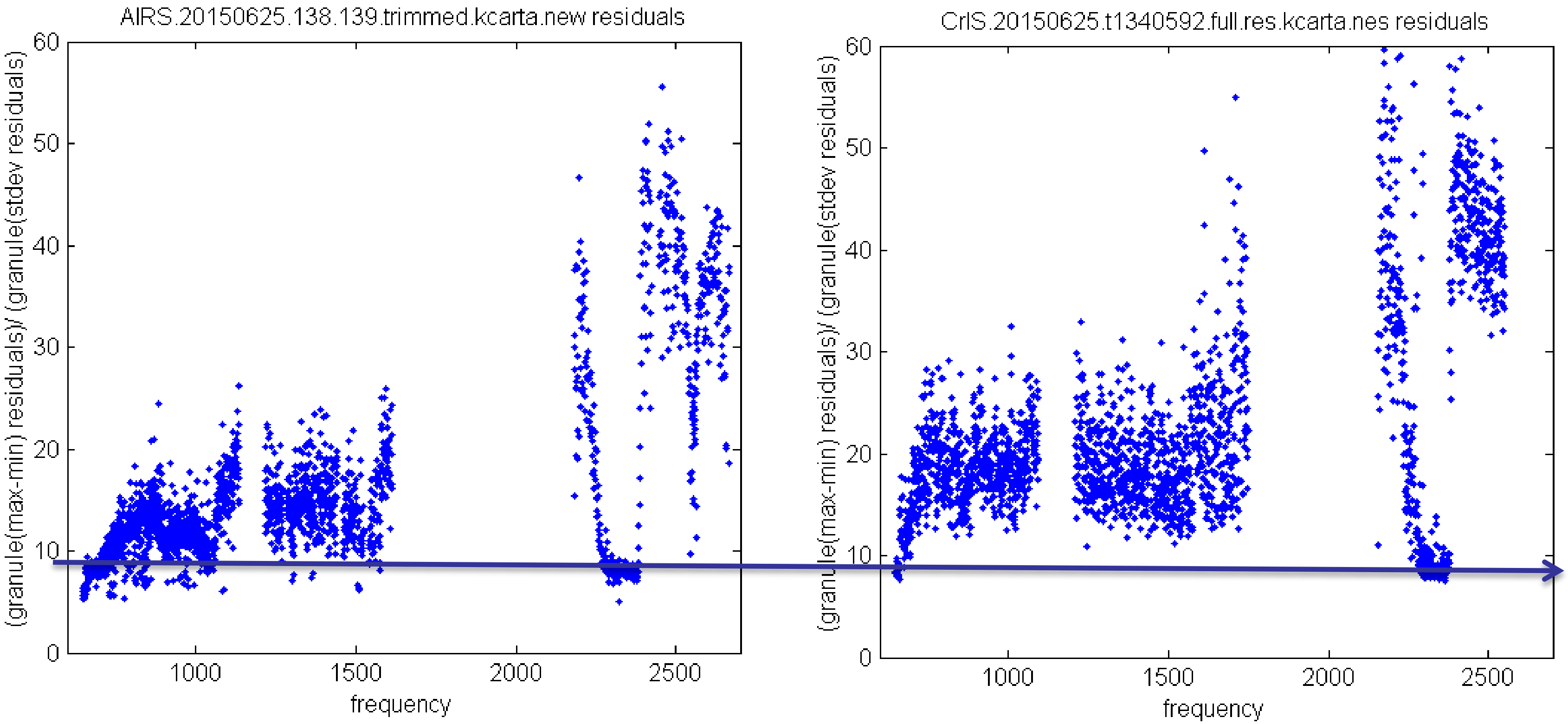
The full resolution CrIS is less noisy than AIRS in the Longwave band , about equal to AIRS in the midwave band, and much noisier than AIRS in the shortwave band.



The Gaussian characterization of the AIRS and CrIS reconstruction residuals ignores the non-Gaussian component

The Gaussian characterization of the AIRS and CrIS reconstruction residuals ignores the non-Gaussian component

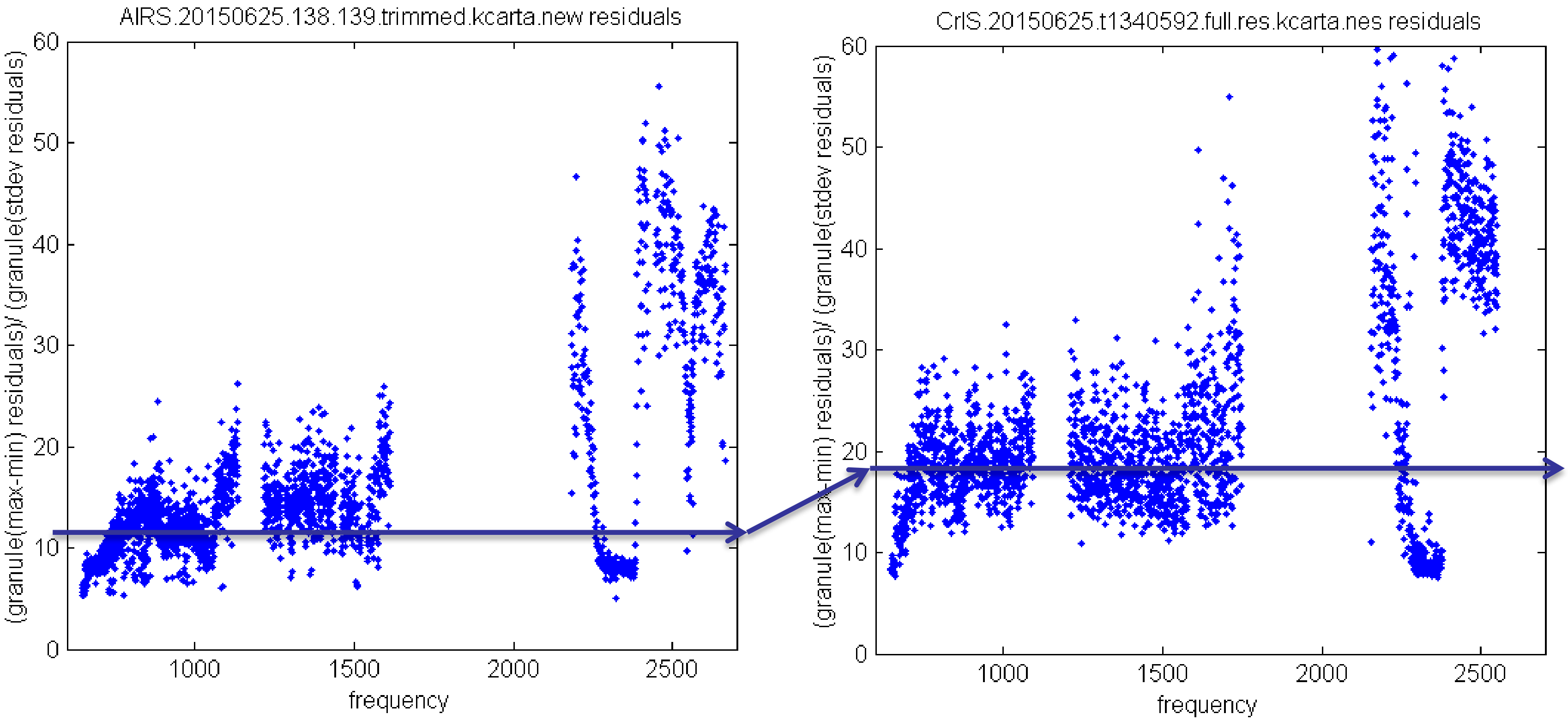
We characterize the non-Gaussian component by the (maximum-minimum) PC reconstruction residuals from the granule divided by the standard deviation.



For channels which never see the clouds the residual are Gaussian for AIRS and CrIS

The Gaussian characterization of the AIRS and CrIS reconstruction residuals ignores the non-Gaussian component

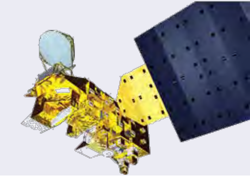
We characterize the non-Gaussian component by the (maximum-minimum) PC reconstruction residuals from the granule divided by the standard deviation.



For channels which see the clouds, CrIS has more non-gaussian outliers than AIRS.

In the shortwave channels AIRS and CrIS have more large number of non-Gaussian outliers. This is related to the limitations in the shortwave cloud scattering parameters.

Summary



We use synthetic EV to reconstruct tropical ocean AIRS and CrIS spectra. In the atmospheric window channels the reconstruction residual for AIRS and CrIS are very close to the instrument noise level.

We see PC reconstruction residuals as large as 0.6K using hitrans2012 and line-by-line calculations in the AIRS and CrIS spectra in regions of co2 and water vapor absorption. This is related to the limitation of the Radiative Transfer Model (RTM) which effects AIRS and CrIS equally.

CrIS channels which do see clouds in the temperature and water sensitive regions have significantly more non-Gaussian outliers than equivalent AIRS channels. At this point we have no good explanation for this. This impacts the fidelity of the measurement of extrema, which are a key component of climate research.

Non-Gaussian outliers in CRIS which are not seen in AIRS suggest instrument artifacts which may be addressed in future releases of the CrIS calibrated radiances.

Retrievals and data assimilation depend on the fidelity of the Radiative Transfer Model (RTM or forward algorithm).

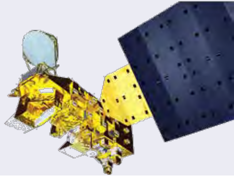
Unexpected reconstruction residuals mean that the conversion from atmospheric state to spectra is not well understood.

PC residuals are not sensitive to calibration offsets which effect many channels.

This is the strength of the analysis of pairwise differences of TSNO presented elsewhere.

Discussion of our CrIS findings with the CrIS calibration team are planned.

Discussion with the UMBC team regarding artifacts in the Radiative Transfer Model have started.



Questions/Comments?