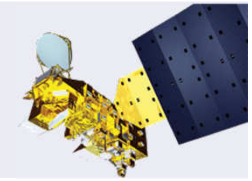

Principle Component Analysis of AIRS and CrIS Radiances

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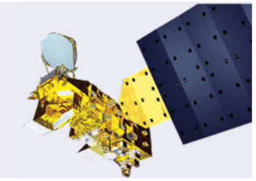
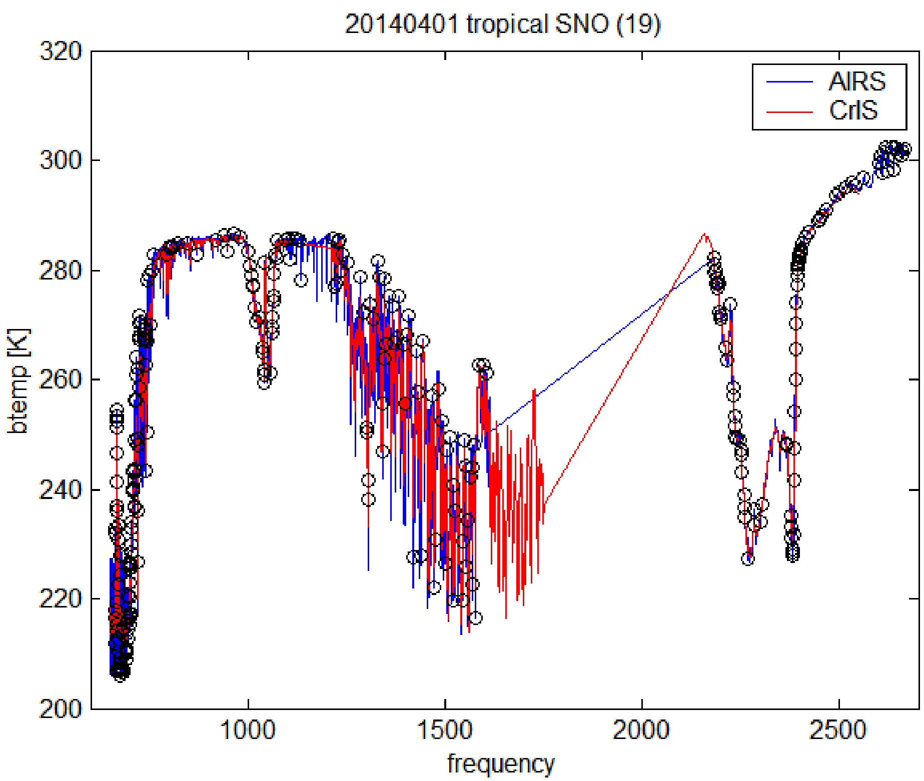
AIRS Science team meeting April 23, 2015

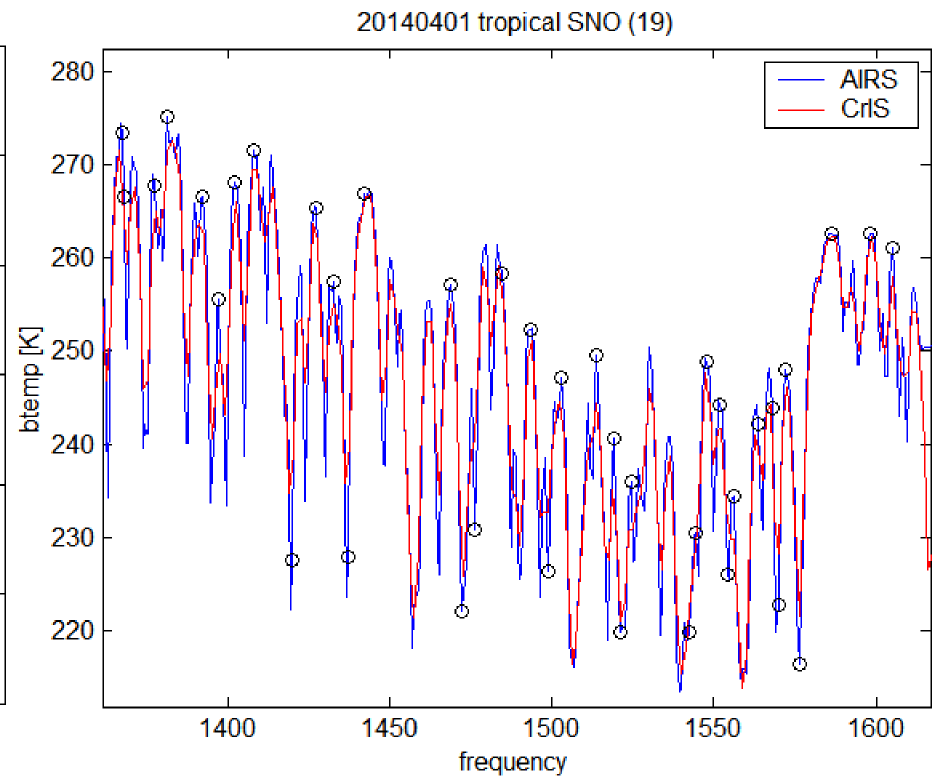
Outline



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

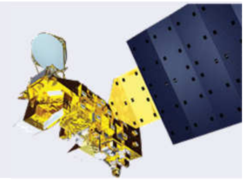
How close do real AIRS and CrIS spectra agree with our expectations?





o = 324 AIRS Channels ingested by ECMWF

PC Analysis gives insight into this question



We use a set of spectra (the “training set”) to define a rotation matrix called Eigen Vectors (EV) (also called Eigen Functions)

We can then describe the spectrum in terms of the amplitudes of the EV called Principle Components (PC) also referred to as Eigen Values.

We could use training sets created from a representative set of observed spectra. This produces empirical EV. This technique is used for regression retrievals.

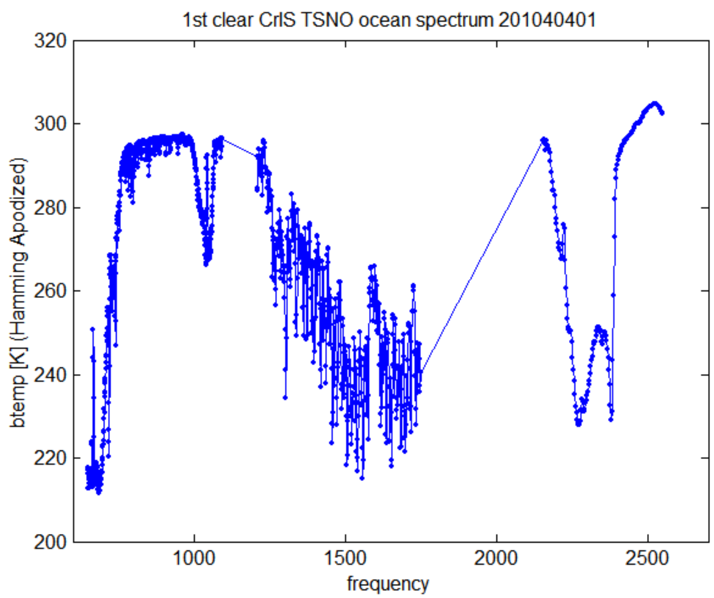
We use training sets created from a representative set of simulated spectra. This produces synthetic EV. The simulated spectra represent what we expect the spectra of clear and cloudy scene to look like based on RTA, scattering code and our understanding of the instruments.

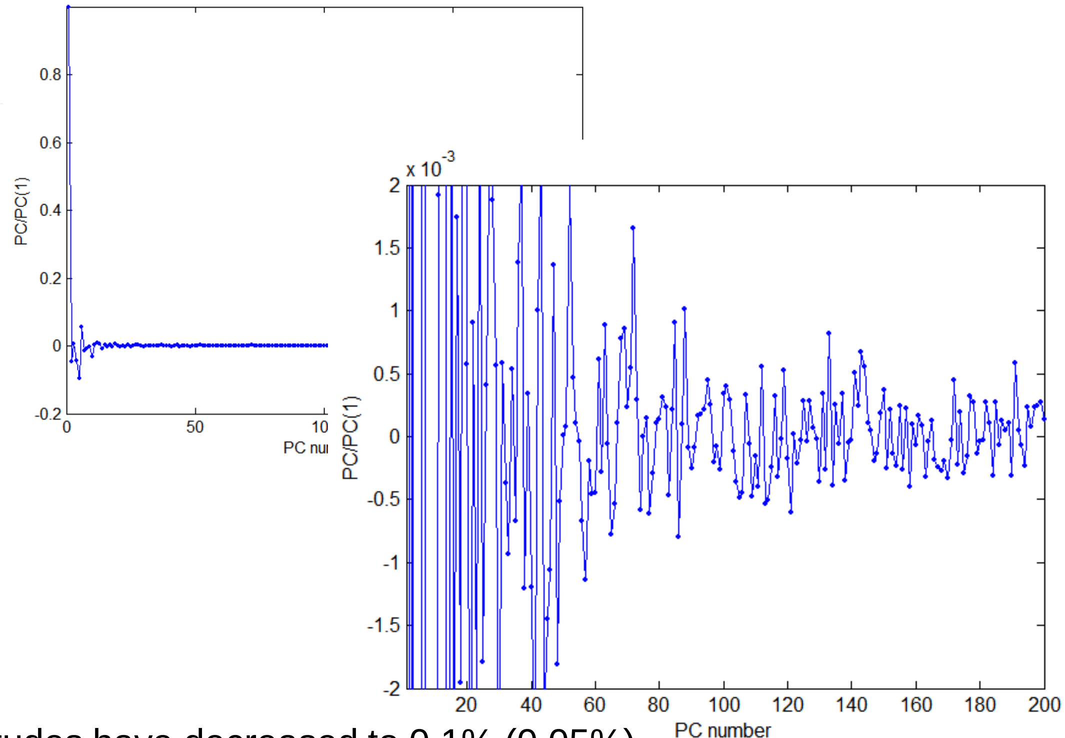
We illustrate this with AIRS and CrIS spectra from tropical zone Simultaneous Overpasses (8km and 10 minutes within 3 degree of nadir) called SNO from all days in April 2014.

The first 100 PC capture the information at the noise level.

We have millions of spectra of representative atmospheric condition for AIRS and CrIS calculated by Sergio Machado (UMBC) and Dan Zhou (LARC).

We have used these spectra to create EV and used the EV to decompose spectra in to PC. The EV are zero mean and are normalized to the same standard deviation.

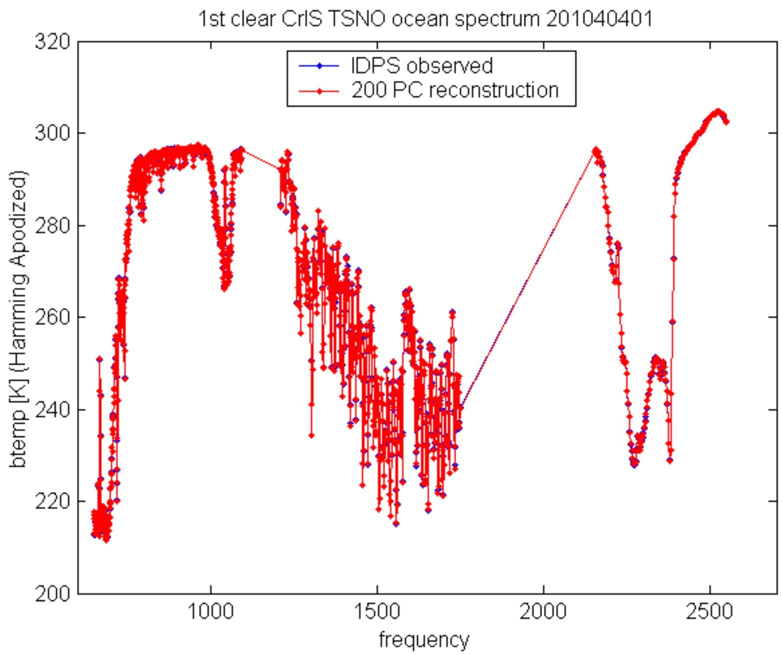


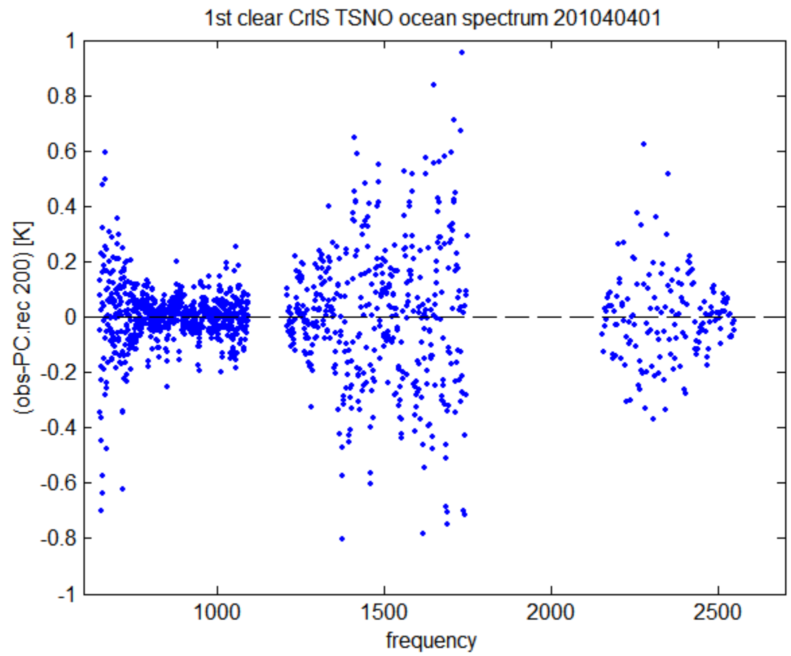


At about 100 PC (150 PC) the amplitudes have decreased to 0.1% (0.05%) . After then the PC look like random noise.

Single CrIS spectrum PC Reconstruction

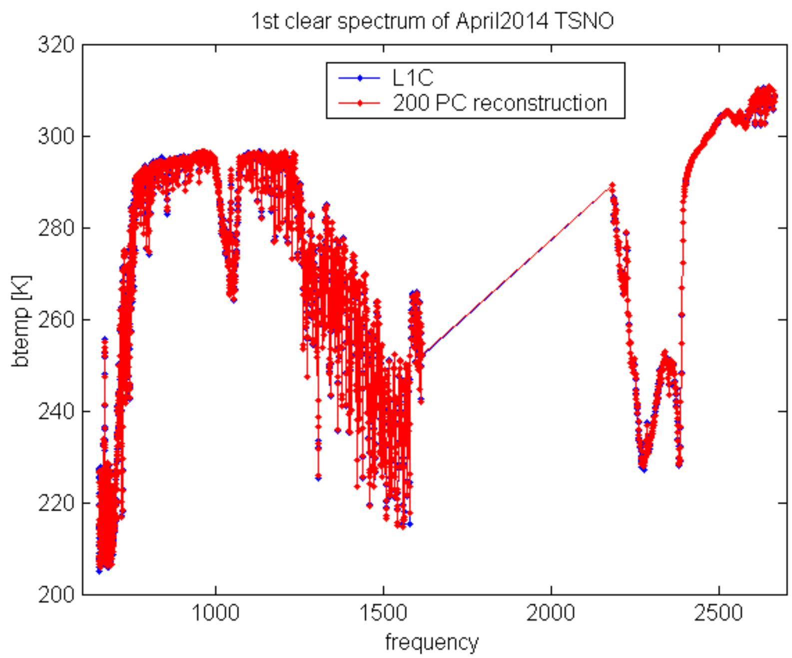
We use the first 200 PC to reconstruct the observed spectrum and calculate the reconstruction residual (obs-PC.rec200). The residual is dominated by the noise in a single spectrum.

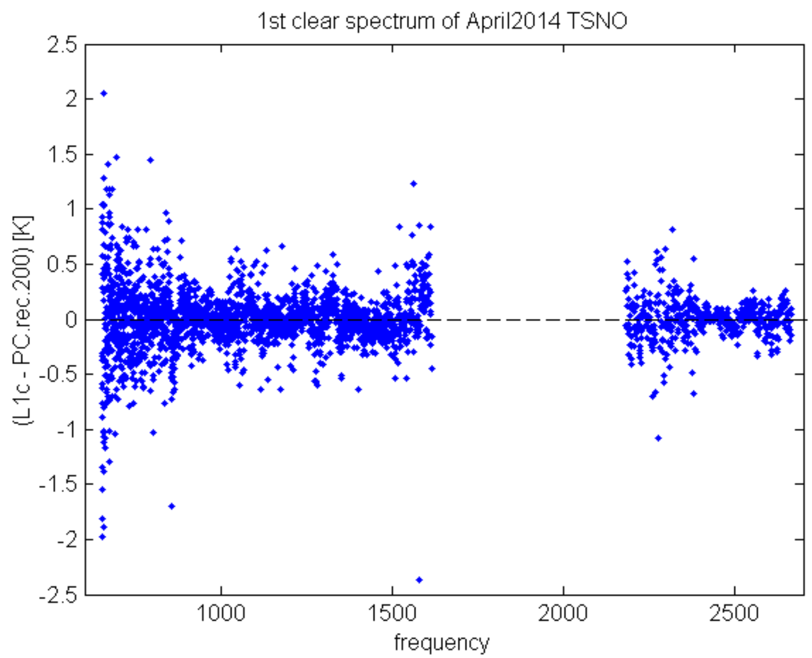




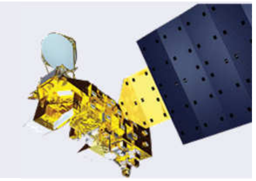
Single AIRS L1c spectrum PC Reconstruction

We now use the first 200 PC to reconstruct the observed spectrum and calculate the reconstruction residual (obs-PC.rec200). The residual is dominated by the noise in a single spectrum.





PC reconstruction of 9520 clear ocean SNO provides a solid statistical data set



The residuals from a single spectrum reconstruction are dominated by the random instrument noise.

We have 28650 SNO from the tropical zone from all days in April 2014.

About 20,000 of the SNO are from the tropical oceans. We focus on the 9520 tropical ocean spectra where the bt900 from AIRS <u>and</u> CrIS differs from the known SST by less than 5K (3.5K of this is due to water vapor and emissivity).

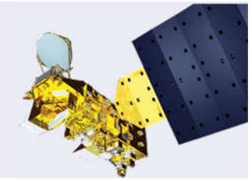
These are fairly clear spectra. An FOV at 300K where 2% of the area is covered by 200 K deep convection, but otherwise cloud free is 2K colder than the expect surface brightness temperature!

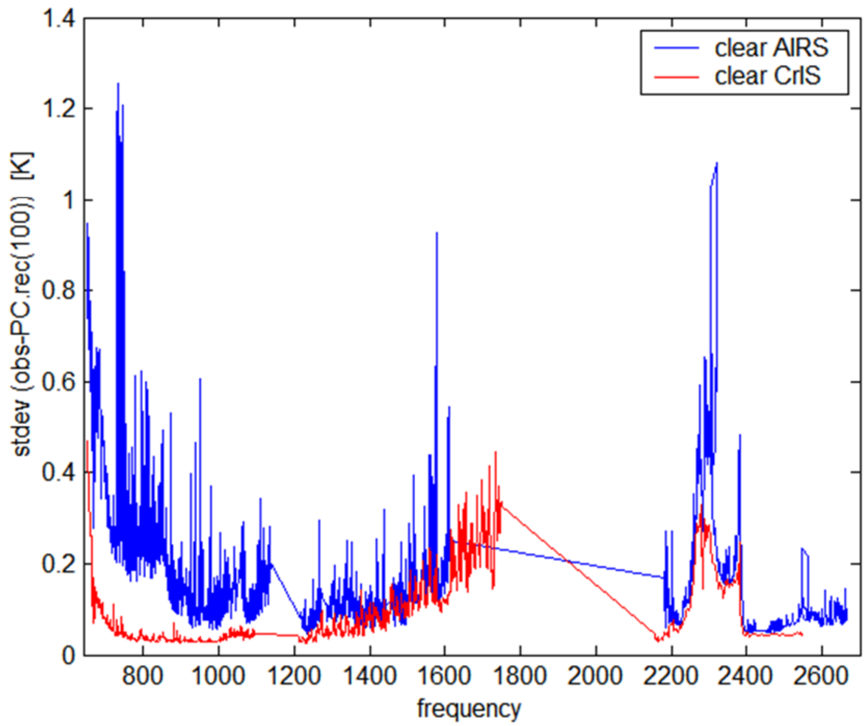
Focus on the relatively clear spectra eliminates the concern that the EV training for very cloudy spectra may be controversial.

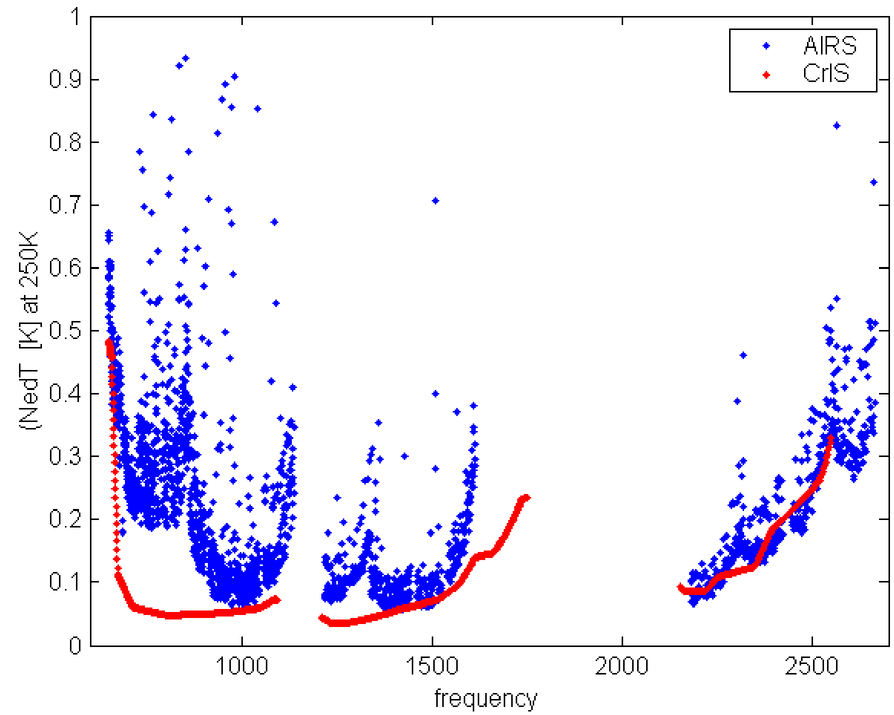
Evaluate the mean and the standard deviation of the PC reconstruction residual.

In the following plots only AIRS channel with NeDT<1K and Gaussian noise are shown. Channels with NeDT>1K, non Gaussian noise or gap filled (L1c) are not shown.

As expected, the stdev(obs-PC.rec) mimics the instrument noise-equivalent delta T.







The standard deviation of the PC reconstruction residual for CrIS is less than for AIRS, except in the shortwave band. This is consistent with the generally lower noise in the CrIS data.

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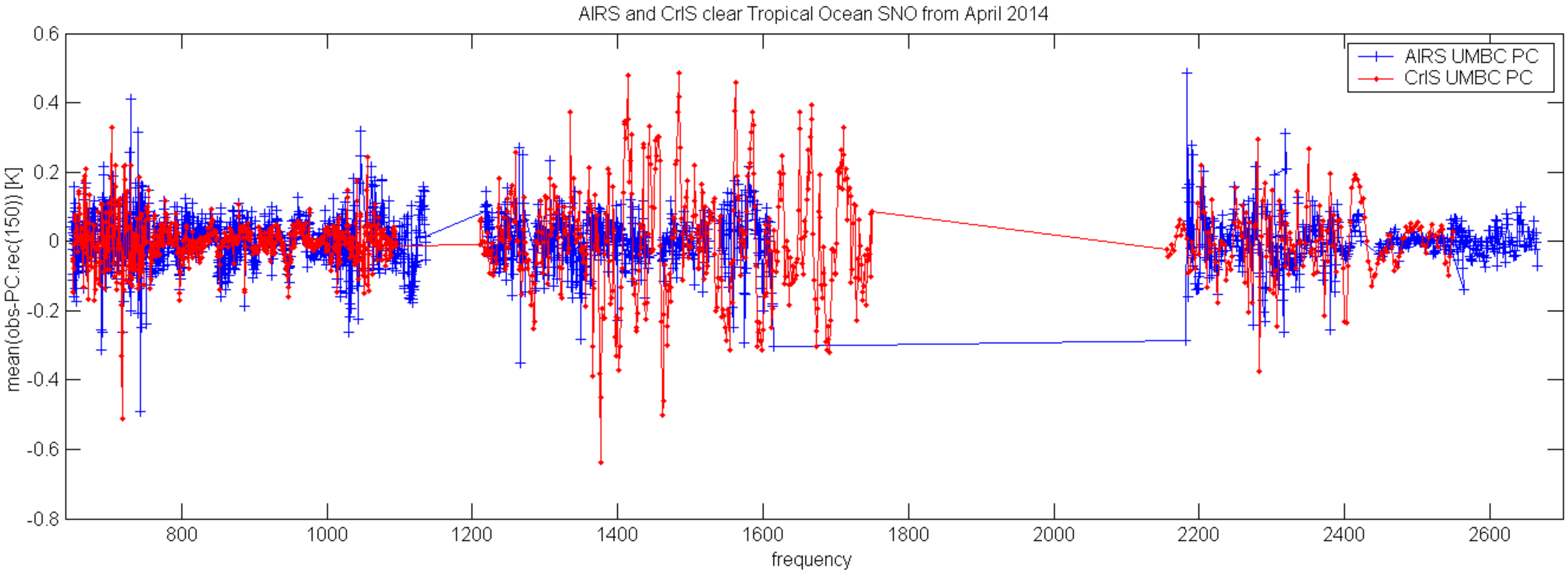
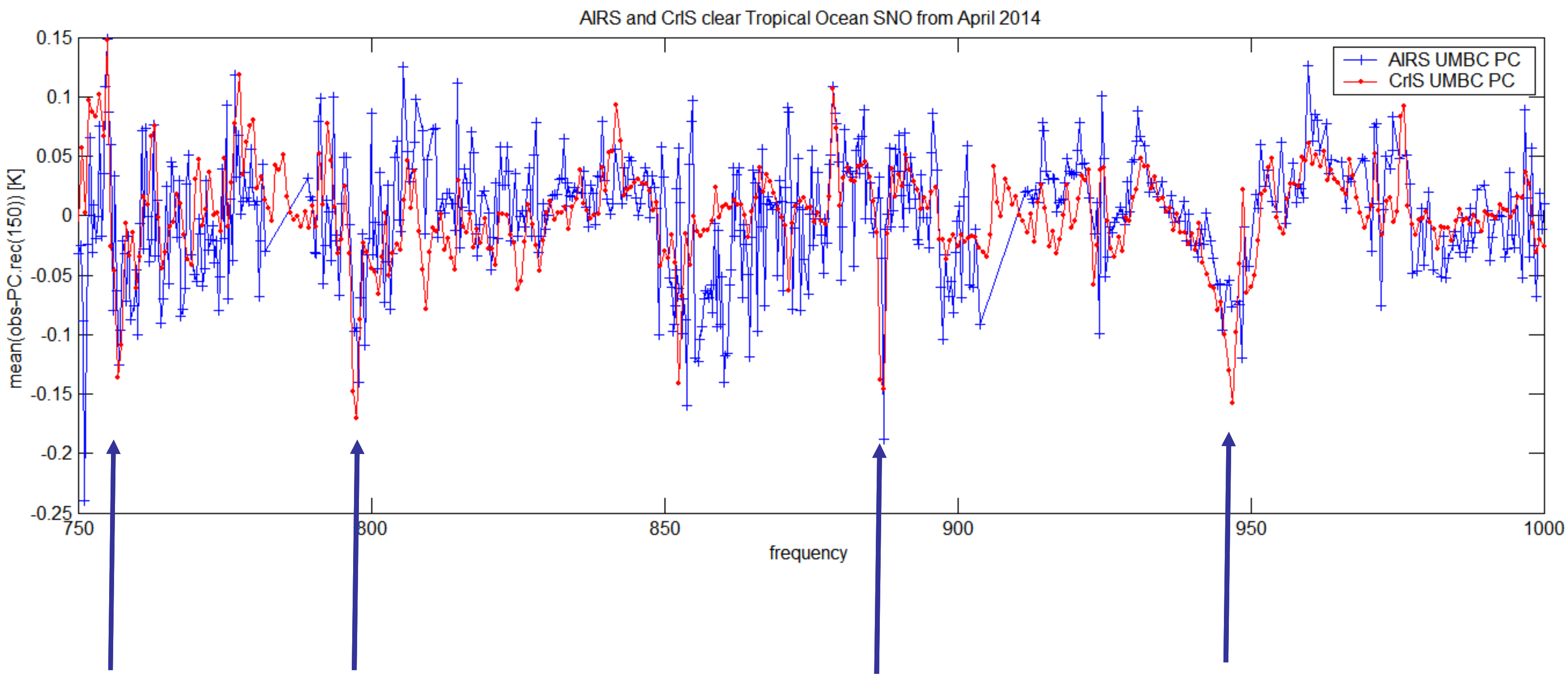
The mean(obs-PC.rec) reveals unexpected similarities and differences



Since the standard deviation of the PC reconstruction is typically much less than 1 K, the probable error of the mean is less than 10 mK (1/sqrt(9520)).

The bias averaged over all channels for AIRS and CrIS is essentially zero, but there are many AIRS and CrIS channels which have much more than 100 mK bias.

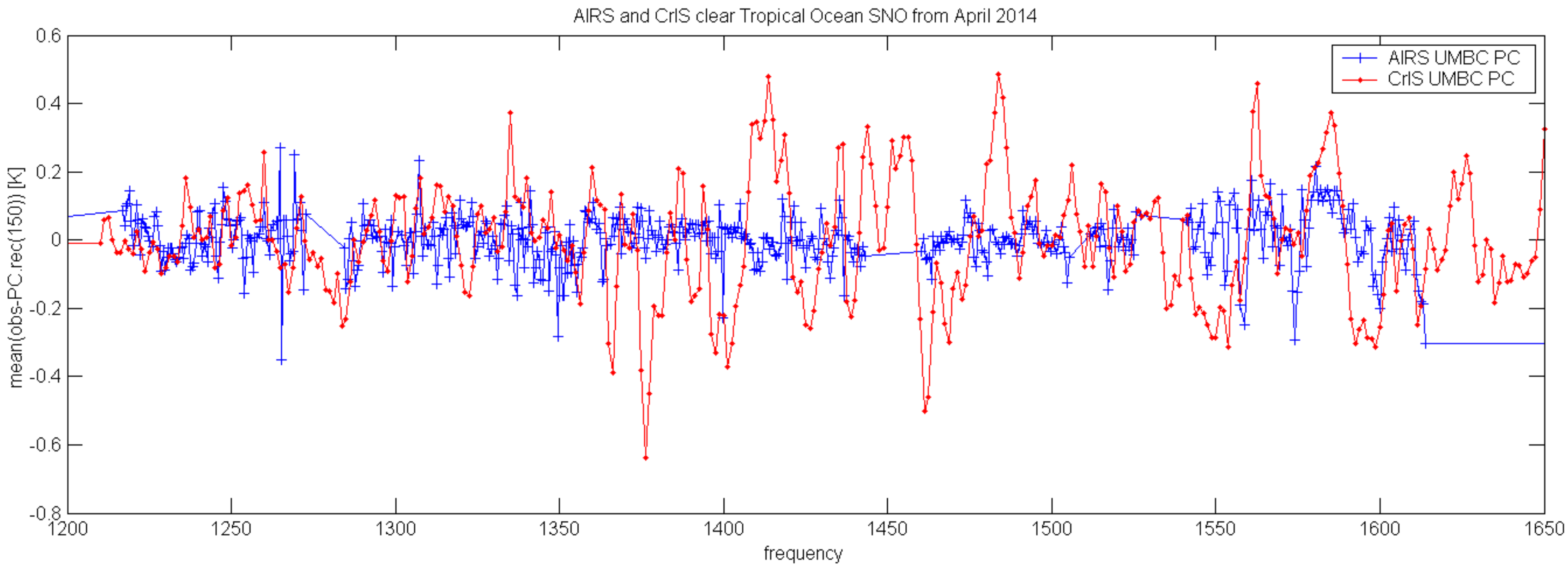
The mean(obs-PC.rec) reveals unexpected spectral features common to AIRS and CrIS



co2 at 791.7 cm-1

Ignoring the higher noise in the AIRS residuals, there are correlated features in the AIRS and CrIS residuals. The features are replicated in the UMBC and LARC reconstructions.

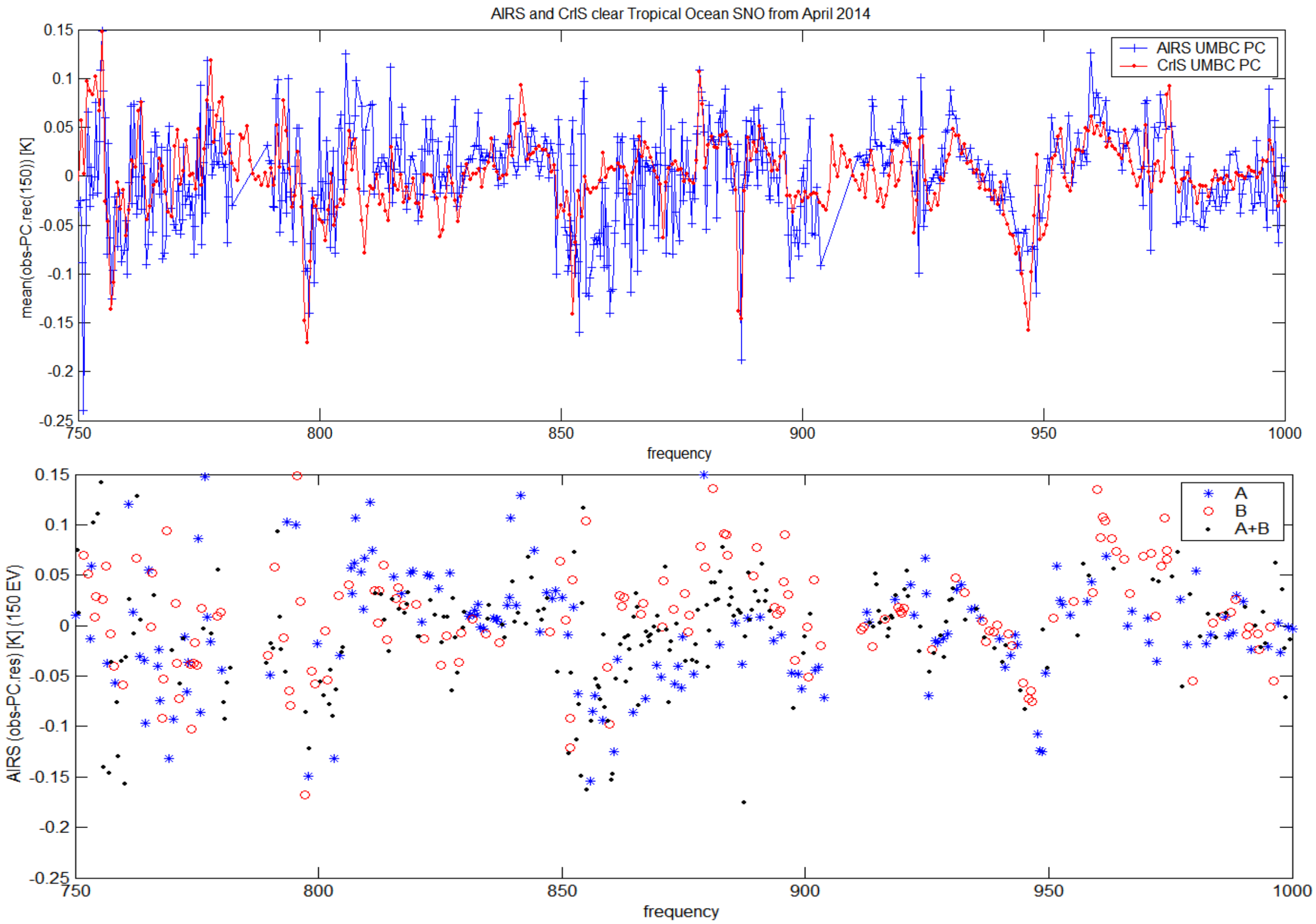
The mean(obs-PC.rec) reveals unexpected differences between AIRS and CrIS



There are bias extending over may CrIS channels as large as 0.5K in the CrIS Midwave band.

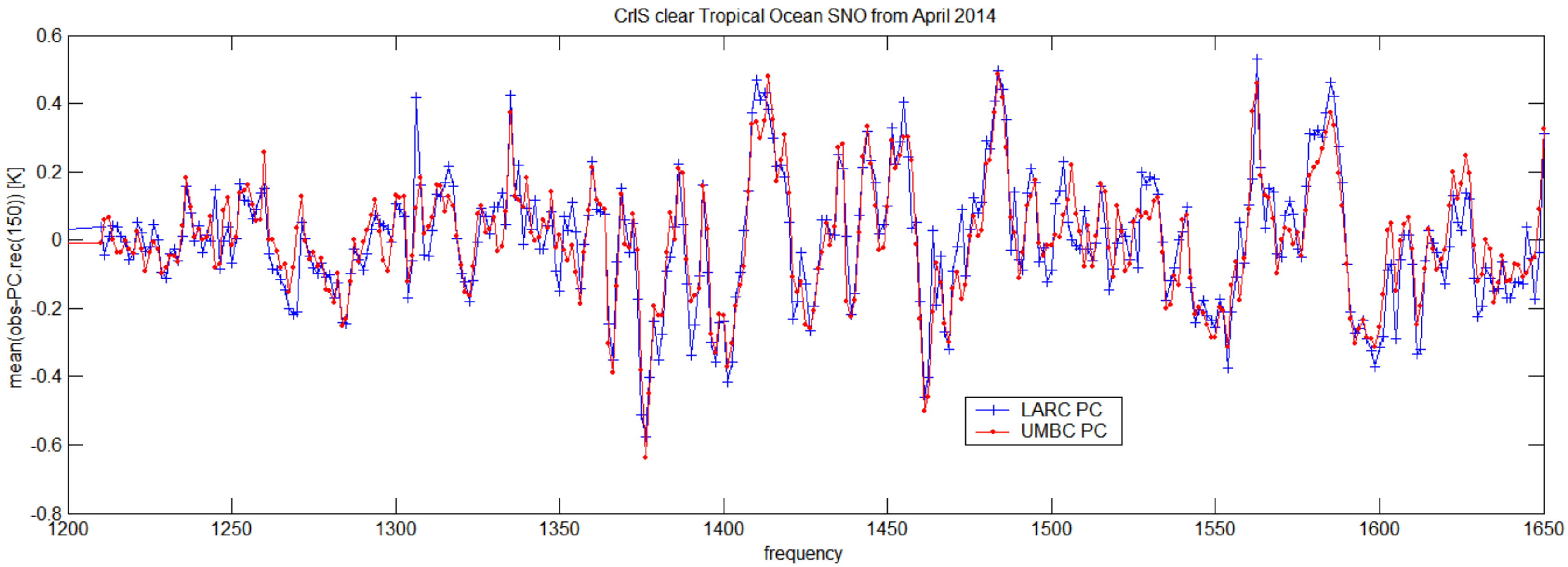
AIRS shows bias as large as 0.2K for some individual channels, but much more random variability.

The mean(obs-PC.rec) reveals A/B stated related calibration errors in the AIRS data



The bias in (obs-PC.rec) reveals 0.05K A/B state related calibration errors in the m7 – m10 detector modules. These were first pointed out by Dave Tobin in 2004 using cold cloud spectra. Here we see them for warm clear spectra.

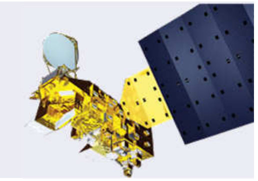
The mean(obs-PC.rec) reveals CrIS artifacts in the Midwave (water vapor) band which are seen using the LARC and UMBC based EV.



The artifacts repeat almost exactly using the UMBC and the LARC simulation trained EV. The CrIS and UMBC clear RTA are correlated, but the EV training sets are independent.

It is not clear how to interpret the difference between the small reconstruction residuals from AIRS and the much larger residuals from CrIS. This is not an RTA related effect.

Synthetic EV reveal how well the observed spectra agree with expectations.



We use training sets created from a representative set of simulated spectra to create synthetic EV. The simulated spectra represent what we expect the spectra look like based on RTA, scattering code and our understanding of the instruments.

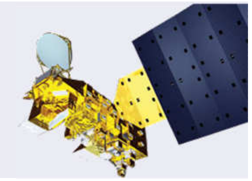
For a large ensemble of spectra we expected the mean reconstruction residual to be zero. Instead we see spectra structures as a large as 0.5K.

There are some spectral region where the bias is seen in AIRS and CrIS. In these area the RTA used by UMBC and LARC to simulate the data left out some atmospheric species or the species or the region is sensitive to the stratospheric temperatures.

For AIRS bias value as large as 0.1K may be attributed to SRF error which propagate in the RTA. A/B state related calibration errors at the 0.05K level are seen.

The large bias in the reconstruction residual in the water vapor band is only seen in CrIS. Since it is not seen in the AIRS RTA, it is creates by the unique features in the CrIS RTA or the CrIS calibration.

Summary



We use synthetic EV to reconstruct relatively clear tropical ocean AIRS and CrIS spectra

We see significant PC reconstruction residuals in the AIRS and CrIS spectra.

The AIRS channels with significant reconstruction residuals are already known and those channels are not used for retrievals and data assimilation.

For CrIS we see unexpected reconstruction residuals in water vapor channels.

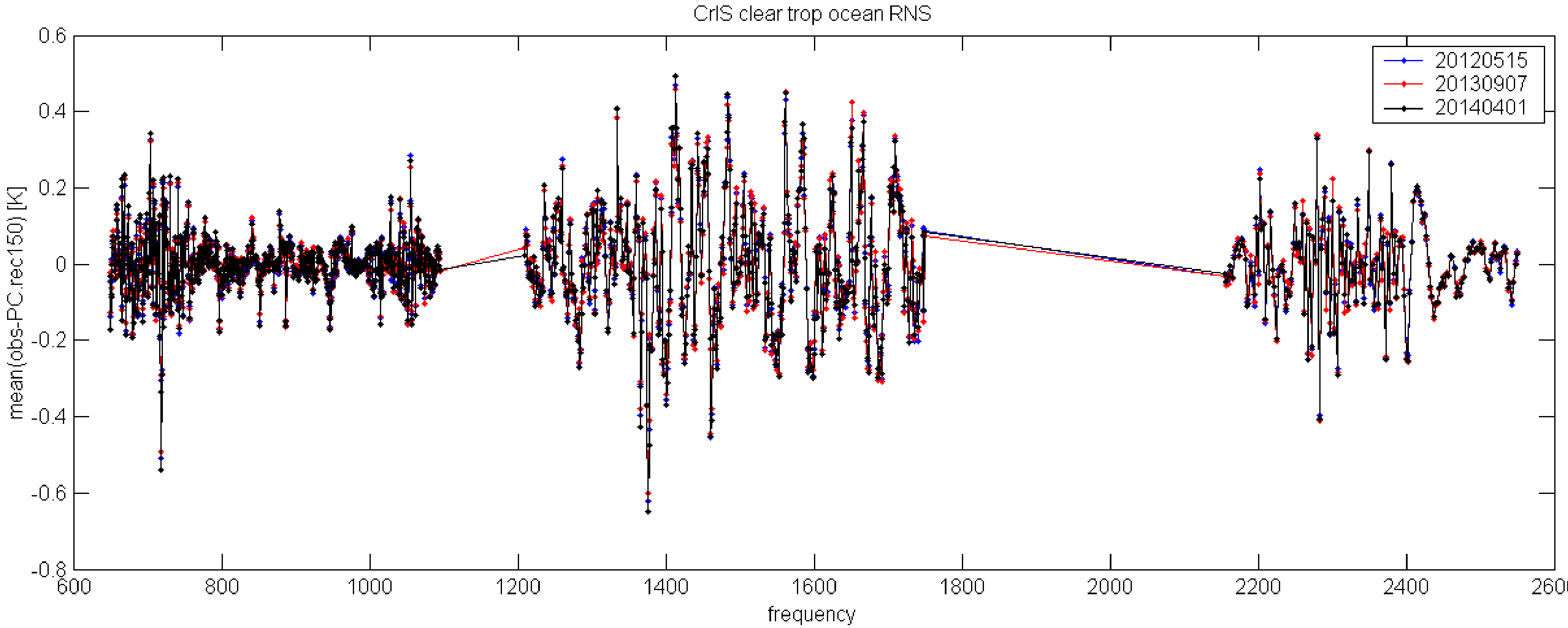
Unexpected reconstruction residuals mean that the conversion of the atmospheric state in the spectra (the forward algorithm) is not well understood. This causes problems with the retrievals and direct assimilation.

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

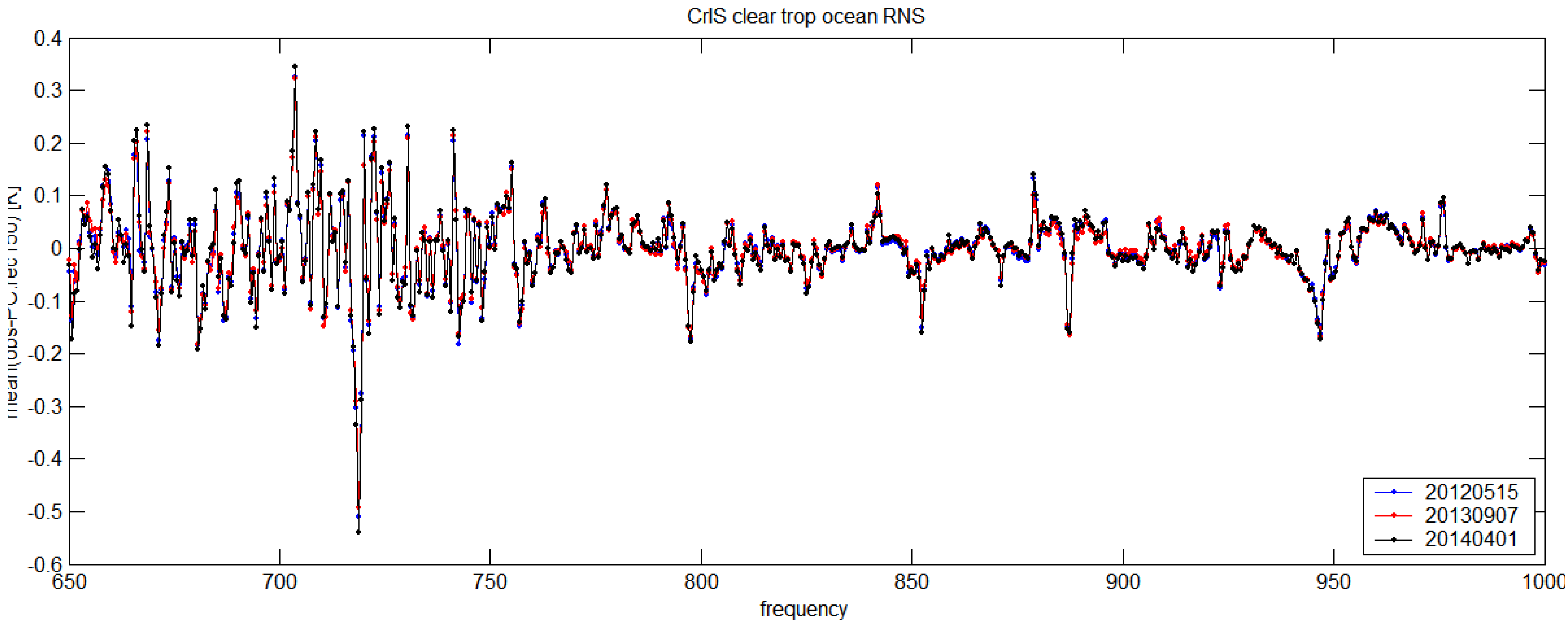
Discussion with the UMBC team regarding artifacts in the RTA have started.

Any Questions?

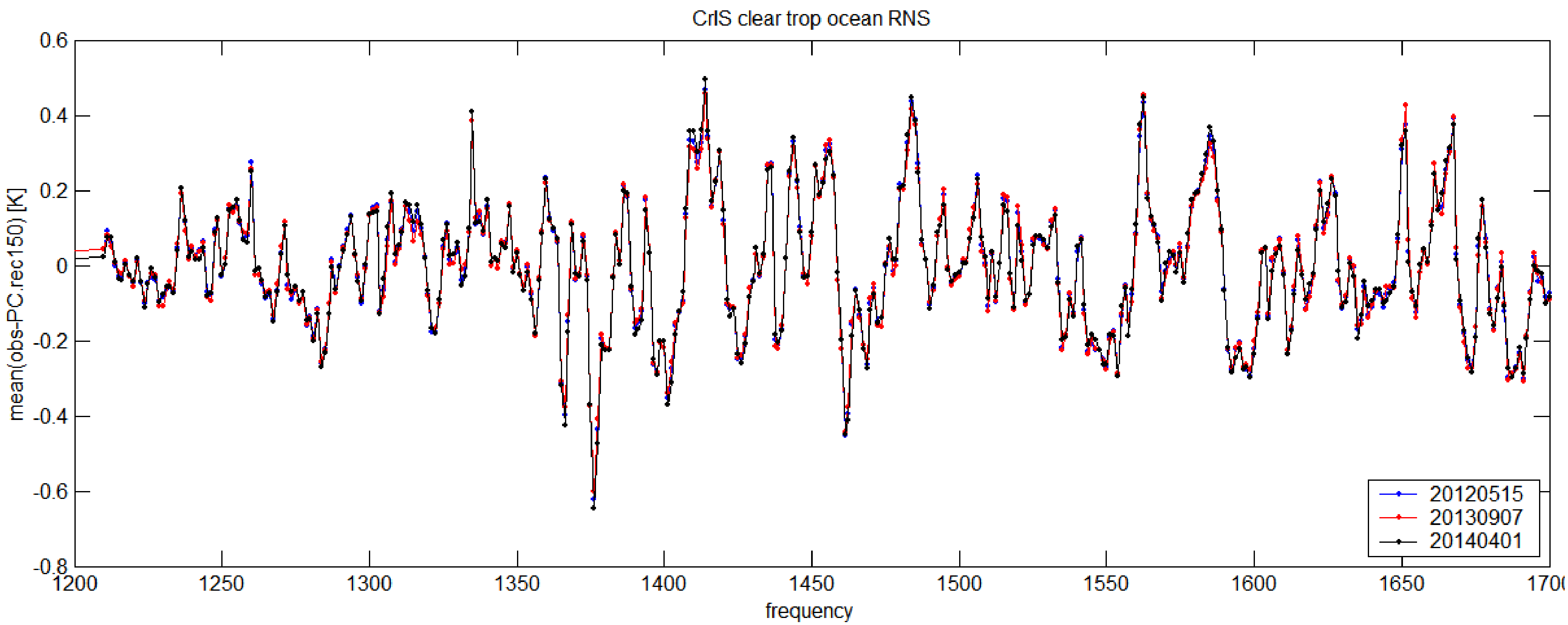
The mean(obs-PC.rec) spectral features are seen in CrIS clear tropical ocean spectra from 2012, 2013 and 2014.



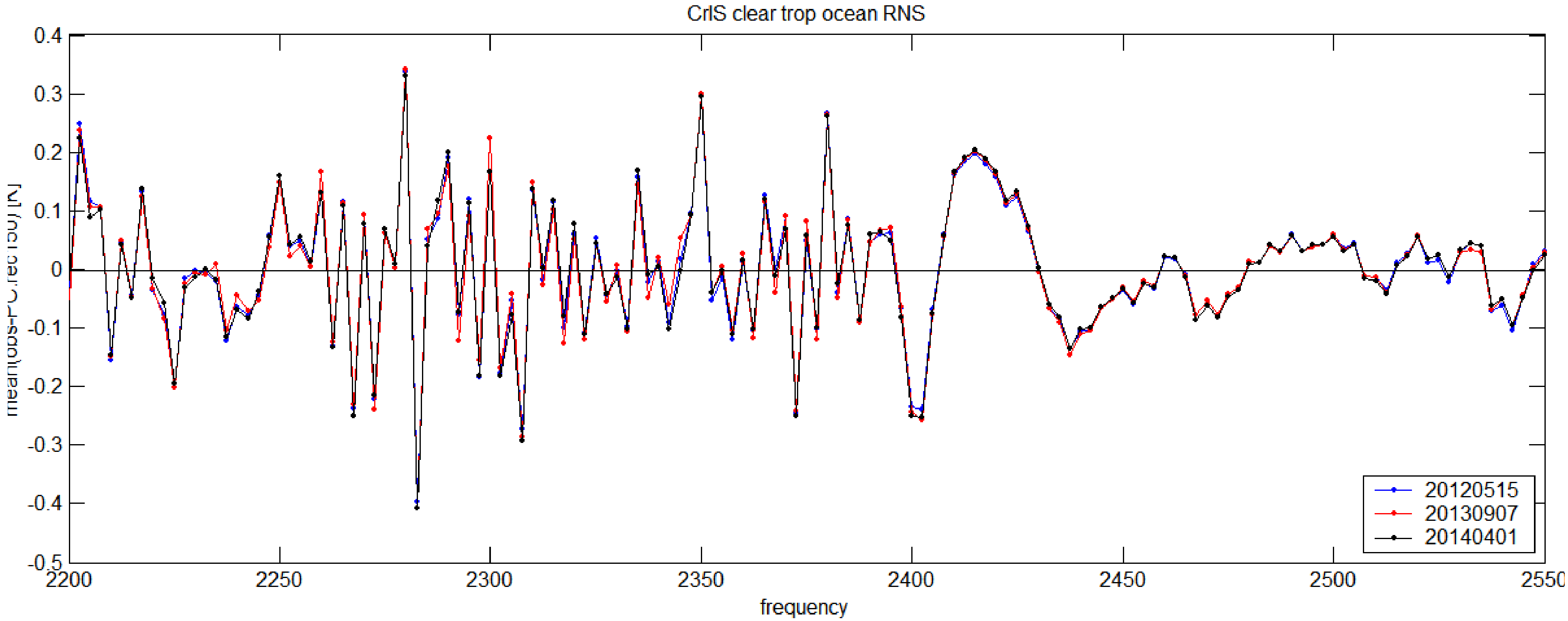
The mean(obs-PC.rec) spectral features are seen in clear tropical ocean spectra from 2012, 2013 and 2014(UMBC based EV).



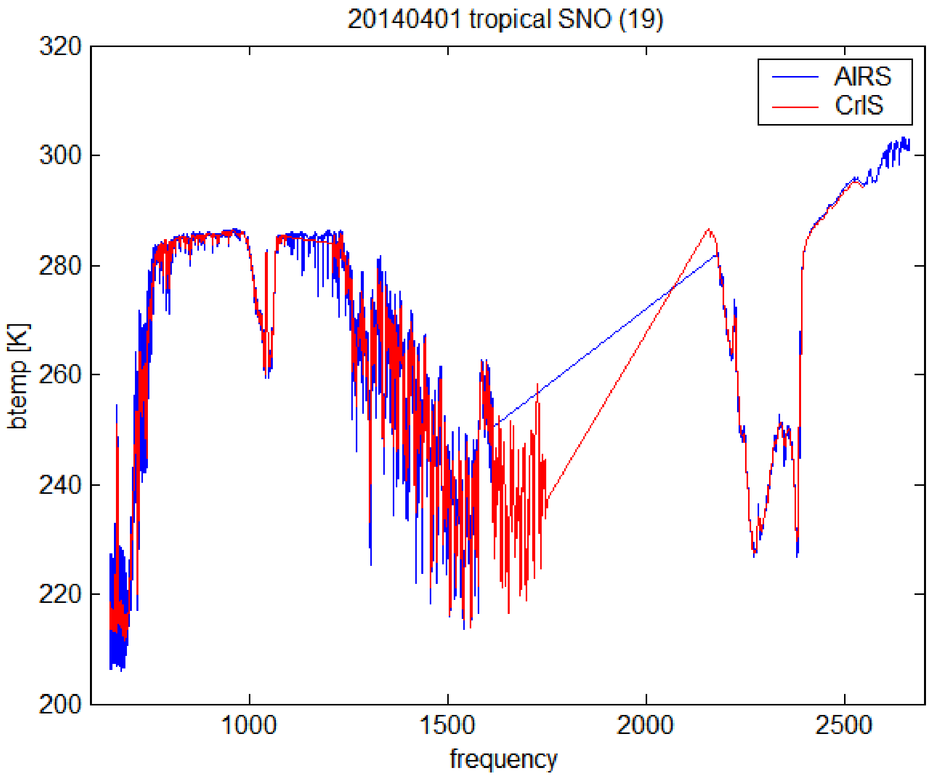
The mean(obs-PC.rec) spectral features are seen in clear tropical ocean spectra from three days from 2012, 2013 1ne 2014(UMBC based EV).

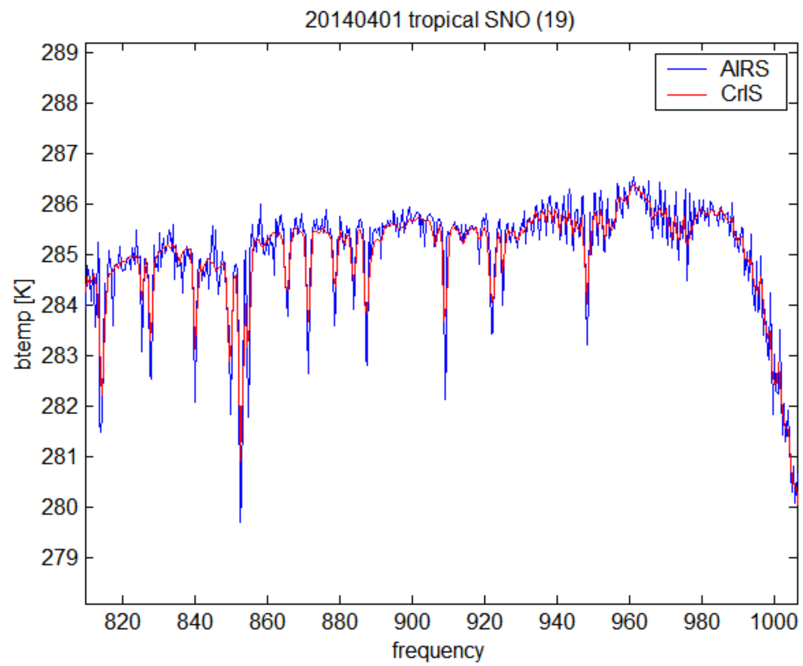


The mean(obs-PC.rec) spectral features are seen in clear tropical ocean spectra from 2012, 2013 1ne 2014(UMBC based EV).



How close do real AIRS and CrIS spectra agree with our expectations?





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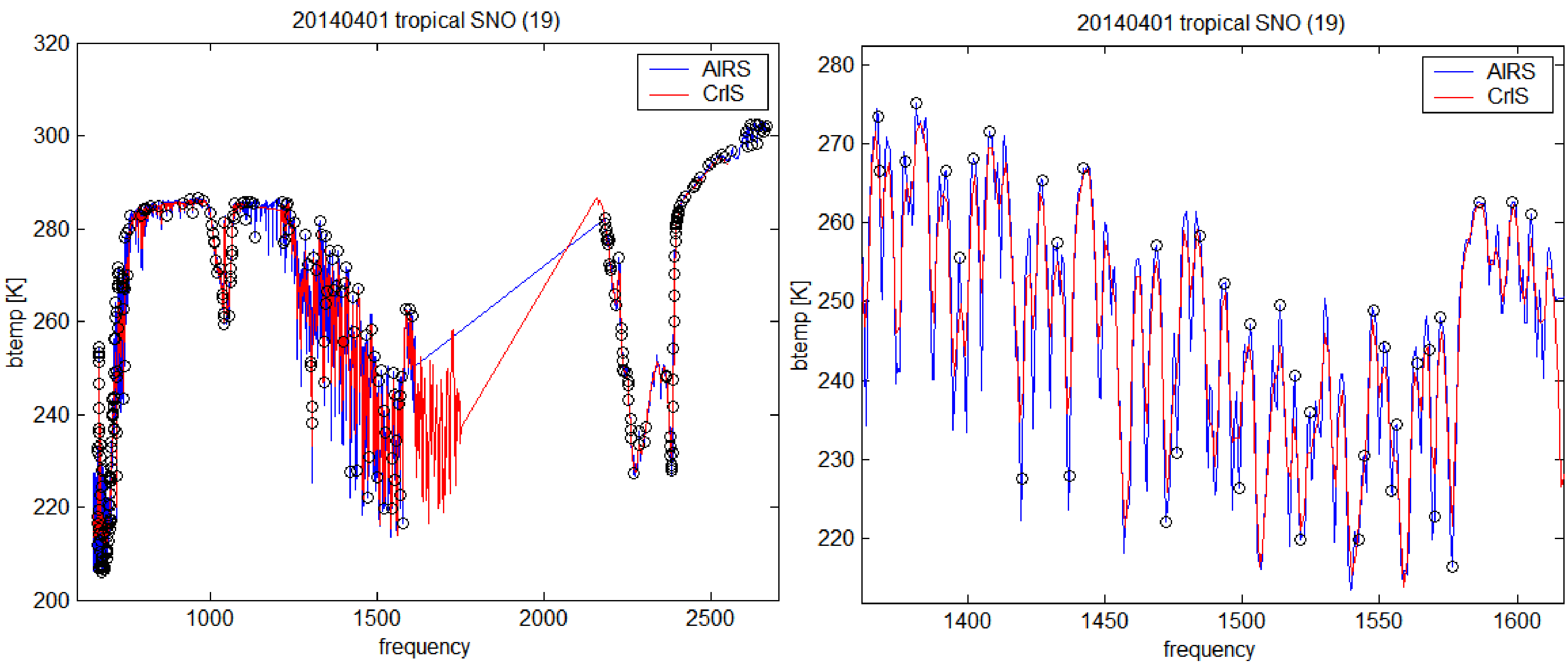
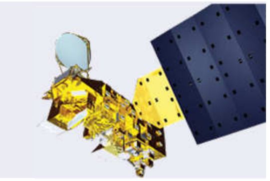
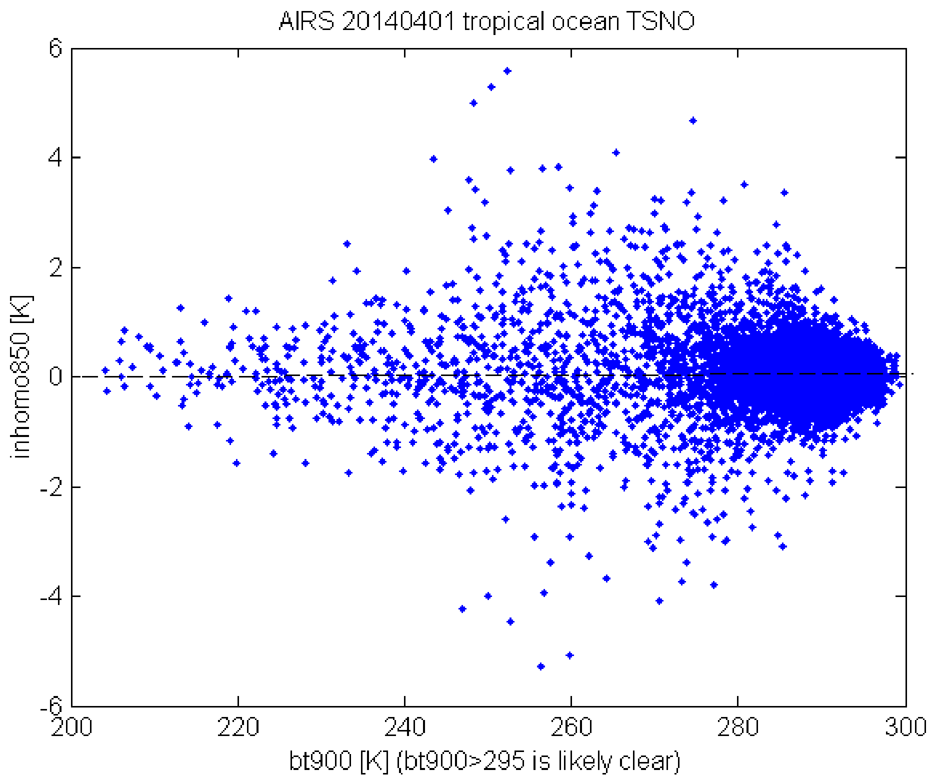
ECMWF uses closely the same channels for AIRS, IASI and CrIS.





The AIRS Cij effect reveals high spatial contrast for spectra with bt900<295K



The btemp from a clear 300K surface is only 1K warmer than if 2% of the surface is covered by deep convection (200K).

The highest spatial contrast in the tropical oceans occurs for 240K < bt900 < 280 K.