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Lessons from the AIRS, IASI and CRIS hyperspectral infrared sounder data.

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Outline

Hardware: Differences and similarities

L1B and QC

Random nadir spectra for Climate Quality assessment

Lessons for the specification of future hyper-spectral instruments to be included in the SPIE paper.

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Hardware: Differences and similarities

AIRS is a grating array spectrometer with 2378 independently calibrated channels

> AIRS calibration artifacts are visible as offsets between radiometrically equivalent adjacent channels in the same spectrum.

CRIS and IASI are FTS spectrometers with 27 (12) independently calibrated detector elements channels

> CRIS and IASI calibration artifacts are visible as offsets of entire spectra generated by different detector elements.

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AIRS Quality Control is channel oriented rather than spectrum oriented

AIRS L1B uses an 8 bit CalFlag. Data is good if all bits are zero

- 65 of 2378 channel (2.7%) are dead
- About 65 channels (2.7%) have NEDT250>1K
- 94% of the 2378 channels are good for all spectra.

Ignoring the 130 dead or bad channels, 99.93% of the AIRS spectra are essentially always available.

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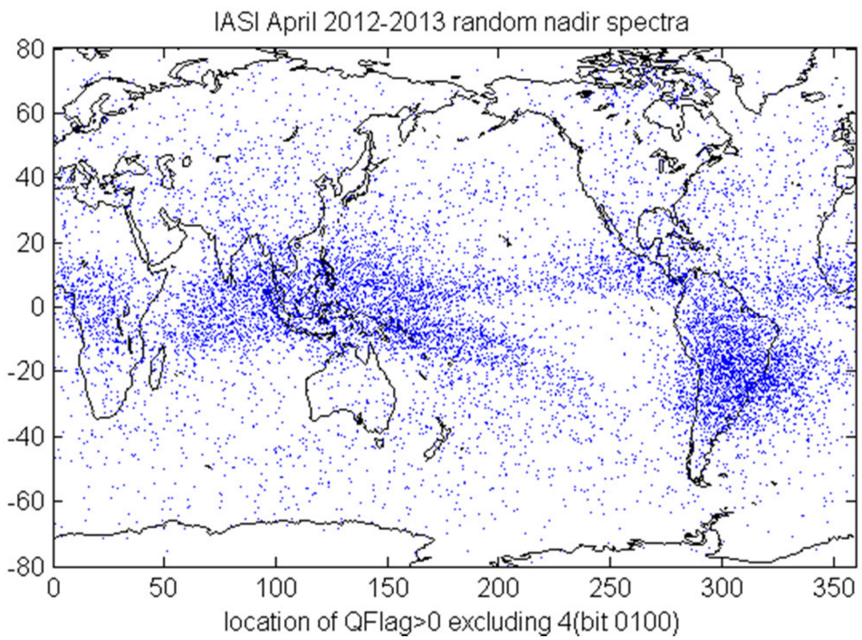
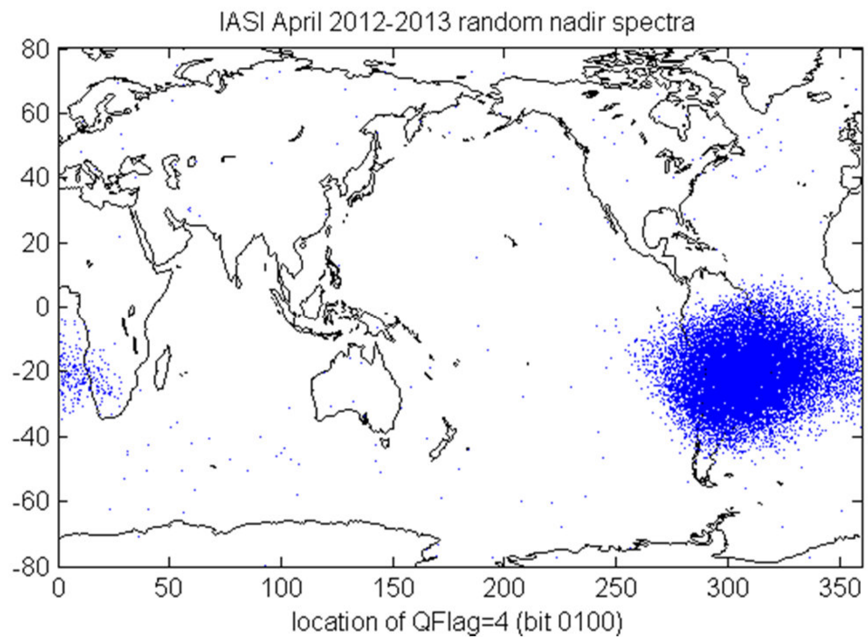
IASI Quality Control is spectrum oriented

No L1B is available from IASI. The L1C uses an 8 bit quality flag. On average 0.8% of the spectra are flagged low quality. The location of low quality spectra is not spatially uniform.





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CRIS Quality Control is left almost totally to the user.

CRIS uses a collection of indicators, but no single quality flag. About 1% of the data have lat/lon/sza encoded with -999.8. For an additional 0.5% of the data the imaginary component is larger than 10% of the real component. For these data there is no obvious geographical pattern.

All CRIS examples shown in the following use the NGST operational L1B filtered by valid coordinates, radiance not zero, 160K<bt900<350K, std(imaginary)>0, std(imaginary)<0.6 and std(imaginary)/mean(real)<0.1 in the LW band. This has virtually no effect on mean, but effects hot and cold extremes. Our CRIS data set includes bt900 as low as 138K and as high as 386K (over tropical ocean!!!) , which were eliminated by our QC filter

We focus on the window channel at 900 1/cm to avoid issues of SRF differences between AIRS, CRIS and IASI.

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Climate Quality

An instrument produces climate quality data, if the in-depth analysis of the data does not produce artifacts which can be misinterpreted as climate.

Unresolved differences in the mean or the extremes for two equivalent instruments in orbit at the same time are artifacts.

An accurate calibration at all scene temperatures and conditions is a necessary, but not sufficient condition for climate quality.

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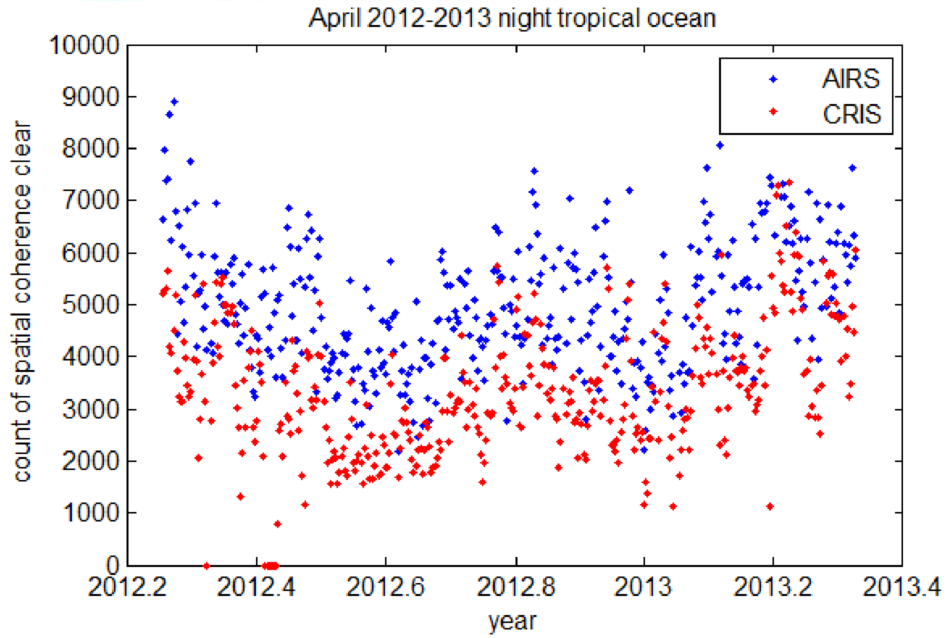
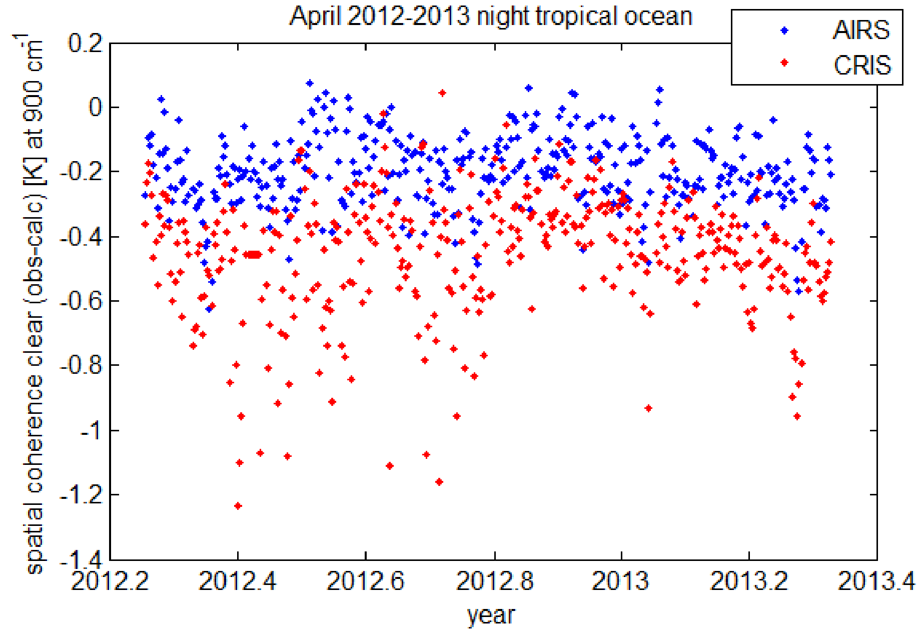
Agreement for (obs-calc) can be misleading



AIRS identifies typically 5000, CRIS 3300 spatial coherence clear spectra for night tropical ocean.



AIRS has a cold bias of -0.20K, CRIS has a cold bias of -0.45K.

This result means little for the absolute calibration accuracy or the data usability for climate, since the clear condition eliminates clouds as well as instrument artifacts.

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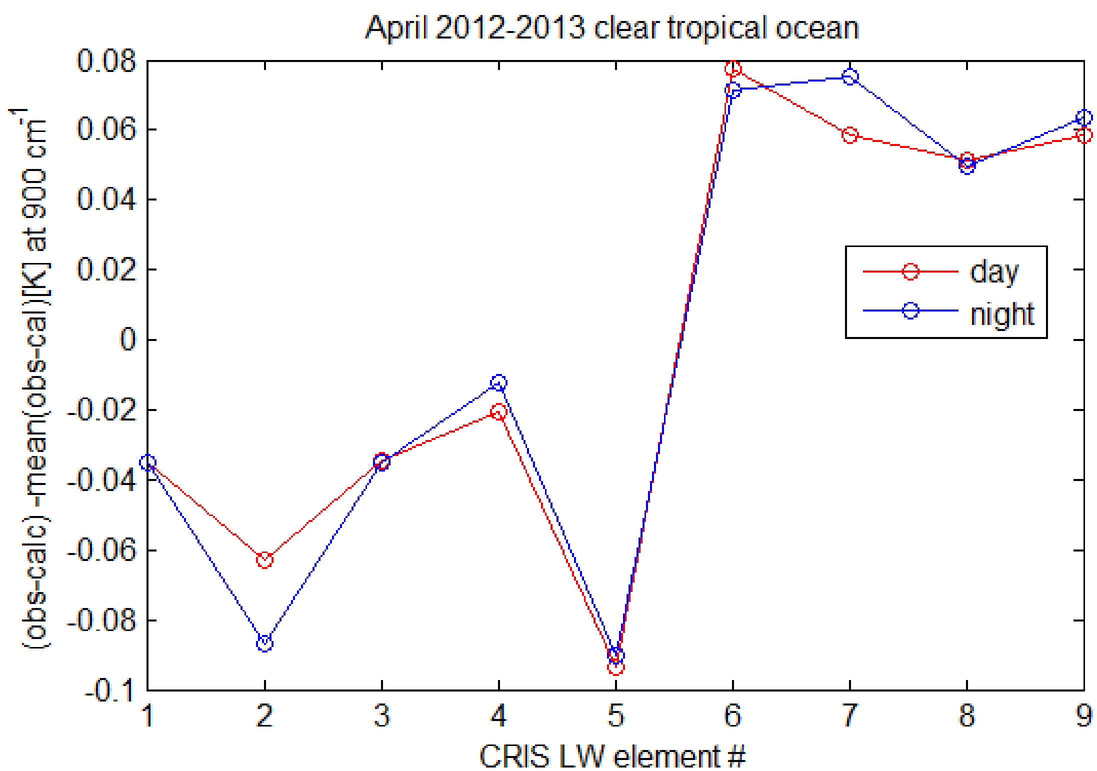
The is day/night difference in the CRIS (obs-calc) bias for the 9 array elements under tropical ocean warm clear conditions is consistent, but relative small.



The CRIS (obs-calc) for the different 3x3 elements differ from the mean by up to 80mK (stdev=0.058K) at the mean brightness temperature at 900 cm-1 of 296K.

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Use Simultaneous Nadir Overpasses (SNO) and Random Nadir Spectra (RNS) as objective test for climate quality.

The identification of “clear” is subjective. Accepting more spectra as clear will increase the negative bias.

The clear filter acts as an extremely tight QC filter. Cloudy as well as artifacts are rejected as cloudy.

The clear data are not globally representative.

Simultaneous Nadir Overpasses of AIRS and CRIS can be objectively selected. CRIS and AIRS SNO have been collected at JPL. (Analyzed by L. Strow)

Random Nadir Spectra from AIRS, IASI and CRIS can be objectively selected and compared.

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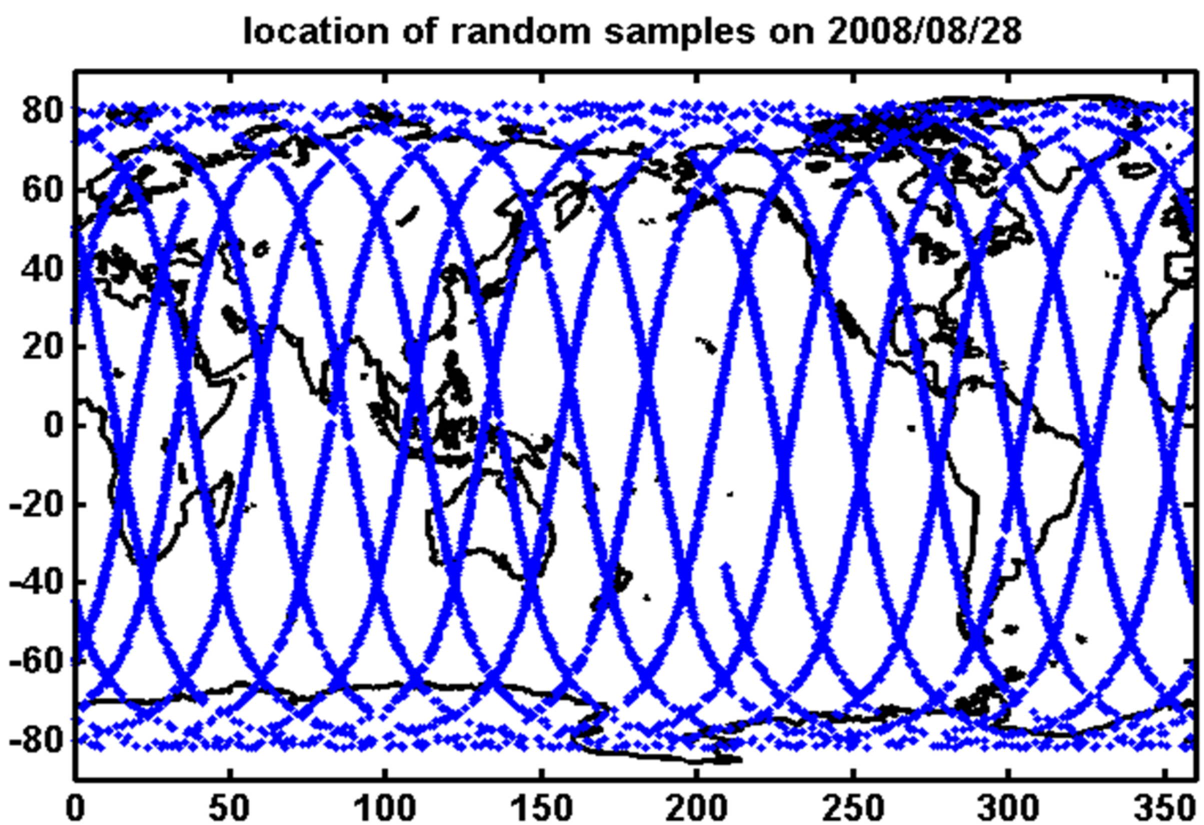
Random Nadir Spectra can be used as objective test for climate quality



Global distribution of the 20,000 random nadir samples from AIRS. One year of data produces over 7 million spectra.

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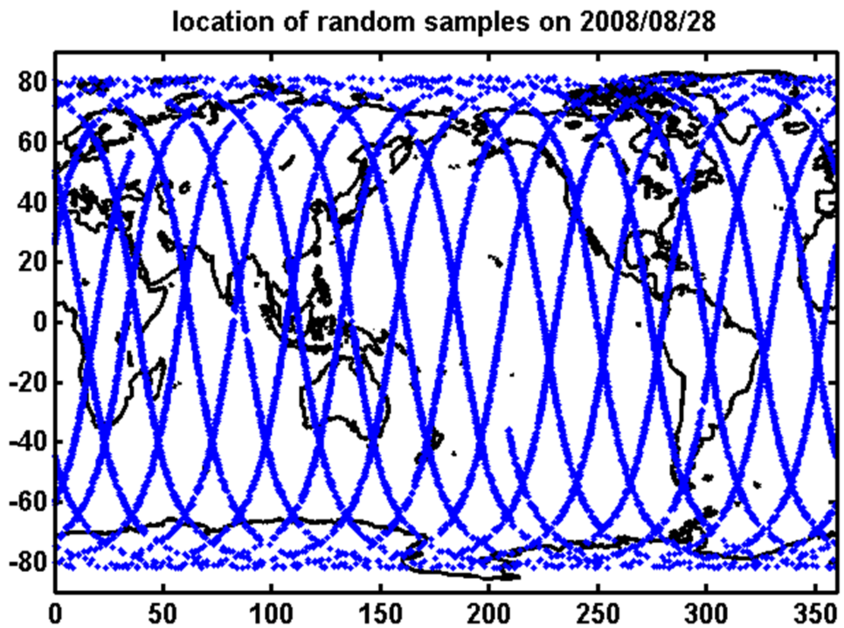
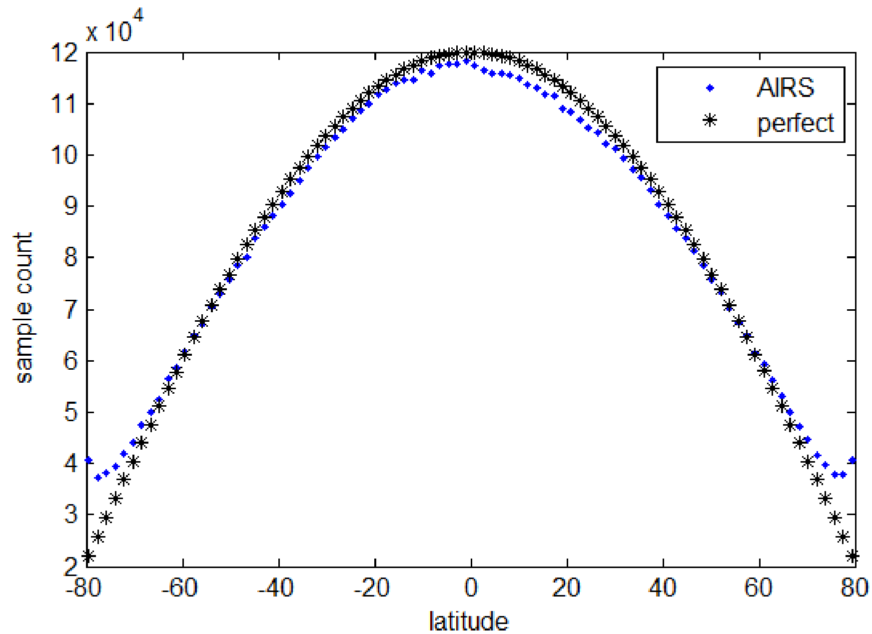
Random Nadir Spectra can be used as objective test for climate quality only if the zonal distribution is normalized to a perfect distribution.



Global distribution of the 20,000 random nadir samples from AIRS. One year of data produces over 7 million spectra.



Global distribution of one year of AIRS RNS (7 million spectra) compared to the ideal distribution. The observed distribution is not perfect because of imperfect sampling and missing data unrelated to data quality.

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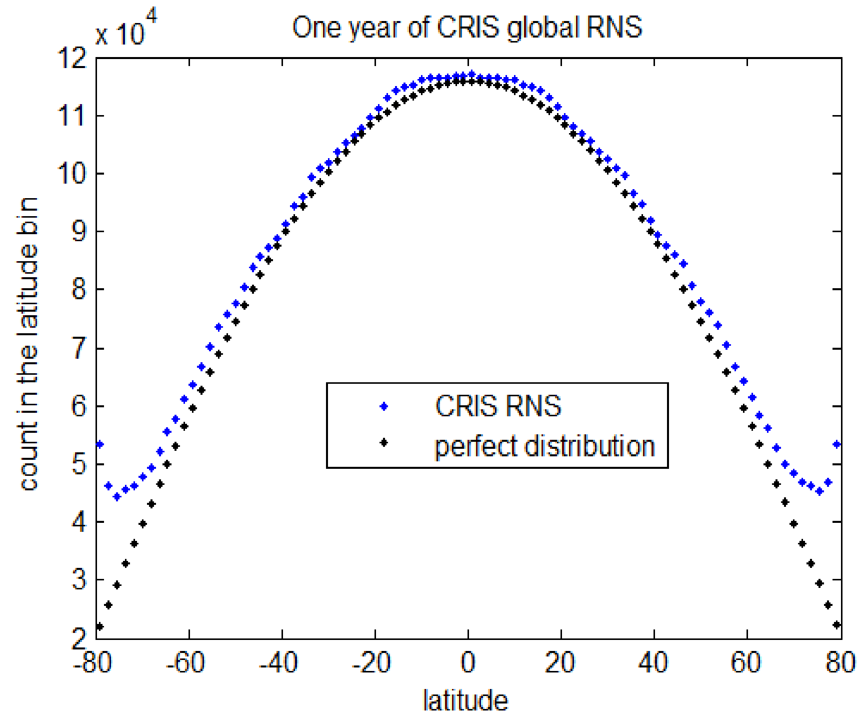
In order to compare the global PDF from different instruments the spatial coverage has to be accurately normalized.

We do this by normalizing the Random Nadir Spectra in narrow latitude zones using

$$Np(lat) = No * \cos(lat)$$

No is selected such that the observed N(lat) is larger than the Np(lat)



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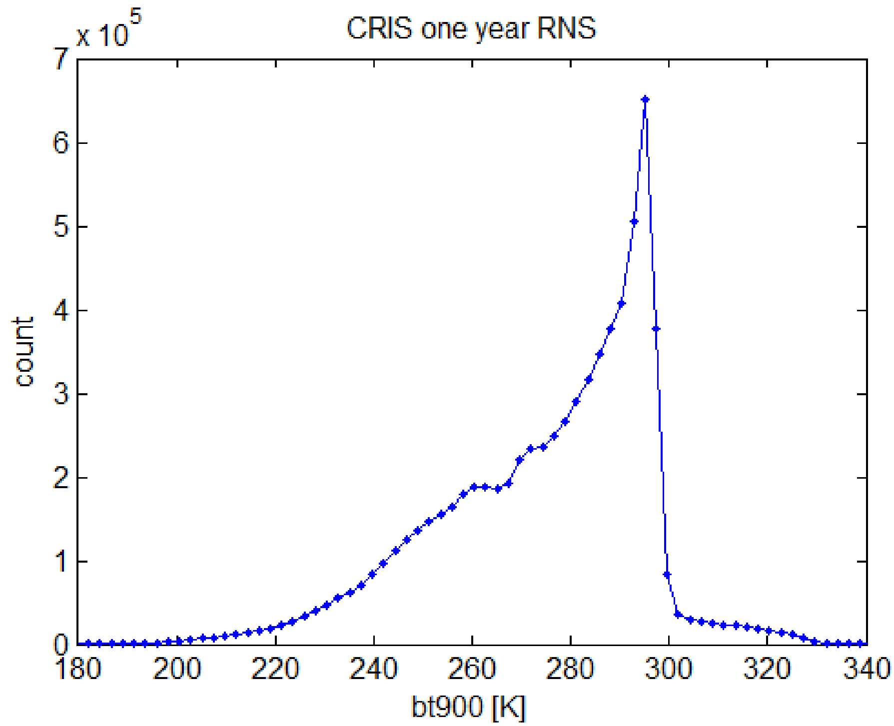
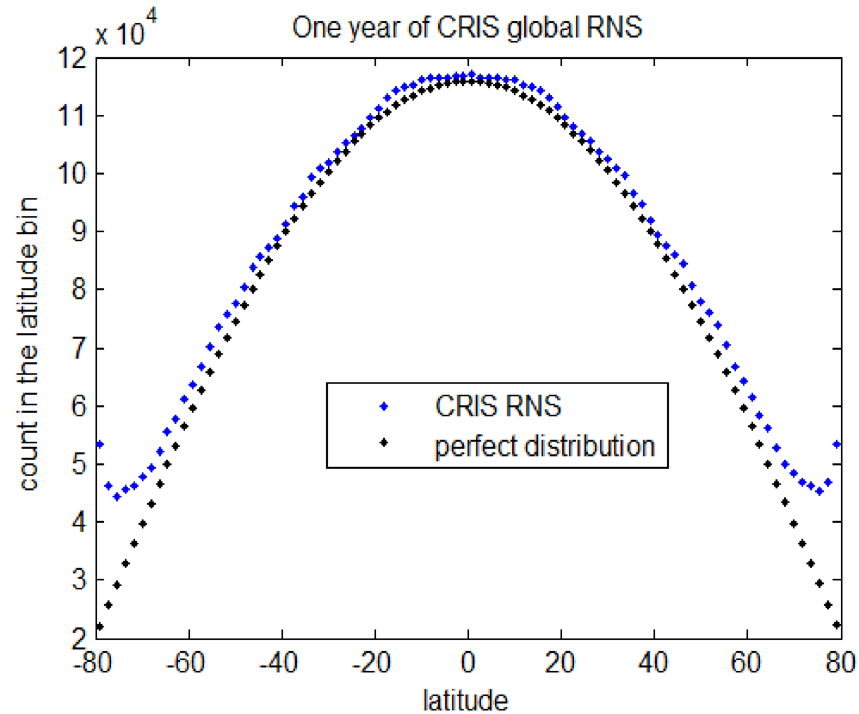
The PDF of the RNS have to be latitude normalized.





After latitude normalization the CRIS bt900 has a mean= 275.10 K for 7.2 million spectra (PE=0.008 K) averaged over all 9 detector elements

The latitude normalization randomly selects the number of samples calculated for a perfect distribution for each 2 degree wide latitude bin.

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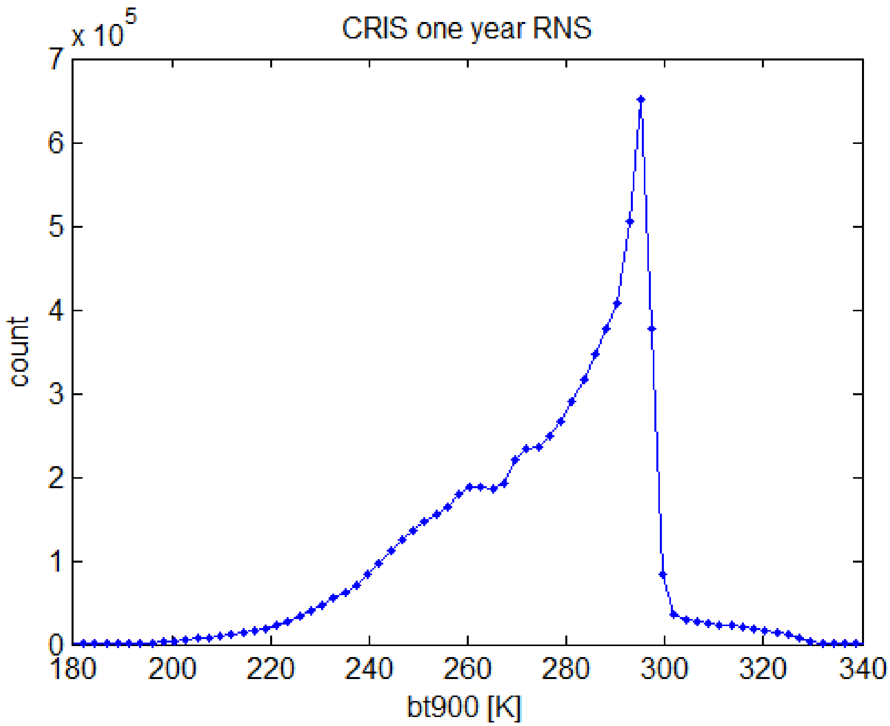
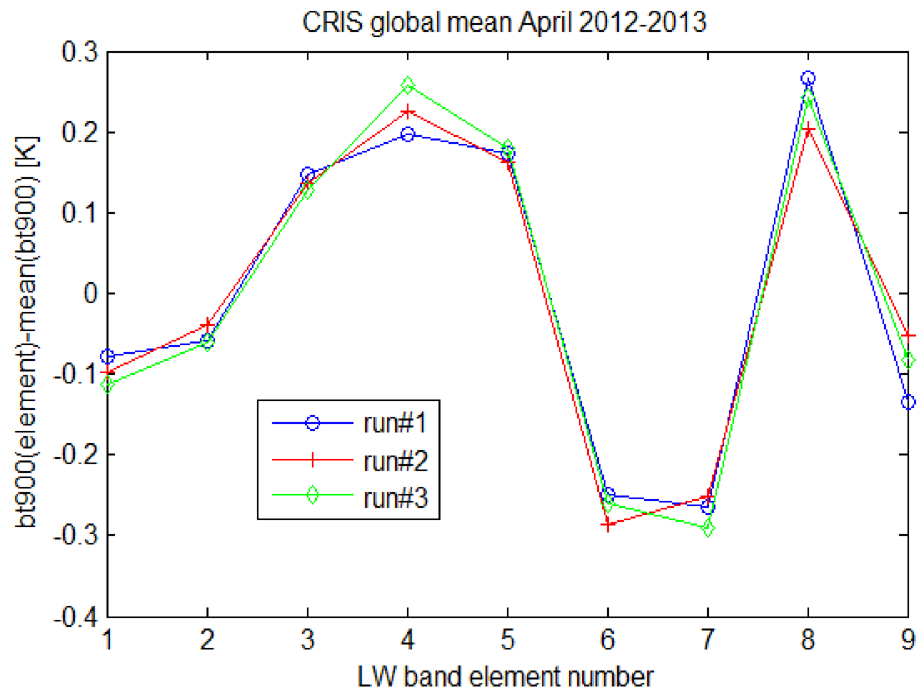
The mean of the PDF of the CRIS LW band detectors differ by +/-0.3K from the mean for all elements.





After latitude normalization the CRIS bt900 has a mean= 275.10 K for 7.2 million spectra (PE=0.008K) averaged over all 9 elements

The mean of the latitude normalized PDF for the individual detectors differs by +/-0.3K from the mean for all elements.

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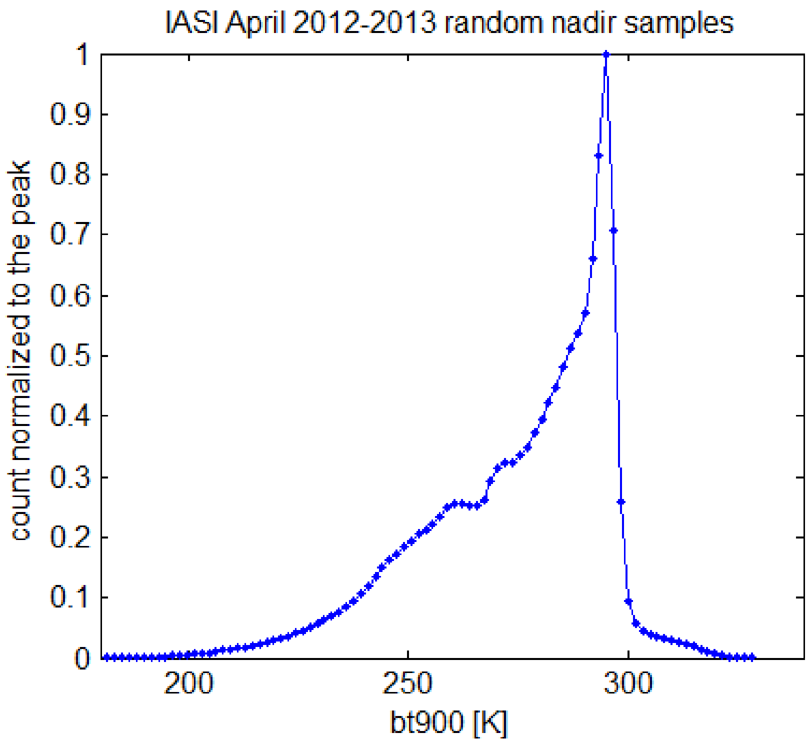
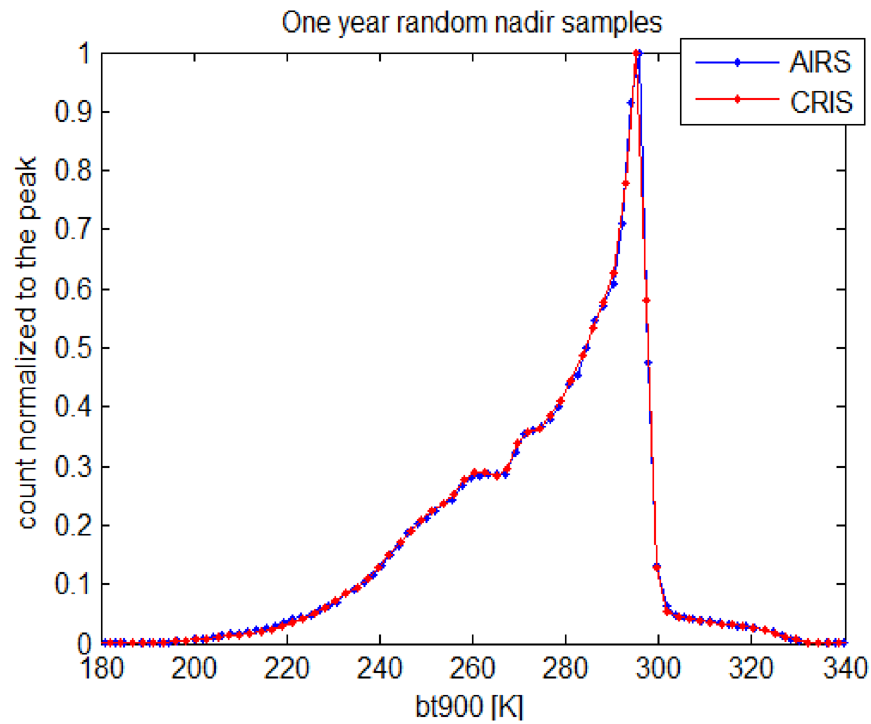
The latitude normalized AIRS. IASI and CRIS mean PDF agree within 50 mK ! !??





After latitude normalization the IASI has a mean= 275.20±0.011 K averaged over all 4. The elements differ from the mean by up to ±0.03K

After latitude normalization the CRIS bt900 has a mean= 275.10±0.008 K averaged over all 9 elements. The AIRS mean=275.13±0.008 K

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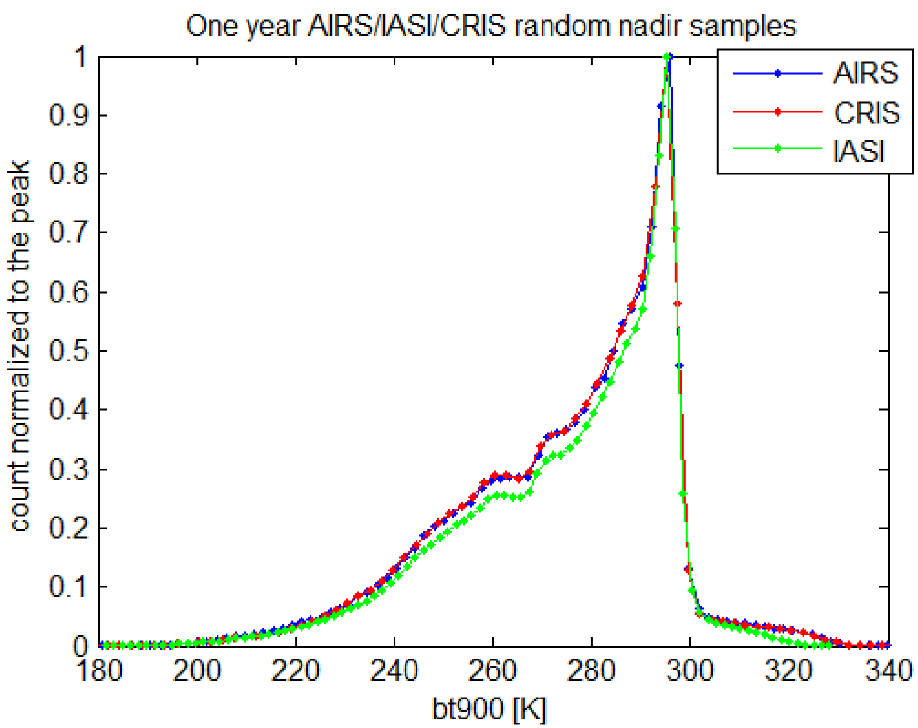
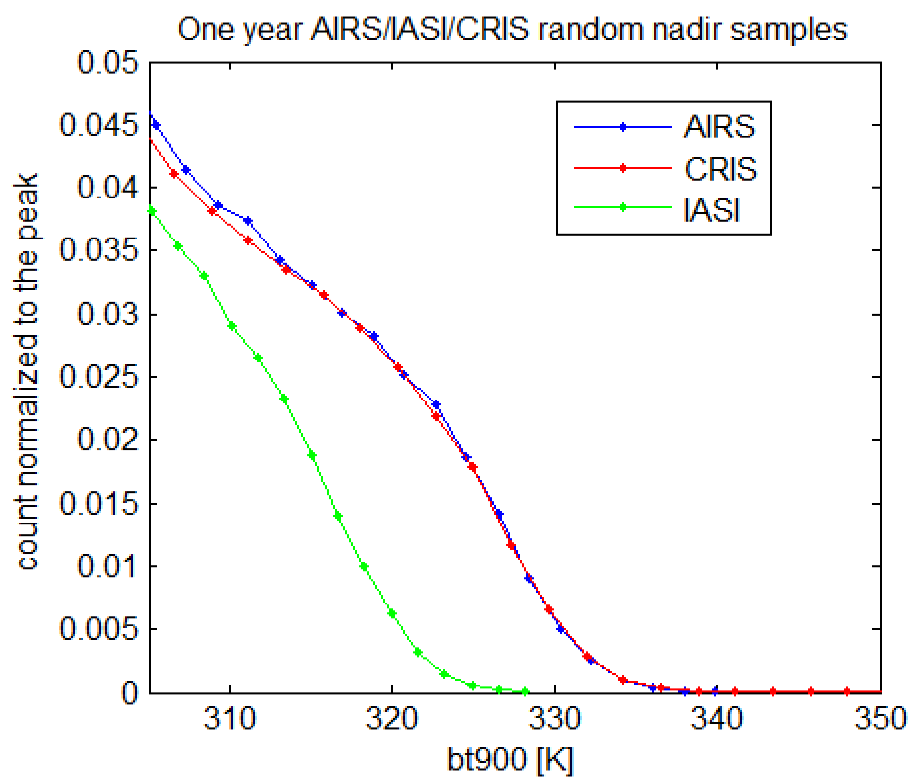
The IASI orbit has fewer clouds, but colder surface temperatures.





mean= 275.21 K range=[180.8 328.99] 3.6 million spectra (PE=0.011 K)

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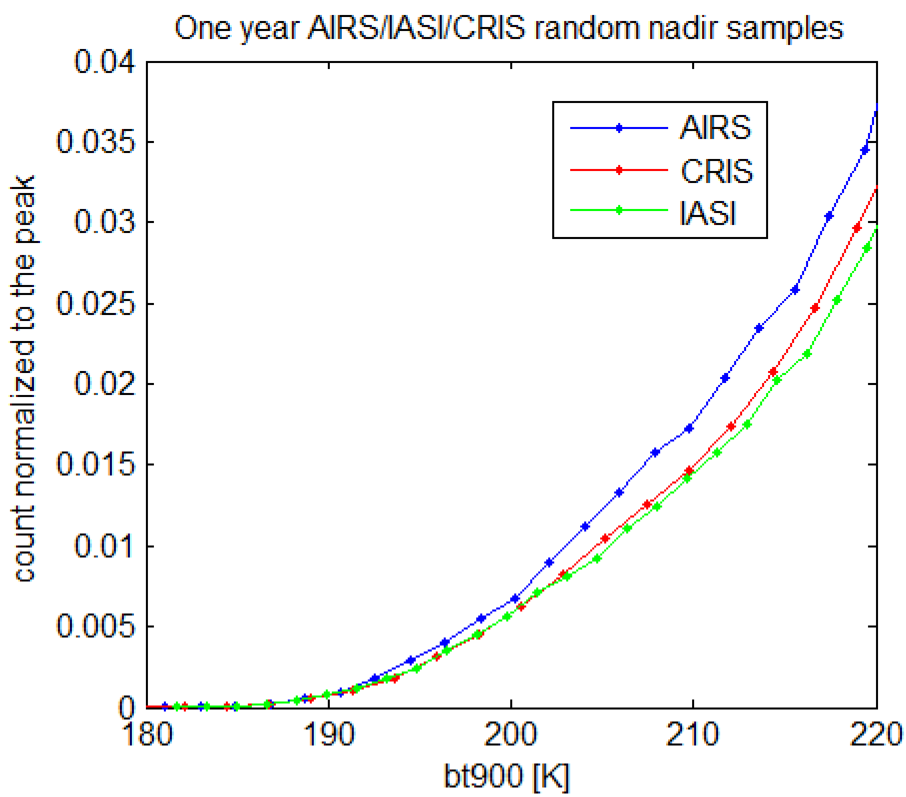
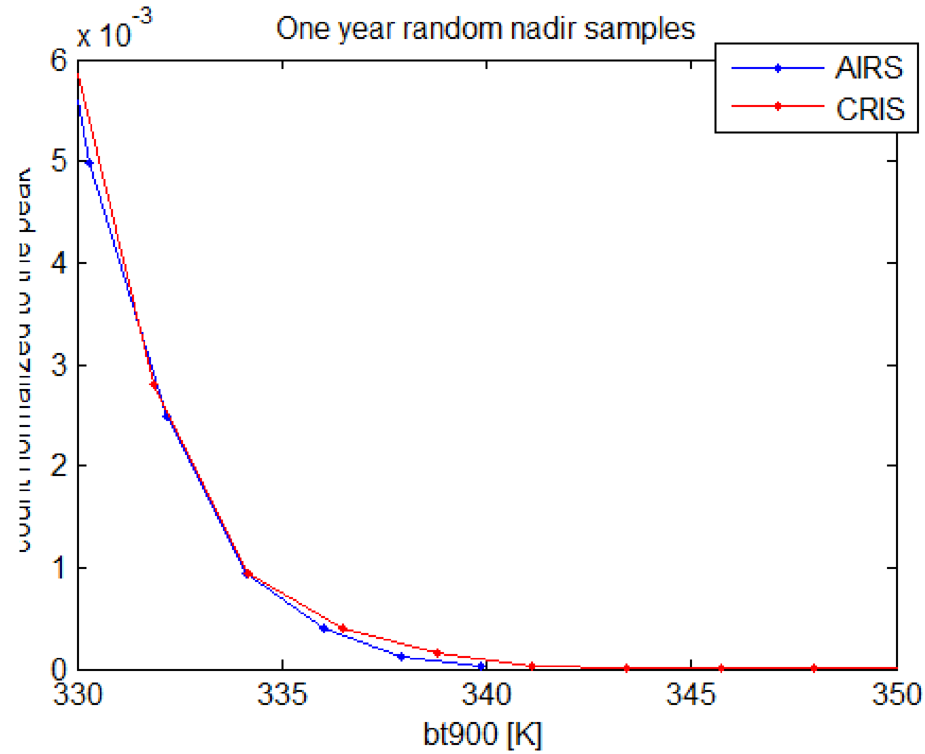
Systematic differences between AIRS and CRIS at extreme hot and cold temperatures are artifacts related to the different response of the CRIS detector elements.





The difference in the extreme values are significant, given that we are dealing with more than 7 million spectra. The IASI extreme values are different due to the difference in the orbit. There are no IASI points warmer than 330,

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Summary

We use the latitude normalized PDF from one year of Random Nadir Spectra to characterize AIRS and CRIS.

The latitude normalized AIRS and CRIS mean PDF agree within 8 mK. This may be the result of extensive AIRS/CRIS cross-calibration.

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Summary

We use the latitude normalized PDF from one year of Random Nadir Spectra to characterize AIRS and CRIS.

The latitude normalized AIRS and CRIS mean PDF agree within 8 mK. This may be the result of extensive AIRS/CRIS cross-calibration.

The mean of the PDF of the CRIS LW band detectors differ by +/-0.3K from the mean for all elements.

The latitude normalized IASI mean bt900 (averaged over all 4 LW elements) is 0.1K warmer than AIRS and IASI. This is surprisingly little given the difference in the orbit with less clouds. The 4 IASI elements differ from the mean by up to ±0.04. This is much less than CRIS.

Systematic differences between AIRS and CRIS at extreme hot and cold temperatures are artifacts related to the different response of the CRIS detector elements.

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Summary continued

In order to continue the AIRS data record with CRIS, there should be no unexplained differences, considering that the two instruments are in the same orbit and have very similar FOV.

With the current (NGST L1b) CRIS calibration there are significant differences, which would be interpreted as climate change, if CRIS and AIRS were not flying at the same time.

The difference in the extreme hot and cold cases would be of particular interest to climate change.

These differences may be decreased by reprocessing the CRIS data with a better algorithm than the NGST L1b. This requires additional analysis.

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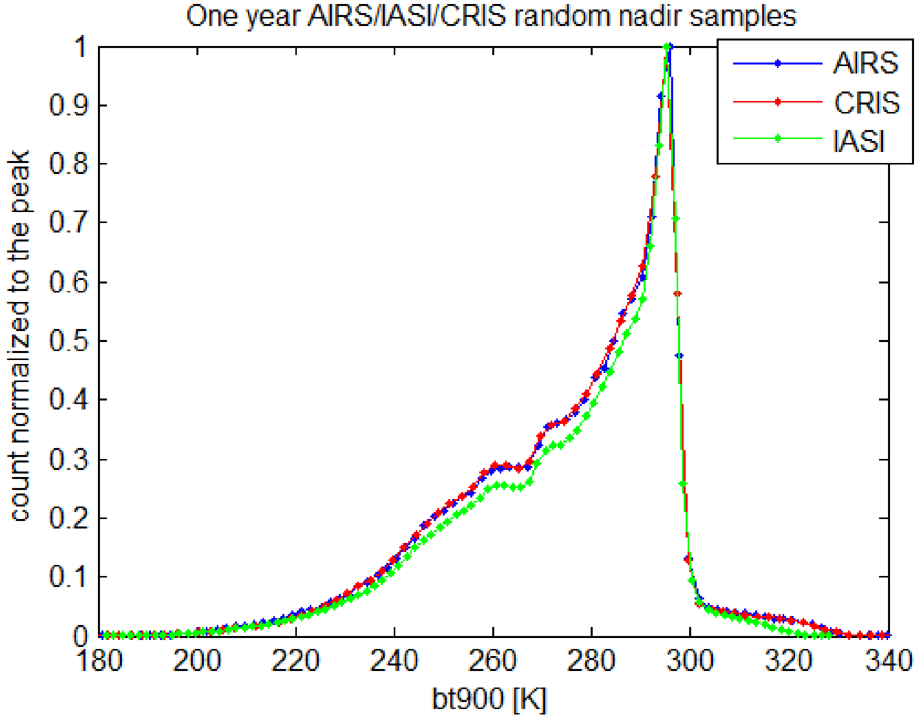
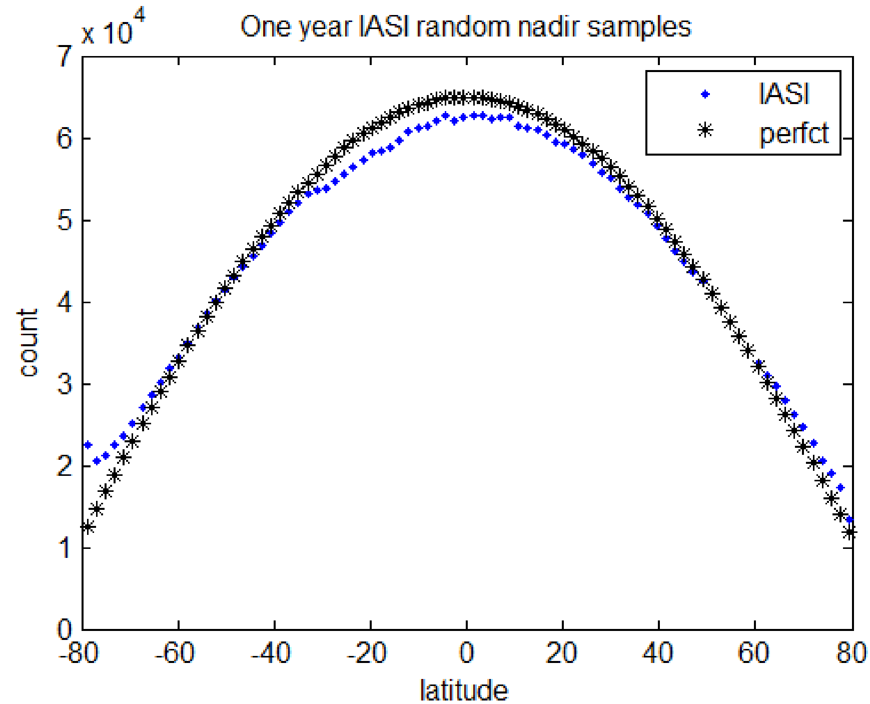
IASI PDF of the RNS after latitude normalization. Surprisingly, the mean IASI bt900 agrees within the error bars with AIRS and CRIS, but the shape of the PDF differs.





IASI mean= 275.21 K range=[180.8 329.0]
3.6 million spectra (PE=0.011 K)

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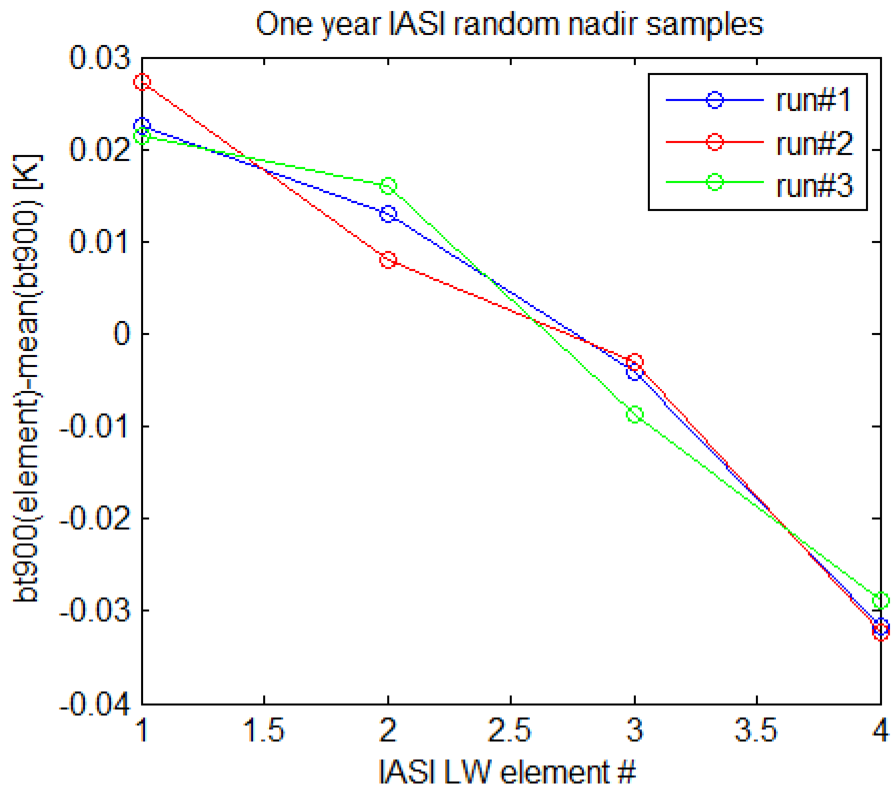
FOV distribution mstats3(xm3);
% xmean= 275.2062 xsig= 0.0201
range=[275.17 275.23]   4 pts



% i= 1 count_old= 4 % xmean= 275.2276 xsig=20.8634 range=[182.9542 328.8395] 831072 pts (PE=0.02289)
% i= 2 count_old= 4 % xmean= 275.2223 xsig=20.7144 range=[180.8496 328.9913] 831072 pts (PE=0.02272)
% i= 3 count_old= 4 % xmean= 275.1975 xsig=20.7211 range=[181.6992 327.7970] 831072 pts (PE=0.02273)
% i= 4 count_old= 4 % xmean= 275.1774 xsig=20.7413 range=[182.0623 327.3042] 831072 pts (PE=0.02275)

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