Two years of IASI/AIRS comparison

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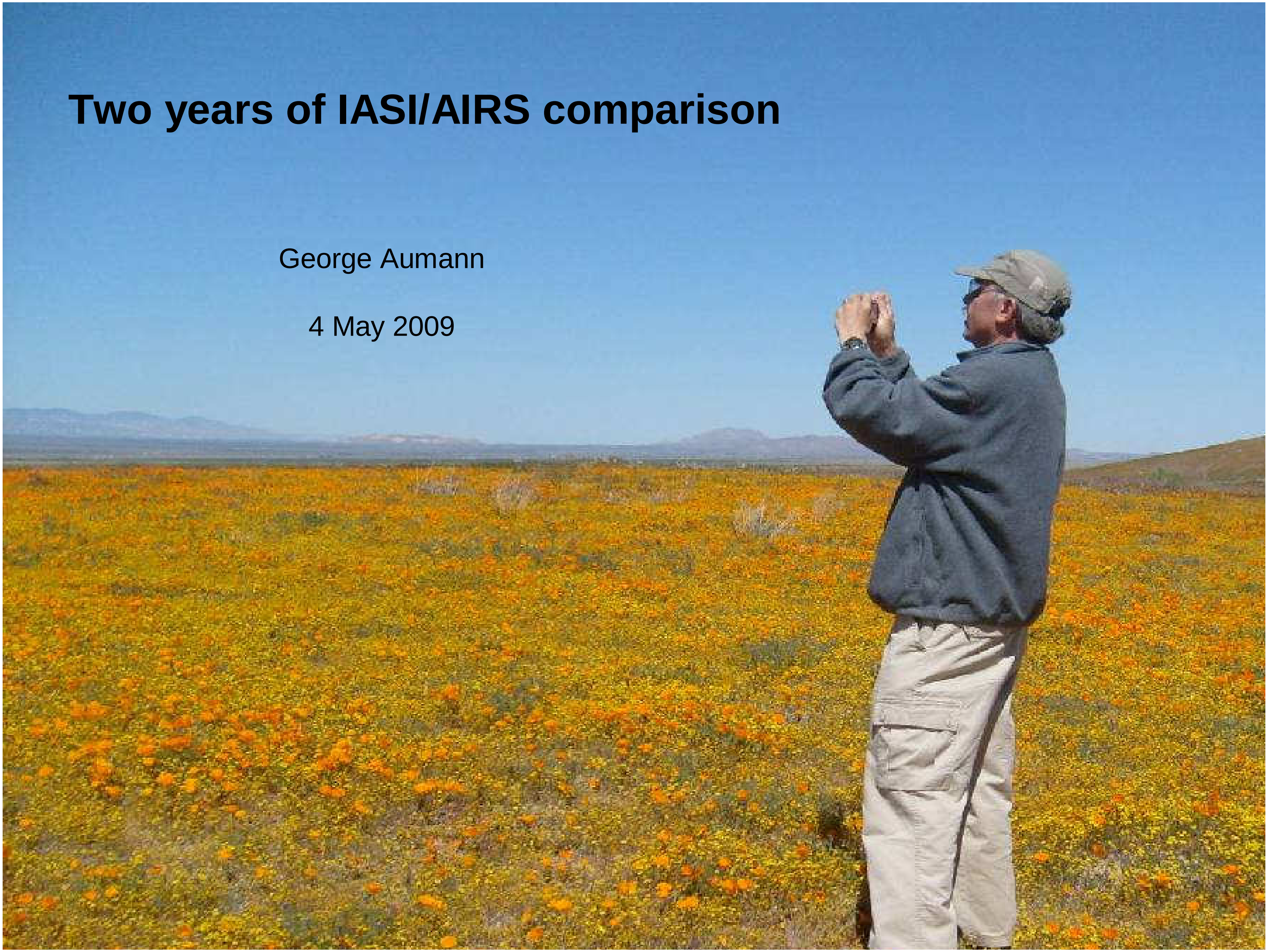
4 May 2009



Why are we doing this?

Interlacing the IASI and AIRS data gives the first hyperspectral insight into diurnal cycle.

Many interesting things can be seen in the AIRS/IASI comparison which may be related to climate change.

Any insight we gain from the analysis of IASI data will prepare us for CRIS data.

We compare AIRS and IASI data for 625 days between May 2007 and March 2009.

We focus on calibration and noise characterization under very clear and typical cloudy conditions in the non-frozen oceans.

This contrasts the extreme 2% of the spectra (clear) with the other 98% of the data.

Only IASI spectra identified as good (Qflag=0) are used

Analysis of uniform “clear” spectra

Clear is in quotation marks since there are no cloud filter with a finite yield which removes the effects of clouds at the 10 mK level

The clear filters use spatial coherence at 1231 cm-1 and a spectral test which eliminates low stratus (less than 10 mm water vapor)

No external information (like the surface forecast) is used in the clear filter. This allows us to use the surface forecast (RTGSST) to validate the quality of the clear filter.

The same thresholds are used for the clear filter day and night.

The clear analysis is based on (obs-calc) in the 2616, 1231, 961 and 790 cm-1 window channels.

The method is totally analogous to what we have done on AIRS.
The calculated brightness temperature uses the known RTGSST, the Masuda emissivity. AIRS and IASI RTA from UMBC (Nov.2007). Diurnal cycle correction from Kennedy et al. (2005)

The water vapor absorptipon correction uses a proxy
Q= bt1231.25-bt1227.75 (day and night for the 1231, 961 and 790 cm-1 channels)
bt2616.25-bt2607.75 (night only for the 2616 cm-1 channel)

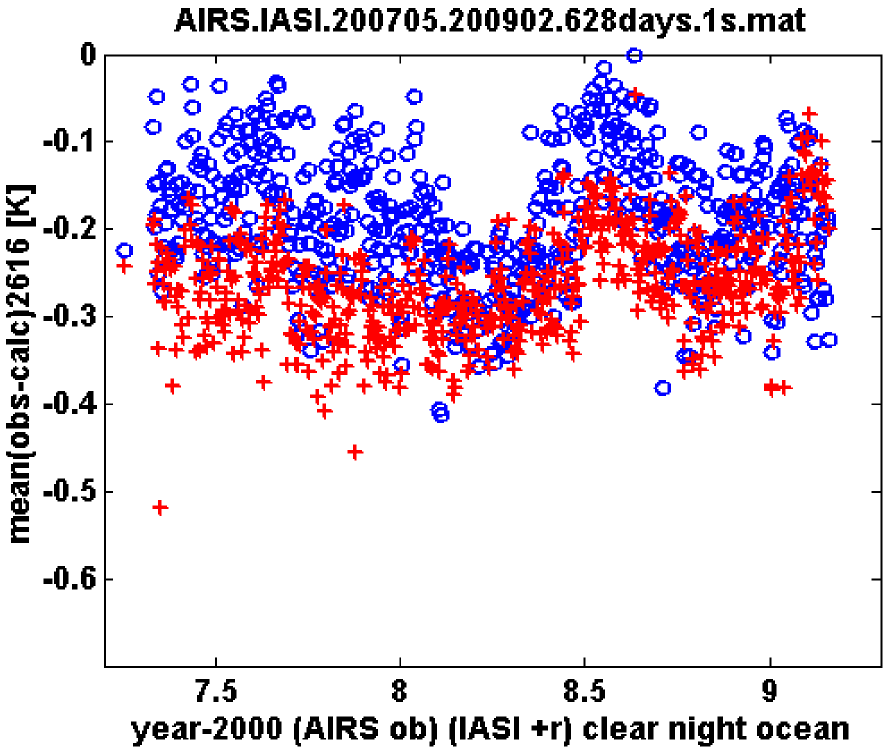
The water vapor transmission correction is derived from the RTA.

Typically 0.3K for AIRS 0.5K for IASI at 2616 cm-1
3 K for AIRS and IASI at 1231 and 961 cm-1.

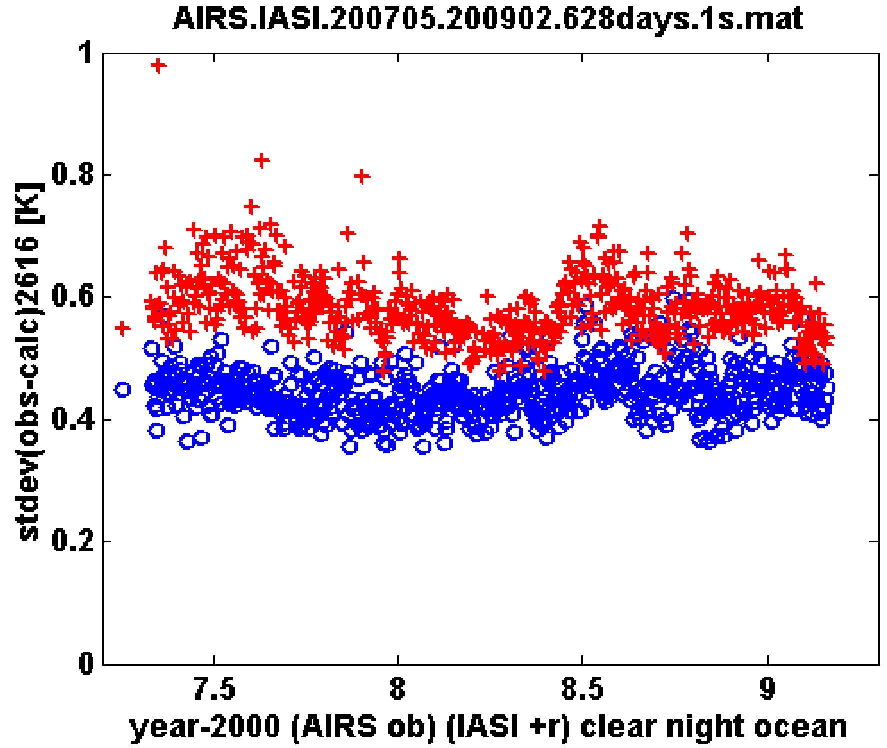
The IASI 2616 cm-1 and 2607 cm-1 window channels are very noisy (NEDT=1.2K at 280K). We replaced them with the mean of the best 90 window and strongest 40 water channels between 2600 and 2650 cm-1. NEDT.2616.effect=0.1K at 300K.

The IASI and AIRS (obs-calc).2616 mean are consistent.
IASI stdev is higher than expected.

Mean



stdev



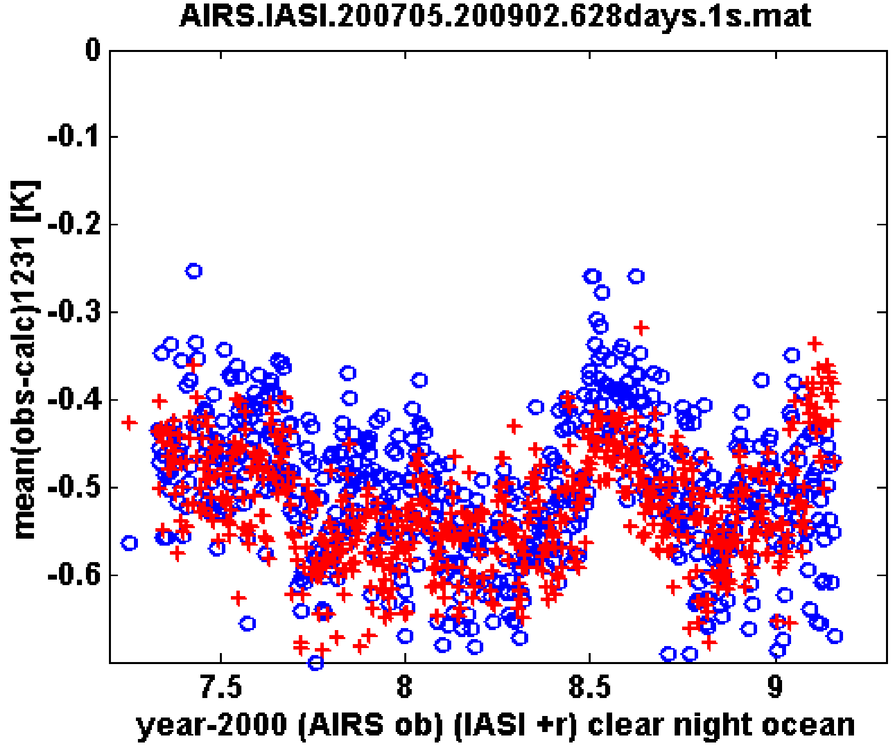
blue=AIRS red=IASI

blue=AIRS red=IASI

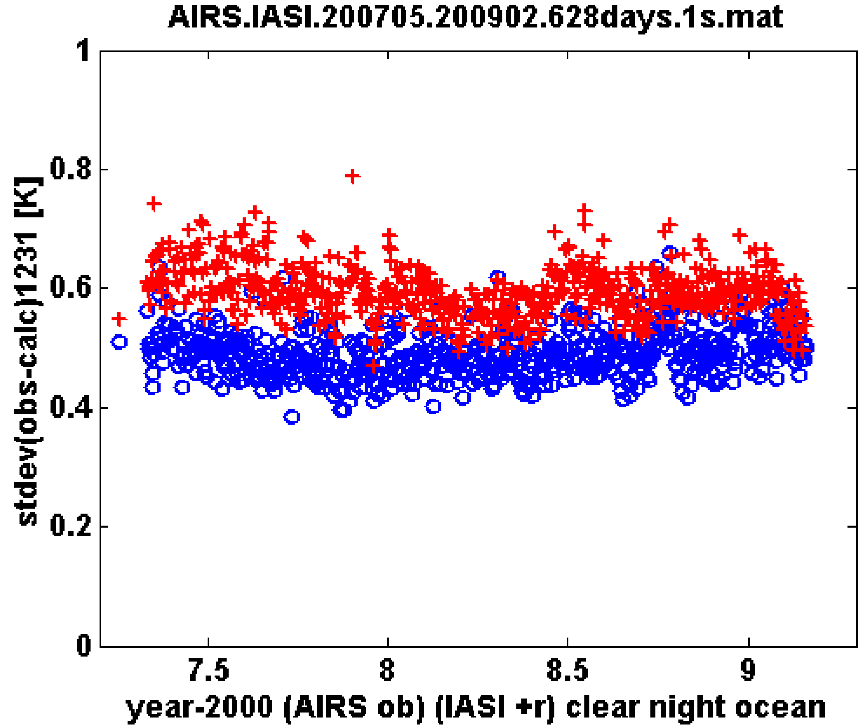
Each dot represents the 3 sigma trimmed standard deviation from one day (night) of several thousand points. Inspite of this we get big outliers in the IASI data.

AIRS and IASI (obs-calc) at 1231 cm-1 have a consistent bias
IASI stdev is higher than expected.

bias



stdev



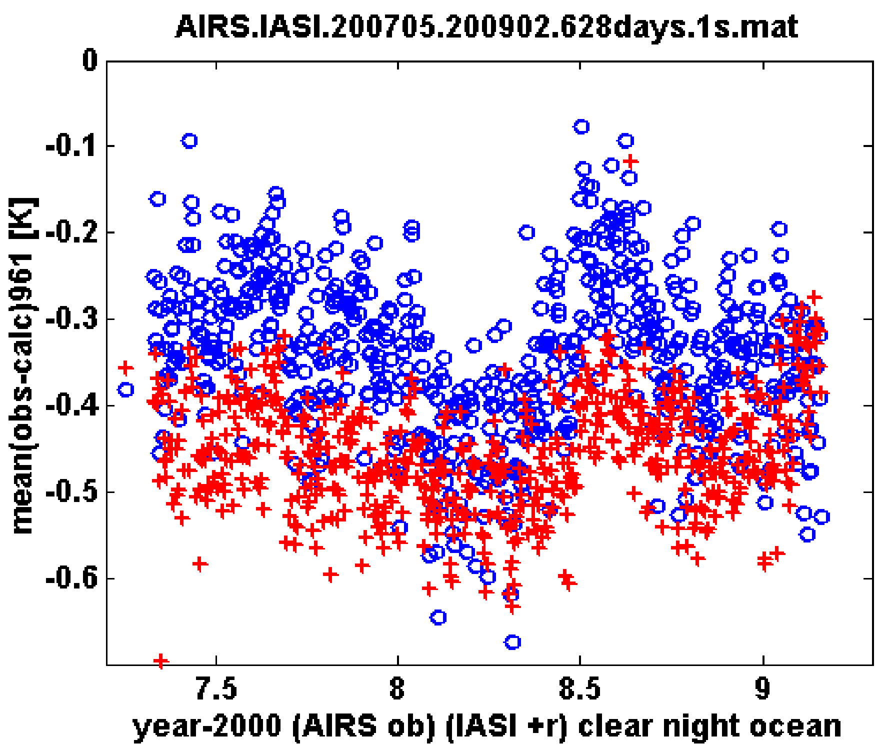
blue=AIRS red=IASI

Each dot represents the mean from one day (about 5,000 points)

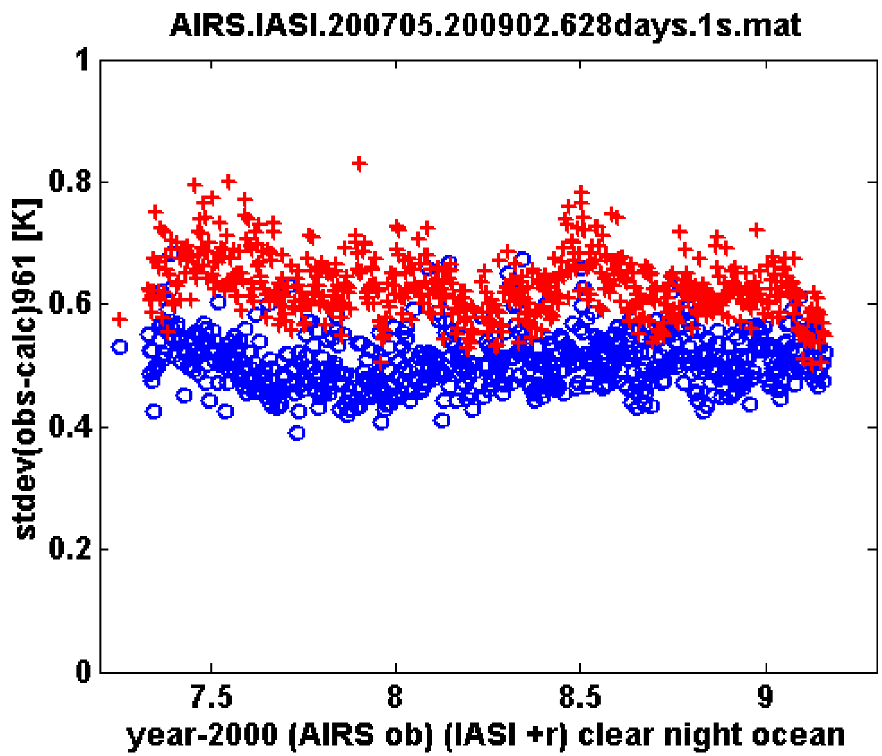
The AIRS and IASI bias track seasonally because both make measurements in the almost same clear areas.

At 961 cm-1 the bias between AIRS and IASI is consistent.

Mean



stdev



IASI and AIRS bias are consistent

1% of contamination with 250K clouds corresponds to 240 mK cold bias at 2616 cm-1
510 mK at 1231 cm-1
640 mK at 961 cm-1

	bias 2616	bias 1231	bias 961	stdev 2616	stdev 1231	stdev 961
AIRS	-0.19	-0.50	-0.34	0.44	0.49	0.50
IASI	-0.27	-0.53	-0.46	0.58	0.59	0.63

Both AIRS and IASI 1231 and 961 channels have 200 mK more cold bias than the 2616 cm-1 channel. Qualitatively consistent Planck function and 1% cloud contamination at the 100 mK level.

IASI noise is 0.32K more than expected under clear conditions

	bias			stdev		
	2616	1231	961	2616	1231	961
AIRS	-0.19	-0.50	-0.34	0.44	0.49	0.50
IASI	-0.27	-0.53	-0.46	0.58	0.59	0.63

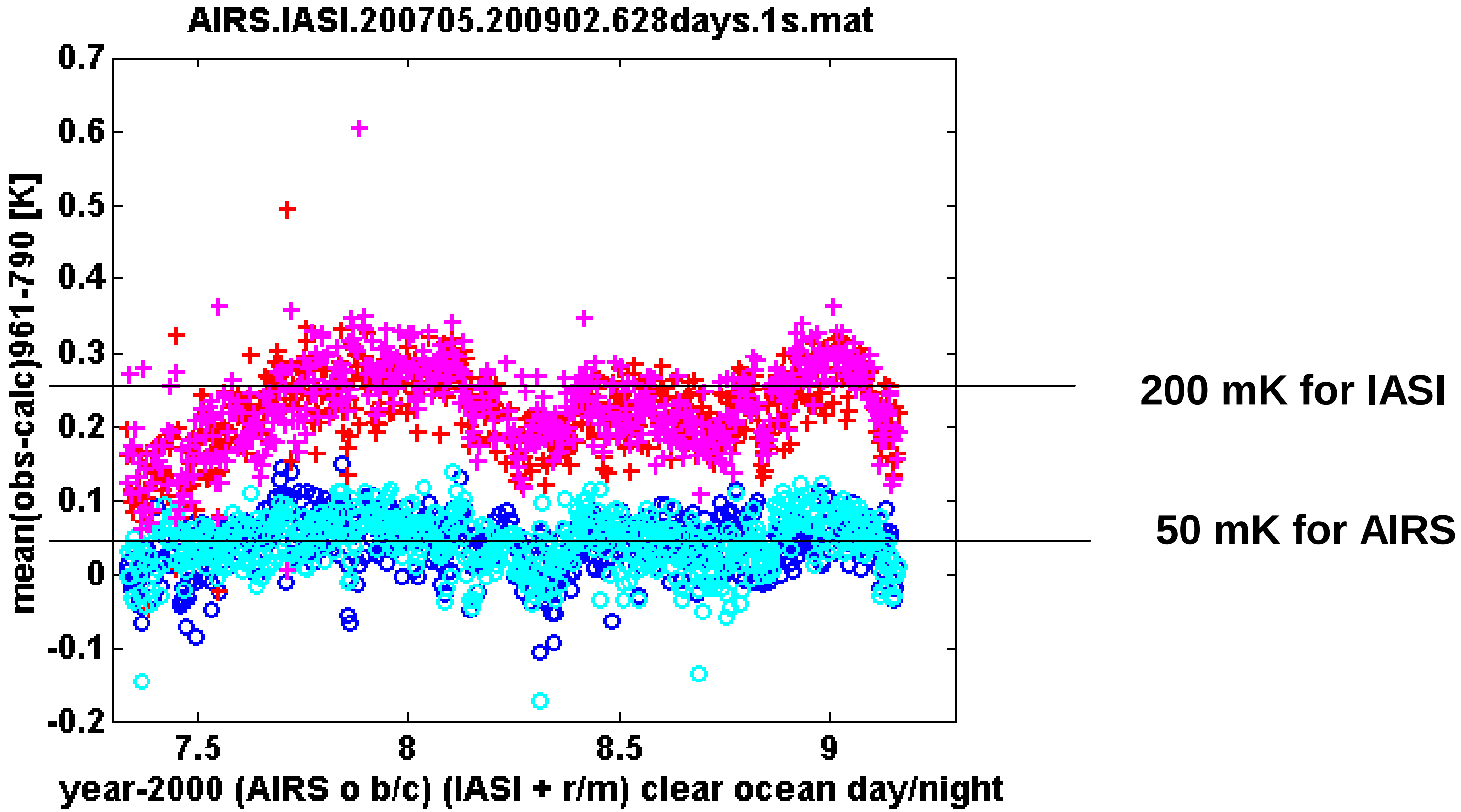
IASI is consistently more noisy by 0.32 K in all three channels

Since the bias in the three channels is consistent,
and there is a high correlation between the clear areas measured
We interpret the 0.32K of excess noise in the IASI data under clear conditions.

Assuming the additional noise in the IASI data is gaussian distributed (i.e. has a mean of zero), it will not effect climate applications.

IASI and AIRS cirrus in the clear spectra is inconsistent.

Bias

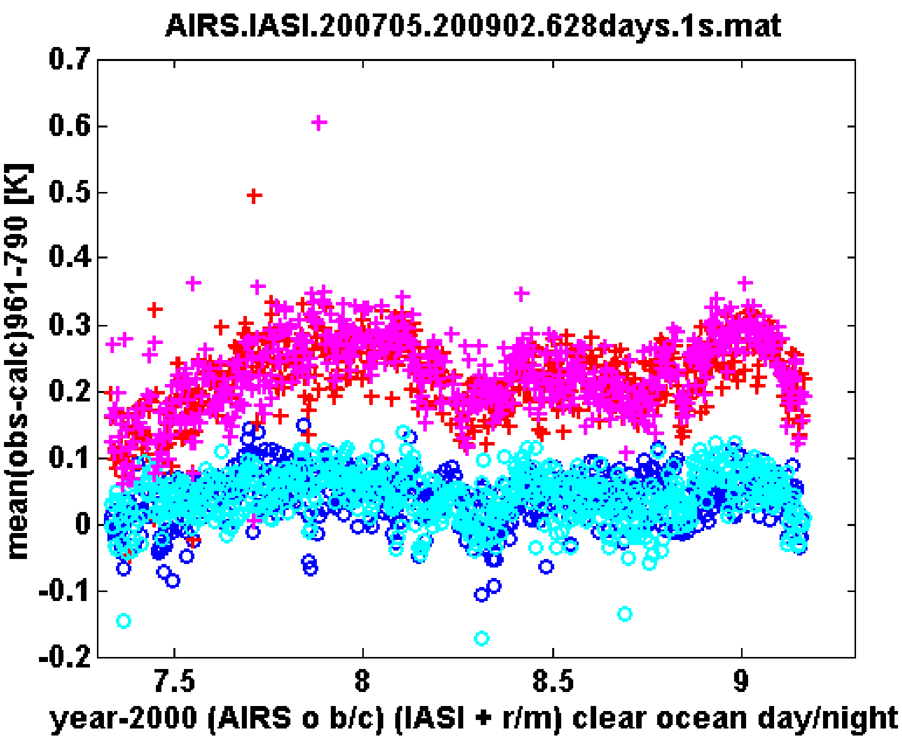


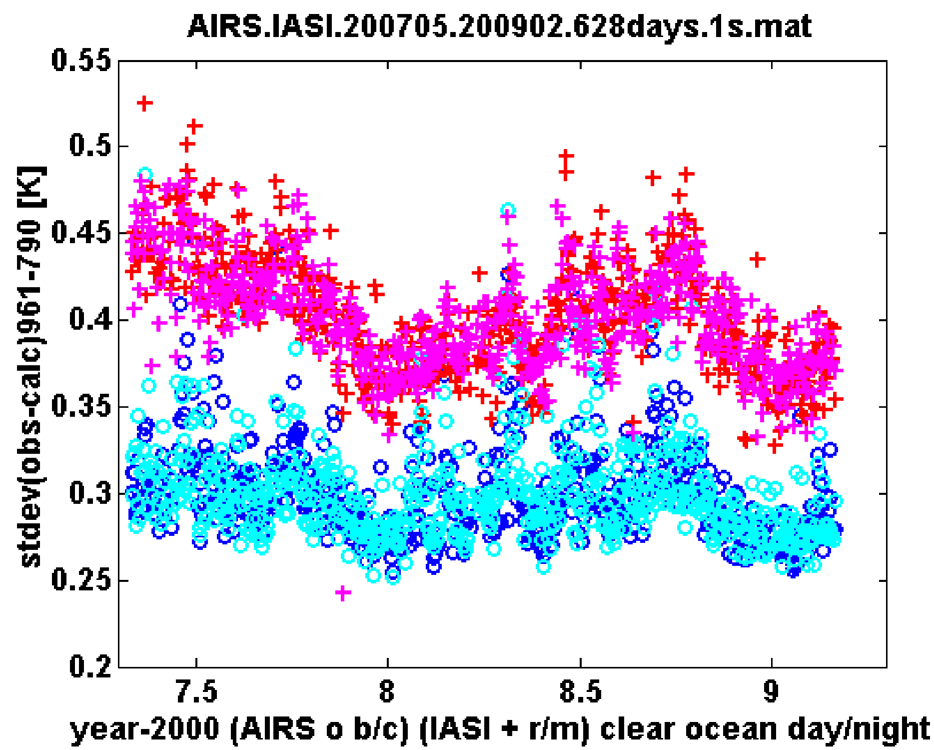
(obs-calc)961-790 is a measure of cirrus.
According to AIRS (blue/cyan) there is 50 mK of cirrus day and night
According to IASI (red/magenta) there cirrus is about 200 mK

The IASI slope between 790 and 961 cm-1 appears to have a 0.3K jitter

The discrepancy between IASI and AIRS also shows up in stdev(obs-calc)961-790

Bias | **stdev**





Stdev(obs-calc)961-790 for AIRS is consistent with the NeDT

Stdev(obs-calc)961-790 for IASI is 0.3K larger than expected from the NeDT

Lessons from the comparison under clear conditions

The 2616 cm-1 comparison between AIRS and IASI shows excellent agreement. Averaging 60 IASI channels produces close to the expected NEDT improvement.

The 1231 and 961 cm-1 comparison between AIRS and IASI are consistent, but 200 mK colderer than expected from 2616 cm-1. Residual cloud contamination.

The Kennedy (2005) diurnal cycle Tsurf correction look correct.

The 200 mK discrepancies between IASI and AIRS in the slope across the 961-790 window channels which relate to cirrus in clear spectra.

The higher noise in the IASI slope suggest that the IASI data are incorrect.

There is a souce of 0.3K excess noise in the IASI data in the three bands and in the slope across IASI band 1, even under clear conditions.

Under clear tropical ocean conditions the AIRS and IASI window channels show correlated patterns which indicate the persistence of clear conditions.

Cloudy data analysis

Only 2% of the data are clear.

98% of the data are cloudy to various degrees.

The metric of cloudiness uses the 1231 cm-1 window channel

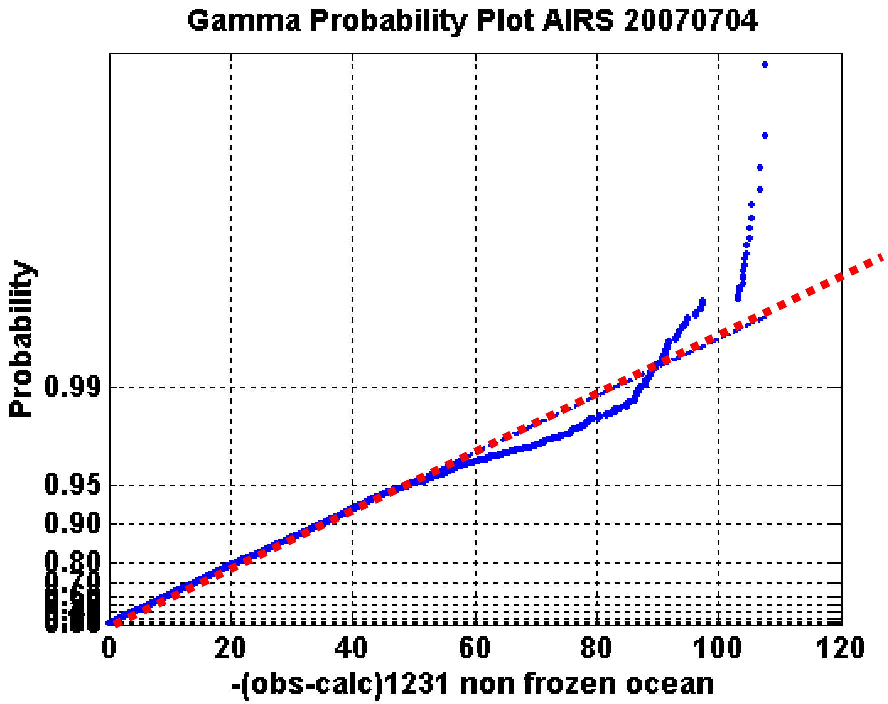
Under clear conditions bias(obs-calc).1231 is within 250 mK of zero and stdev(obs-calc).1231 is of the order of the channel noise and gaussian distributed. This is the case for AIRS and IASI.

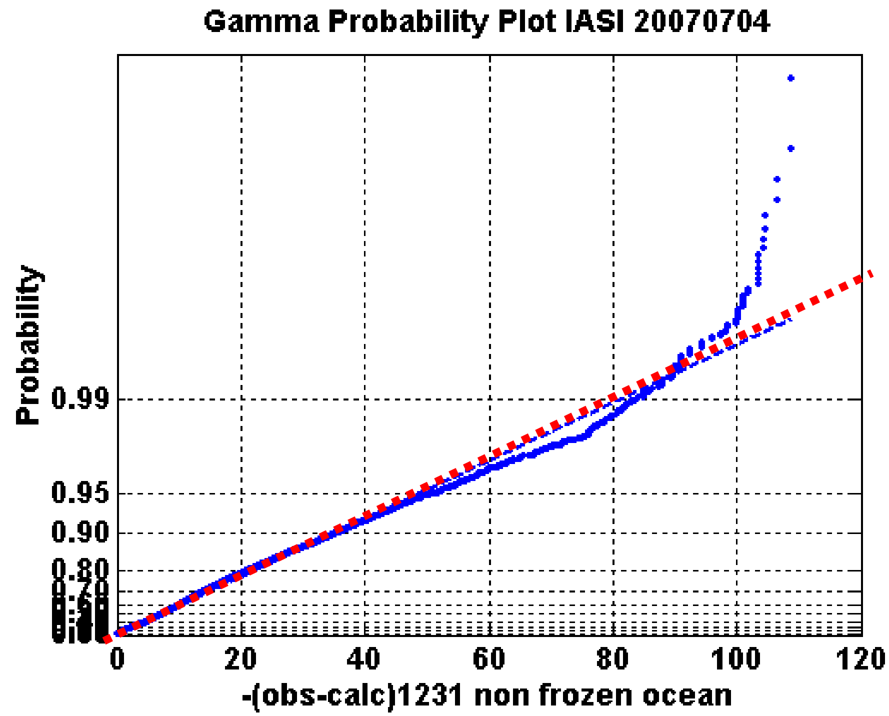
Define Infrared cloud forcing as d1231= (obs-calc).1231

Infared Cloud forcing is approximately gamma distributed

AIRS

IASI



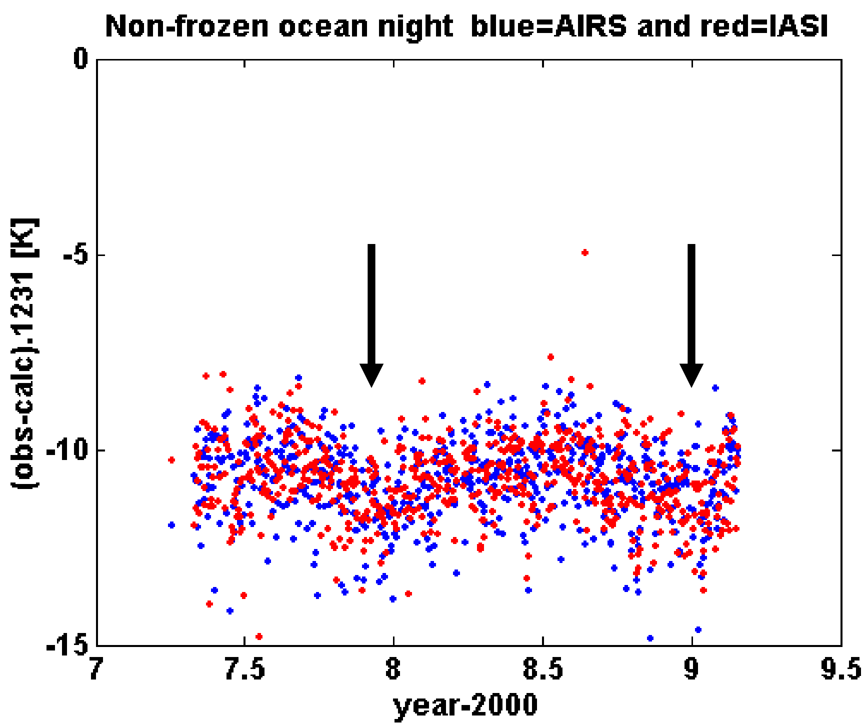


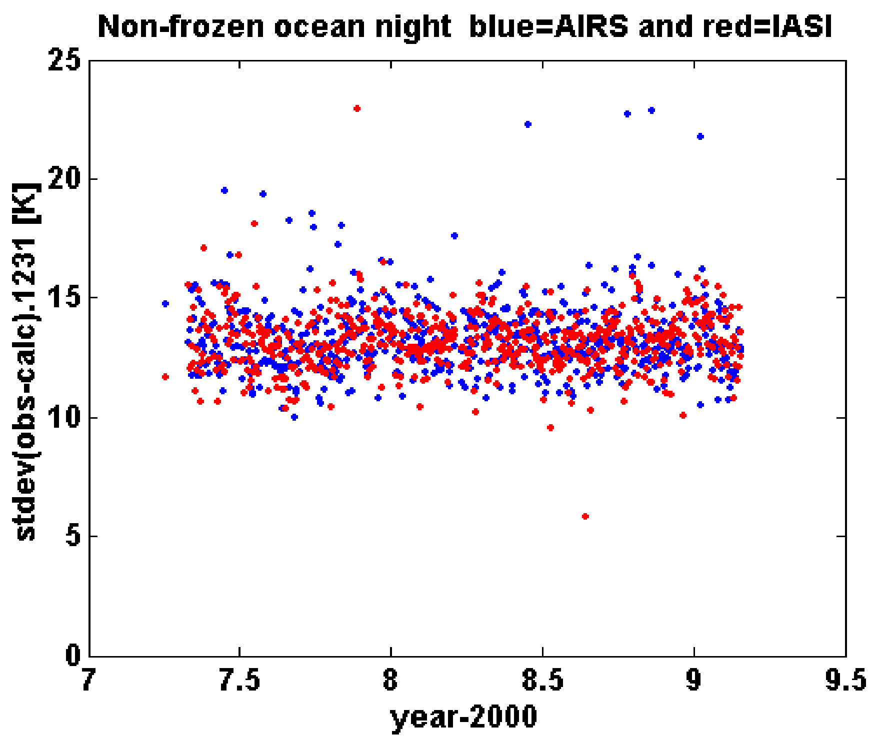
The detailed shape of the cloud forcing distribution is interesting for climate studies.

The cloud distribution for IASI and AIRS can be approximated by the same gamma distribution (stdev = 1.4* mean)

(obs-calc)1231 mean

stdev





Mean AIRS = -11.78 IASI = -10.82

Stdev AIRS 13.1 K IASI = 13.1K

AIRS 13.1/11.78=1.11 IASI 13.1/10.82=1.21 Clouds are rougher for IASI than for AIRS.
Large scale annual patterns are seen in the AIRS and IASI data.

Cloud variability can be suppressed by looking at left right differences

The comparison of AIRS and IASI under average cloudy conditions is dominated by cloud variability.

If we can suppress the cloud variability, we can look at instrument effects.

We contrast the random near nadir footprints with clear near nadir footprints.

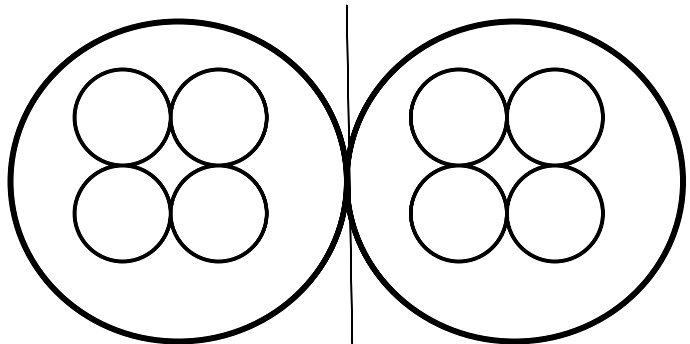
Only Qflag=0 data are used from IASI.

Evaluation of cloud effects uses random nadir footprints

AMSU 14 AMSU 15

left Nadir right

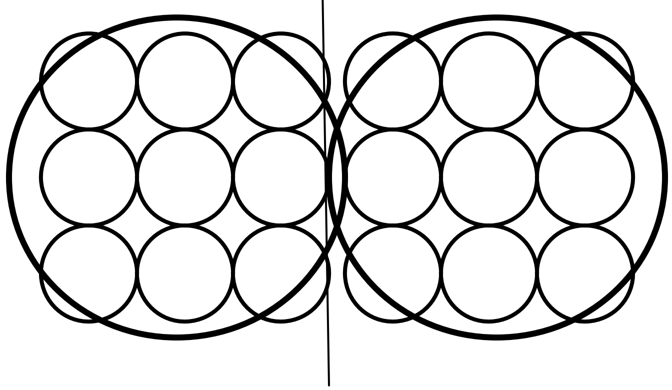
IASI



For each AMSU scan line
Pick 1 of 8

Create a subset of IASI spectra from AMSU footprint 14 = IASI left
AMSU footprint 15 = IASI right

AIRS



For each AMSU scan line
Pick 1 of 18

Create a subset of AIRS spectra from AMSU footprint 14 = AIRS left
AMSU footprint 15 = AIRS right

For each AMSU scan line a random number generator was used to decide which 1 of 8 IASI and which 1 of 19 AIRS spectra to save.

This produces a random selection of right/left data.

Approximately 5000 left and 5000 right data sets were saved each day.
About 1500 of these were from the 9:30am/1:30 pm overpasses of non-frozen ocean, about an equal number from the 9:30pm/1:30am overpasses.

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Evaluate the statistics of

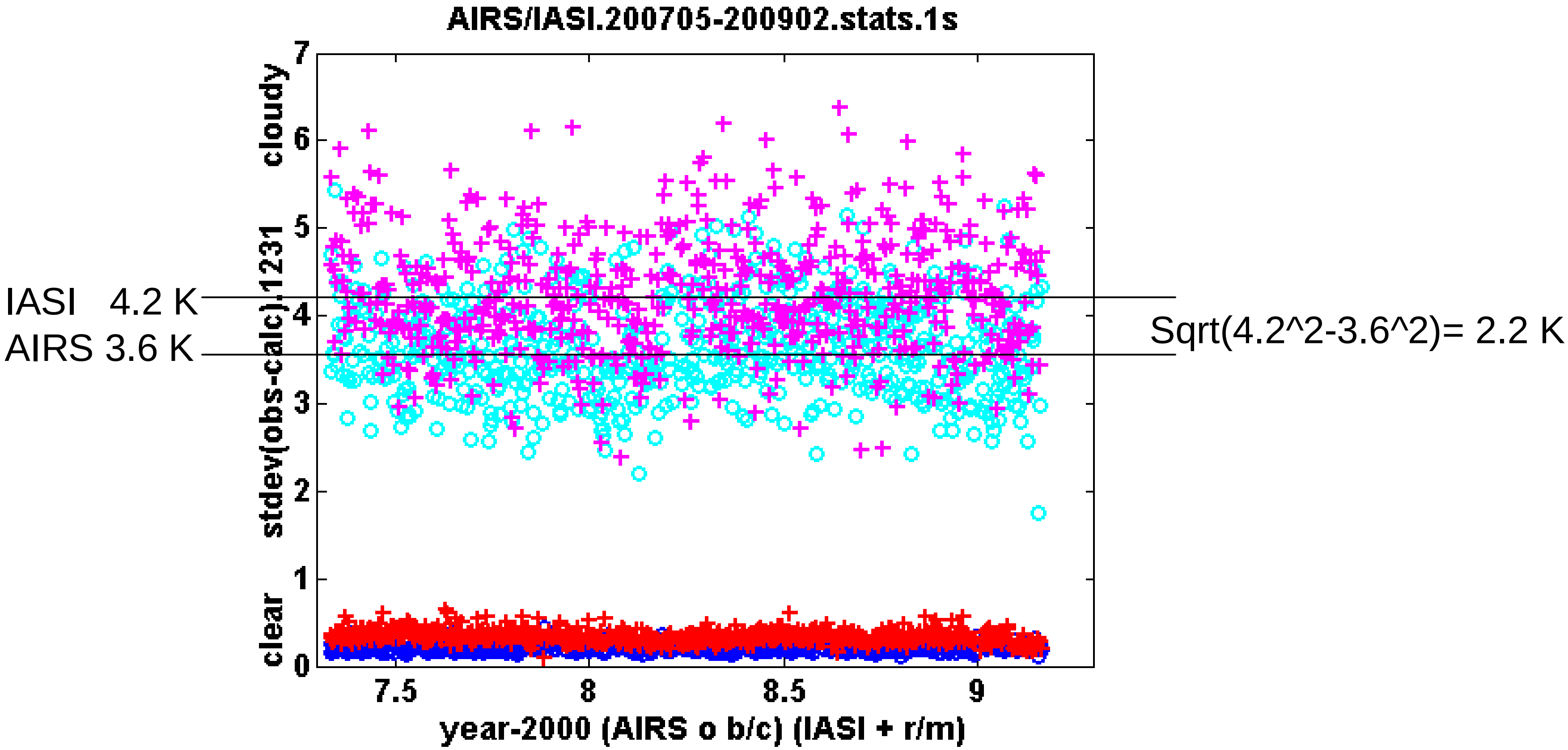
LR.IASI = (daily mean.IASI.left) – (daily mean.IASI.right)
LR.AIRS = (daily mean.AIRS.left) – (daily mean.AIRS.right)

Since the mean d1231 and the distribution of cloud forcing for AIRS and IASI is almost identical, the expectation from a geophysical viewpoint is that

1) mean = zero (Cloud forcing is symmetric with respect to nadir)
2) stdev for AIRS and IASI should be comparable
3) Under clear conditons the observed stdev should be sqrt(2)*channel NeDT.

IASI window channel shows 2 K excess noise under average cloudy conditions

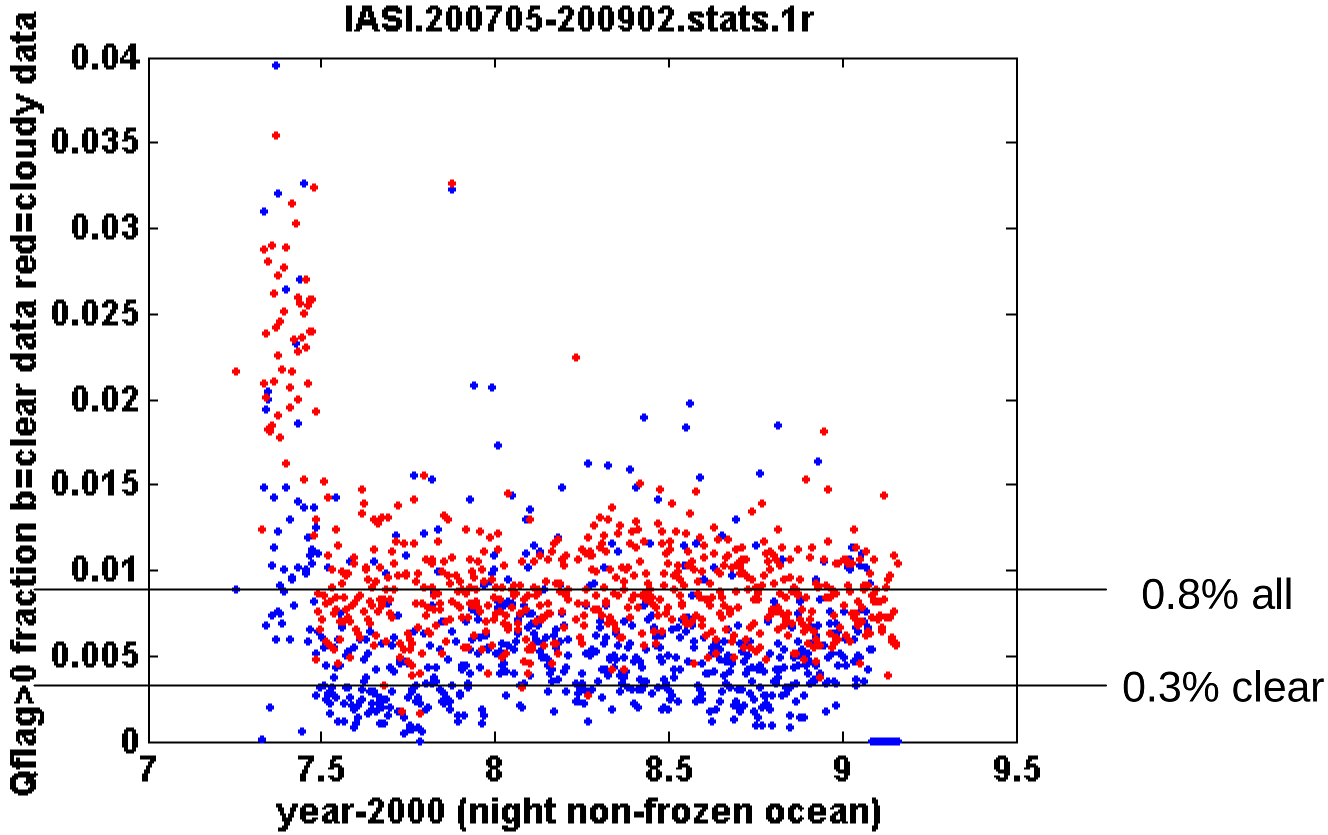
Under clear conditions stdev(left-right) of 1231 cm-1 for AIRS and IASI are close to the NeDT.
Under average cloudy IASI (+ cyan) is more noisy than AIRS (o magenta)



Obs-calc).1231 clear/cloudy for 325 days

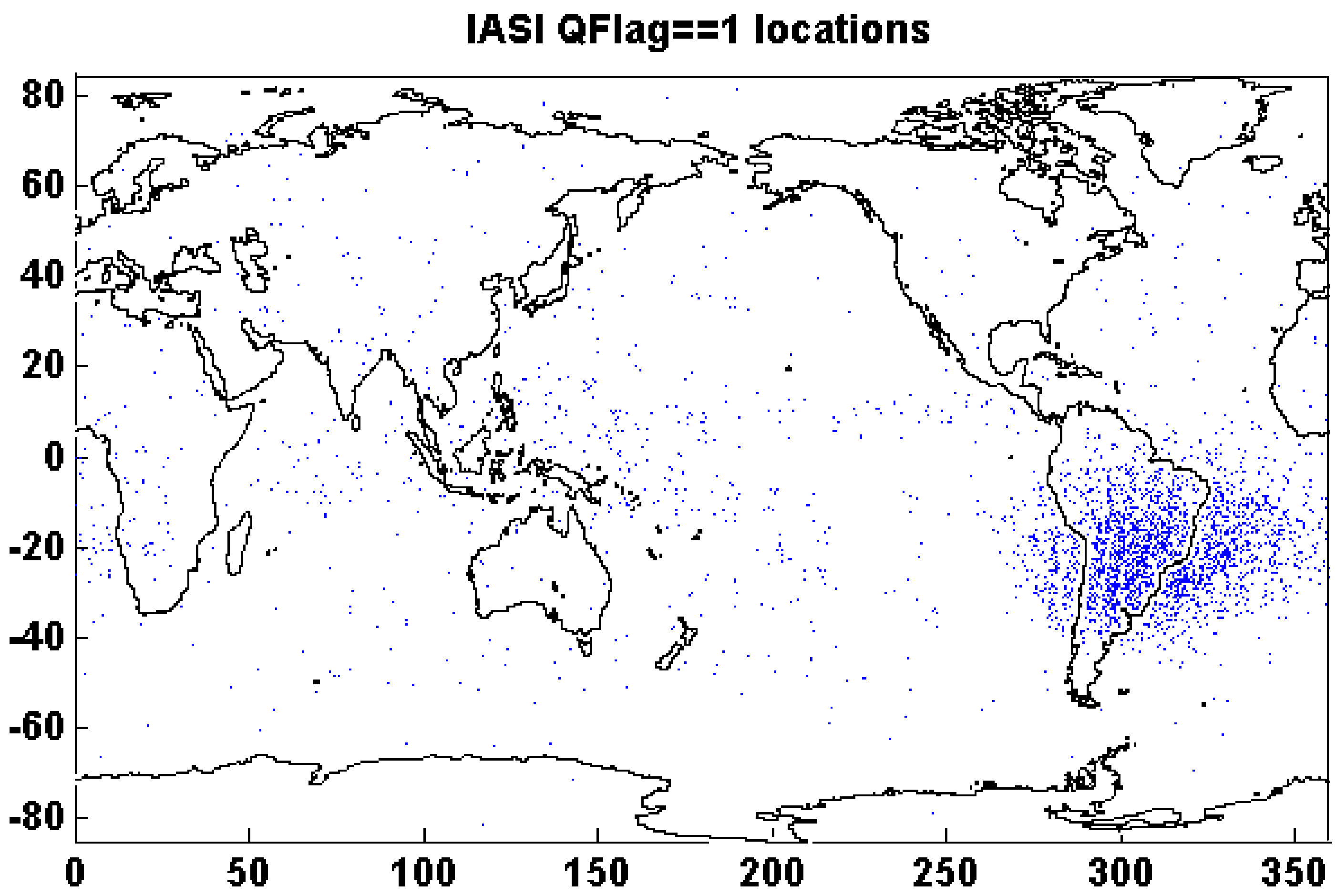
+ Red/Mag = stdev(IASI.left-right) 0.34/4.2
O Blue/Cyn = stdev(AIRS.left -right) 0.33/3.6

The L1C Qflag provides direct evidence that IASI has difficulties with clouds



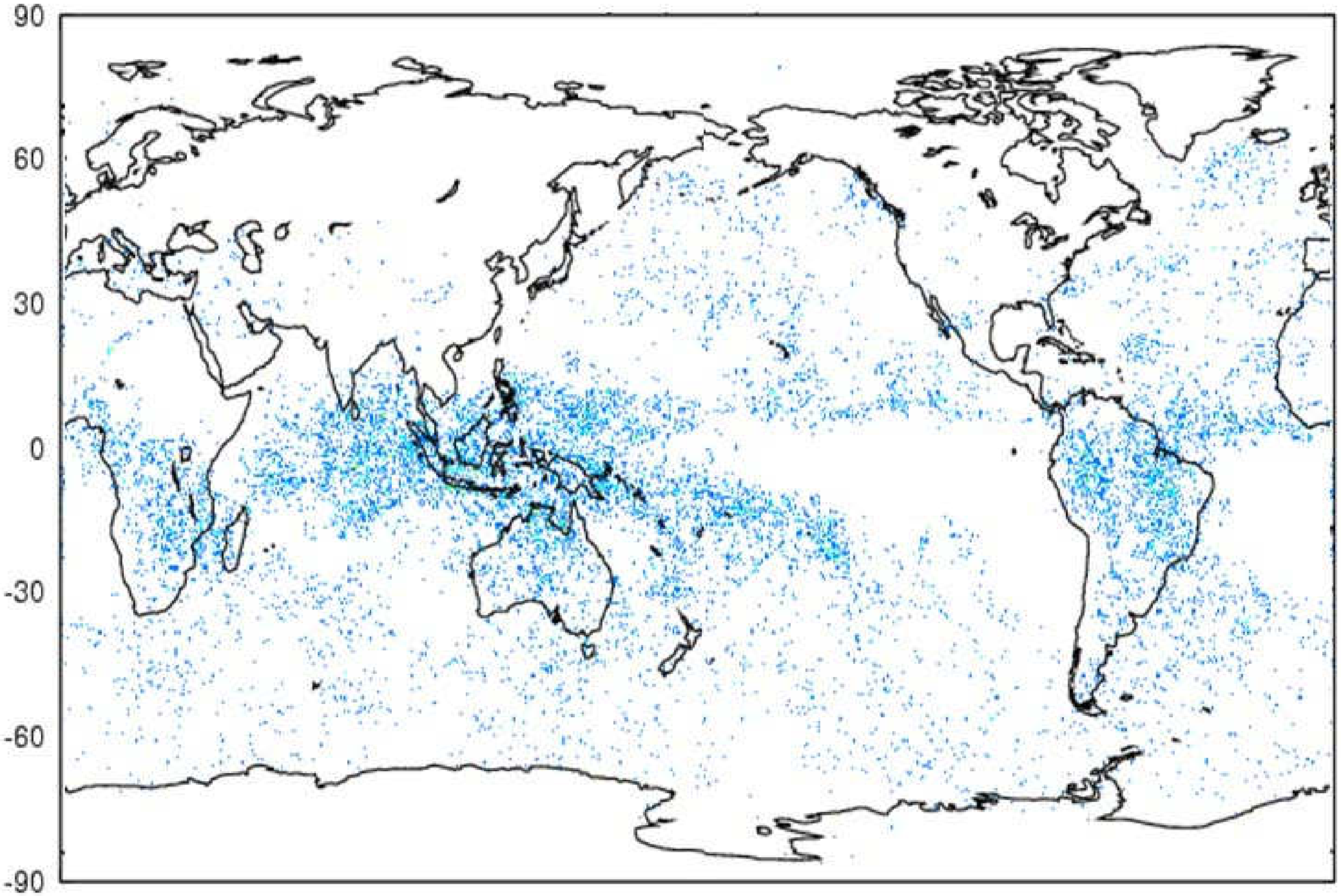
IASI processing flags 0.8% of all spectra are flagged bad (red points)
0.3% of uniform clear spectra are flagged bad (blue)

About 50% of IASI spectra marked bad (Qflag=1) are in the SAA



Random nadir samples February 2009

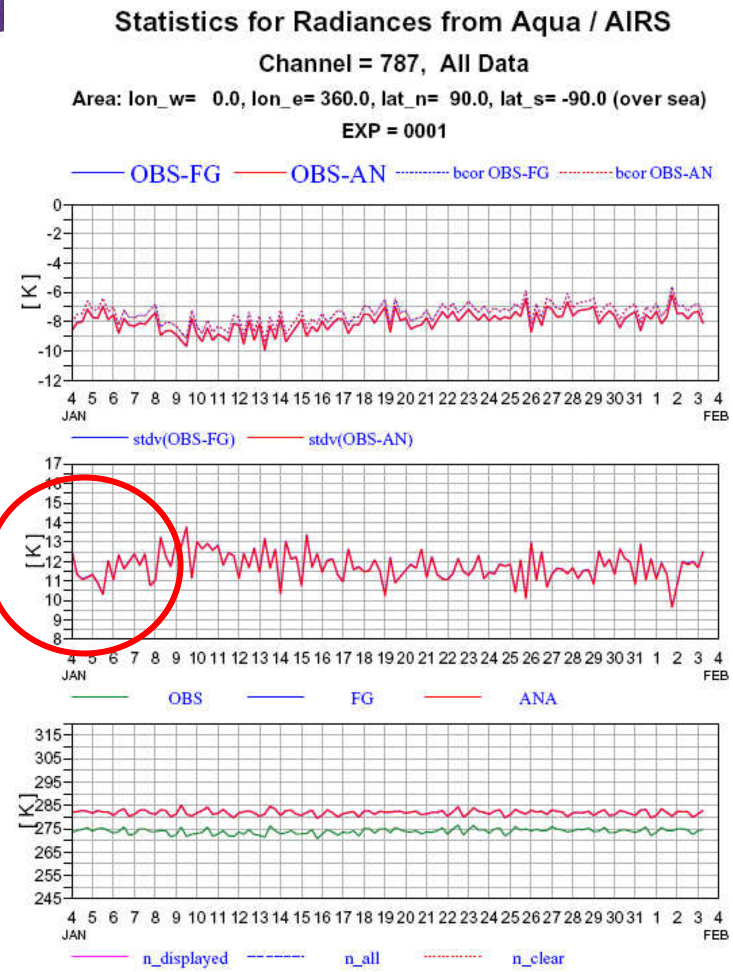
Cloud effects show in the the spatial distribution of spectra identified as bad, but not due to RAD hits. The locations over oceans mimics the ITCZ

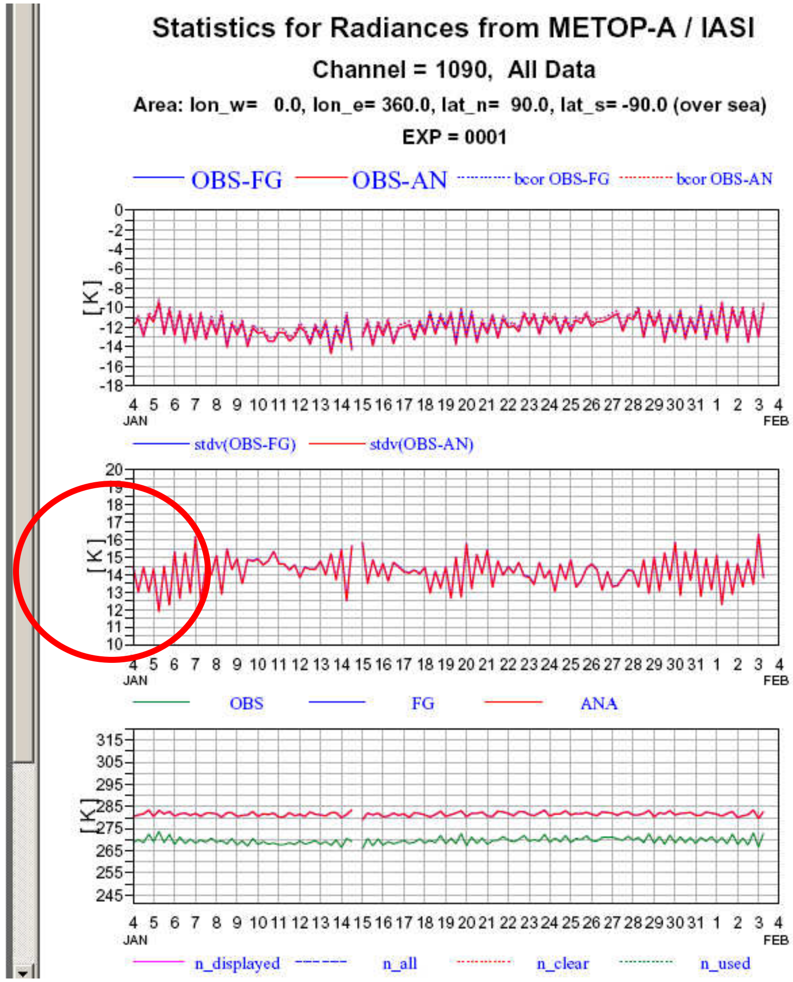


E. Pequignot - ISSWG2 – 2009/04/21

Curious low incidence over the NH continents

The ECMWF web page shows enhanced noise for IASI when all data are tested.





AIRS
mean = 8 stdev=12K

(obs-calc)923 cm-1

IASI
mean=-12 stdev=14K

Clouds always produce a high variability in infrared radiances.

A instrument may ampify this variability. This amplified variability acts as excess noise.

Since clouds are gamma distributed, the excess noise is also gamma distributed.

Qflag=1 appears to catch many IASI spectra which are worse than some threshold.

Gamma distributed noise has a non-zero mean.
This results in a bias in the IASI cloudy radiance data.

The 0.3 K of unexpected noise seen in the “clear” IASI data are a manifestation of cloud noise due to the 0.25K cold bias seen in the IASI and AIRS data.

Lessons from 2 years of AIRS /IASI cloudy data

IASI appears to ampify cloud variability. This amplified variability acts as excess noise.

Excess cloud noise in the IASI is gamma distributed and does not average to zero. This results in a bias in the IASI cloudy data. This is a concern for climate applications.

Summary from 2 years of AIRS /IASI clear and cloudy data

The 2616 cm-1 channel is very useful for calibration monitoring. The water vapor correction is only 0.3K (AIRS), 0.5 K for IASI. This channel is not available on CRIS.

The combination of 2616 and the 1231 or 961 cm-1 window channels are useful for separating residual cloud contamination effects from radiometric calibration effects.

IASI and AIRS calibration compare very well for large averages under spatially uniform scene conditions. The observed difference in key channels are small with respect to geophysical variability.They are large from a climate perspective.

IASI shows 200 mK of cirrus contamination of clear spectra, AIRS shows none.

The IASI data are fairly stable relative to AIRS.

Summary from 2 years of AIRS /IASI clear and cloudy data

Radiometric accuracy and observational noise can be deduced from observations under clear and cloudy conditions, even with IASI and AIRS in different orbits. This is significant for the validation of CRIS performance.

Under clear and average cloudy conditions IASI channels shows gamma distributed excess noise. This noise has non-zero mean and will produce an observational bias in climate applications.

Spectral and radiometric integrity are required under clear and cloudy to securely interprete the AIRS and IASI results for climate.

The AIRS data come from the ACDS (AIRS Climate Data Subset) available from the GSFC/DACC .

The IASI data come from the ACDS equivalent prototype of of a IASI Climate Data Subset under development at the PEATE at JPL.

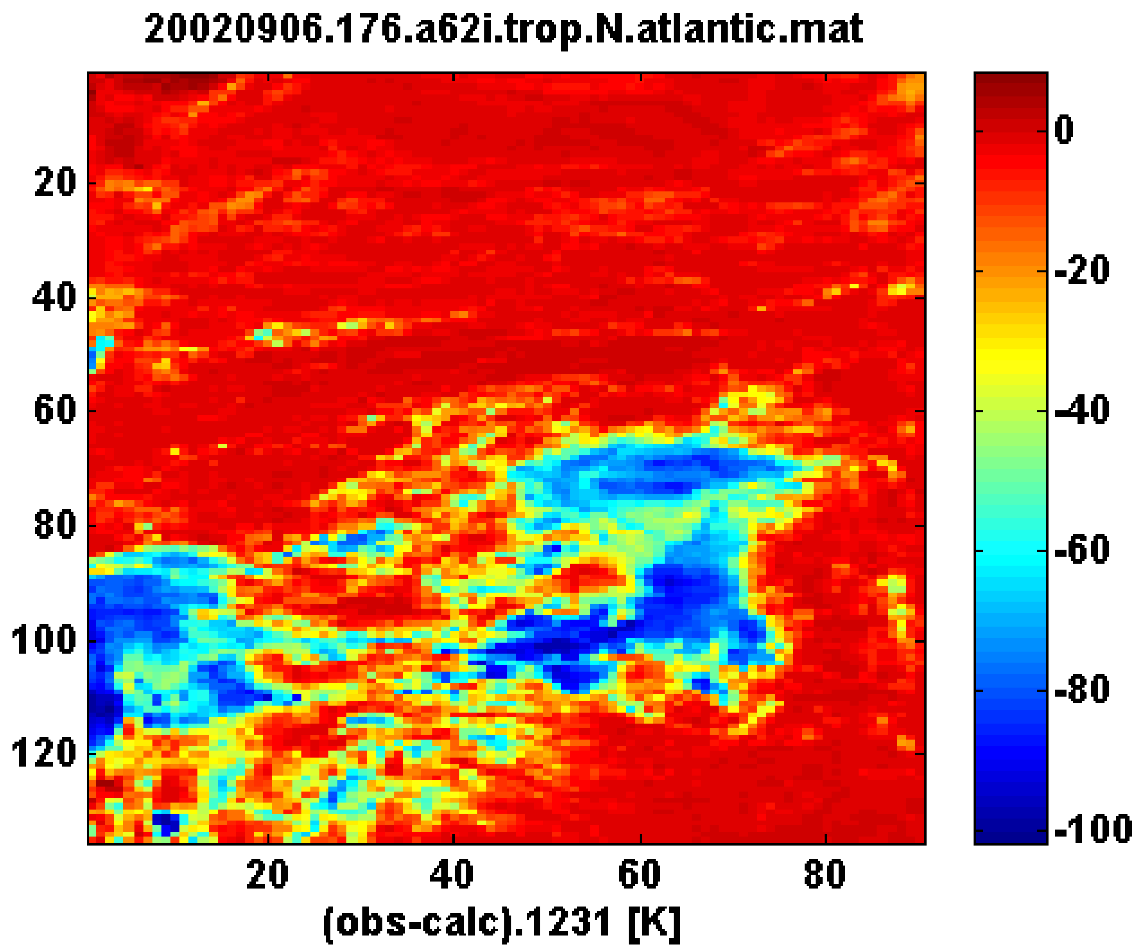
NASA

JPL

Mean and stdev of infrared cloud effects are sensitive to data processing

Example of infrared cloud forcing from AIRS focus day #3

Mean=-16.56 stdev=23.98 unedited
-15.78 stdev=22.84 1% largest edited out



Deep Convective Cloud bt1231<220K fraction over ocean makes no sense. Why should IASI have same DCC frequency at 9:30 AM as AIRS at 1:30 PM but lower than AIRS at 9:30PM, while the convective cycle over ocean supposedly peaks in the evening?

	day	night	
AIRS	1.9%	1.7%	Probable Error=0.015%
IASI	2.0%	1.4%	

```
>> id=2;iz=16;trim3sig(xa(:,id,iz)./xa(:,57,iz));
% mean= 0.0168 std=0.0033    622 pts [  0.007 -   0.027 ]  (  3 pts 3 sig trimmed )  PE 0.000131
>> id=2;iz=16;trim3sig(xi(:,id,iz)./xi(:,57,iz));
% mean= 0.0143 std=0.0029    621 pts [  0.005 -   0.024 ]  (  7 pts 3 sig trimmed )  PE 0.000116
>> id=2;iz=15;trim3sig(xa(:,id,iz)./xa(:,57,iz));
% mean= 0.0191 std=0.0037    621 pts [  0.009 -   0.031 ]  (  4 pts 3 sig trimmed )  PE 0.000147
>> id=2;iz=15;trim3sig(xi(:,id,iz)./xi(:,57,iz));
% mean= 0.0202 std=0.0037    620 pts [  0.006 -   0.035 ]  (  8 pts 3 sig trimmed )  PE 0.000150
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