

INTER-COMPARISON BETWEEN IASI AND OTHER MULTI-SPECTRAL INSTRUMENTS: ONE YEAR OF DUAL-METOP DATA

Dorothee Coppens, Bertrand Théodore, Dieter Klaes

EUMETSAT, EUMETSAT-Allee 1, 64295 Darmstadt, Germany

Abstract

Since the launch of the second Metop platform in September 2012, two IASI (Infrared Atmospheric Sounding Interferometers) instruments are flying on the same orbit, overflying the same area with 50 minutes delay. This provides a unique opportunity to perform inter-comparisons and cross-monitoring. To do so, different methodologies have been implemented to provide complementary results giving qualitative and quantitative information on both instruments in terms of radiometric and spectral inter-calibration. This includes comparisons between the two IASI but also with other instruments covering infrared regions flying on the same platform like AVHRR and HIRS; comparisons with CrIS flying on Suomi/NPP have also been performed.

We will present an overview of one year of dual Metops monitoring. Such a monitoring, besides giving us confidence that the two IASI are very well radiometrically and spectrally intercalibrated, provides a way to trace changes in the configuration of the instruments and to detect the tiny differences between them. In addition, it allowed us to emphasize some issues with the channel 5 of AVHRR/Metop-B, while comparisons with HIRS data revealed that some of its channels are not as consistent with IASI on Metop-B than on Metop-A.

Comparison with CrIS is performed both using SNOs which occur every seven weeks and also on a daily basis using double differences. This provides useful feedbacks on the instruments: we will indeed show that they compare very well and that the non-linearity issue present in the band 1 of CrIS data has been reduced in the last version of the products.

1) Introduction

The Infrared Atmospheric Sounding Interferometer (IASI) is currently flying on Metop-A since October 2006. Since the reception of the first calibrated spectra, IASI L1 NRT radiance monitoring is done at EUMETSAT, based on the comparison of measured and modelled IASI L1C spectra generated by the radiative transfer model RTTOV v9.3 using ECMWF forecast files. Since August 2011, the monitoring of IASI L2 products (temperature, humidity, ozone...) is performed as well on a daily basis in comparison with ECMWF files. With the launch of Metop-B in September 2012, both monitoring are done in parallel for the two instruments, providing self-consistency checks and interesting inter-comparisons, using double differences or direct comparisons done on a large number of spectra.

The monitoring has been extended with inter-comparisons with other multispectral instruments like AVHRR (section 2), HIRS (section 3) and CrIS (section 4).

2) Comparison between IASI and AVHRR

With the launch of the second Metop, the operational IASI monitoring has been extended to make systematic comparisons between AVHRR on each Metop with pseudo AVHRR channels using IASI. The figures below show an example for the two IR channels, the two Metops (IASI-A on the left, and IASI-B on the right), during five days, from 1st of March to the 5th of March 2014. The differences are given in radiances (Y axis has been multiplied by 1000).

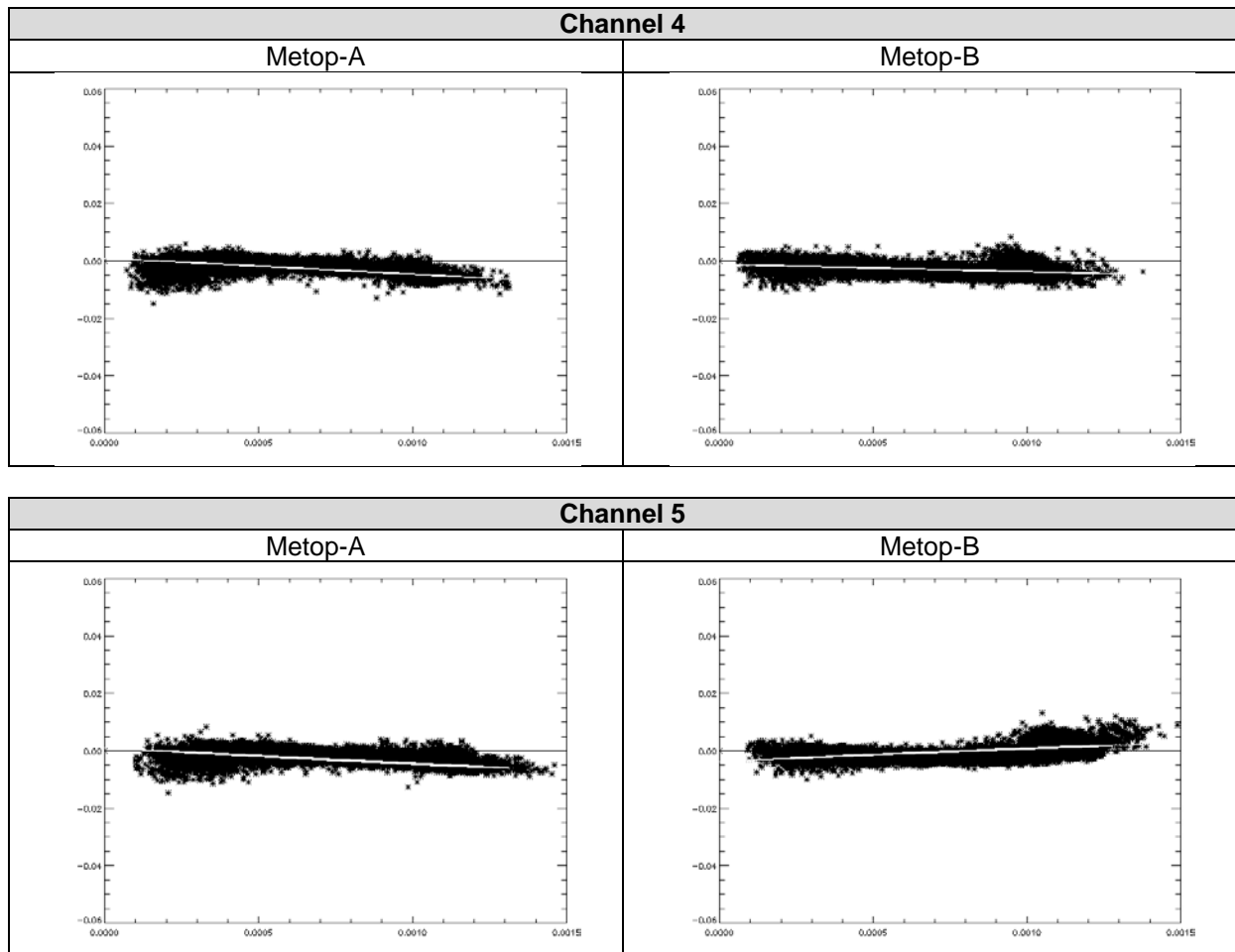


Figure 1: Differences between IASI and AVHRR in NedT at 280K for the channels 4 (top) and 5 (bottom) for Metop-A on the left and Metop-B on the right.

This has been done regularly during Metop-B commissioning. The four curves give always the same trend. It appears that one channel, the channel 5 on Metop-B, looks to be a bit out of family. Indeed, the channel 5 on Metop-B has a positive slope as shown in the tables below, compared to the 3 other channels.

Ch 4	slope	Y-intercept
M02	-5.52929	0.000977684
M01	-2.50335	-0.00118306

Ch 5	Slope	Y_intercept
M02	-4.89576	0.00107940
M01	4.1248	-0.00382163

After investigation, it might appear that this channel could be the only one well represented. This is under investigation on NOAA side.

3) Comparison between IASI and HIRS

The radiance comparison of IASI and HIRS on-board Metop is performed on all pixels with a distance smaller than 3 km between IASI and HIRS. All sky conditions are included (clear, cloudy, day and night). The radiance differences IASI - HIRS are given in NedT at 280K. On the figures below are shown the average and standard deviation for all HIRS channels in clear situations for day and night conditions, Metop-A and the left and Metop-B on the right. The comparison between HIRS and IASI on Metop-B are a bit different than the one done on Metop-A. Some HIRS-B channels are colder than IASI-B-like for the channel 4 and some others are much warmer like the channel 15 and 16, as shown on the figures below. The averages are given on the top and the standard deviations in the bottom.

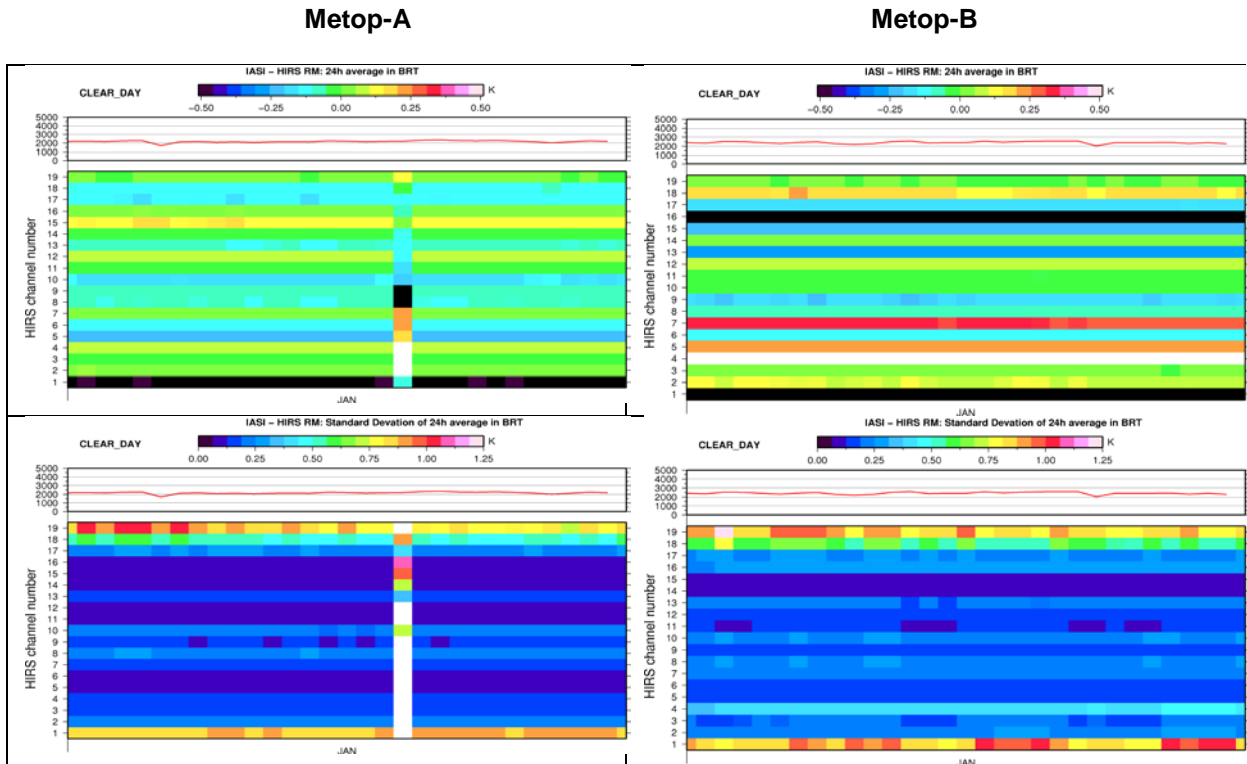


Figure 2: IASI-HIRS Differences: averages (top) and standard deviations (bottom). METop-A is shown on the left, and Metop-B on the right.

Taking the channel 4 as an example, the following figures show the comparison between daily averaged ($IASI_{HIRS} - HIRS$) for each Metop (left), and daily averaged differences between same instruments for both Metop (right). We see that ($IASI_{HIRS} - HIRS$) for Metop-B presents a bias of 0.8 K. The figure on the right shows that the difference observed in the case of Metop-B is coming from the HIRS pseudo channels using IASI. Because IASI-A is perfectly inter-calibrated with IASI-B as it is shown at the top left of this poster, it means the difference observed is coming from the HIRS instrument Spectral Response function used.

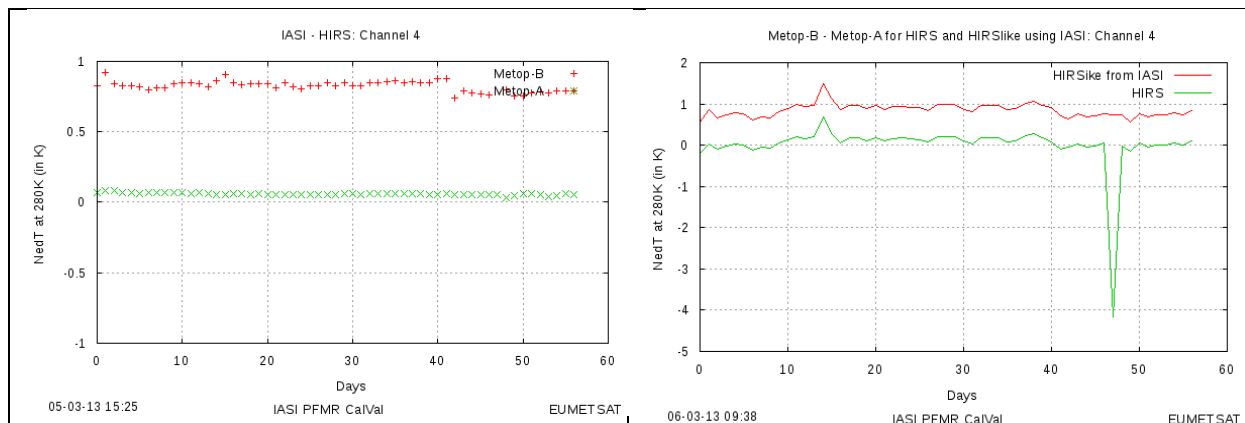


Figure 3: Left: Daily averaged differences between IASI convolved with HIRS SRF and HIRS for Metop-A in green and Metop-B in red. Right: Metop-B – Metop-A differences using HIRS in green and IASI convolved with HIRS SRF in red.

One can conclude that IASI and HIRS are well correlated for Metop-A and Metop-B, except some channels where the differences can be explained by the use of a non-appropriate Instrument Spectral Response Function.

4) Comparison between IASI and CrIS

In the frame of its agreement with NOAA, EUMETSAT is distributing products from the Cross-track Infrared Sounder (CrIS) instrument to the users via the EUMETCAST network. Both spectral characteristics and spatial resolution make CrIS very similar to the IASI instruments flying on both Metop. The inter-calibration aims at monitoring the quality of the CrIS products disseminated as well as providing a new calibration reference using IASI. This inter-comparison is performed using two approaches, at SNOs and using double differences.

a) Using direct comparison simultaneous nadir overpasses (SNOs)

The criteria used are 2 minutes time and 6.5 km distance differences every 7 weeks at +/-70° lat. The figure 4 shows an example in July 2013 for the North Pole, with IASI-A in red and with IASI-B in blue.

20130706 - 02:38 to 02:44 - IASI-A/CrIS

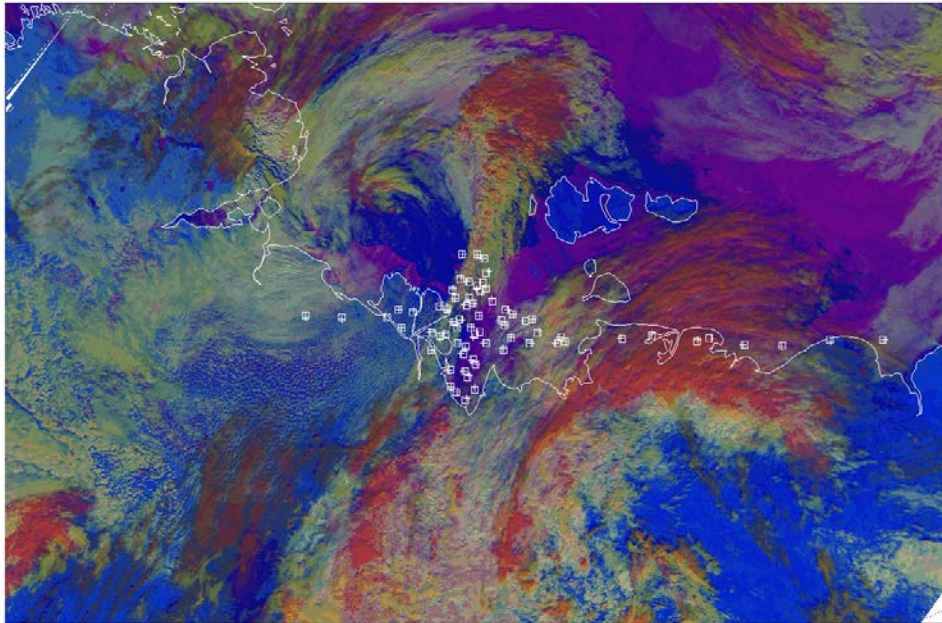


Figure 4: Example on SNOs for the North Pole, with IASI-A in red and with IASI-B in blue in July 2013.

The figure 5 shows the spectral difference between the two IASIs and CrIS for the northern SNOs. Both differences agree remarkably well, emphasizing the excellent consistency between the IASI instruments aboard the two Metop. An overall very good agreement between IASI and CrIS with the latter being slightly warmer in band 1. Noteworthy enough is the fact that the slope of the difference in band 1 is observed to be the same, being computed either with IASI-A or IASI-B.

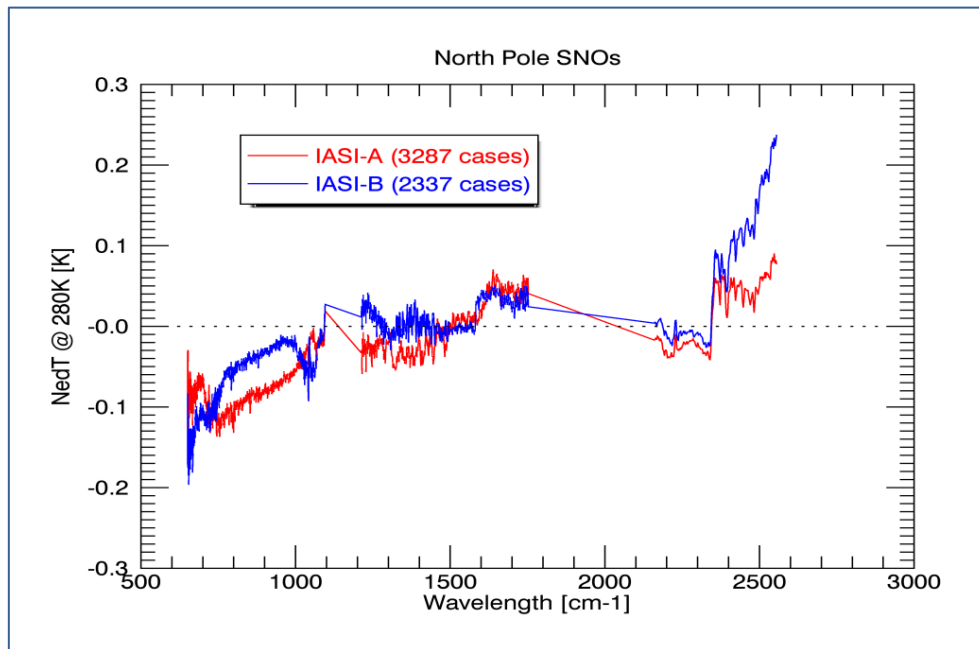


Figure 5: Average IASI-CrIS spectral difference expressed in NedT at 280K for the northern coincidences, for Metop-A (red) and Metop-B (blue).

The following features are noteworthy:

- An overall excellent agreement between IASI (both A and B) and CrIS: the spectral difference indeed never exceeds 0.2 K;

- A definite tendency of CrIS to be slightly warmer at longer wavelength: the spectral difference IASI-CrIS exhibits a slope in band 1 for both Metop-A and Metop-B and for both northern and southern SNOs that could indicate a possible flaw in the CrIS non-linearity correction.
- The same comparisons have been done with southern coincidences and it has been shown the same general agreement, except maybe in band 3 that is very sensitive to solar light.

b) Using the double differences techniques with simulations

The double differences technique using synthetic spectra has been previously used in the past to assess the radiometric consistency of IASI and AIRS (see for instance Elliott et al. [2009]). It is a useful complement of the SNOs method as it permits to extend the comparison to a broader geographical area; also the evaluation of the radiometric consistency can be performed every day, without waiting for the SNOs to occur, thus allowing a daily monitoring of its quality.

In this method, IASI and CrIS spectra are simulated using RTTOV 10.2 fed with temperature and humidity taken from ECMWF forecast fields; as no information were available in the ECMWF fields on the distribution of trace gases we have used standard profiles. These spectra, referred to as "CALC", are compared with the corresponding observations ("OBS"). Assuming that there is no differences between the errors induced by the use of ECMWF fields as well as by the RTM in the simulation of both IASI and CrIS spectra, these errors cancel to first order when doing the double difference i.e. we have in average:

$$(OBS-CALC)_{IASI}-(OBS-CALC)_{CrIS} \cong OBS_{IASI}-OBS_{CrIS}$$

In this method, it is important to use the same criteria to select the scenes from both instruments. We have selected CrIS and IASI scenes obtained in the following conditions:

- close to nadir (satellite zenith angle lower than 10 degrees);
- by night time (sun zenith angle larger than 120 degrees);
- in mid-latitudes or the tropics (latitude lower than 60 degrees);
- over sea;
- by clear sky.

Because we did not have the cloud information in most of the CrIS products, we have considered that a pixel is clear if:

- brightness temperatures at 11 microns ("surface channel" hereafter referred to as BT11) is larger than 280 K;
- differences between BT11 and the surface temperature is larger than 0 and lower than 5K;
- differences between BT11 and the brightness temperature at 3.9 microns is larger than -3K and lower than 1.5K;
- differences between the observed and the computed spectra is lower than 1K in the channel corresponding to BT11.

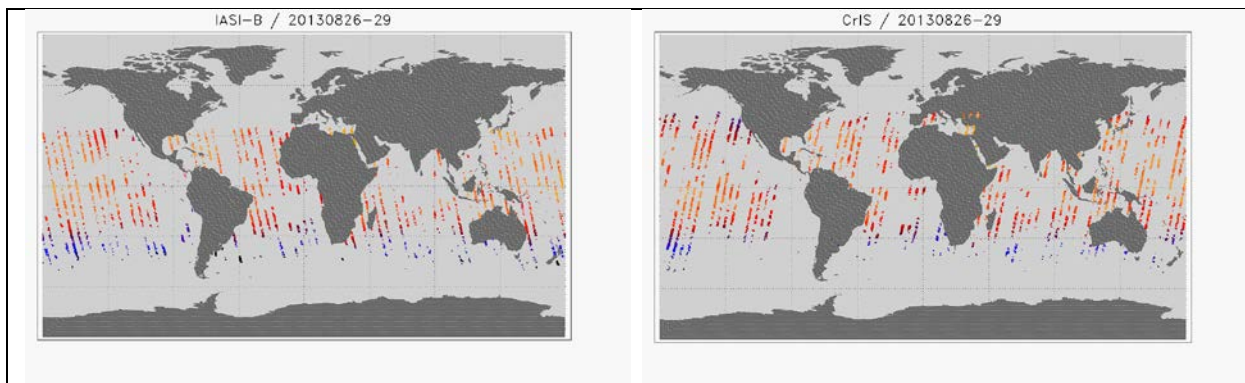


Figure 6: Geographical coverage of the clear IASI-B (left) and CrIS (right) clear pixels over 4 days.

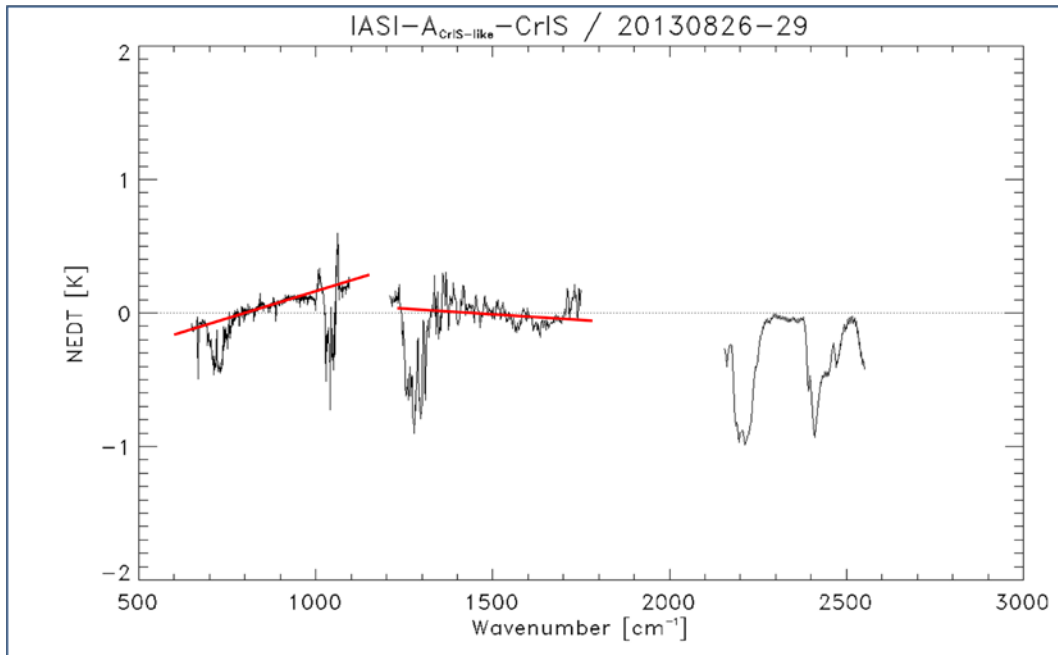


Figure 7: Spectral difference IASI-A – CrIS computed from the residuals OBS-CALC for both instruments for 4 days in August 2013.

The (Obs-Calc) differences are not as good as the ones from SNOs. More cloud filtering needs to be done. The figure 7 shows the spectral difference $OBS_{IASI} - OBS_{CrIS}$ computed from the OBS-CALC residuals for IASI-A and CrIS using four days in August 2013. It can be seen that:

- there are some peaks in the spectral difference: they are attributable to the fact that standard profiles of trace gases were used when computing the residuals. The signature of ozone is in particular clearly visible;
- if we ignore the peaks, there is an excellent agreement between IASI-A and CrIS, at least in band 1 and 2 (red lines on the figure). As already noted when using the SNOs, the maximum difference is of the order of 0.2K in band 1 and much less in band 2.
- there is a linear variation of the difference IASI-CrIS in band 1. This confirms the result obtained from the SNOs that CrIS (or IASI) non-linearity correction is not optimal;
- the difference is slightly higher in band 3. It must be noted however that the spectral sampling of CrIS is ten times the spectral sampling of IASI in this region. Both instruments thus not sample the same atmospheric layers and transforming IASI into a CrIS-like equivalent cannot solve the problem. The comparison in this band thus does not make much sense.

5) Comparison between IASI and IASI

Taking advantage of dual Metops, the operational monitoring has been extended to produce inter-comparisons between the two IASI, using double differences between IASI-A (Obs-Cal) and IASI-B (Obs-Cal). This inter-comparison has been developed during IASI-B commissioning and is now part of the monthly monitoring of the two IASI, providing self-consistency checks. This is always done between on-board and on-ground processing configuration updates. All spectra used have been taken by night, over sea, excluding the polar regions. The scheme below shows IASI-A – IASI-B differences from April 2013 (end of commissioning) to the actual configuration.

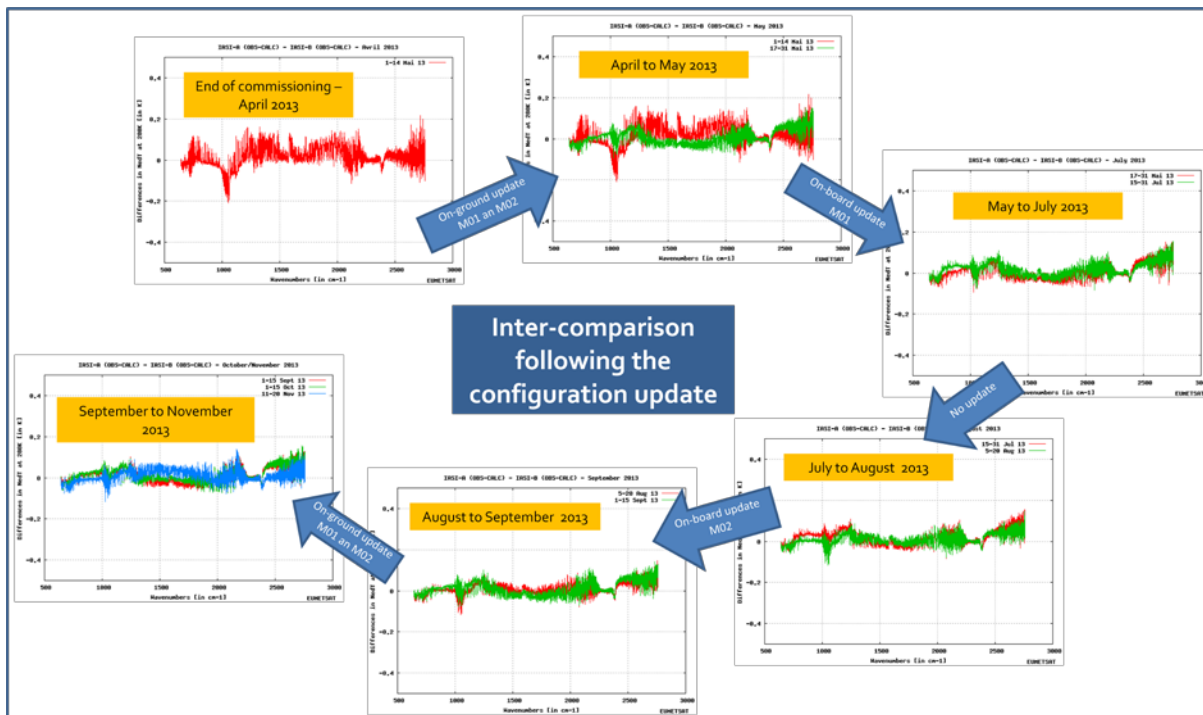


Figure 8: Inter-comparisons between the two IASI, from April 2013 (end of commissioning) to March 2014.

The difference in NedT at 280K remains between $\pm 10^{-1}$ K (the specification for Obs-Cal is 0.1K at 280K), which shows a good radiometric consistency between the two IASI. One can follow the configuration evolution quite accurately, giving a continuous status on the two IASI inter-calibration. The last configuration update gives the best fit between the two instruments. Note that this monitoring is done for 15 day per month, taking into account any configuration change.

6) Conclusion and perspectives

The comparison between each IASI with modelled radiances computed from ECMWF forecasts provides a good daily consistency check of IASI-A and IASI-B measurements. The reports are available on: <http://www.eumetsat.int/Home/Main/ServiceStatus/index.htm?l=en>. This monitoring gives an opportunity to perform inter-comparisons with other hyperspectral instruments (IASI, AVHRR, HIRS and CrIS).

The double differences comparison was implemented operationally to provide monthly check between the two IASI and especially when there is an update in the ground IASI level 1 processing. In addition, a direct comparison has been also implemented at EUMETSAT, providing not only a radiometric analysis but also a spectral consistency check. The outcomes of this monitoring will be available soon.

Furthermore, the global IASI monitoring is supplemented by the comparison with HIRS and AVHRR since 2007, and we have shown that gives interesting feedbacks for the other instrument, especially for those on Metop-B.

We are providing intercomparison with CrIS since its dissemination by EUMETSAT in July 2012. The inter-calibration between CrIS and the two IASI is performed using double differences with the forecasts files. This is done on clear scenes, at night, over ocean. It permits to check the quality of the CrIS products disseminated by EUMETSAT, and also to provide interesting consistency checks between the two instruments. We are also making direct comparison at SNOs (Simultaneous Nadir Observations) which occurs every seven weeks, allowing punctual checks. In general, except slight differences in band 1 due to the non-linearity correction, there is a good consistency between the two instruments.