



## Ether & IASI CALibration/VALidation

**M**etop-B has become, as of last April 24, the prime satellite, putting IASI Metop-B centre stage and making it the object of everyone's attention. IASI Metop-A remains fully functional, and its performance, still quite good, allows the continuation of scientific studies undertaken since its launch. Data available on Ether are handled daily and let researchers from different laboratories monitor the composition and even the real-time evolution of the atmosphere.

Since the launch of its “big brother” in 2006, IASI-B has successfully passed every qualifications and functions test, and every assembly and integration exercise conducted by CNES, Astrium, ESA and TAS, leading to a perfect launch on September 17, 2012.

Thereafter came the progressive “turning on” of equipment, the “cleaning out” instruments, and the first attempts of so-called “flight takings”. Once again CNES was in charge and, once again, all ran perfectly. The functional flight taking even finished a little earlier than anticipated.

At the time, ESA transferred the responsibility of the Metop-B satellite and its instruments to Eumetsat. A few days before the flight taking ended, once the first scientific data had been received, the CAL/VAL phase began. Its purpose was to fine tune the instrument in order for it to perform at its best. You'll have this entire newsletter to see that the target was reached, once again, beyond our expectations.

Thanks to genuine teamwork—contributors from CNES (performance experts, managers from the Centre of Technical Expertise and from the level 1 production chain), industry supporters (AKKA, Thalès, Noveltis, CapGémini), Eumetsat teams and scientists from LMD—, this CAL/VAL phase allowed all the users to obtain quality outputs from the new IASI instrument within six months (with quality as good as or even better than from IASI Metop-A).

We would like to warmly thank all those who played a role in the flight taking, especially in the CAL/VAL phase, which required significant preparation work, notably the “early dissemination” of Metop-B data on Ether.

Going forward, in operational mode, the outputs will be broadcast to all users via Ether (restricted access for level 1 data, free access for level 2 data). Full of curiosity, we eagerly await new scientific discoveries and meteorological applications made with IASI's data and its related instruments (HIRS4, AMSU-A, MHS) on board Metop-A and Metop-B.

Carole Larigauderie

IASI Mission Project Manager for CNES

## IASI and climate change: A long road

According to one theory, independently expressed by Kaplan and King as early as 1959, that we can determine atmospheric or ground variables from multi-spectral or multi-angular observations of the earth's atmosphere, various instruments (radiometers, spectrometers, interferometers) have been boarded on polar or geostationary satellite-platforms. Since the end of the 1970s, vertical sounders such as imaging sensors make continuous global observations of the earth and its atmosphere. From "first generation" works (NOAA's operational series, uninterrupted since 1978) to the recent launch of Metop-B (September 2012), and including "Aqua/Train", Gosat, Suomi NPP, Meteosat and GOES, concomitant and/or complementary satellite observations have allowed to achieve, particularly due to the spectacular upgrading of their spectral resolution, precise 3D profiles of water vapours, ozone, temperatures, concentrations of the main greenhouse gases (CO<sub>2</sub>, CH<sub>4</sub>, CO...) and macro and micro-physical characteristics of clouds or aerosols, essential characteristics of continental surfaces (spectral emission and temperature). In parallel, development of calculation and storage capabilities has brought this discipline into the era of the study of climatic variables via the analysis of long temporal series on a global scale. With some 8,461 channels covering the whole thermal infrared spectrum, IASI has a high spectral resolution and demonstrates very good performance regarding radiometry, geographical cover and space resolution. Following IASI on Metop-A and now on Metop-B, the indispensable continuity of measurements over the decades to come will be ensured by the launch of Metop-C, scheduled in 2018, and then through 2030 by the new generation of IASI-NG instruments.

*Noelle Scott — LMD*

### IASI: A GSICS reference

Going from these 3D representations to pertinent research about climate variability or evolution requires a great deal of quality and stability of satellite data. The first program of reanalysis of the satellite data, launched by NOAA and NASA in the middle of the 1990s, which involved LMD ("Pathfinder" program), intended to outline the approach for such research. Since, the international system of inter-calibration of WMO satellite instruments, in which CNES is actively involved, has taken over. The purpose of the Global Space-based Inter-Calibration System (GSICS) is to ensure the comparability of space measurements recorded at different times by different instruments and programs, and to link them to absolute references and norms. The

mission of GSICS is to contribute to a better use of the observations made in space and to allow for a new calibration of archived data.

Through its participation in the GSICS work group for the inter-calibration of weather sensors, CNES has shown the added value of the IASI performance. Today, IASI is the reference sensor of the GSICS for thermal infrared purposes.

*Denis Jouget — CNES*

*Noelle Scott — LMD*

### CNES CAL/VAL & inter-calibration

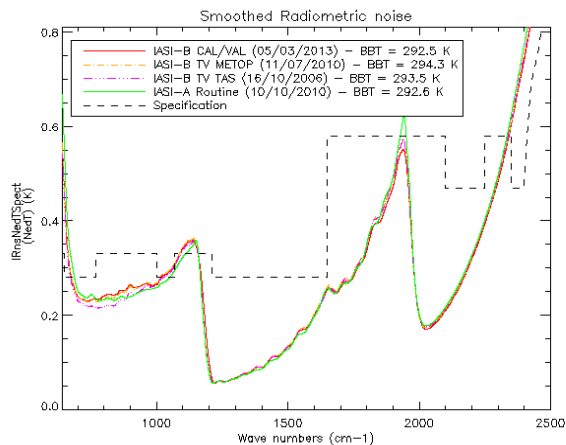
Metop-B was launched on September 17, 2012. After a period of decontamination and cold descent, the CAL/VAL of IASI-B began on October 23, 2012, upon reception of the first interferogram, and ended on April 17, 2013.

The goals of the IASI Metop-B CAL/VAL were:

- To tune the on-board and ground-based data processing algorithms' parameters in actual space conditions;
- To upgrade potential instrumental artefacts in the users' data in order for the data to be easily usable;
- To completely configure the instrument and to guarantee that its performance conforms to specifications and ground-based tests;
- To validate the IASI outputs by comparing them to data received from other infrared instruments.

Performing CAL-VAL for six months demonstrated that the instrument, the acquisition of interferograms, and the on-board and ground-based processes work perfectly and have optimized settings. Performance conforms to and even surpasses specifications.

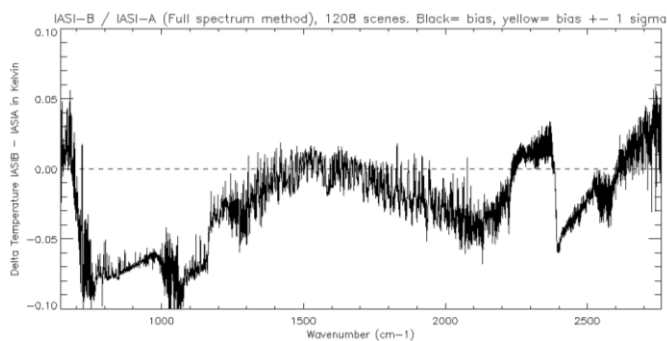
- Regarding radiometry, the relative inter-pixel calibration is better than 0.1K and the absolute calibration is approximately 0.1K. The radiometric noise conforms to specifications and is very close to that measured on IASI-A (see figure below).



- Relative inter-pixel spectral calibration is higher than 0.2ppm. The absolute spectral calibration was estimated by comparing it with simulations. It is lower than 2ppm. This evaluation has shown that some enhancements are necessary in the understanding of radiative transfer and of spectroscopy in some regions of the infrared spectrum.
- The stability of the interferometric axis is 20 $\mu$ rad; the position of the PSFs' centre of gravity is known within 20 $\mu$ rad. The geolocation precision of IASI's pixels is 200m (co-registration IASI/IIS  $\sim$ 100m, co-registration IIS/AVHRR  $\sim$ 100m). Stability of the line of sight is  $\sim$ 350m.
- Finally, the availability of the spectrums at the user level is about 99.5%.

The cohabitation of the two IASI also made possible an estimation of the inter-calibration between the two sensors in order to ensure the continuity of the IASI mission. Radiometric inter-comparison was estimated at IASI TEC, the centre of technical expertise at CNES, based on a group of particularly stable and homogenous observations (for the surface and the atmosphere) made almost simultaneously by IASI-A and B from all latitudes and with similar sight geometries.

The two IASI are within  $\sim$ 0.1K of each other (see figure below).



The spectral inter-calibration, based on clear tropical co-localised views, is about 0.25ppm.

Finally, radiometric inter-calibration of both IASI with AIRS and CRIS sensors during orbit crossings at high latitudes is approximately 0.1K.

*Elsa Jacquette, Éric Péquignot, Denis Jouglet — CNES*

## Ether's contribution

Ether obtains 35Go of data every day from the IASI Metop-A and B missions that are archived and made available, representing an overall volume of around 75To.

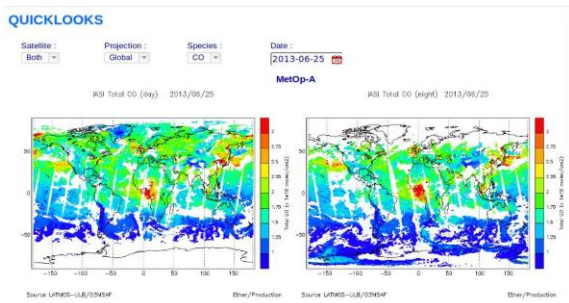
From its IPSL centre via the Eumetsat system (antenna and acquisition channel), Ether retrieves the IASI data in NRT. These highly voluminous data (BUFR format) are managed, archived and made available for users who can either repatriate them or use them directly in a computing cluster called "ciclad" (496 computing cores, 1,2Po of data).

Upon the launch of Metop-B, the LMD team provided expertise in the area of inter-comparison/inter-calibration of the IASI-B data, further to calibration/validation works conducted by CNES and Eumetsat. Thus, last fall the Ether technical centre at IPSL, in cooperation with the team from LMD, prepared the necessary environment for these IASI-A and IASI-B processes by making the first IASI Metop-B data available (early dissemination, from January to April 2013). These were AMSUA, HIRS4 and MHS (L1b) data associated with the installation of version 7.4 of the AAPP software (ATOVS and AVHRR Pre-processing Package) on the "ciclad" cluster.

IASI Metop-A data acquired since 2007 and IASI Metop-B data acquired since April 2013 are available to all users following a simple registration for level 2 data.

Apart from the acquisition/archiving/distribution of these data, Ether offers a set of integrated and consistent services related to IASI such as:

- Timeline providing the history and forecast (on Metop-A and B) of operations and processes having an impact on the different IASI outputs for levels 1 and 2;
- "OBR" multi-criterion extraction tool for level 1C IASI Metop-A and B data. The data tool for IASI level 2 data will be available for users in July 2013;
- Generation of Quick Look maps for CO and surface temperatures for Metop-A and/or B. Maps for humidity levels will be available as of September 2013;



- The GEISA-IASI database regularly upgraded for IASI chemical species;
- Metop-A CO data coproduced by LATMOS and ULB;
- Finally, further to these space data, datasets from the IASI instrument collected during balloon flights.



All of these services are available on the Ether homepage <http://www.pole-ether.fr> by clicking on the IASI icon (red square).

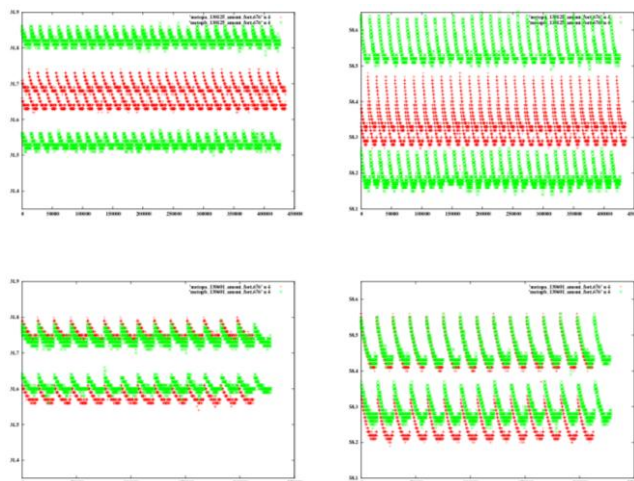
Cathy Boonne — IPSL

Mireille Paulin — CNES

### Some validation results by LMD

For a long time, LMD has defined **an inter-calibration approach** of the LEO/LEO nature, which uses different accompanying instruments together, and **a stand-alone approach**. Used in parallel, these two approaches prove to be a powerful tool to identify unexpected or undesired behaviours of on-board instruments, the latter allowing identification of which instrument deviates from the others. The major constraint behind the two approaches is that the instruments and the “accompanying channels” be chosen for their space, time, spectral and radiative coherence. With IASI/Metop-A and IASI/Metop-B, spatiotemporal coincidence is excellent. By definition, spectral coincidence of the channels is perfect.

**Result of the inter-calibration:** A problem in the values of the lines of sight between Metop-A and Metop-B, highlighted by LMD during the IASI Conference in February 2013, has since been corrected by CNES.



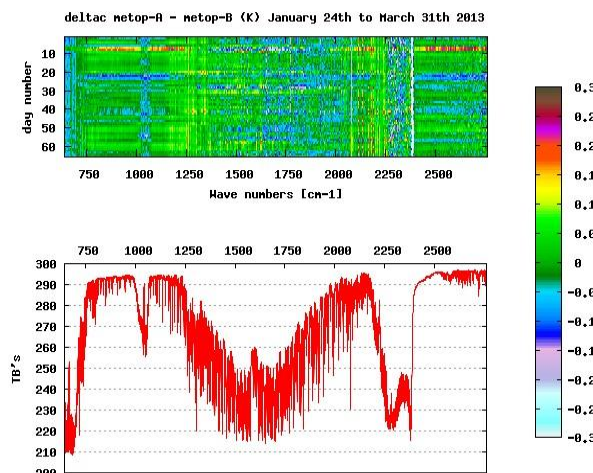
**Figure a:** Differences of behaviour between satellite lines of sight (SLA) of Metop-A (red) and Metop-B (green) for two different lines of sight (~31°—left figures—and ~58°—right figures).

Upper figures: The problem for each of these lines of sight.

Lower figures: The same type of graph after CAL/VAL operations by CNES (É. Péquignot *et al.*).

Everything falls into order and we can observe a nearly superimposed behaviour for Metop-A and B.

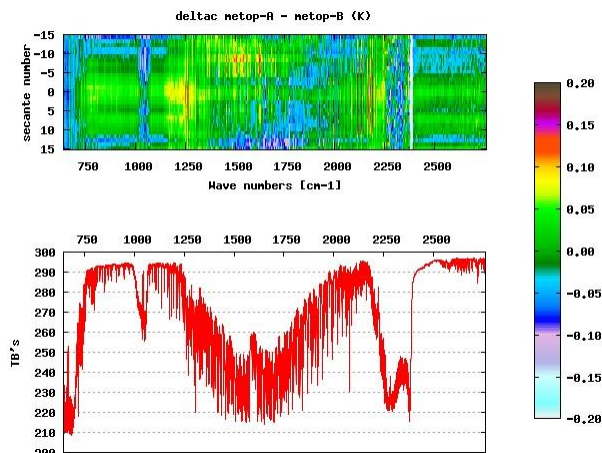
**Results of the stand-alone approach:** Simultaneously observing Metop-A and Metop-B by means of a study of double differences using the “stand-alone” approach, our efforts focused on the search for deviations between two identical channels (see figure b) and for a possible dependence between observations along the scan line (see figure c).



**Figure b:** Temporal series of the daily averages of double differences (IASI-A—IASI-B) in “calc-obs”



residues from January 23 to June 10, 2013 (upper figure). The differences are very low, within the range from  $-0.1$  to  $0.1\text{K}$ . We note “red” signatures on the graph around January 30 due to a lack of data from Metop-B. The lower figure represents the average spectrum of brightness temperatures, allowing us to link results from the upper figure to the scene temperatures.



**Figure c:** Variation in the average double differences (IASI-A—IASI-B) in “calc-obs” residues by line of sight around the sub-satellite track. These results are averaged over the period from January 23 to June 10. The differences are very low, within the range from  $-0.15$  to  $0.15\text{K}$ .

All of these works are underpinned by the 4A/OP model, the offline ARSA, GEISA and TIGR databases, as well as by the analysis and reanalysis by ECMWF. The unarchiving and processing take place on Ether/Ciclad, ADA/IDRIS and ClimServ.

As of today, the statistics have centred on several hundreds of thousands of collocations between 4A/OP and analysis made by the European Centre of the tropical zone, the night, and the sea. **In both cases, the gap between Metop-A and Metop-B is remarkably low.** This confirms, in a completely independent way, certain results obtained elsewhere by CNES.

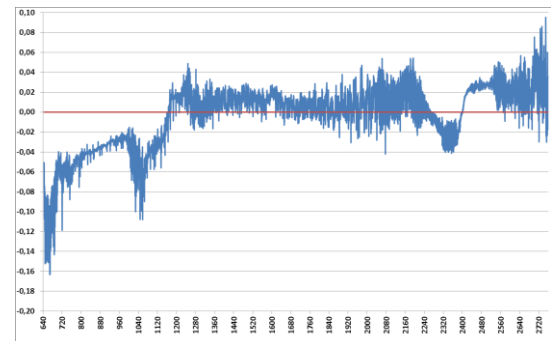
Thanks to the original “stand-alone” and double differences method, the LMD approach has also introduced a unique way to explore behaviours of the IASI instrument along scan lines.

<http://ara.abct.lmd.polytechnique.fr/>

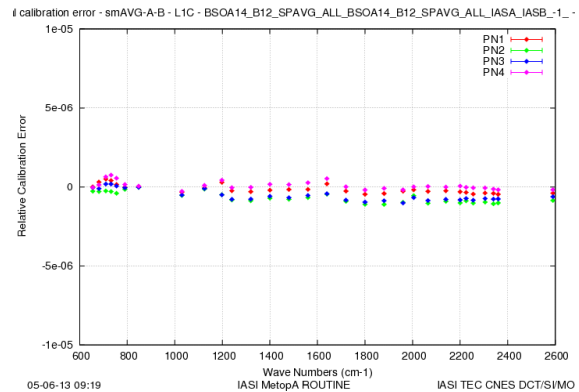
Noelle Scott, Laurent Crépeau, Raymond Armante, Jérôme Pernin, Mayssa BenSassi, Alain Chédin — LMD  
 Éric Péquignot — CNES

**Massive averages for climatology and IASI-A/IASI-B inter-calibration**

Data provided by Ether have also been used by CNES to calculate massive averages of all the IASI-A and IASI-B spectrums ( $\sim 50$  millions) independently of each other over the same periods. The difference between these massive averages demonstrates in an independent way that the radiometric inter-calibration between IASI-A and B is approximately  $0.1\text{K}$ .



The spectral inter-calibration over these massive averages is also confirmed (some  $0.25\text{ppm}$  on average).



Denis Jouglet, Thierry Phulpin — CNES

## Continued...

The three independent approaches of inter-calibration presented here have proven the continuity of the IASI mission and allow to affirm that the reference of the infrared sounders can now be transferred from IASI-A to IASI-B by GSICS.

Regarding the scientific objectives—for these works follow, underpin or interfere with several approaches aiming to render level 2 data—, we are considering continuing this research, making these validation results available to any interested group, and strengthening discussions between LMD/CNES and the international community within the context of GSICS.

In its environment at CNES, IPSL and OMP, with its ability to receive, share and archive levels 1 and 2 outputs from Metop-A and Metop-B, Ether is one of the essential elements to extending and spreading this discipline on an international scale.

*Noelle Scott — LMD*

*Denis Jouglet, Mireille Paulin — CNES*

## More from Ether

New data and services put at your disposal on the Ether website: <http://www.pole-ether.fr>

- Levels 1 & 2 GOSAT data (CO<sub>2</sub> and CH<sub>4</sub>) from TANSO-FTS (Fourier transform spectrometer) and TANSO-CAI (cloud and aerosol imager) instruments continuously since December 2012 (for access, email [sebastien.payan@upmc.fr](mailto:sebastien.payan@upmc.fr)).
- IUPAC, an international database of kinetic and photochemical data, since June 2013 (open access on the Ether website).
- TAPAS is a free online service used by the astronomical community that allows to filter the observed spectrum with the simulated transmission spectrum in order to obtain the targeted spectrum “outside of the atmosphere”.

Of course, all the services and databases already available on the Ether website:

- ECCAD: Emissions of atmospheric Compounds & Compilation of Ancillary Data;
- IAGOS: In service Aircraft for a Global Observing System;
- NDACC: Network for Detection of Atmospheric Composition Change;
- Girafe: Software allowing the calculation of forecast trajectories of fire panaches and other compounds;
- MIMOSA: Advection model allowing the calculation and visualisation of potential vorticity fields (analysis and forecast), notably useful for launching balloons;
- REPROBUS: 3D chemistry-transport model calculating temporal evolution of 55 chemical species, including trace gas...
- ...

For all requests related to Ether, please contact us at [ethersvp@ipsl.jussieu.fr](mailto:ethersvp@ipsl.jussieu.fr)

*Cathy Boonne — IPSL*

*Damien Boulanger — OMP*