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The IASI technical expertise center : IASI tuning and performance monitoring

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CNES is involved in many earth observation missions. In particular, it plays a key role in the performance monitoring and tuning of in-flight payloads. In that respect, so-called "technical expertise centers" are set up to analyze the status of each instrument under CNES responsibility and, if necessary, to generate new configuration either for in-flight payload or ground segment. This consists in an appropriate pool of technical and human resources dedicated to a particular instrument. The generic architecture of an "expertise center" will be presented in the context of IASI system. The IASI expertise center will be described in details with particular emphasis on its complexity and diversity. Indeed, together with a software aimed to monitor IASI performances and to generate IASI configurations, IASI expertise center includes the IASI level 1 ground segment as well as a numerical model of the instrument. Finally, the main outcomes of the IASI expertise will be presented : the IASI performances, after almost three years in orbit, will be reviewed.

I. Introduction

IASI, Interféromètre Atmosphérique de Sondage Infrarouge –*Infra Red Atmospheric Sounder*-, is a key payload element of the METOP series of European meteorological polar-orbit satellites (EPS, cf. Fig 1). It has been developed by CNES in the framework of a cooperation agreement with EUMETSAT. The first flight model was launched in 2006 onboard the first European meteorological polar-orbiting satellite : METOP-A. The second and third instruments will be mounted on the METOP-B and C satellites whose launches are actually scheduled in 2012 and 2016.

A. The CNES role in IASI

CNES has technical oversight responsibility for the instruments development up to their deliveries to EUMETSAT. Moreover, CNES has developed the onboard processing software (Data Processing Software - DPS), the level 1 processing chain (L1/PPF) and the software deployed at the IASI expertise center (IASI-TEC). During exploitation phase, CNES is responsible for the instrument calibration, operates IASI-TEC and maintains the IASI L1/PPF. The latter is operated by EUMETSAT in Darmstadt (Germany)

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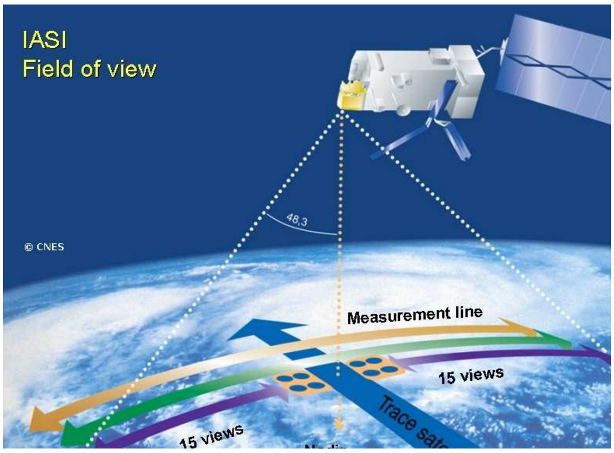

B. Instrument overall design, performances and scientific objectives

IASI is an infrared spectrometer – or sounder - associated with an imager : the Integrated Imaging Subsystem (IIS). A detailed description of IASI is available in Ref. 1 and 2. By definition, a spectrometer is an instrument that provides the energy distribution of light. The IASI sounder is based on a Michelson interferometer. Because of a limited bandwidth, the interferograms are processed by the DPS which performs the inverse Fourier transforms and the radiometric calibration. This leads to data rate reduction from 45 to 1.5 Mb/s. Thanks to the infrared imager (IIS), the IASI soundings are coregistered with AVHRR (http://noaasis.noaa.gov/NOAASIS/ml/avhrr) imager onboard METOP-A.

IASI has been designed for operational meteorological soundings with a very high level of accuracy (specifications on temperature accuracy: 1K for 1 km and 10 % for humidity) being devoted to improve medium range weather forecast. Trace gases column amount (CO, CH4, N2O) are retrieved with an accuracy better than 10 % and 5 % for Ozone.

C. IASI system

The IASI system is composed of the on-board segment (the instrument and the associated on-board processing software), the ground segment (the level 1 processing chain) and the IASI expertise center. The latter is in charge of the instrument performance monitoring, performance-related anomaly investigation, the development and validation of new algorithms and the maintenance of the on-board and ground softwares. The IASI system relies on the CNES-EUMETSAT cooperation. The main interfaces between the IASI expertise center and EUMETSAT are presented in Fig. 2.

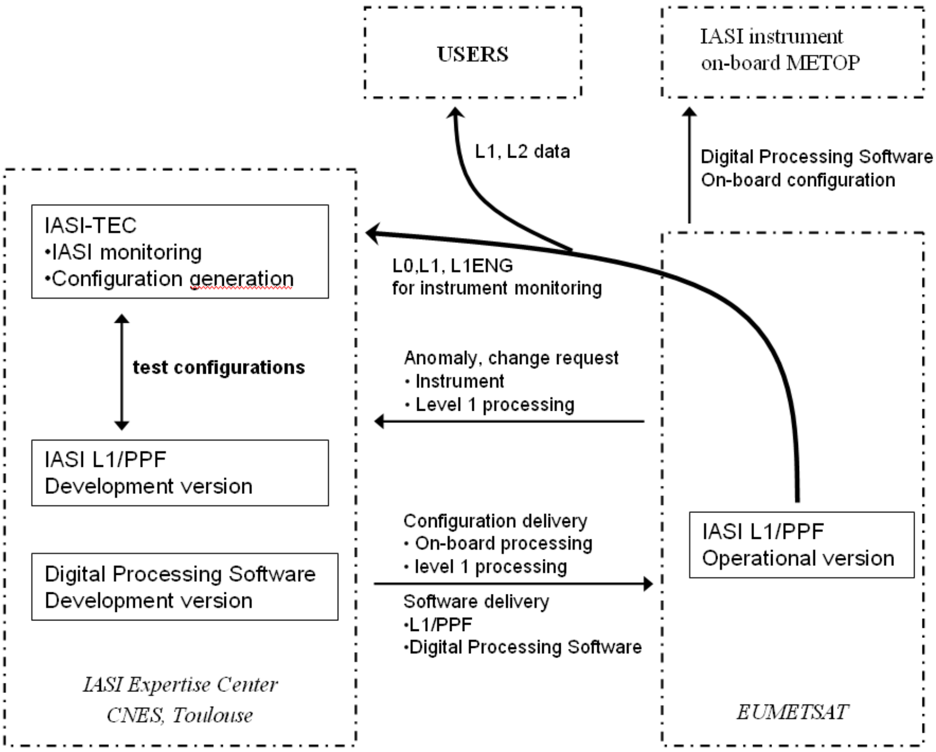

Figure 2. IASI technical expertise center main interfaces

II. IASI expertise center : architecture and organization

Technical expertise centers are set up to analyze the status of each instrument under CNES responsibility and, if necessary, to generate new configurations either for in-flight payload or ground segment. This consists in an appropriate pool of technical and human resources dedicated to a particular instrument. This concept is applied to many instruments at CNES like for examples : the Spot family (QIS, *Qualité Image Spot*), IIR on board CALIPSO (CALIPSO-TEC, for CALIPSO Technical Expertise Center) or Parasol. Those Technical expertise centers are operated at the “Image and instrument exploitation” team at the CNES Toulouse Space Center. This team also maintains transversal means that are of mutual interest, like intercalibration tools.

A. Hardware architecture

The IASI expertise center hardware architecture is organized around a 25 To linux data storage server and a data base under Oracle on which 9 work stations are all connected to. The incoming IASI data flux is delivered by a near-real time satellite transmission from EUMETSAT. The content of the data ingested by the IASI expertise center is tunable as a function of the mission phase. A clone of the IBM processing facility that is operational at EUMETSAT is also included, this is essential to make L1/PPF speed test.

B. Flexibility

One of the most important characteristic of any technical center is to allow for a true human resources flexibility. This is imposed by a very variable charge as a function of the mission phases, and this is made possible thanks to the general CNES organisation. There’s a least a factor of 3 in the number of required persons between critical phases - like during the instrument commissioning or in case of serious anomaly investigation - and the routine phase. The IASI expertise center architecture has been adapted accordingly. The number of work stations has been dimensioned to support high activity phase. In the meantime, the data exchange, and more generally working in collaboration, are make very easy thanks to the data server and the data base.

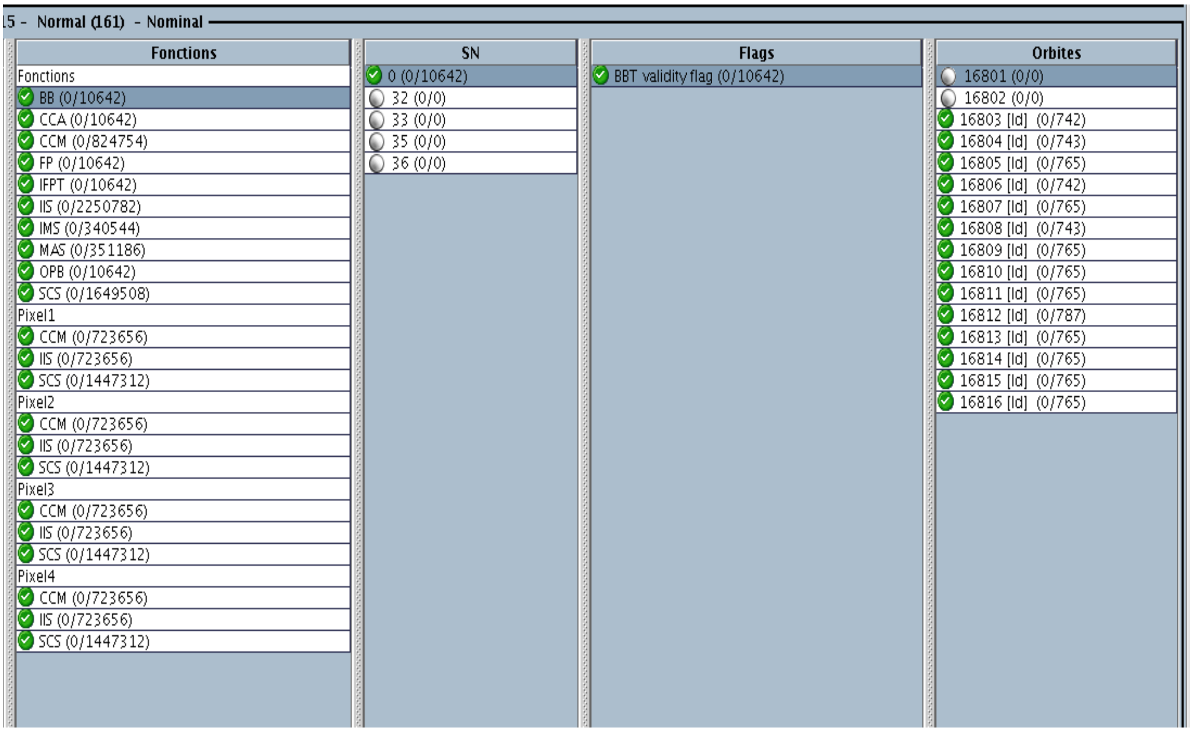

Figure 3. Instrument monitoring panel for one day. All the main instrument subsystems status are available (BB=Black Body, CCM=Corner Cube Mechanism, MAS=Main Acquisition Subsystem …).

C. Software architecture

A software, named IASI-TEC, has been specifically developed to meet the main IASI expertise center requirements : monitor the instrument and generate the configuration files. One of its main features is to read all the incoming IASI products and make a systematic data quality check. In this respect, so-called level-1 engineering products are of prime interest since they contain all the data quality flags and quality indexes related to the instrument itself, but also to all the main processing steps. The result of this monitoring is accessible thanks to a control panel (cf. Fig. 3). This allows a fast and efficient analysis of the IASI status. In order to complete the control panel that gives an instantaneous picture of the instrument health, long term synthesis of the most important parameters are generated.

Then, to address more specific issues, particular tools dedicated to on-demand tasks are included in the IASI-TEC software. Those tools are related to rather stable parameters for which an important processing is required. This is the case for the coregistration between the IIS and the IASI sounder which is very time consuming. However, because IASI imager and sounder are parts of the same instrument, there are mechanically linked together. Therefore, monitoring the IASI IIS-sounder coregistration with a frequency of 3 months is sufficient. This particular case illustrates well the trade-offs that have to be defined in the organisation of any expertise center. It's a matter of compromises between parameters stability, parameters criticity and resources needed. These compromises are defined during the project development phase and are validated at the end of the commissioning phase, after a detailed study of the instrument in-flight behaviour. As a support in the investigation of any critical anomaly, the IASI expertise center also includes the IASI instrument numerical model, a breadboard of the DPS and a local copy of the L1 processing chain.

III. IASI Level 1 processing chain

The IASI L1/PPF process –raw- L0 data and compute level 1 data that mainly consists of fully calibrated and uniformly apodized spectra. As the main use of those spectra is operational meteorology, one of the most stringent constraint is a near real-time processing. Indeed, with a data flux of about 40 Gb/day, a parallelization of the code has been mandatory and is actually implemented using multi-threading.

Together with spectra, IASI L1/PPF also generates data quality flags that are of prime importance for operational usage. In fact, each step of the board and ground processing generates intermediate data quality flags. At the end of the processing, the flags are combined to create a unique and binary data quality flag. It's the one used by operational meteorological centers to plug or unplug IASI data in their models. Those data quality flags are included in so-called engineering data that are intensively used by IASI TEC. Indeed, IASI engineering data contains the main quantities that describes the status of the instrument (temperature, voltages), but also a series of data quality flags and index reflecting board and ground processing.

IASI L1/PPF takes benefit from the CNES-EUMETSAT collaboration. It's an evolving software; both institutions are able to generate anomaly reports or propose modifications. End users can also contribute to this effort through EUMETSAT. A good example of such a cooperative effort are the so called "Day-2 evolutions" that have just been completed. It's a joint proposal from CNES and EUMETSAT which consists in a major evolution of IASI L1/PPF, impacting configurations and L1 product formats and quality. Several aspects have been considered. In particular, the data availability will be improved by making the general quality flag dependant on the spectral band. In fact, the band that mainly contributes to data rejection because of its high sensitivity to space environment is also the one that is the less used by operational centers. To speed up the operational usage, IASI data will now include the cloud mask extracted from AVHRR. Then, IASI-AVHRR pseudo-channels have also been added to allow for a systematic cross-monitoring of this two instruments. The "Day-2 version of L1/PPF" should be introduced into the EUMETSAT operational ground segment in spring 2010

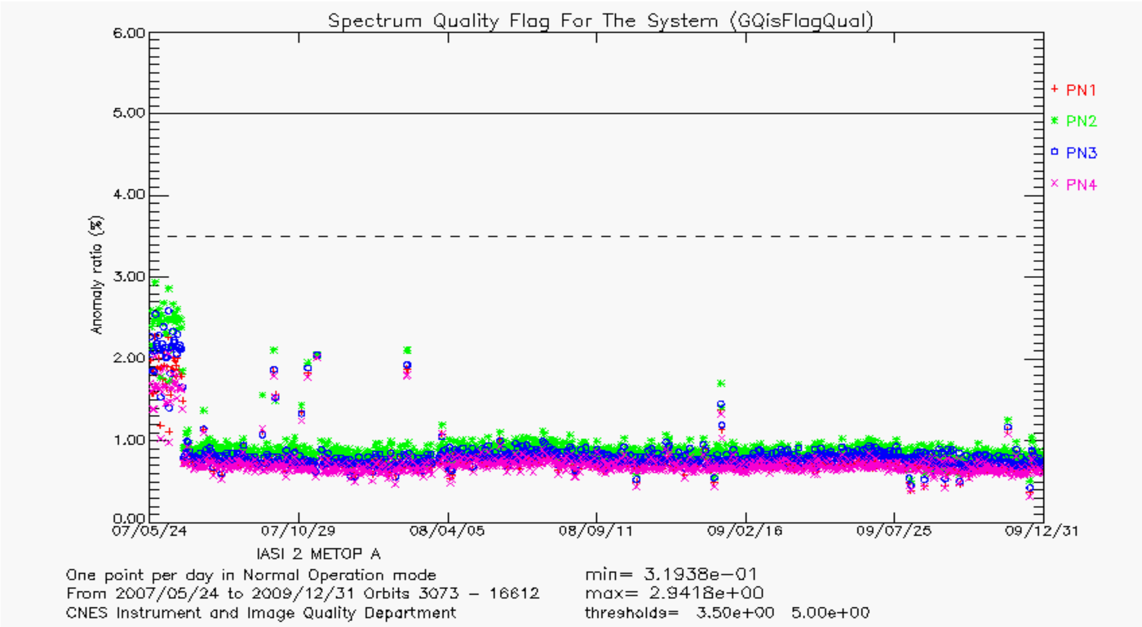

Figure 4. IASI L1 data quality orbit average as a function of time since the instrument has been turned on for the 4 IASI sounder pixels. One should note that the actual data rejection ratio is actually lower than 1%. The impact of the end of commissioning configuration delivery is clearly noticeable around June 2007.

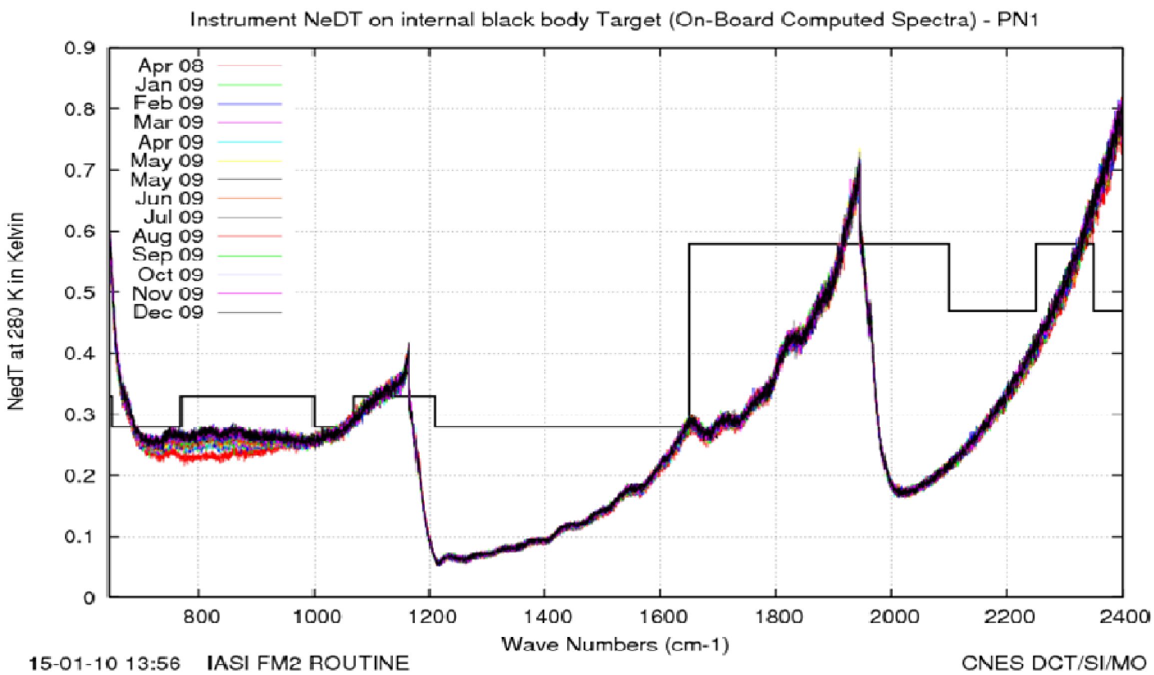

Figure 5. IASI radiometric noise as a function of wave numbers and time for pixel 1. The impact of ice pollution is clearly visible around 850 cm^{-1}.

IV. IASI tuning and monitoring

Currently, the IASI-TEC software systematically monitors 182 parameters reflecting the instrument health and the processing quality. Among those, 158 are monitored on a long term basis thanks to long term synthesis that are generated every month. Finally, more complex tasks can be addressed using one of the 20 tools that are specifically designed for on-demand study.

A. Reporting, communication and meeting

A regular public reporting will be provided to IASI users thanks to quarterly reports that are going to be freely distributed on the IASI web site[7]. These reports are completed by monthly reports that are internally distributed to IASI experts. Then, regular meetings, involving IASI experts, are coordinated by the IASI technical expertise center. There, the main monitoring results are analysed, potentially opened anomalies are reviewed and, if required, actions are taken to address all open issues. Because IASI is on-board METOP-A, which is operated by EUMETSAT, the IASI expertise center team has recurrent interactions with EUMETSAT. Short-term interactions are insured by regular teleconferences, typically twice a month in routine phase. More formal meetings are performed on a yearly basis and involve a broader audience: a mid-term review at EUMETSAT and an annual review at CNES.

B. Optimization of the instrument configuration

Using the results from the performance monitoring, a new configuration of the instrument can be proposed. Before any new configuration is used operationally, they are systematically tested at the IASI expertise center using the local copy of L1/PPF or of the DPS. As an illustration, one can refer to Fig. 4 which reflects the general data quality as a function of time since the beginning of IASI operations. Please note, that the step observed around June 2007 is due to the end of commissioning configuration delivery that had impacts on both board and ground configurations. As it can be seen in Fig 4., more than 99% of IASI data are classified as good quality. Moreover, the data quality is very stable over time.

Configuration parameters delivery can be classified in two categories : exceptional and periodical. Exceptional deliveries are related to configuration parameters that are generally stable in time but not predictable before the launch, or that have to be changed after an anomaly. As an illustration, this is the case for the on-board coding table, or the default value for the interferometric axis. Most of the parameters that need an exceptional delivery have been updated during the commissioning phase. On the other hand, periodic deliveries are associated to parameters that evolves slowly with time but which have significant impacts on the performance. As an example, one can cite the scanning mirror reflectivity which evolves slowly with time because of pollution.

Over the last three years, 22 sets of updated configuration files have been delivered to EUMETSAT since the beginning of IASI operations.

C. Periodical operations : external calibrations and decontamination

So-called "monthly external calibrations" are executed to provide IASI data fully dedicated to instrument monitoring. Each month, about three hours of data are accumulated in this particular instrument mode. During these periods, intensive acquisitions of the on-board calibration targets give a very precise assessment of the native instrumental noise. On the other hand, concentrated nadir observations allow to check the spectral calibration stability by oversampling night homogeneous scenes over the sea. Finally, the reflectivity of the scanning mirror is calculated by combining scanning mirror back views with cold space views.

[7] http://smsc.cnes.fr/IASI/

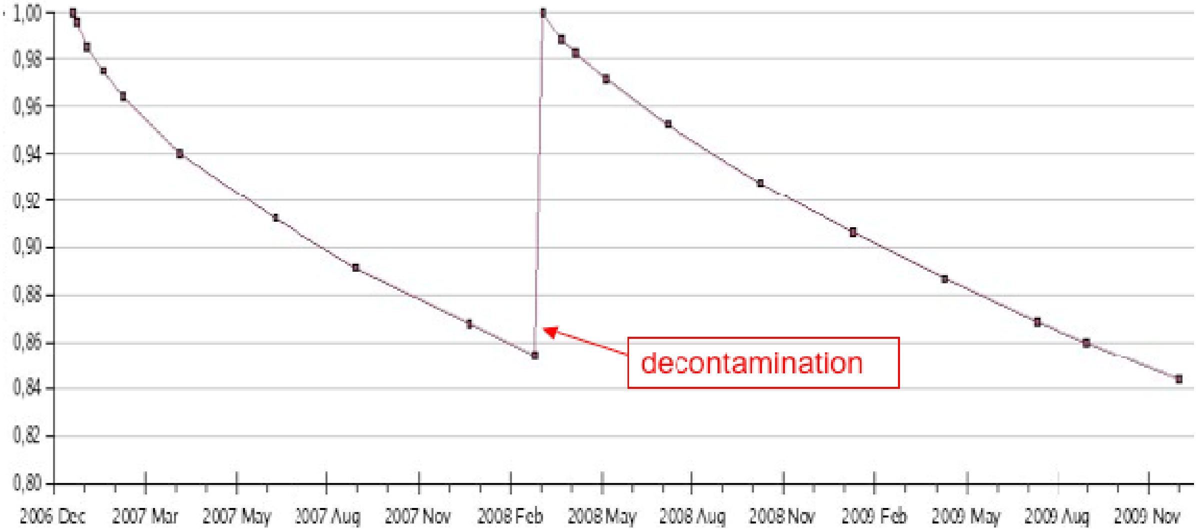

Figure 6. Optical transmission of IASI as a function of time at 850 cm^{-1}. One should note the perfect recovery of the system after the last decontamination in march 2008. The lower limit for the transmission being 0.8, the next decontamination is planned for end of 2010.

The field lens of the IASI optical system is included in the cold box that hosts the detectors. That unfortunately makes it sensitive to ice pollution. This effect is clearly visible in the instrumental noise which increases significantly with time in the regions where ice absorption is maximum (cf. Fig. 5). Fortunately, this effect can be cured by a so-called decontamination procedure. This simply consists in reheating the instrument. However, IASI thermal control system is passive, so the mission interruption related to a decontamination lasts a few days. This is very disadvantageous with respect to METOP prime objective : operational meteorology. Hence, it is very important to precisely plan this kind of event. This is done using the 850 cm^{-1} channel of the instrumental noise which is the most affected by ice absorption. To be in line with the specifications, the optical transmission must not go below 0.8. The first IASI decontamination went very smoothly in march 2007. That decontamination has been performed a few months before the expected date to reduce the mission outage by using a period during which the instrument thermal control was already stopped because of an anomaly. A perfect recovery of the optical transmission has been observed as illustrated in Fig. 6. More details on IASI-related operations can be found in Ref. 3.

V. Conclusion

We report on the IASI expertise center that is deployed in CNES Toulouse. Actually, the concept of "technical expertise center" is also applied to other instruments under CNES responsibility, like the SPOT family for example. In our case, the idea is to create a synergy between all experts by providing a working space dedicated to IASI. The latter includes appropriated hardware, software and a data base which optimize of the exchange and data flux between all protagonists. It is "by design" flexible to adapt the human resources to any mission phases or potential anomaly.

The IASI expertise center has continuously and rigorously monitored the METOP-A high resolution atmospheric sounder IASI for more than 3 years. It plays a key role in maintaining the whole IASI system performance. Using the feedback from the instrument commissioning phase, a monitoring strategy has been defined for the routine phase. This allows to report that the instrument is actually behaving very well: radiometric, geometric and spectral performances are all compliant with the specifications. Generally speaking, the instrument is very stable over time. We note a global satisfaction of the instrument operator : EUMETSAT as well as of all the end users : meteorological centers, the climatology and atmospheric chemistry scientific communities.

Although the instrument stability originates from the instrument design and realization quality, it is maintained in-flight thanks to periodical deliveries of instrument and level 1 configurations. Moreover, the quality and availability of IASI data will be improved by the recent evolutions of the L1 processing chain. The IASI expertise center is currently working on the integration of an intercalibration tool with the Atmospheric Infrared Sounder AIRS onboard Aqua[8]. It will then move to the preparation of the second IASI commissioning phase whose launch onboard METOP-B is planned for 2012. Then, IASI-1 and IASI-2 should be in operation at the same time for at least a few months: this is going to be a unique chance to make an in-flight intercalibration of both instruments.

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[3]L. Buffet, these proceedings.

Glossary

- **AVHRR** : Advanced Very High Resolution Radiometer. It's embarked on-board METOP. AVHRR data are used to geolocalized IASI products.
- **CNES** : *Centre National des Etudes Spatiales*, French Space Agency
- **DPS** : Digital Processing Software. IASI on-board software, it processes interferograms and generates pre-calibrated spectra.
- **IASI** : *Interféromètre Atmosphérique de Sondage Infrarouge*, Infra Red Atmospheric Sounder. It includes a sounder and an imager (IIS, Integrated Imaging Subsystem).
- **IASI expertise center** : deployed at the CNES Toulouse Space Center. It's responsible for the IASI performance monitoring and IASI tuning.
- **IASI L1/PPF** : IASI level 1 processing chain. Developped and maintained by CNES, operated by EUMETSAT.
- **IASI-TEC** : the software operated at the IASI expertise center, it allows the instrument monitoring and the generation of IASI ground and on-board configurations.
- **EPS** : European meteorological polar-orbit satellites
- **METOP** : Meteorological Operational satellite programme, it forms the space segment of EUMETSAT's Polar System (EPS). METOP-A has been launched in 2006, METOP-B and METOP-C launches are planned for 2012 and 2016.
- **EUMETSAT** : European Organisation for the Exploitation of Meteorological Satellites

[8] http://airs.jpl.nasa.gov/