Validation Report – IASI-A Level 1c FCDR release 1

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V1	11 May 2018		Draft Version
V1A	30 September 2018		USC/MDB review and template update
V1B	18 December 2018		Final version
V2	17 April 2019		Final version for DRR
V3	18 July 2019		Draft version after reply to the RIDs
V3A	2 October 2019		Final version after DRR and EUM QA review

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1 INTRODUCTION

The Infrared Atmospheric Sounding Interferometer (IASI) instrument is currently flying on Metop-A, Metop-B and Metop-C. The instrument provides Level 1 radiance products that are used in data assimilation systems and retrieval schemes to derive Earth atmospheric and surface information. IASI on Metop-A (called IASI-A hereafter) has been launched in 2006 and still provides very high quality radiance spectra for the intended applications.

In order to provide well-flagged and calibrated radiance products to (near-) real time applications, the algorithmic processing chain is regularly updated with new features to generate measurements that overcome instrument imperfections arising over time. This is not optimal for climate applications that need very stable long time-series.

To build a 10+ years IASI-A Level 1c (L1c) Climate Data Record (CDR, [AD 1]), i.e. "a time series of measurements of sufficient length, consistency and continuity to determine climate variability and change", EUMETSAT has reprocessed the data with the most updated version of the processing chain (version 7.4 as of 2017). To ensure the needed quality of the data, a validation has been performed and the results are presented in this report.

1.1 Purpose and scope

This report provides the results of the validation exercise done on the Metop-A IASI L1c reprocessed data for the period of July 2007 to December 2017 (Release-1). The reprocessing was done by EUMETSAT, using the last updated auxiliary files provided by CNES and the full orbit Level 0 products retrieved from the EUMETSAT archive. Each update of the processing chain is analysed by comparing the operational L1c product with the reprocessed L1c product over the same period.

This report is submitted to the Product Validation Review Board in order to provide a recommendation on the release of the reprocessed Metop-A, IASI L1c data record.

1.2 Structure of this document

This document has the following sections:

Section 1 This introduction

Section 2 IASI Level 1c product overview

Section 3 Reprocessing of the IASI level 1c data

Section 4 Validation results

Section 5 Summary and conclusion

1.3 Applicable Documents

Number	Document Name	EUMETSAT Reference Number
AD 1	The Climate Data Record Generation Process Description	EUM/OPS/SPE/10/1947, v1c
AD 2	Climate Service Development Plan	EUM/STG-SWG/40/16/DOC/21
AD 3	IASI Level 1 Product Format Specification	EUM.EPS.SYS.SPE.990003
AD 4	L1 Day-2 Product Specifications	EUM/OPS- EPS/SPE/08/0231
AD 5	Product user guide: IASI level 1c FCDR release 1	EUM/OPS/DOC/19/1069211

1.4 Reference Documents

Number	Document Name	EUMETSAT Reference
RD 1	IASI Level 1: Product User Guide	EUM/OPS- EPS/MAN/04/0032
RD 2	IASI Quarterly Performance Report, CNES	https://iasi.cnes.fr/sites/default/files/drupal/201710/default/iasi_m02_quarterly_2010-12_2011-02_0.pdf
RD 3	IASI mission rationale and requirements	IA-SM-0000-10-CNE/EUM
RD 4	Metop-A AVHRR/3 Cloud Detection	EUM/OPS/TEN/09/5312
RD 5	An improved artificial neural network CO retrieval for IASI L2 processor	EUM/MET/TEN/09/0232

1.5 Other references

Aulighé, T., A. P. McNally, and D. P. Dee., 2007: Adaptive bias correction for satellite data in a numerical weather prediction system *Quart. Journ. of the Royal Meteorol. Soc.*, **133**, 631-642.

Bormann, N, Bonavita, M, Dragani, R, Eresmaa, R, Matricardi, M, McNally, A, 2015: Enhancing the impact of IASI observations through an updated observation error covariance matrix, *ECMWF Technical Memorandum*; https://www.ecmwf.int/en/elibrary/8292-enhancing-impact-iasi-observations-through-updated-observation-error-covariance

Chalon, G., Cayla, F., and Diebel, D., 2001: IASI: An Advanced Sounder for Operational Meteorology, *Proceedings of the 52nd Congress of IAF*, Toulouse France, 1-5 Oct. 2001.

Hébert, P., D. Blumstein, C. Buil, T. Carlier, G. Chalon, P. Astruc, A. Clauss, D. Siméoni, B. Tournier, 2004: IASI Instrument: technical description and Measured Performances. *Proceedings of the 5th International Conference on Space Optics* (ICSO 2004), 30 March –2 April 2004, Toulouse, 49 - 56.

Hilton, F., R. Armante, T. August, C. Barnet, A. Bouchard, C. Camy-Peyret, V. Capelle, L. Clarisse, C. Clerbaux, P. Coheur, A. Collard, C. Crevoisier, G. Dufour, D. Edwards, F. Faijan, N. Fourrié, A. Gambacorta, M. Goldberg, V. Guidard, D. Hurtmans, S. Illingworth, N. Jacquinet-Husson, T. Kerzenmacher, D. Klaes, L. Lavanant, G. Masiello, M. Matricardi, A. McNally, S. Newman, E. Pavelin, S. Payan, E. Péquignot, S. Peyridieu, T. Phulpin, J. Remedios, P. Schlüssel, C. Serio, L. Strow, C. Stubenrauch, J. Taylor, D. Tobin, W. Wolf, and D. Zhou, 2012: Hyperspectral Earth Observation from IASI: Five Years of Accomplishments. *Bull. Amer. Meteor. Soc.,* **93**, 347–370.

Lonjou V., L. Buffet , J. Chinaud , C. Larigauderie , F. Meunier and E. Péquignot, 2010: The IASI technical expertise center : IASI tuning and performance monitoring, American Institute of Aeronautics and Astronautics.

Siméoni, D., Astruc, P., Miras, D., Alis, C., Andreis, O., Scheidel, D., Degrelle, C., Nicol, P., Bailly, B., et al., 2004: Design and development of IASI instrument, *SPIE Conference*, Aug 2004.

USGS, "GTOPO30", 1996: https://www.usgs.gov/centers/eros/science/usgs-eros-archive-digital-elevation-global-30-arc-second-elevation-gtopo30?qt-science_center_objects=0#qt-science_center_objects.

1.6 Acronyms

Acronym	*Meaning*
AVHRR	Advanced Very High Resolution Radiometer
BRD	BoaRD configuration
BT	Brightness Temperature
Cal/Val	Calibration/Validation activities
CD	Compensation Device
CDR	Climate Data Record
CNES	Centre National d'Etudes Spatiales
DPS	Digital Processing Subsystem
EPS	EUMETSAT Polar System
FCDR	Fundamental Climate Data Record
FOV	Field of View
GRD	GRounD configuration
GSICS	Global Satellite Inter-Calibration System
IASI	Infrared Atmospheric Sounding Interferometer
IIS	Integrated Imaging System
IMS	Instrument Management Subsystem
K	Kelvin
L1c	Level 1c
LEO	Low Earth Orbit
Metop	Meteorological operational satellite
NEΔT	Noise Equivalent difference Temperature
NRT	Near Real Time
NZPD	Number sampler of the Zero Path Difference
NWP	Numerical Weather Prediction
ODB	Operational Data Base
Op	Operational
PDU	Product Dissemination Unit
PPF	Product Processing Facility

Acronym	*Meaning*
QIS	Quality Index for the Sounder
RD	Referenced Document
Rep	Reprocessed
SDB	Spectral Data Base
STD	STandard Deviation
TEC	Technical Expertise Center (part of CNES)
USGS	United States Geological Survey
UMARF	Unified Meteorological Archive and Retrieval Facility
VM	Virtual Machine

2 IASI LEVEL 1C PRODUCT OVERVIEW

The Infrared Atmospheric Sounding Interferometer (IASI) is an infrared sounder providing atmospheric and surface information (Chalon et al., 2001; Simeoni et al., 2004). The IASI system has been designed by CNES (Centre National d'Etudes Spatiales) and it includes three instruments that are mounted on the Metop satellite series. Metop-A, -B and -C were launched in 2006, 2012, and 2018, respectively.

To achieve a global coverage, the IASI instrument [RD 1] observes the Earth up to a viewing angle of 48.3 degrees on either side of the satellite track (Figure 1). For each view, the instrument measures an atmospheric cell of about 3.3 degrees x 3.3 degrees, or 50 km x 50 km at nadir view. Each cell is viewed simultaneously by a 2 x 2 array of detectors. This geometrical arrangement, combined with the step-by-step scanning mode, gives IASI a Field of View (FOV) that is compatible with the other instruments on the Metop platform. The pixel diameter of 12 kilometres is a trade-off between radiometric performance and statistics indicating the likelihood of acquiring valid measurements, depending on cloud cover.

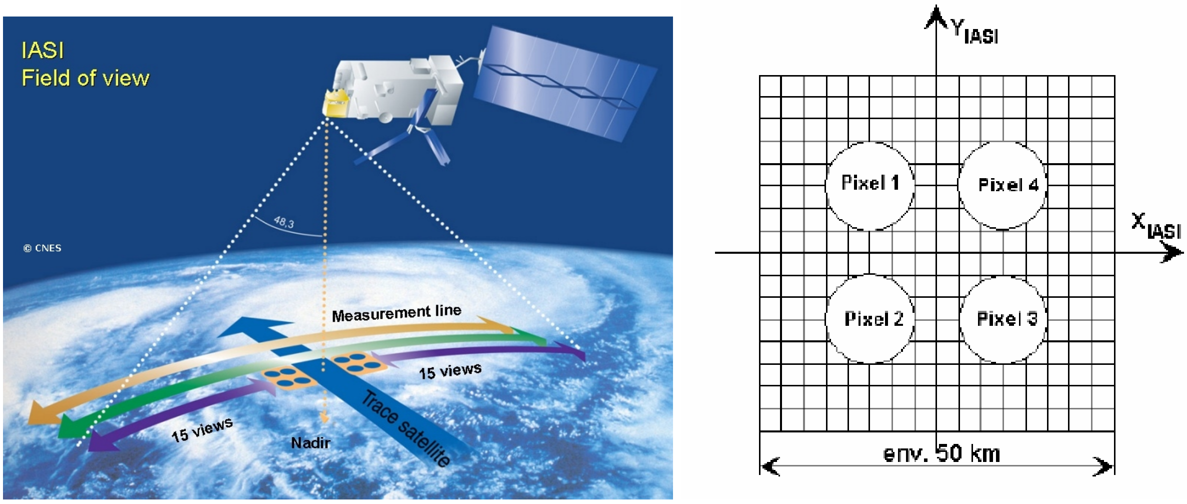


***Figure 1**: The IASI observing system (left, www.cnes.fr). Field Of View (FOV) of the sounder and the imager (right).*

The IASI instrument is based on a Michelson interferometer that produces interferograms. An Inverse Fourier Transform is applied to retrieve atmospheric radiance spectra in three bands (Table 1). Part of the radiance calibration (radiometric) is performed on-board by the digital processing subsystem. The spectral calibration is processed on-ground in the EPS (EUMETSAT Polar System) ground segment located at EUMETSAT. IASI soundings are systematically co-registered with the Integrated Imager System (IIS) and the Advanced Very High Resolution Radiometer (AVHRR) imager (another instrument on the Metop satellites) to perform the geolocation and to support cloud detection. The processing chain has been developed by the Technical Expertise Centre (TEC) in CNES Toulouse.

Band	Range (cm^{-1})	Range (µm)
1	645 to 1210	15.5 to 8.26
2	1210 to 2000	8.26 to 5
3	2000 to 2760	5 to 3.62

Table 1: *The three IASI spectral bands*

IASI Level 1c (L1c) data is mainly designed for operational Numerical Weather Prediction (NWP) and climate applications. Many studies have demonstrated that the quality of the near real-time product is much better compared to the requirements. For that reason, the instrument is used in GSICS (Global Satellite Inter-Calibration System) as a reference for cross-calibration of other infrared sensors and diverse validation/impact studies (Hilton et al., 2012; Bormann et al., 2015). The quality of the IASI L1c product is also crucial to derive unbiased atmospheric parameters and built homogeneous data records. Temperature, humidity, O_3, CH_4, CO and N_2O gas constituents and trace gas can be derived from the measurements with a high degree of accuracy (Hébert et al., 2004).

Weather refers to short-term changes in atmospheric conditions, while climate deals with events happening over a much longer period. Climate change at a specific location refers to gradual variations in the average weather conditions over a long period. For that reason, it is crucial to produce stable and homogeneous time-series of radiance spectra that will be used to retrieve Level 2 atmospheric parameters. Most of the changes and updates in the operational processing chain of IASI do not have a large impact on Numerical Weather Prediction (NWP) systems (thanks to variational/adaptive bias corrections tools, Auligné et al, 2009) whereas it can be significant while studying longer periods.

3 PROCESSING AND REPROCESSING OF IASI LEVEL 1C DATA

3.1 Overview of the processing chain

As mentioned earlier, IASI produces interferograms which need in-depth processing before they can be used for NWP and climate applications. The interferograms are processed by an on-board Digital Processing Subsystem (DPS), which performs the inverse Fourier transform, the radiometric calibration and the band-merging, in order to decrease the IASI data transmission volume This part of the processing is referred to as the level 0 processing. The level 1 processing is performed on-ground and produces resampled, apodised, calibrated and geo-localised radiance spectra. An AVHRR radiances classification inside IASI sounder pixels is also provided. The full processing chain is contained within the Product Processing Facility (PPF) and processing is controlled by a set of auxiliary files: BoaRD configuration (BRD), GRounD configuration (GRD), and Operational DataBase (ODB). Parameters in these files are updated as required to adjust the on-ground and on-board processing.

As shown in Table 2, level 1 data comprises 5 products that are derived from the processing steps mentioned above. At points along the processing chain, quality flags are generated to ensure that the measurements meet the original requirements. Details on the requirements in terms of noise equivalent for each processing step can be found in [RD 2]. These requirements are also applicable to reprocessed data.

Product Name	*Product ID*	*Content*
Level 1a	IASI_xxx_1A	Decoded spectral and image data after additional radiometric calibration corrections, spectral calibration appended, location and co-location with AVHRR/3 images.
Level 1b	IASI_xxx_1B	Re-sampled spectrum.
Level 1c	IASI_xxx_1C	Re-sampled spectrum with apodisation
Verification Product	IASI_VER_01	Verification data: raw interferogram and calibration coefficients used on-board.
Engineering Product	IASI_ENG_01	All parameters: output of IASI SW used by the TEC for evaluation.

***Table 2**: List of IASI Level 1 Products*

3.2 Significant changes of the processing chain of IASI-A

The IASI-TEC team at CNES and EUMETSAT processes/generates and monitors various parameters reflecting the instrument health, the processing and the data quality (Loujou et al., 2010). Examples of the daily monitoring report can be found online:
http://oiswww.eumetsat.int/epsreports/html/index.php?instrument=IASI&sat=M02

The main monitoring results are continuously analysed to identify and fix any anomaly or potentially optimise the instrument configuration. These changes may slightly modify the final product and affect the homogeneity of a long time-series. An important aim is to benefit from applying the latest updates made to the product / processing retroactively to all the data produced in the entire period being reprocessed.

Although IASI-A is a very stable instrument, reprocessing of the products has been conducted in order to take into account two major changes:

- "Day-2 evolution" algorithms and product-format evolutions [AD 4] in May 2010 to include:
    - Detailed flags on the IASI on-board processing
    - Cloud and land/sea information in the IASI L1c products

- Slight improvement of the spectral harmonization implemented in February 2011.

Reprocessing allows the recovery of missing data, which have been lost due to the strict near-real-time processing conditions, and to fill any gaps found in the time-series.

All throughout its lifetime, the IASI instrument is automatically calibrated and closely monitored. Every 29 days, the instrument is set to a *special* mode for a 4-hour duration, called external calibration mode, to achieve an in-depth monitoring of the exact same scene. No data are available to the users during these periods.

In addition, updates are regularly applied, with almost no impact on L1c radiances, to maintain the good quality of the products. For example, new GRD auxiliary files are produced yearly to update the Scan Mirror Reflectivity coefficients.

The list of updated parameters and the calendar of changes are given in Appendices 1 and 2. The IASI L1c product user guide [RD 1] provides more details.

4 VALIDATION OF THE REPROCESSED DATA

The validation exercise aims at demonstrating the benefits of the reprocessing. Effects of changes in the processing chain that has been described in the previous section are illustrated by comparing the operational with the reprocessed version of the product. The requirements for the reprocessed products are the same as the operational [RD 3].

4.1 "Day-2 evolution" algorithms and product format evolutions

The so-called "Day-2 evolutions" was a major evolution of the IASI processing chain [AD 4]. It has been implemented in May 2010, and has affected the L1c product formats and quality. To be more specific, *1)* the data monitoring was improved by making the general quality flag dependent on the spectral band (Table 1); *2)* the cloud and land/sea information has been changed to be directly extracted from the AVHRR radiances. More details on this major evolution can be found in [Loujou et al., 2010]. Consequently, the format of the reprocessed products from 2007 to 2010 has been changed. It now contains twelve additional on-board and on-ground quality flags as well as improved land/sea and cloud fraction products.

4.1.1 Introduction of new quality flags

The quality of IASI products are presently insured using a wide range of on board and on ground quality indices, also called flags. The definition of flags can be find in [AD 3] and [AD 4] as well as in the following paragraph.

In this section, the flags of the reprocessed products are assessed. Before May 2010 (day 2 evolution), the products only contained one flag summarizing the data processing quality and only the old quality flag was available. After this date, 12 new flags referring to the on board and on ground processing qualities have been introduced in addition to the old flag called "Old QIS".

• List and definition of the calibration flags

- *Overflow/Underflow* – for measurements that exceed on-board coding tables's capacity of the encoded spectra.
- *Spectral calibration error* (Spectral cal.) – ensures a good ground spectral calibration - quality.
- *Radiometric noise-calibration error* (Rad. post-cal.) – due to internal emissions
- *Old Quality flag* (Old QIS) – only flag available in the operational products before May 2010. It summarizes all flags for all bands in the IASI level 1 data.

• List and definition of the on-board processing flags

- *NZPD* – position of the central fringe of the interferogram monitoring to prevent large differences between on board and reduced spectra.
- *Band spikes* – spikes produced by photons hitting the detector and their impact on band 1, 2, and 3.
- *On board overall quality* – quality indicator for each of the pixels.

• List and definition of the instrument flags

- <u>*Hardware*</u> - any anomalies related to the hardware performance.
- <u>*Missing sounder*</u> - missing IASI data due to an anomaly.
- <u>*Integrated Imaging Subsystem*</u> (Missing IIS) - missing IIS data due to an anomaly. IASI is associated with this instrument for the radiative scene classification in degraded mode.
- <u>*AVHRR input data*</u> (Missing AVHRR) - missing AVHRR data.

The Figure 2 shows, for each of the 4 pixels, an example of the time-series of the 13 quality flags present in the reprocessed IASI L1c data (pixel 1 in red, pixel 2 in green, pixel 3 in blue and pixel 4 in magenta). The 13 new flags associated to IASI L1c data have been produced and are available for the entire reprocessed period.

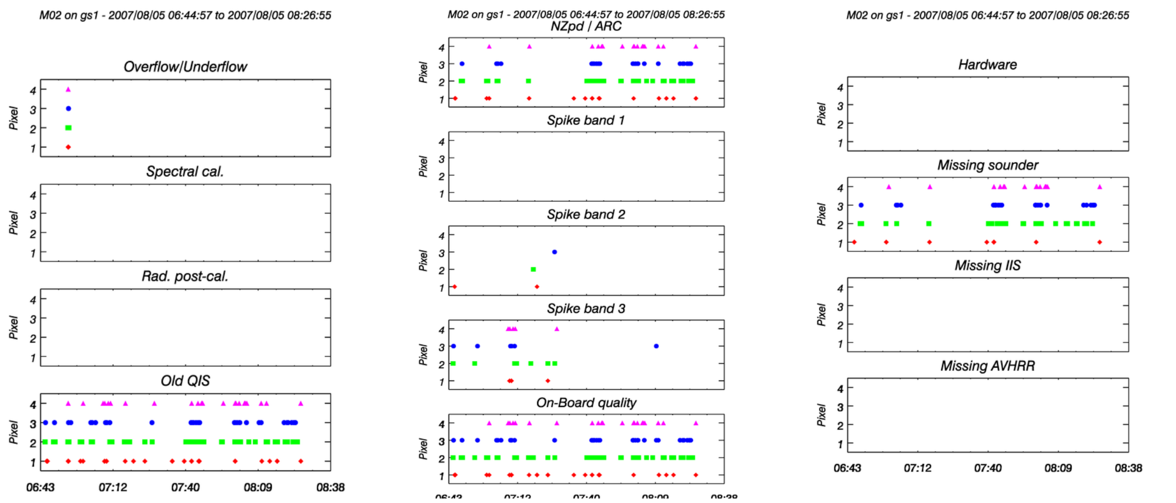


***Figure 2**: Time-series of new quality flags included in the products before May 2010 after reprocessing of the data (Old QIS was the only quality existing flag in the real time operational data up to May 2010).Each colour refers to one pixel (pixel 1 in red, pixel 2 in green, pixel 3 in bleu and pixel 4 in magenta). All FOVs are considered. The plots were done for Metop-A 6 August 2007 06:44:57 to 8:26:55*

4.1.2 New information in the products: cloud and land fraction

Cloud and land mask information from AVHRR have been included in the reprocessed IASI L1c products [RD 4]. The information was not included in the operational data until May 2010. Both parameters are retrieved from the AVHRR Level 1b product, which is read and used by the IASI Level 1 PPF (Product Processing Facility). The fractional cloud cover and the fractional land cover are defined as the sum of AVHRR pixel weights based on the IASI Point Spread Function (PSF) within the IASI FOV covered by cloud and land/coast, respectively. The fractional cloud cover and land cover are calculated for every IASI FOV. IASI with AVHRR FOVs are collocated to obtain the radiance cluster and provide the corresponding weight of the AVHRR pixels using the normalized IASI Points Spread Function (PSF). The information that has already been calculated within the AVHRR level 1 PPF are re-used for the calculation of fractional cloud and land cover in the IASI level 1 PPF.

4.1.2.1 Cloud fraction

The cloud fraction is available in the reprocessed IASI L1c data. It was absent in the operational products before May 2010. Figure 3 shows an example of the cloud fraction present in a reprocessed products for the 10th of October 2007 where cloud features in the atmosphere can be observed. More details regarding the validation can be find in [RD 4]

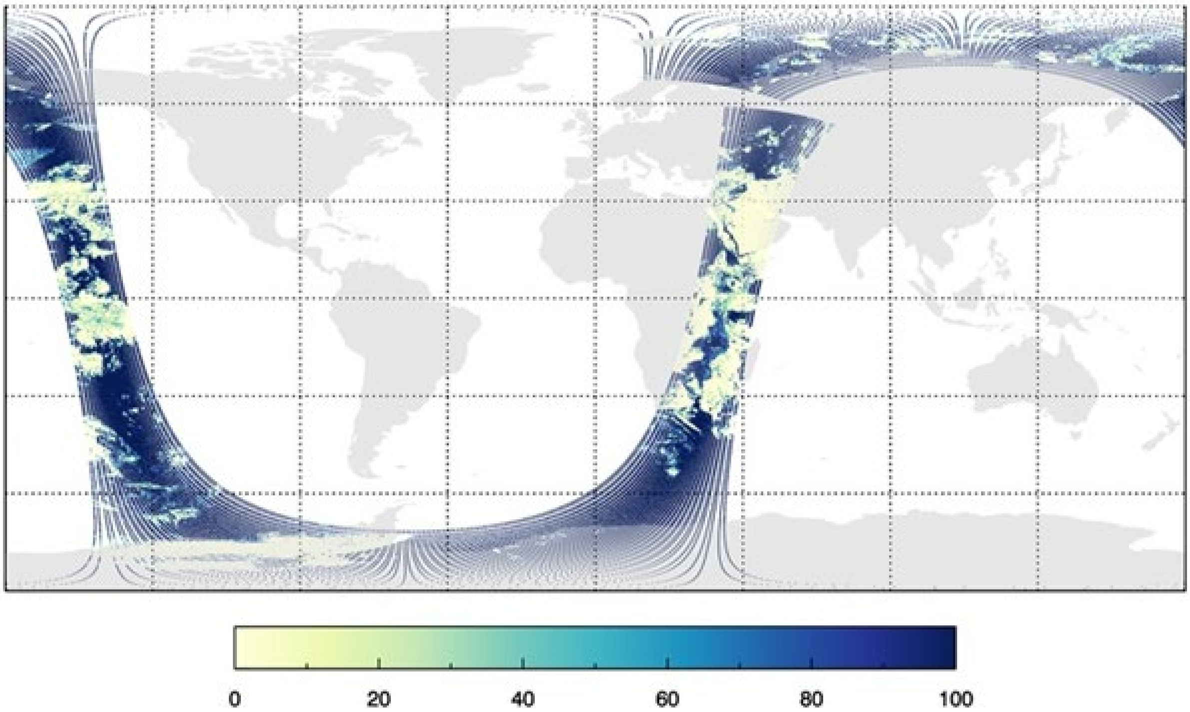


***Figure 3:** Example of the fractional cloud fraction (in %) for one orbit between 06:35 and 08:14 UTC on the 17th October 2007.*

4.1.2.2 Land fraction

The land fraction is available in the reprocessed files before May 2010 as well. It was absent in the operational products before this date. The land fraction is based on the land sea mask in the AVHRR L1b files (USGS, 1996) and is an averaged over each IASI FOV. Figure 4 shows an example of the land fraction corresponding to the 22nd of October 2007. Along the coast, the land/sea fraction changes progressively following the amount of land/sea AVHRR pixels contained within an IASI pixel.

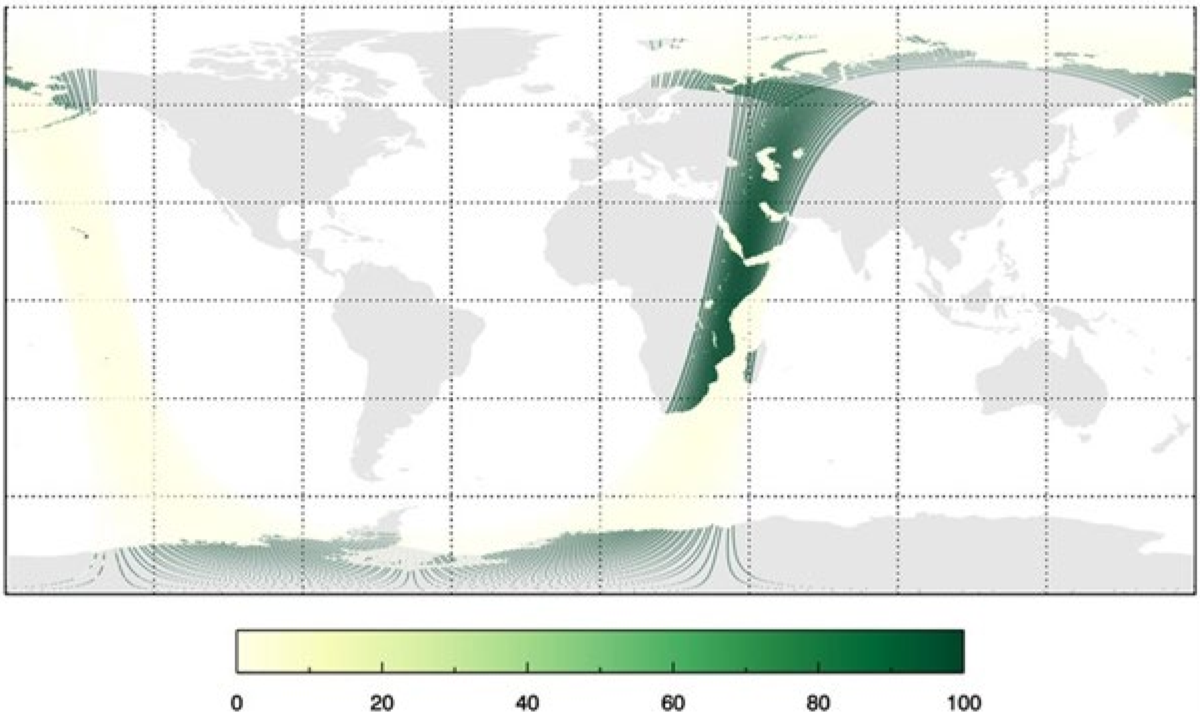


Figure 4: *Example of the fractional land fraction (in %) for one orbit between 06:29 and 08:11 UTC on the 22nd October 2007.*

4.2 Improving spectral harmonisation

The spectral harmonisation consists of removing the impact of instrument spectral response from the radiance spectra. It aims at generating IASI L1c radiances that *a)* have the same spectral response function for all spectral channels, *b)* have no instrument-dependant long-term temporal variation, and *c)* are independent of the detector position.

In February 2011, it was noticed that the inter-pixel (Figure 1) radiance differences in the IASI-A L1c products were exceeding 0.1K at some wavelengths [RD 2]. This problem was shown to affect particularly one pixel (the pixel 2 – because it is the most affected by the instrument response function deformation), and this effect could particularly be seen in the CO retrievals [RD 5]. Therefore, a slight adjustment of the spectral harmonisation has been performed in February 2011 and no anomaly was observed after that month. All products have been reprocessed to take into account the new correction.

4.2.1 Reduction of the pixel anomaly (before/after)

One method to evaluate the impact of the spectral harmonisation is to compute the inter-pixel difference converted into Noise Equivalent delta Temperature (NEΔT).

The pixel anomaly is defined as the difference between the averaged radiances for each channel of the spectra measured in the pixel 2 (all scan positions) and the averaged radiances for each channel of the spectra measured in each other pixel (1, 3 and 4, all scan positions). It introduces a radiance anomaly between pixels.

$NE\Delta T_\nu$ (equation (1) is defined as the magnitude of the signal that would be required to match the noise of the detector at a specific temperature and is expressed as:

$$NE\Delta T_{\nu} = < \frac{L_{\nu}(Px_2) - L_{\nu}(Px_i)}{\frac{\partial B(\nu, 280K)}{\partial T}} > i = 1,3,4 \qquad (1)$$

with $L_\nu(Pxi)$ is the IASI radiance at wavenumber ν for pixel i, B is the Planck function. $NE\Delta T_\nu$ is computed as the average (indicated by <>) of the differences in radiance at wavenumber ν between two pixels (the anomaly). About 10 million pixel differences are used to produce statistics (23 scanlines per Product Dissemination Unit (PDU) times 30 FOV per scanline times 480 PDU per day times 31 days for one month) per pixel (pixels 1, 3, 4).

Figure 5 shows the radiance anomalies in NEΔT at 280K for three different pixels (pixels 1, 3 and 4), with respect to pixel 2 *a)* before (old correction) and *b)* after the reprocessing (new correction), as a function of wavenumber in October 2010 and April 2011. These 2 months were selected to demonstrate that the reprocessing reduces the pixel anomaly and it is neutral after the processing chain update in February 2011. The remaining peaks and slight deformation were expected since they are related to the band merging/overlaps. As a results, the quality of the product for the period prior the update of the spectral harmonisation is slightly improved, even if the performances were already well within specifications [RD 3]. To go further into details, the Table 3 and Table 4 show the values of the standard deviation (STD) before and after February 2011 for pixels anomalies with respect to pixel 2. The STD is a factor 3 smaller than for the operational data before February 2011. After this date, the STD of the operational and reprocessed are very similar as expected.

	Operational data	***Reprocessed data***
Anomaly (in K)		
Px2-Px1	0.0903	0.0367
Px2-Px3	0.0607	0.0227
Px2-Px4	0.0608	0.0358

Table 3: *Standard deviation (in K) of the anomalies corresponding to the 23rd of April 2010 before the harmonisation is applied to the operational products.*

	Operational data	***Reprocessed data***
Anomaly (in K)		
Px2-Px1	0.0375	0.0367
Px2-Px3	0.0257	0.0249
Px2-Px4	0.040	0.0370

Table 4*: Same as Table 3 but for the 17th of December 2012 after the harmonisation is applied to the operational products.*

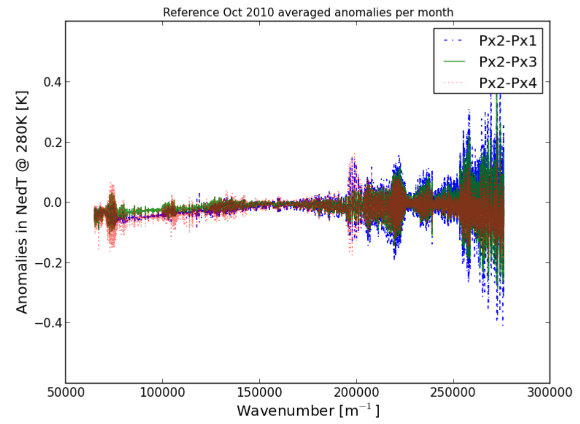
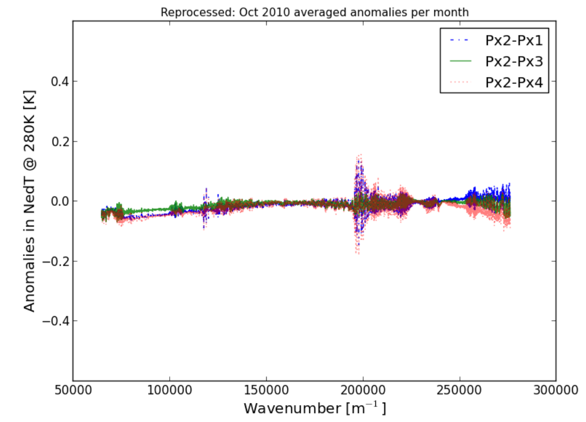
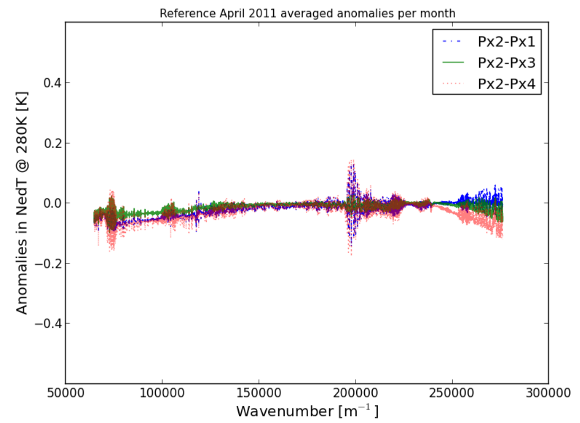
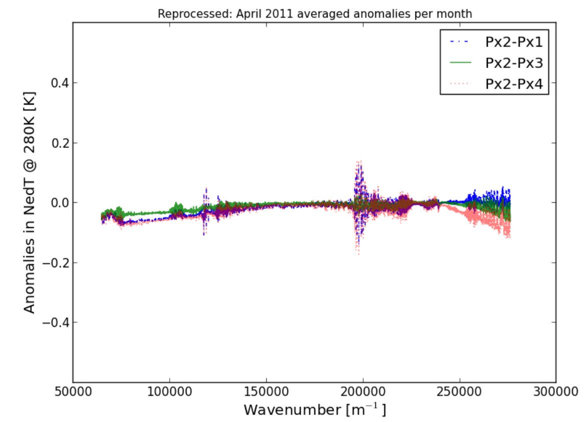
a) Operational IASI L1c data	***b) Reprocessed IASI L1c data***
October 2010	
	
April 2011	
	

Figure 5: *Averaged NEΔT radiances anomalies in Brightness Temperature for the month of October 2010 (period where the correction was not used in real time) and April 2011 (period where the correction was used). The peaks around 2000 cm^{-1} are due to the band merging/overlap (Table 1).*

4.2.2 Time-series of radiance anomalies per pixel

As mention in section 4.2.1, the pixel anomaly is defined as the difference between the averaged pixel 2 radiances and the averaged radiances over each of the pixels 1, 3 and 4. All scan positions are considered. Figure 6 and Figure 7 present an example of the anomalies for October 2007 and April 2011, which correspond to the first period of the reprocessed data and the first period after the change, respectively. It can be observed that despite some variability, the reprocessed products are well within the IASI requirements [RD 3] and that as expected, the CO band have a better quality [RD 5]. It presents smaller differences, especially for band 3 at 2300 cm^{-1}. All periods have been checked in the same way.

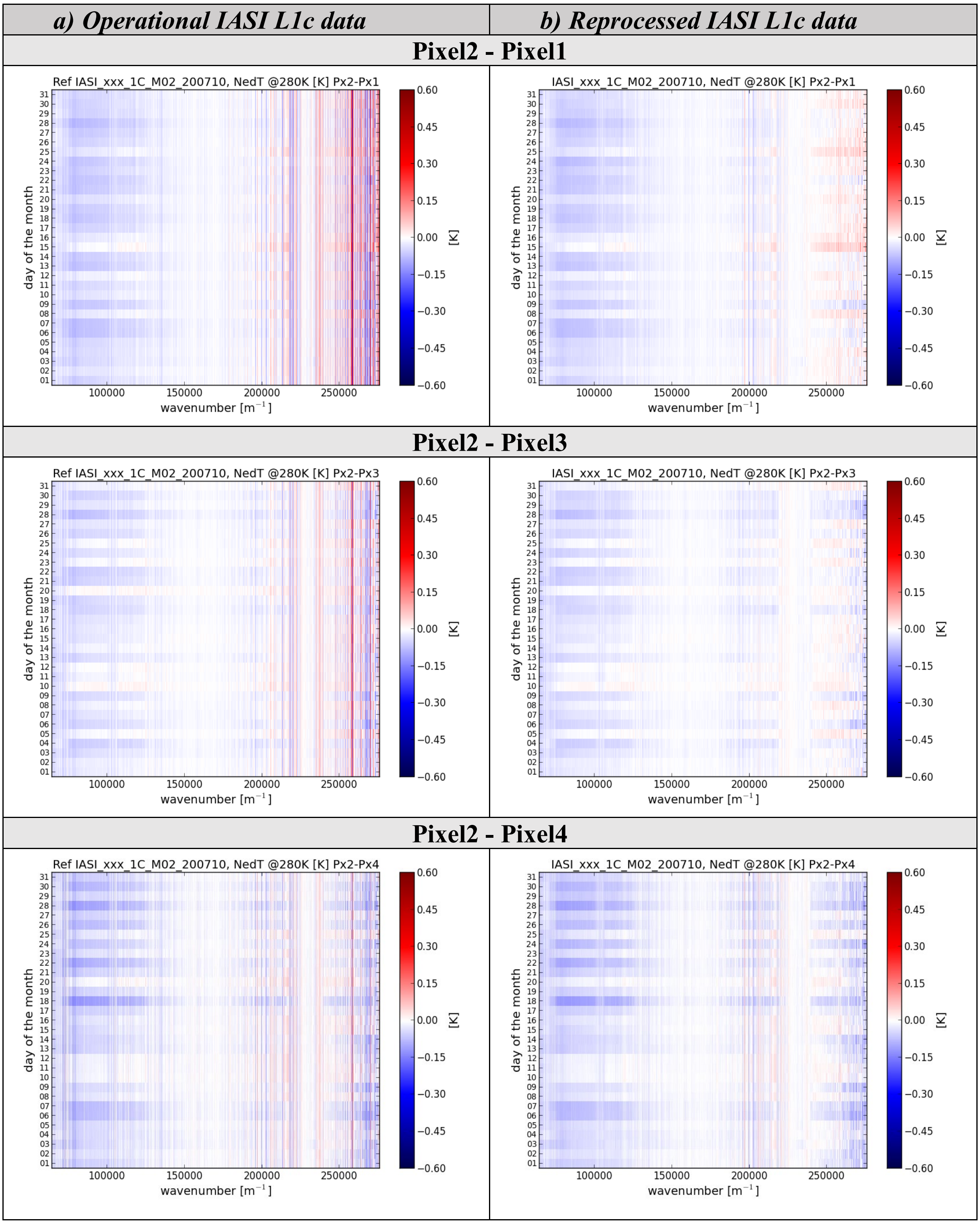


Figure 6: *Daily pixel anomalies in NEΔT at 280K (K) (Pixel 2 minus pixel 1, 3 and 4) with respect to IASI-A wavenumbers (m^{-1}) for October 2007 a) before and b) after the reprocessing.*

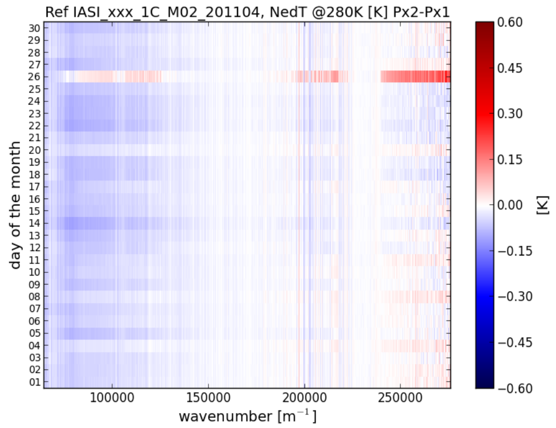
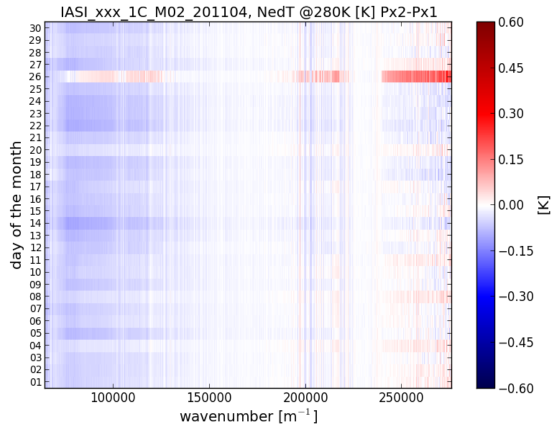
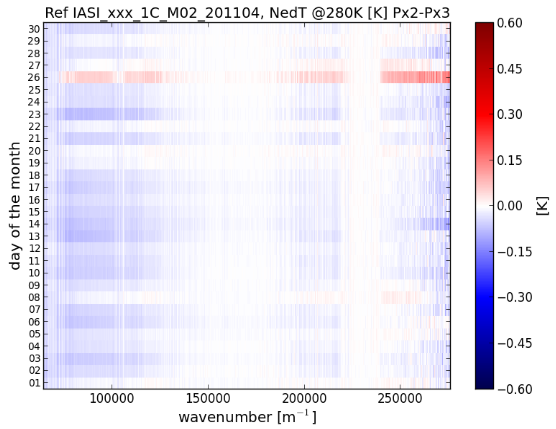
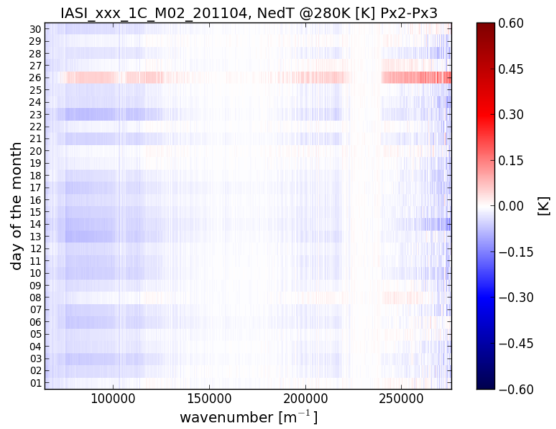
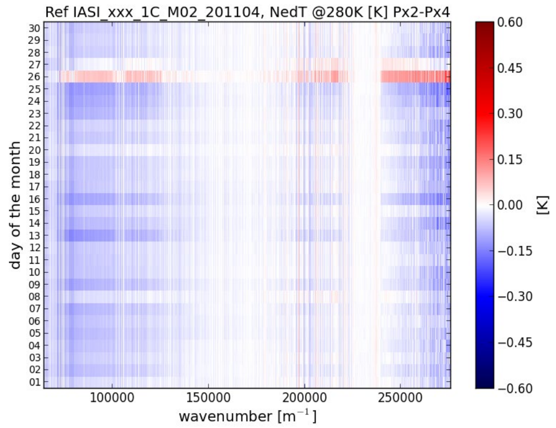
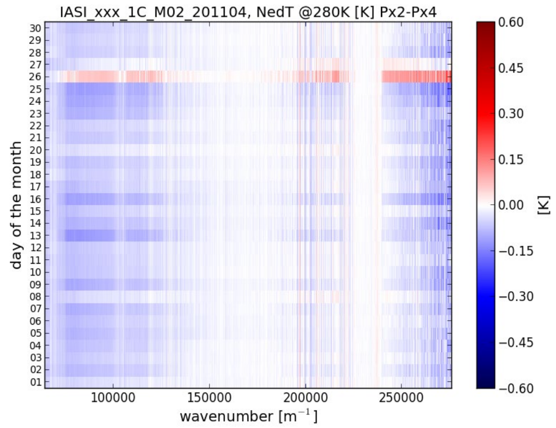
a) Operational IASI L1c data	*b) Reprocessed IASI L1c data*
Pixel2-Pixel1	
	
Pixel2-Pixel3	
	
Pixel2-Pixel4	
	

Figure 7: *Same as Figure 6 but for April 2011.*

4.2.3 Hovmöller diagram

In addition, to show the improvements to the IASI-A L1c data due to the adjustment in the spectral harmonisation, which took place in February 2011, Figure 8 shows the difference between the operational and the reprocessed data as a Hovmöller diagram for the period of 2011. The graphic shows for each time step a pixel-to-pixel comparison of the full IASI spectrum. The data are based on the nadir FOV and the second pixel. Radiances of both datasets are compared and the difference is converted into NEΔT at a given reference temperature of 280K. In February 2011, the modification in the operational processing clearly results in a reduction of the noise particularly seen in the spectral band 3, which includes the CO band. Afterwards, the operational and reprocessed IASI L1c data are in good agreement, as expected

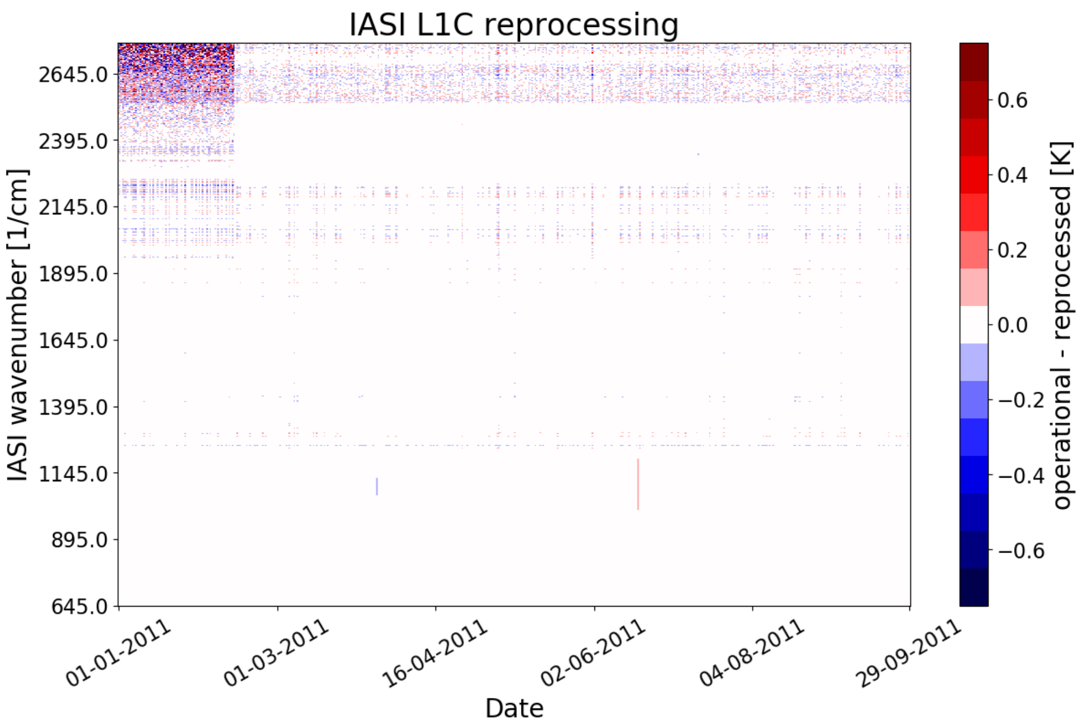


Figure 8: *The Hovmöller diagram shows the pixel based difference between the IASI - A L1c operational data and the reprocessed data in NEΔT (K). The time is displayed on the x-axis and the spectral channels on the y-axis. In February 2011, the adjustment in the spectral harmonisation is shown by the reduced bias in the long wavelength band.*

4.3 Time difference between operational and reprocessed products

Comparing an NRT operational dump (from Svalbard to Svalbard) with a reprocessed one, we have noticed an additional slight difference due to data production rules. This has no impact for the users. Each of the operational and reprocessed dump files cover a full orbit subdivided into Product Dissemination Unit (PDUs). The operational processing chain needs a slightly larger time window to process the PDUs [RD 2]. It can happen that some reprocessed PDUs belong to a different orbit either the previous or the next one. The duration of a reprocessed and NRT orbits can differ by a maximum of plus or minus 3 minutes.

Figure 9 presents an example of the orbit duration in seconds of the operational and reprocessed files for the month of November 2007. The differences in the orbit duration between operational and reprocessed files are also shown in Figure 10. Both operational and reprocessed data show very consistent total time duration of the orbit covered by each file, which is about 1.68 hours. Nevertheless, some of the reprocessed files were found to have irregularities when compared to the operational ones in the orbit duration. This can be observed for several files especially between the 15th of November 2007 and the 25th November 2007.

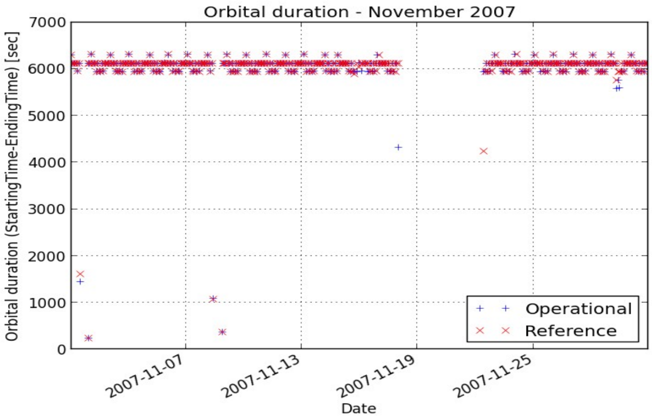


***Figure 9**: Orbital duration of each of the operational and reprocessed files for November 2007.*

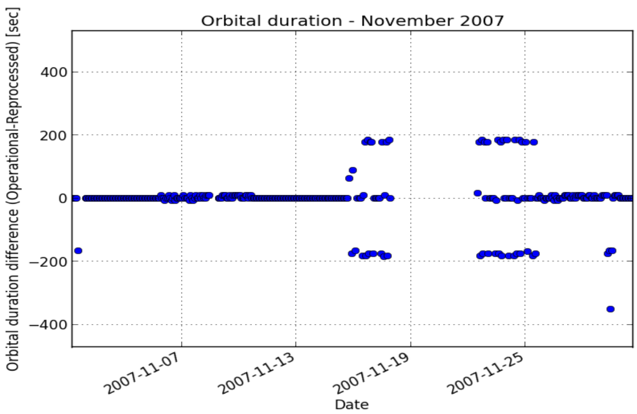


***Figure 10:** Orbital duration difference between the operational and reprocessed files for November 2007.*

4.4 Filling the gaps

In addition to take into account all improvements, the advantages of reprocessing the data is to recover the few missing data lost in the real-time processing chain. In fact, operational near-real time constraints can induce loss of data because of errors in file transfers, late input data, dissemination, level 1 processing chain stop, or any other technical reason [RD 2]. Reprocessing usually retrieves such missing data and processes them into a more complete data record. Around 99.3% of the original IASI data were successfully reprocessed.

Figure 11 shows an example of gap filling which permits to have continuous reprocessed data records. Daily pixel anomalies (in NEΔT at 280K pixel 2 minus pixel 3) are represented with respect to wavenumbers for May 2010 *a)* before and *b)* after the reprocessing. As indicated by the red circle in Figure 11a, one day is missing in the operational product on the 29th of May 2010. The Figure 11b indicates that, after the reprocessing, the missing data has been recovered.

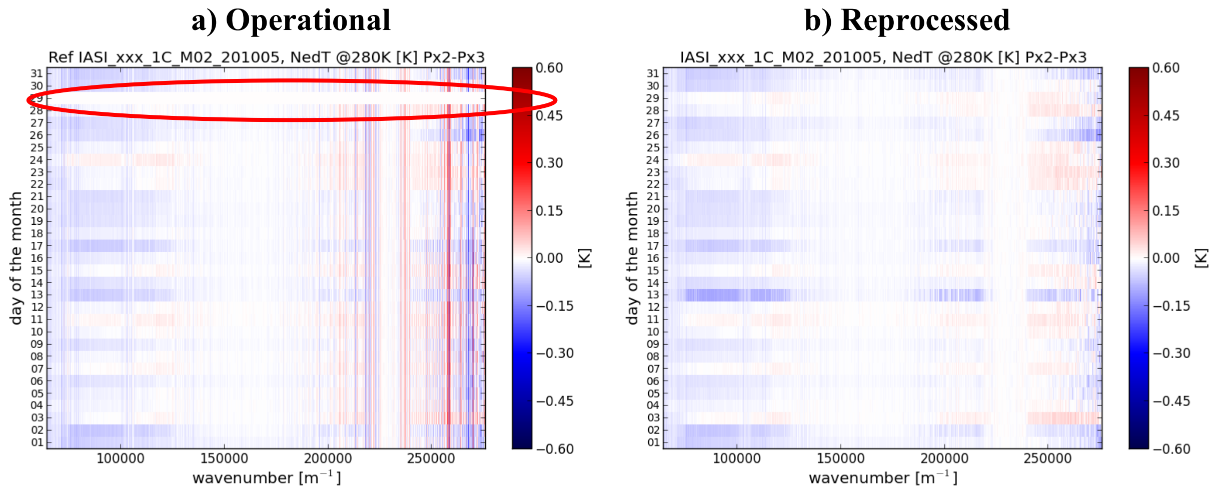


Figure 11: *Daily pixel anomalies in NEΔT at 280K (K) (pixel 2 minus pixel 3) with respect to IASI-A wavenumbers (m-1) for May 2010 a) before and b) after the reprocessing. The red circle highlights missing data (29/05/2010) that has been recovered thanks to the reprocessing.*

5 SUMMARY AND CONCLUSION

This report has provided the results of the validation exercise done on the Metop-A IASI L1c reprocessed data for the period of July 2007 to December 2017 (Release-1). The reprocessing was done by EUMETSAT, using IASI level 1 PPF version 7.4 and the last updated auxiliary files provided by CNES, and the full orbit Level 0 products retrieved from the EUMETSAT archive. Each update of the processing chain has been analysed by comparing the operational L1c product with the reprocessed L1c product over the same period (before/after the change).

The reprocessing was shown to be useful to take into account three major evolutions in the processing chain: *a)* The "Day-2 evolution" algorithms (product format changes, quality flags, as well as cloud and land/sea information), *b)* The slight improvement of the spectral harmonization in February 2011 (affecting mainly the CO channels) and *c)* To fill the few gaps found in the time-series. The impact was shown to be slightly positive on the data quality overall and specially for the earlier period before February 2011.

Limitations and perspectives:
This report has evaluated in detail every benefit of the reprocessing (new flag information, pixel anomaly reduction etc. …) from the major changes in the operational processing chain. Reprocessed data are compared with the original operational versions and the analysis covers the period "before/after" the change. Even if all periods have been evaluated but not presented, future validation work will greatly benefit from a long-term time-series evaluation.

Appendix 1 List of updated parameters

1) Time dependant parameter updates

Parameters	**Definition**
IWnpWnSWRef	representative wavenumber of the spectral window
IWnpModulNat, IWnpPhaseNat	representative magnitudes and natural phase of the harmonics of the Fourier transform of the spectral window
IWnpWnSW	spectral position of the samples of the spectral window
IDefSssWnShiftMax	maximum spectral shift which is admissible
IDefSssWnShiftMin	minimum spectral shift which is admissible
IDefInterPixNZpd	nominal values of inter-pixel for each PN and each CD
ISmaRBB, ISmaRCS, ISmaREW	scan reflectivity when sighting respectively the black body, the cold space and the Earth
IDefIISAVHRROffsetGuess	update of IIS/AVHRR offset guess after switch to IMS-B

Table 2: *Updated parameters due to an evolution of the IASI instrument and that are time dependant.*

2) Stable parameter updates

Parameters	**Definition**
IDefSsdModulCutoff	validity threshold for the harmonic magnitude
IdefS1bSigI	semi-width at mid-height of the Gaussian for the smoothing of the interferogram extremity
IDefOffsetSondIISModel	parameters of the orbital model of the Sounder-IIS Offset
IDefPSFSondBaryCentreY, IDef-PSFSondBaryCentreZ	Y and Z barycentric coordinates of the IPSF in the sounder ref- erence frame
IDefPsfSondWgt	Weights of the IPSF points
IDefPsfSondY, IDefPsfSondZ	Y and Z coordinates of the IPSF description in the IPSF cold plane
IDefIASIScanAngle	Sighting angles of the scan mirror
IDefSsdModulCutoff	Validity threshold for the harmonic magnitude

Table 3: *Updated parameters that are stable with time.*

Appendix 2 Calendar of Changes in the processing chain

Reprocessing periods	*Dates*	*Periods defined by changes*
1st	July 09, 2007 - October 22, 2007	Update of 12 BRD and GRD parameters
2nd	October 22, 2007 - March 03, 2008	Update of reduced spectra
3rd	March 04, 2008 - February 24, 2009	Update of reduced spectra
4th	February 24, 2009 - May 01, 2010	On ground relation with On-Board configuration update of reduced spectra (offset for PN3 CCD0 and 1)
5th	May 02, 2010 - April 20, 2011	Resampling through the Spectral Data Base (ODB) scan mirror reflectivity: ISmaRBB, ISmaRCS, ISmaREW
6th	April 21, 2011 - July 18, 2012	On-Board configuration PTSI 13 update of reduced spectra (offset PN3 CCD 0 and 1)
7th	July 18, 2012 - August 28, 2013	Scan temperature and scan mirror reflectivity: ISmaRBB, ISmaRCS, ISmaREW
8th	August 29, 2013 - June 17, 2014	Reduced spectra update
9th	June 18, 2014 - April 13, 2015	Scan mirror reflectivity update
10th	April 14, 2015 - August 05, 2015	Update of IIS/AVHRR offset guess after switch to IMS-B
11th	August 06, 2015 - April 30, 2016	Top upload