IASI L2 PPF v6.2 - Validation Report
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## Document Change Record

<table>
<thead>
<tr>
<th>Issue / Revision</th>
<th>Date</th>
<th>DCN. No</th>
<th>Changed Pages / Paragraphs</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1 Draft</td>
<td>17/05/2016</td>
<td></td>
<td>Initial draft</td>
</tr>
<tr>
<td>V1A Draft</td>
<td>20/05/2016</td>
<td></td>
<td>Completed with figures and text</td>
</tr>
<tr>
<td>V1B</td>
<td>23/05/2016</td>
<td></td>
<td>Version completed and submitted to the PVRB</td>
</tr>
<tr>
<td>V1C</td>
<td>30/05/2016</td>
<td></td>
<td>Updated maps total column CO and land surface emissivity with 13 days worth of data.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Fixed typos</td>
</tr>
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<td></td>
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<td></td>
<td>Numbered Conclusion items in §6</td>
</tr>
</tbody>
</table>
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1 INTRODUCTION

1.1 Purpose

The document presents assessment results for the IASI Level 2 (L2) products generated with the version 6.2, the latest revision of the IASI L2 Product Processing Facility (PPF, also referred to as processor or processing chain). The v6.2 is the second incremental upgrade to the IASI L2 processor since the operational release of the version 6 in September 2014.

This report is intended to all Users of the IASI L2 products. It provides detailed information about the IASI L2 sounding products performances in terms of yield/coverage and precision. It illustrates the continuity and improvements as compared to the former revision v6.1.

This validation report is also intended to the Product Validation Review Board, to complete the qualification process for this new revision and support its operational release.

1.2 Background and Scope

Extensive validation studies were carried out for the release of the IASI L2 processor version 6. The uncertainties assessments were performed by comparisons to in situ (e.g. atmospheric radio-sondes, maritime buoys...) and ground-based measurements (e.g. precipitable water-vapour with radio-occultation instruments, Lidars, Microwave atmospheric sounders, land surface radiometers...), as well as comparisons to numerical models or to other satellite data. The results can be found in the IASI L2 v6 validation reports [RD-1, RD-4] and in external validation papers [RD-2, RD-3].

The present assessment focuses on establishing evidences of the continuity and improvements as compared to the version 6.1. This is achieved by intercomparisons of the former revision (v6.1) and the new revision (v6.2) to common external references, essentially here ECMWF model analyses as concerns temperature and humidity profiles. More systematic uncertainty characterisation with other validation sources, including in situ data, or techniques will be subject to longer-term validation and monitoring activities and involve external cooperations.

1.3 Processor versions and data description

The analyses presented in this report relate to the versions 6.2.0 to 6.2.2 of the PPF, obtained from off-line processing on the Technical and Computing Environment (TCE) of EUMETSAT and from routine production on GS2 since the 08/04/2016. The patches 6.2.1 and 6.2.2 were released to fix minor anomalies dealing with auxiliary information provided together with the retrieved geophysical quantities. These patches have no impact on the atmospheric parameters forming the IASI L2 products, whose retrieval algorithms have been unchanged.

Both Metop-A and Metop–B products are evaluated. They are presented separately in this document to demonstrate their consistency. A small data gap is present in the time series used in the present evaluation, namely from the 1st to the 4th of May 2016, due to the interruption of the related data flux from the validation ground segment to the TCE.
1.4 Summary of the changes to the processing chain

The version 6.2 contains an important algorithm update of the first-guess all-sky products, with the introduction of the PWLR-cube algorithm and of the configuration of the subsequent optimal estimation method (OEM). The following table summarises the motivations for the changes to the processing chain and the products concerned.

<table>
<thead>
<tr>
<th>Processing function</th>
<th>Issues in v6.1</th>
<th>Fix/Evolution in v6.2</th>
<th>Products enhanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>First-guess</td>
<td>Aging microwave instruments on Metop-A, data degradation/loss. The first guess retrieval is running in infrared-only mode since September 2015</td>
<td>PWLR(^1) (1) The MW measurements are now represented as PC scores in the predictors and the Metop-A eigenvectors do not include the recently lost AMSU channel 8, such that joint MW/IR retrieval has been re-enabled for Metop-A.</td>
<td>All-sky first-guess Temperature Humidity</td>
</tr>
<tr>
<td>First-guess OEM</td>
<td>The retrieval with the OEM was not successful in places, typically for bare continental surfaces.</td>
<td>The land surface emissivity input to the OEM is now computed with the PWLR(^1) algorithm, instead of a static atlas in v6.1. In the subsequent OEM, separate observation error covariance matrices for land and sea surfaces have been introduced. As a consequence, the yield and quality of atmospheric sounding over bare surfaces (e.g. Sahara) is increased and becomes consistent with the quality of the retrievals reached in other maritime and continental locations.</td>
<td>Clear-sky final: Temperature Humidity Land surface emissivity</td>
</tr>
<tr>
<td>FORLI (2)</td>
<td>Small biases in tropospheric constituents were reported The quality flag QFLAG, essential for Users for data selection, was not yet activated.</td>
<td>Includes the latest FORLI release, v20151001_1 Bias for CO reduced QFLAG activated</td>
<td>CO profile CO quality flag</td>
</tr>
</tbody>
</table>

(1) Piece-Wise Linear Regression-cube (PWLR\(^1\)): statistical method exploiting the horizontal correlation in adjacent measurements, while keeping the retrieval resolution of the individual IASI footprints.
(2) Fast Optimal Retrieval on Layers for IASI (FORLI) [RD-5], library developed by ULB (Bruxelles) and LATMOS (Paris) laboratories and delivered via the O3M-SAF.

1.5 Applicable Documents

<table>
<thead>
<tr>
<th>Id</th>
<th>Title</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD-1</td>
<td>EPS Programme End User Requirements Document</td>
<td>EUM/EPS/MIS/REQ/93/001</td>
</tr>
</tbody>
</table>

1.6 Reference Documents

<table>
<thead>
<tr>
<th>Id</th>
<th>Title</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>RD-1</td>
<td>IASI L2 PPF v6: Validation Report</td>
<td>EUM/TSS/REP/14/776443</td>
</tr>
<tr>
<td>RD-3</td>
<td>“Identification and intercomparison of surface-based inversions over Antarctica from IASI, ERA-Interim, and Concordiasi dropsonde data”</td>
<td>Boylan et al., JGR 2016, submitted</td>
</tr>
<tr>
<td>RD-4</td>
<td>OSI-SAF Metop-A IASI Sea Surface Temperature L2P (OSI-SAF/CDOP2/M-F/TEC/RP/210,</td>
<td></td>
</tr>
<tr>
<td>RD</td>
<td>Description</td>
<td>Reference/Link</td>
</tr>
<tr>
<td>-----</td>
<td>------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>RD-5</td>
<td>“FORLI radiative transfer and retrieval code for IASI”</td>
<td>Hurtmans et al., JQSRT 2012, doi:10.1016/j.jqsrt.2012.02.036</td>
</tr>
<tr>
<td>RD-6</td>
<td>Group for High-Resolution Sea Surface Temperature (GHRSSST)</td>
<td><a href="https://www.ghrsst.org/">https://www.ghrsst.org/</a></td>
</tr>
<tr>
<td>RD-7</td>
<td>Algorithm Theoretical Basis Document for Land Surface Temperature, LSA-SAF</td>
<td>SAF/LAND/IM/ATBD_LST/1.0</td>
</tr>
<tr>
<td>RD-8</td>
<td>SAF for Land Surface Analysis – Validation Report LST, LSA SAF</td>
<td>SAF/LAND/IM/VR_LST/I_08</td>
</tr>
<tr>
<td>RD-9</td>
<td>Product User Manual – Land Surface Temperature, LSA SAF</td>
<td>SAF/LAND/IM/PUM_LST/2.4</td>
</tr>
</tbody>
</table>
## 1.7 Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANN</td>
<td>Artificial Neural Network</td>
</tr>
<tr>
<td>ARM</td>
<td>Atmospheric Radiation Measurement (US program)</td>
</tr>
<tr>
<td>AVHRR</td>
<td>Advanced Very High Resolution Radiometer, the imager on-board Metop</td>
</tr>
<tr>
<td>CALC</td>
<td>Usually refers to synthetic radiances calculated with a radiative and an atmospheric state vector which may come from the NWP or the L2.</td>
</tr>
<tr>
<td>Cal/Val</td>
<td>Calibration / Validation</td>
</tr>
<tr>
<td>ECMWF</td>
<td>European Centre for Medium-Range Weather Forecasts</td>
</tr>
<tr>
<td>EPS</td>
<td>EUMETSAT Polar System</td>
</tr>
<tr>
<td>EUMETSAT</td>
<td>European Organisation for the Exploitation of Meteorological Satellites</td>
</tr>
<tr>
<td>EURD</td>
<td>End User Requirements Document</td>
</tr>
<tr>
<td>EOF</td>
<td>Empirical Orthogonal Function</td>
</tr>
<tr>
<td>FG</td>
<td>First Guess</td>
</tr>
<tr>
<td>GCOS</td>
<td>Global Climate Observing System</td>
</tr>
<tr>
<td>GHRST</td>
<td>Group for High Resolution Sea Surface Temperature</td>
</tr>
<tr>
<td>GRUAN</td>
<td>GCOS Reference Upper-Air Network</td>
</tr>
<tr>
<td>IASI</td>
<td>Infrared Atmospheric Sounding Interferometer</td>
</tr>
<tr>
<td>IASI-A</td>
<td>IASI onboard Metop-A</td>
</tr>
<tr>
<td>IASI-B</td>
<td>IASI onboard Metop-B</td>
</tr>
<tr>
<td>IFOV</td>
<td>Instantaneous Field Of View</td>
</tr>
<tr>
<td>LATMOS</td>
<td>Laboratoire Atmosphères, Milieux, Observations Spatiales (Paris, France)</td>
</tr>
<tr>
<td>LSA</td>
<td>Land Surface Analysis</td>
</tr>
<tr>
<td>LST</td>
<td>Land Surface Temperature</td>
</tr>
<tr>
<td>L2</td>
<td>Level 2</td>
</tr>
<tr>
<td>MACC</td>
<td>Monitoring Atmospheric Composition and Climate</td>
</tr>
<tr>
<td>MODIS</td>
<td>Moderate Resolution Imaging Spectroradiometer</td>
</tr>
<tr>
<td>MWR</td>
<td>Microwave radiometer</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration (US)</td>
</tr>
<tr>
<td>NPROVS</td>
<td>NOAA Products Validation System</td>
</tr>
<tr>
<td>NRT</td>
<td>Near-Real Time</td>
</tr>
<tr>
<td>NWP</td>
<td>Numerical Weather Prediction</td>
</tr>
<tr>
<td>OBS</td>
<td>Observations (usually refers to L1c radiances)</td>
</tr>
<tr>
<td>OEM</td>
<td>Optimal Estimation Method</td>
</tr>
<tr>
<td>O3M-SAF</td>
<td>Ozone and atmospheric chemistry Monitoring Satellite Application Facility</td>
</tr>
<tr>
<td>OSI-SAF</td>
<td>Ocean and Sea Ice Satellite Application Facility</td>
</tr>
<tr>
<td>PC</td>
<td>Principal Components</td>
</tr>
<tr>
<td>PPF</td>
<td>Product Processing Facility</td>
</tr>
<tr>
<td>PWV</td>
<td>Precipitable Water Vapour</td>
</tr>
<tr>
<td>PWLR</td>
<td>Piecewise Linear Regression</td>
</tr>
</tbody>
</table>
1.8 Regional stratification

The products assessments are performed globally and the statistics presented in this document may be stratified against the following reference geographic classes.

<table>
<thead>
<tr>
<th>Class</th>
<th>Label</th>
<th>Surface pressure</th>
<th>Surface type</th>
<th>Latitude</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>North Polar cap</td>
<td>&lt; 1050 hPa</td>
<td>land and sea</td>
<td>&gt; 60°</td>
<td>day and night</td>
</tr>
<tr>
<td>2</td>
<td>North Sea</td>
<td>&gt; 900 hPa</td>
<td>sea</td>
<td>[30° ; 60°]</td>
<td>day and night</td>
</tr>
<tr>
<td>3</td>
<td>North Land</td>
<td>&gt; 900 hPa</td>
<td>land</td>
<td>[30° ; 60°]</td>
<td>day and night</td>
</tr>
<tr>
<td>4</td>
<td>High Elevation</td>
<td>&lt; 900 hPa</td>
<td>land</td>
<td>[−60° ; 60°]</td>
<td>day and night</td>
</tr>
<tr>
<td>5</td>
<td>Intertropic Sea</td>
<td>&gt; 900 hPa</td>
<td>sea</td>
<td>[−30° ; 30°]</td>
<td>day and night</td>
</tr>
<tr>
<td>6</td>
<td>Intertropic Land</td>
<td>&gt; 900 hPa</td>
<td>land</td>
<td>[−30° ; 30°]</td>
<td>day and night</td>
</tr>
<tr>
<td>7</td>
<td>South Polar cap</td>
<td>&lt; 1050 hPa</td>
<td>land and sea</td>
<td>&lt; -60°</td>
<td>day and night</td>
</tr>
<tr>
<td>8</td>
<td>South Sea</td>
<td>&gt; 900 hPa</td>
<td>sea</td>
<td>[−60° ; 30°]</td>
<td>day and night</td>
</tr>
<tr>
<td>9</td>
<td>South Land</td>
<td>&gt; 900 hPa</td>
<td>land</td>
<td>[−60° ; 30°]</td>
<td>day and night</td>
</tr>
</tbody>
</table>

Table 1: Definition of the validation geographic classes
1.9 Cloudiness stratification

The products assessments are performed globally and the statistics presented in this document may be stratified against the cloudiness classes defined in the flag FLG_CLDNES introduced for the first time in the IASI L2 v6.

Three cloud detection methods are used in combination in the IASI L2 PPF v6. They are based on AVHRR imagery, NWP and IASI measurements. In the latter case, the method implements artificial neural networks (ANN). The various tests may conclude to contradictory clear/cloudy classifications because of different sensitivities and of the uncertainties associated with their respective methodologies (e.g. uncertainties in the a priori surface emissivity and temperature in the NWP test, lack of contrast between snow and clouds for the detection with AVHRR images or in the ANN classification). The different test results are consolidated into the enumerated flag FLG_CLDNES summarising the level of confidence in the clear-sky/cloudiness assessment of the IASI IFOV. This flag controls the choice of the subsequent retrieval methods in the processing chain. It is also created as an answer to several users’ requests for a more concise cloudiness summary.

The flag FLG_CLDNES flag is set as follows:
### Reason for flagging

<table>
<thead>
<tr>
<th>Reason for flagging</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No clouds detected with the NWP, AVHRR and ANN cloud tests</td>
<td>1</td>
</tr>
<tr>
<td>Potential small cloud contamination (at least one cloud test detected a cloud) but no clouds could be characterised with confidence</td>
<td>2</td>
</tr>
<tr>
<td>Cloud detected and characterised. The retrieved equivalent cloud amount is lower than 80%</td>
<td>3</td>
</tr>
<tr>
<td>Cloud detected and characterised. The retrieved equivalent cloud amount is higher than 80%</td>
<td>4</td>
</tr>
</tbody>
</table>

### 1.10 Document Structure

- **Section 1**  General information (this section)
- **Section 2**  Summary of the assessment results
- **Chapter 3**  Conclusions and recommendations
2 ASSESSMENT OF THE CO PRODUCT

The validation of the CO product (including profiles, averaging kernels and processing quality information) is performed by the Ozone and atmospheric composition monitoring Satellite Application Facility (O3M-SAF) of EUMETSAT. The validation has started with the activation of the IASI L2 PPFv6.1 and the FORLI-CO library [RD-5], integrated in the operational chain. It is expected to conclude with the activation of the v6.2, which includes a few algorithm enhancements in FORLI and the definition of a quality flag.

Thorough verification activities have been performed to ensure the exact correspondence between the off-line FORLI-CO v20151001_1 productions in the research line at the University Libre de Bruxelles (ULB) and with its integration into the operational IASI L2 processor at EUMETSAT. The FORLI-CO integrated and the IASI L2 PPF matches the stand-alone reference version within the numerical precision of the machines.

As information to the Users, the impact of the various modifications in v6.2 as compared to v6.1 is illustrated with an evaluation of the changes on the CO total column.

![Figure 2: Histogram of the CO total column differences v6.2-v6.1 for the period 12/05/2016–24/05/2016.](image)
Figure 3: Map of the CO total column for the version 6.2 (upper left) and the version 6.1 (upper right). Map the mean (lower left) CO total column differences v6.2-v6.1 and standard deviation (lower right) for the period 12/05/2016–24/05/2016.
3 ASSESSMENT OF THE TEMPERATURE AND HUMIDITY PROFILES

3.1 First-guess PWLR³ temperature retrievals

3.1.1 Metop-B v6.1 and v6.2 first-guess Temperature vs ECMWF analyses

Figure 4: FLG_CLDNES class 1. IASI-B L2 compared to ECMWF ANA temperatures. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 PWLR is black, v6.2 PWLR³ is red.
Figure 5: FLG_CLDNES class 2. IASI-B L2 compared to ECMWF ANA temperatures. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 PWLR is black, v6.2 PWLR is red.
Figure 6: FLG_CLDNES class 3. IASI-B L2 compared to ECMWF ANA temperatures. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 PWLR is black, v6.2 PWLR is red.
Figure 7: FLG_CLDNES class 4. IASI-B L2 compared to ECMWF ANA temperatures. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 PWLR is black, v6.2 PWLR is red.
3.1.2 Metop-A v6.1 and v6.2 first-guess Temperature vs ECMWF analyses

Figure 8: FLG_CLDNES class 1. IASI-A L2 compared to ECMWF ANA temperatures. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 PWLRI is black, v6.2 PWLRI is red.
Figure 9: FLG_CLDNES class 2. IASI-A L2 compared to ECMWF ANA temperatures. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 PWLR is black, v6.2 PWLR3 is red.
Figure 10: FLG_CLDNES class 3. IASI-A L2 compared to ECMWF ANA temperatures. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 PWLR is black, v6.2 PWLR is red.
Figure 11: FLG_CLDNES class 4. IASI-A L2 compared to ECMWF ANA temperatures. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 PWLR is black, v6.2 PWLR is red.
3.2 First-guess PWLR$^3$ humidity retrievals

3.2.1 Metop-B v6.1 and v6.2 first-guess Humidity vs ECMWF analyses

Figure 12: FLG_CLDNES class 1. IASI-B L2 compared to ECMWF ANA humidity. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 PWLR is black, v6.2 PWLR$^3$ is red.
Figure 13: FLG_CLDNES class 2. IASI-B L2 compared to ECMWF ANA humidity. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 PWLR is black, v6.2 PWLR is red.
Figure 14: FLG_CLDNES class 3, IASI-B L2 compared to ECMWF ANA humidity. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 PWLR is black, v6.2 PWLR is red.
Figure 15: FLG_CLDNES class 4. IASI-B L2 compared to ECMWF ANA humidity. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 PWLR is black, v6.2 PWLR is red.
3.2.2 Metop-A v6.1 and v6.2 first-guess Humidity vs ECMWF analyses

Figure 16: FLG_CLDNES class 1. IASI-A L2 compared to ECMWF ANA humidity. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 PWLR is black, v6.2 PWLR is red.
Figure 17: FLG_CLDNES class 2. IASI-A L2 compared to ECMWF ANA humidity. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 PWLR is black, v6.2 PWLR is red.
Figure 18: FLG_CLDNES class 3, IASI-A L2 compared to ECMWF ANA humidity. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 PWLR is black, v6.2 PWLR is red.
3.3 Yield recovery with the all-sky first-guess products from Metop-A

Since the end of September 2015 and the permanent degradation of the Metop-A/AMSU channel 8, the first-guess retrieval is running in infrared-only mode for Metop-A, solely exploiting IASI-A measurements while it nominally shall exploit AMSU and MHS microwave measurements in synergy with IASI data and hence provide nearly all-sky atmospheric sounding. The PWLR$^3$ introduced in v6.2 excludes the channel 8 (in addition to the already lost channel 7) on Metop-A and offers more flexibility to cope with potential future degradation of the microwave instruments.

As a result of using IR measurements only for Metop-A with v6.1, the yield of useful sounding products (as assessed from the quality indicators provided with the retrievals) had decreased from about 85% in nominal situations to about 45%, as is illustrated in Figure 20. The v6.2 re-enables the synergistic processing of microwave and infrared information. The yield recovery is illustrated in Figure 21. It is important to note that not only the yield is improved with v6.2 but also the precision of the soundings themselves, as illustrated in the sections 3.1.2 and 3.2.2.
Figure 20: Maps of the first-guess sounding (temperature at 500 hPa) with v6.1 in IR-only mode and Metop-A data on 19/05/2016 (night pixels and good retrievals only).

Figure 21: Maps of the first-guess sounding (temperature at 500 hPa) with v6.2 and Metop-A data on 19/05/2016 (night pixels and good retrievals only).
3.4 Optimal estimation of the temperature profile

The first-guess retrieval (with PWLR\textsuperscript{3}) evaluated in the sections 3.1 to 3.3 provides nearly all-sky sounding. It also initialises the subsequent optimal estimation attempted in cloud-free conditions (i.e. FLG\_CLDNES equal 1 or 2) and using IASI measurements only.

3.4.1 Metop-B v6.1 and v6.2 OEM Temperature vs ECMWF analyses

![Maps showing temperature profile comparison](image)

*Figure 22: FLG\_CLDNES class 1. IASI-B L2 compared to ECMWF ANA temperatures. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 is black, v6.2 is red.*
Figure 23: FLG_CLDNES class 2. IASI-B L2 compared to ECMWF ANA temperatures. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 is black, v6.2 is red.
3.4.2 Metop-A v6.1 and v6.2 OEM Temperature vs ECMWF analyses

Figure 24: FLG_CLDNES class 1. IASI-B L2 compared to ECMWF ANA temperatures. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 is black, v6.2 is red.
Figure 25: FLG_CLDNES class 2. IASI-B L2 compared to ECMWF ANA temperatures. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 is black, v6.2 is red.
3.5 Optimal estimation of the humidity profiles

3.5.1 Metop-B v6.1 and v6.2 OEM Humidity vs ECMWF analyses

Figure 26: FLG_CLDNES class 1. IASI-B L2 compared to ECMWF ANA humidity. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 is black, v6.2 is red.
Figure 27: FLG_CLDNES class 2. IASI-B L2 compared to ECMWF ANA humidity. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 is black, v6.2 is red.
3.5.2 Metop-A v6.1 and v6.2 OEM Humidity vs ECMWF analyses

Figure 28: FLG_CLDNES class 1. IASI-B L2 compared to ECMWF ANA humidity. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 is black, v6.2 is red.
Figure 29: FLG_CLDNES class 2. IASI-B L2 compared to ECMWF ANA humidity. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: v6.1 is black, v6.2 is red.

3.6 Yield recovery over continental surfaces with the OEM products

In the v6.2, the land surface emissivity specified in the input vector to the OEM is dynamic and coming from the PWLR\(^3\) retrieval, as opposed to the situation in v6.1 where this emissivity information was taken from a static climatological atlas. In addition, separate observation error covariance matrices for land and sea surfaces have been introduced.

As a consequence, the yield and quality of atmospheric sounding over bare surfaces (e.g. Sahara) is increased and becomes consistent with the quality of the retrievals reached in other maritime and continental locations. The gain in yield is illustrated in the Figures 30 and 31 displaying successful OEM retrievals with v6.1 and v6.2, respectively. The gain in precision for the sounding products is demonstrated in sections 3.4 and 3.5. It is particularly significant for the humidity profiles with an important reduction of the bias, close to 0 now, and of the random component of the uncertainties.
3.7 v6.2 PWLR\(^3\) vs OEM, a suitable product for regional applications

Owed to their quality and to the very small computation time, the “all-sky” atmospheric sounding and surface products generated by combining microwave and infrared with the piece-wise linear method have raised interest in the IASI L2 products and in particular for their potential for regional applications where timeliness is critical.
EUMETSAT is currently developing a solution to process regional data directly broadcasted by the Metop satellites so as to meet these nowcasting timeliness requirements. We present in Figure 32 and Figure 33 a few key results showing the quality of the PWLR$^3$ retrievals, the all-sky first guess products, as compared to the final OEM sounding products. The Figure 34 and Figure 35 give an indication of the robustness of the PWLR$^3$ retrievals against cloud contamination, in yield and accuracy/precision.

Figure 32: FLG_CLDNES class I. IASI PWLR$^3$ and OEM temperature compared to ECMWF ANA. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: First-guess PWLR$^3$ is black, OEM is red.
Figure 33: FLG_CLDNS class 1. IASI PWLR and OEM humidity compared to ECMWF ANA. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period 15/04/2016 to 15/05/2016. Legend: First-guess PWLR is black, OEM is red.
Figure 34: IASI PWLR³ temperature compared to ECMWF analyses for the period 15/04/2016 to 15/05/2016. The dashed lines are vertical profiles of the mean differences. Solid lines are standard deviation for the period. Cloudiness flag 1 (clear) is black, 2 (likely clear) is red, 3 (partly cloudy) is blue, 4 (fully cloudy) is green.
Figure 35: IASI PWLR\textsuperscript{3} humidity compared to ECMWF analyses for the period 15/04/2016 to 15/05/2016.

The dashed lines are vertical profiles of the mean differences.

Solid lines are standard deviation for the period

Cloudiness flag 1 (clear) is black, 2 (likely clear) is red, 3 (partly cloudy) is blue, 4 (fully cloudy) is green.
4 ASSESSMENT OF THE SURFACE PARAMETERS

4.1 Sea-surface temperature

The IASI L2 sea surface temperature (SST) product is routinely monitored with the Ocean and Sea-Ice Satellite Application Facility (OSI-SAF). Owed to the quality of this product demonstrated since the version 6 [RD-4], the EUMETSAT IASI L2 SST has been included in the SST products collection maintained by the Group for High Resolution SST (GHRSST) [RD-6].

The revision 6.2 of the IASI L2 operational processing chain does not introduce significant algorithm changes as concerns the SST parameter. It is hence expected that the SST generated with the v6.2 are consistent with the SST produced with the v6.1 and that the validation results obtained from the former revision in terms of systematic and random error characteristics are still applicable. In the IASI SST products reformatted in the GHRSST L2P standard, this information is used to assign a quality class to each SST retrieval. The statistics and class stratification are regularly reviewed and potentially subject to changes on a biannual basis when necessary.

We present hereafter non-regression assessments from IASI L2 v6.1 to v6.2 SST performed with ECMWF analyses.

![Figure 36: Maps of the mean (left) SST differences and standard deviation (right) between IASI L2 v6.1 and ECMWF analyses in the period 15/04/2016 to 15/05/2016, for Metop-A (top) and Metop-B (bottom).](image-url)
Figure 37: Maps of the mean (left) SST differences and standard deviation (right) between IASI L2 v6.2 and ECMWF analyses in the period 15/04/2016 to 15/05/2016, for Metop-A (top) and Metop-B (bottom).
Figure 38: Histograms of the SST differences between IASI L2 first-guess (black: v6.1; red: v6.2) and ECMWF analyses in the period 15/04/2016 to 15/05/2016, for Metop-A in the cloudiness classes 1 (clear), 2 (likely clear), 3 (partly cloudy) and 4 (fully clear) from top left to bottom right.
Figure 39: Histograms of the SST differences between IASI L2 first-guess (black: v6.1; red: v6.2) and ECMWF analyses in the period 15/04/2016 to 15/05/2016, for Metop-B in the cloudiness classes 1 (clear), 2 (likely clear), 3 (partly cloudy) and 4 (fully clear) from top left to bottom right.

Figure 40: Histograms of the SST differences between IASI L2 OEM (black: v6.1; red: v6.2) and ECMWF analyses in the period 15/04/2016 to 15/05/2016, for Metop-A in the cloudiness classes 1 (clear), 2 (likely clear) from left to right.
Figure 41: Histograms of the SST differences between IASI L2 first-guess (black: v6.1; red: v6.2) and ECMWF analyses in the period 15/04/2016 to 15/05/2016, for Metop-B in the cloudiness classes 1 (clear), 2 (likely clear) from left to right.

4.2 Land surface temperature

4.2.1 Evaluation with Land-SAF LST products from SEVIRI

The Land Surface Analysis Satellite Application Facility (LSA SAF) generates an operational Land Surface Temperature (LST) product based on the Spinning Enhanced Visible and Infrared Imager (SEVIRI) measurements acquired from the Meteosat Second Generation (MSG) satellites. The retrieved physical parameter is the radiative skin temperature over land and is available under clear sky conditions only. Derived from thermal infrared measurements, it is directly comparable to the IASI LST. Its computation involves a generic split window (GSW) algorithm described in [RD-7] with two adjacent window channels—IR10.8 µm and IR12.0 µm—to correct for the atmospheric absorption. The spatial resolution is approximately 3 km at the sub-satellite point, equal to that of the SEVIRI images in a nominal mode. Coverage includes all of Europe and Africa, along with a portion of South America. See Figure 42.
The periodicity of these products is 15 minutes, which allows a very close temporal coincidence with the successive Metop overpasses and their associated IASI LST retrievals. Each LSA LST comes with a quality flag [RD-9] that indicates the degree of confidence and the error associated with the retrieval. For this study, we only kept the products with “above nominal” and nominal” quality for both the LST and surface emissivity parameters. This corresponds to uncertainties of less than 1 K and between 1 K and 2 K. See [RD-8] and the following web site:

http://landsaf.meteo.pt/

Differences (LSA SAF minus IASI) are computed for each match-up where at least four good LSA LST retrievals can be found within the IASI field of view. The matching SEVIRI points are averaged and only used if their standard deviations remain lower than 5 K; this avoids scenes that are too heterogeneous. The intercomparisons presented hereafter are performed with OEM-retrieved LST for cloud-free IFOVs only, as identified with the flag IASI (FLG_CLDNES = 1 or 2) and SEVIRI, and for daytime and nighttimes separately. Indeed, some differences are expected due to shadow effects coming from the relative Metop/MSG to Sun to Surface viewing and illumination geometry. The latter explains the angular variation of the SEVIRI-IASI LST with IASI scan angle as reported at daytime in Figure 44 and Figure 45, as IASI observes more shadows at the beginning than at the end of the swath, on average. The statistics are computed globally with the exclusion of the Sahara, where satellite LST retrievals usually present very large differences, especially during daytime. The African Sahara and the Arabian Peninsula, presenting specific bare soil types, are therefore isolated and the statistics repeated separately.
Figure 43: Comparison of LSA-SAF (SEVIRI) and IASI L2 LST mean differences (top left) and standard deviation (top right) for the period 28/03/2014 to 09/04/2014 at night time (left panel) and daytime (right panel) for Metop-B.
Figure 44: LSA-SAF(SEVIRI) and IASI LST products correlation (a), variations of the differences with latitude (b) and scan angle (c), their departures distributions (d) and at night time and day times (left and right panels, respectively) and for Metop-B in the period 28/03/2014 to 09/04/2014, Sahara excluded.

Figure 45: LSA-SAF(SEVIRI) and IASI LST products correlation (a), variations of the differences with latitude (b) and scan angle (c), their departures distributions (d) and at night- and daytimes (left and right panels, respectively) and for Metop-B in the period 28/03/2014 to 09/04/2014 for Sahara only.
4.2.2 Validation against surface temperature ground based measurements

This will be done as part of long-term monitoring and validation.

4.3 Land Surface emissivity

In the v6.2, the surface emissivity retrieval is now performed with the PWLR\(^3\) method while it had been retrieved with a linear regression in the EOF radiance and emissivity domains as designed by Dan Zhou (NASA) [RD-10] in the former revisions. In the following figures 48 to 59, we present qualitative comparisons of v6.1 and v6.2 emissivity maps.

The validation of land surface emissivity with external reference data is still subject to research and will be further studied. Meanwhile, the assessment of the relative skills of land surface emissivity products can be assessed by inspection of the radiance residuals between IASI observations (OBS) and synthetic radiances calculated (CALC) using a forward model (here RTTOV) and the different emissivity products as input to the forward model. This can be considered as validation only if the method used to retrieve the geophysical parameter is not based on the minimisation of these OBS-CALC residuals themselves. That condition is met with the PWLR\(^3\), which is a statistical non-linear regression method but would not be met with the OEM. The Figure 46 shows the standard deviation of the OBS-CALC obtained over continental surfaces at night-time in the 139 channels subsequently used in the OEM retrieval of the IASI L2 processor. In this plot, only the channels with index from 50 to 75 are sensitive to the surface. The CALC are computed with the same atmospheric profiles (from the PWLR) and different surface emissivity: the static land emissivity atlas from the University of Wisconsin (UW) [RD-11] and the first-guess statistical retrieval. The latter yields the smaller residuals and hence the best fit to the observations, proving the added-value of the dynamically retrieved surface emissivity as compared to the climatological atlas.

![UW static atlas vs PWLR based on UW atlas](image)

**Figure 46:** Standard deviation of the OBS-CALC computed with the UW static emissivity atlas (blue) and the PWLR statistical retrieval (red) on 01/07/2012 for night-time continental pixels.
Similarly, the relative improvement with the v6.2 as compared to v6.1 is assessed through inspection of OBS-CALC residuals over continental surfaces, using products (temperature, humidity, ozone and surface emissivity) from the former and the new revision of the IASI L2 PPF. In addition, we compare the OBS-CALC residuals in IASI bands 1 and 2 obtained with forecast data from ECMWF (temperature, humidity, ozone) and the static MODIS emissivity atlas from University of Wisconsin. The results presented in Figure 47 are computed with 23978 pixels on 16/05/2016 over land surfaces within [60°S;60°N] latitudes, excluding elevated surfaces above 2000m. It shows the clear improvements with v6.2 and confirms the advantages of using IASI level L2 surface products –and profiles- to fit real observations.

![Figure 47: OBS-CALC standard deviation obtained with ECMWF forecasts and UW static emissivity atlas (black), IASI L2 v6.1 products (blue) and IASI L2 v6.2 products (red) for land surfaces on 16/05/2016.](image-url)
Figure 48: IASI-B L2 land surface emissivity 765.5 cm⁻¹ for PPF v6.2 (left) and PPF v6.1 (right) at daytime (upper panel) and night (lower panel) for the period 12/05/2016–24/05/2016.
Figure 49: IASI-B L2 land surface emissivity 900 cm$^{-1}$ for PPF v6.2 (left) and PPF v6.1 (right) during daytime (upper panel) and night (lower panel) in the period 12/05/2016–24/05/2016.
Figure 50: IASI-B L2 land surface emissivity $991 \text{ cm}^{-1}$ for PPF v6.2 (left) and PPF v6.1 (right) during daytime (upper panel) and night (lower panel) in the period 12/05/2016–24/05/2016.
Figure 51: IASI-B L2 land surface emissivity 1071.25 cm⁻¹ for PPF v6.2 (left) and PPF v6.1 (right) during daytime (upper panel) and night (lower panel) in the period 12/05/2016–24/05/2016.
Figure 52: IASI-B L2 land surface emissivity 1160.25 cm\(^{-1}\) for PPF v6.2 (left) and PPF v6.1 (right) during daytime (upper panel) and night (lower panel) in the period 12/05/2016–24/05/2016.
Figure 53: IASI-B L2 land surface emissivity 1228 cm⁻¹ for PPF v6.2 (left) and PPF v6.1 (right) during daytime (upper panel) and night (lower panel) in the period 12/05/2016–24/05/2016.
Figure 54: IASI-B L2 land surface emissivity 1979.75 cm$^{-1}$ for PPF v6.2 (left) and PPF v6.1 (right) during daytime (upper panel) and night (lower panel) in the period 12/05/2016–24/05/2016.
Figure 55: IASI-B L2 land surface emissivity 2111 cm⁻¹ for PPF v6.2 (left) and PPF v6.1 (right) during daytime (upper panel) and night (lower panel) in the period 12/05/2016–24/05/2016.
Figure 56: IASI-B L2 land surface emissivity 2170.25 cm⁻¹ for PPF v6.2 (left) and PPF v6.1 (right) during daytime (upper panel) and night (lower panel) in the period 12/05/2016–24/05/2016.
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5 ASSESSMENT IN THE RADIANCE SPACE

As introduced in the section 4.3, this is another way to analyse retrieved geophysical parameters which consist in evaluating how well they can reproduce the observed radiances (OBS) by calculating (CALC) simulated radiances with a radiative transfer model. These OBS-CALC differences are also referred to as residuals and can be computed with atmospheric profiles derived from satellite observations or from numerical models.

In Figure 60 and Figure 61, we compare residuals (standard deviations) in the IASI bands 1 and for maritime mid- and low-latitude clear-sky situations on 15/03/2016. The simulated radiances are computed with RTTOV 10.2 as a forward model, using ECMWF forecasts (dark blue), analyses (light blue) and IASI L2 v6.2 PWLR$^3$ profiles and surface parameters (red) as input to the radiative transfer model. The residuals obtained with IASI L2 v6.2 PWLR$^3$ products are significantly smaller than those obtained with ECMWF forecasts in the complete spectral range.

Similarly, the Figure 62 compares the residuals obtained with ECMWF analyses (blue) and with IASI L2 first-guess products (red) for clear-sky land an ocean pixels at high latitudes ($|\text{lat}| > 50^\circ$). Here again, the observations are best fitted in all temperature, water-vapour, surface and ozone spectral regions with the IASI L2 products. These results illustrate the merits of satellite products for near-real time applications as compared to numerical predictions. Remarkably also, the IASI observations are also best fitted with the Level 2 products than with the numerical analyses fields in almost all spectral regions too, including temperature, water-vapour, surface and ozone sensitive channels. Hence, the IASI Level 2 products may advantageously be used in applications requiring the atmospheric state at the place and time of the IASI acquisitions.
Figure 60: Band 1 residuals (standard deviation) on 15/03/2016 for clear-sky oceans between IASI observations and simulations using ECMWF forecasts (dark blue), analyses (light blue) and IASI L2 PWLR\(^3\) products (red).

Figure 61: Band 2 residuals (standard deviation) on 15/03/2016 for clear-sky oceans between IASI observations and simulations using ECMWF forecasts (dark blue), analyses (light blue) and IASI L2 PWLR\(^3\) products (red).
Figure 62: Band 1 residuals (standard deviation) on 15/03/2016 for clear-sky maritime and continental IFOVs in high latitudes between IASI observations and simulations using ECMWF analyses (blue) and IASI L2 PWLR$^3$ products (red).
6 SUMMARY AND RECOMMENDATIONS

The updates to the IASI L2 operational processing chain were motivated by issues with degrading microwave data from Metop-A which prevented nominal synergistic exploitation of MW and IR measurements in v6.1. In addition, unsuccessful OEM retrievals over bare continental surfaces (typically over Sahara) were reported with v6.1. These issues are addressed with the PWLR$^3$, which comes in replacement of the PWLR method in v6.1. While the main aim was to recover the MW+IR synergy for Metop-A, PWLR$^3$ also provides land surface emissivity products and introduces an important algorithm improvement, with the exploitation of neighbouring measurements for geophysical parameters retrieval in any given pixel. The PWLR$^3$ retrieved geophysical parameters feed in the subsequent OEM retrieval, which is now configured with a different observation error matrix for maritime and continental surfaces in v6.2 (a unique matrix was used in v6.1). Importantly also some updates were required to finalise the qualification of the CO product with the O3M-SAF, which are included in the IASI L2 v6.2.

This report compiles monitoring and validation results showing the quality of the version 6.2 as compared to v6.1. From this assessment, performed with numerical model data, other satellite products and inspection of radiance residuals, the following conclusions can be drawn:

i. Many retrieved parameters are significantly improved compared to v6.1. No regressions are reported with the introduction of v6.2. The biases of first-guess and final OEM temperature and humidity profiles have flattened closer to 0 with v6.2 in all locations. The random part of the uncertainty (precision) is also improved; for instance, first-guess temperature profiles are reduced by about 0.1 K over oceans and by a few tenth of a Kelvin over land.

ii. First-guess all-sky retrievals using microwave and infrared measurements are re-enabled for Metop-A with improved performances as compared to v6.1. The yield and precision of sounding products from Metop-A with v6.2 are actually close to the performances reached with Metop-B data, despite the loss of AMSU channels on Metop-A.

iii. The nearly all-sky first-guess products (PWLR$^3$) are very much comparable in accuracy and precision to the performances reached with the optimal estimation method in clear-sky, with typical precision of 0.5 to 0.7 K in the mid-troposphere for temperature and 1 to 1.5 g/kg in the boundary layer for humidity.

iv. The “all-sky” first-guess products (PWLR$^3$) are proving relatively robust against the presence of clouds in the field of view. Statistically, the precision of the temperature sounding only marginally degrades by 0.1 to 0.2 K in the mid-troposphere with partly and fully cloud coverage, respectively. The loss of precision reaches 1 to 2 K in the boundary layer under full cloud coverage, as only the microwave measurements contain information for sounding through the clouds. Similar uncertainty characteristics are obtained for humidity sounding; the all-sky sounding only marginally degrading with cloud contamination over ocean and more noticeably over land in the boundary layer in fully overcast situations.

v. The first-guess SST seems to have improved with a reduction of the bias and slight improvement of the precision by about 0.2 to 0.3 K as compared to ECMWF analyses. The gain is particularly stronger in partly and fully cloudy conditions, with an improvement of 1 to 2 K in precision for Metop-A and of about 0.5 K for Metop-B with v6.2 as compared to v6.1. The OEM retrieved SST, currently feeding the L2P
GHRSST products presents very similar characteristics in v6.2 and v6.1 versions. Hence, continuity is expected here.

vi. The land surface emissivity product has significantly improved, which is evident from the OBS-CALC radiance fit realised in turn with static emissivity atlases, with v6.1 and v6.2 products. Diurnal variations are far less pronounced in the v6.2 products, which is assumed to be more realistic than the stronger contrasts observed in some areas (e.g. Sahara) with the v6.1 emissivities.

vii. The uncertainties in the OEM land surface temperature products, assessed by comparisons against SEVIRI products, are similar to the results obtained with the former IASI L2 revision 6.1 in most places. The novelty with v6.2 is the provision of LST (and profiles) products over bare and desert areas, where OEM retrievals could not reach successful convergence with v6.1. There a precision of 1.5 K is obtained, which is considered a very encouraging result. A slight angular dependence of about 1 K amplitude can be seen in these places. More specific validation work, involving in situ measurements will be required to fully characterise this product. This can be performed as part of long-term product monitoring and validation activities.

viii. As a consequence of better surface emissivity inputs and specific configuration of over land, atmospheric profiles retrieved with the OEM are enabled with v6.2 over land in the intertropical belt, where convergence was not reached with v6.1. Importantly, not only the yield is improved in these continental regions but also the accuracy and precision of the temperature and humidity sounding is now at the quality level reached in other geographical areas. In the boundary layer in intertropical continental places, the bias in humidity has typical flattened closely around 0 and typically below 0.2 g/kg (was oscillating up to 1.5 g/kg with v6.1) and the precision is now about 1.5 g/kg (it was reaching 2 g/kg with v6.1). v6.2 hence completes the global provision of high quality profiles for every location on Earth.

ix. The IASI L2 PPF v6.2 enables the provision of CO products fully verified against the stand-alone off-line research production at ULB, including an algorithm improvement to fix a small bias reported in the retrieved abundance profiles. It also enables the provision of the quality indicator QFLAG, an important flag for the Users to perform CO data acceptance and selection.

It is recommended to proceed with the operational release of the IASI L2 PPF v6.2, which fixes a few anomalies, enhances the sounding products further and provides improved land surface emissivity products. This release is also required to complete of the CO product qualification process with the O3M-SAF and is expected to lead to its full validated and operational status.
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