IASI L2 processor at EUMETSAT: status and perspectives

Thomas AUGUST

Xavier CALBET, Dorothée COPPENS, Marc CRAPEAU, Tim HULTBERG, Dieter KLAES, Rose MUNRO, Anne O’CAROLL, Bertrand THEODORE, Dan Zhou, Frank Goetsche, Folke Olesen, Cathy CLERBAUX, Pierre COHEUR, Daniel HURTmans
Outline

1. The current operational IASI L2 products: version 5

2. IASI L2/ Metop-B: preliminary results

3. On-going developments, towards the version 6
1. IASI L2 version 5

The products structure

Disseminated in NRT (sensing + 2 h)

- **TWT**: Temperature (vertical profiles), Humidity (vertical profiles), Surface Temperature (Land & Sea)
- **EMS**: Surface emissivity
- **CLD**: Cloud detection and characterisation
- **OZO**: O₃ total & partial (0-6, 0-12, 0-16 km) columns
- **TRG**: CO, N₂O, CH₄, CO₂ Total columns
- **v6**: CO & O₃ profiles + AK, SO₂, HNO₃
1. Input data pre-processing
2. Cloud detection and characterisation
3. Statistical retrievals: T, q, Ts, ε, CO (N₂O, CH₄, CO₂)
4. Optimal Estimation Method (OEM): T, q, Ts, O₃
# 1. IASI L2 version 5: Revision history

<table>
<thead>
<tr>
<th>Date</th>
<th>Revision number</th>
<th>Short description</th>
</tr>
</thead>
<tbody>
<tr>
<td>14/09/2010</td>
<td>v5.0.6</td>
<td><strong>Improved T profiles, CO</strong> and <strong>O₃</strong> operational […]</td>
</tr>
<tr>
<td>30/11/2010</td>
<td>IASI L2 PPF v5.0.6</td>
<td><strong>Surface emissivities</strong> disseminated in trial-mode</td>
</tr>
<tr>
<td>02/12/2010</td>
<td>IASI L2 PPF v5.1.0</td>
<td>Production and dissemination of <strong>T,q retrievals</strong> under <strong>partly cloudy</strong> conditions in answer to a user request</td>
</tr>
<tr>
<td>07/02/2011</td>
<td>IASI L1 PPF</td>
<td>Auxiliary spectral database update to <strong>reduce inter-pixel differences</strong> in band 3</td>
</tr>
<tr>
<td>14/03/2011</td>
<td>IASI L2 PPF v5.1.1</td>
<td><strong>CO</strong> &amp; <strong>N₂O</strong> retrieved and disseminated for all IFOVs</td>
</tr>
<tr>
<td>24/03/2011</td>
<td>IASI L2Pcore SST</td>
<td><strong>IASI SST</strong> becomes part of the <strong>GHRSSST</strong> (Group for High Resolution SST) project</td>
</tr>
<tr>
<td>20/10/2011</td>
<td>v5.2.1</td>
<td><strong>Improved cloud screening</strong> for cloudy T,q retrievals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fixed polar cloud-top pressure retrievals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Changed RTM to <strong>RTTOV-10</strong></td>
</tr>
<tr>
<td>28/02/2012</td>
<td>v5.3</td>
<td>New algorithm for cloud fraction and height assignment,</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>cloud product yield increased by 30%</strong></td>
</tr>
<tr>
<td>16/07/2012</td>
<td>v5.3.1</td>
<td>Bug fix in WV profiles encoding =&gt; low humidity encoded as NaN. Very rare occurrence.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SST L2P SSES update</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adapted chain to M01 products</td>
</tr>
<tr>
<td>2013</td>
<td>v6</td>
<td>... In the next slides ...</td>
</tr>
</tbody>
</table>
1. IASI L2 version 5

19-24 March 2010
Temperature profiles
IASI L2 – ECMWF Analysis

Intertropical Ocean cases

NWP forecast monitoring
Courtesy F. Rabier
(Meteo-France)

Temperature profiles: validation

- v5
- v4

rms ~ 0.7 K
1. IASI L2 version 5

Temperature profiles: validation

Ps < 900 hPa
19-24 March 2010

IASI - ECMWF

1. IASI L2 version 5

Temperature profiles assessment

- v5
- v4

✓ Yield increased x1.7
✓ rms ≤ 1 K [200-800 hPa]
1. IASI L2 version 5

Humidity profiles assessment

19-24 March 2010

IASI - ECMWF

- v5
- v4

➢ Improve retrievals in the lower troposphere

IASI L2 Status - 3rd IASI Conference, 4-8 February 2013
1. IASI L2 version 5

T, q profiles: monitoring at NOAA

http://www.star.nesdis.noaa.gov/smcd/opdb/poes/NPROVS.php

Credits: NOAA / NESDIS Center for Satellite Applications and Research.
1. IASI L2 version 5

T, q profiles: monitoring at NOAA

T @ 850 hPa

Credits: NOAA / NESDIS Center for Satellite Applications and Research.
1. IASI L2 version 5

T, q profiles: monitoring at NOAA

T @ 500 hPa

Credits: NOAA / NESDIS Center for Satellite Applications and Research.
1. IASI L2 version 5

T, q profiles: monitoring at NOAA

Credits: NOAA / NESDIS Center for Satellite Applications and Research.
1. IASI L2 version 5

WV @ 850 hPa

Credits: NOAA / NESDIS Center for Satellite Applications and Research.
1. IASI L2 version 5

T, q profiles: monitoring at NOAA

WV @ 700 hPa

NOAA/NESSDIS/STAR NPROVS Collocation Summary Statistics
700 mb water vapor

Credits: NOAA / NESDIS Center for Satellite Applications and Research.

IASI EUM
IASI NOAA
COSMIC UCAR
AIRS AQUA
1. IASI L2 version 5

T, q profiles: monitoring at NOAA

WV @ 500 hPa

Credits: NOAA / NESDIS Center for Satellite Applications and Research.

NOAA/NESDIS/STAR NPROVS Collocation Summary Statistics (500 mb water vapor v5)

Credits:
- IASI EUM
- IASI NOAA
- COSMIC UCAR
- AIRS AQUA

Slide: 17
1. IASI L2 version 5  

T, q profiles: monitoring at NOAA

Credits: NOAA / NESDIS Center for Satellite Applications and Research.
1. IASI L2 version 5

- IASI L2 products monitored since 2007 @ CNMCA
- Performances with v5 confirmed

Courtesy of A. Vocino (CNMCA)
1. IASI L2 version 5

The cloud-top pressure

- Cloud-top pressure
  - Retrieved vs CALIOP (cloud profiling Lidar/ CALIPSO)
  - September - December 2010
  - CALIOP L2 v3 1 km resolution
  - $\Delta t < 10$ mn
  - $\Delta d < 10$ km from IASI IFOV centre
  - $\sigma$(CALIOP CTP) < 50 hPa within IASI IFOV to isolate single-layer clouds

Outliers fixed with v5.2.1 (20/10/2011)
1. IASI L2 version 5

Sea Surface Temperature

19-24 March 2010

AATSR - IASI (v5)

- Aerosol optical depth (MODIS) 20/03/2010

Global figures

Cold bias: 0.4 K
σ ~ 0.4 K

Outside aerosol areas

Cold bias: 0.25 K
σ < 0.3 K

Monitored with buoys

IASI L2P SST
Part of the GHRSST project

ECMWF - IASI
1. IASI L2 version 5

LST

Retrieved vs

in situ measurements

IR radiometers measuring ground and sky brightness temperature from 9.6 to 11.5 µm, operated by Folke Olesen and Frank Goettsche (IMK/KIT)

3 validation sites:
Evora (Portugal), Gobabeb and RMZ-farm (Namibia)
1. IASI L2 version 5

LST
Retrieved vs in situ measurements

Gobabeb (Namib desert)
405 m asl

- IASI L2
- ECMWF

Credits: B. Theodore
1. IASI L2 version 5

LST
Retrieved
vs
_in situ_ measurements

RMZ-Farm (Namibia)
1360 m asl

- IASI L2
- ECMWF

_LST, ε OEM retrieval
Credits: Dan Zhou (NASA)_

August 2010
LST
Retrieved vs in situ measurements
Evora (Portugal) 300 m asl

IASI L2
ECMWF

August 2010

See Poster #36
Bertrand Théodore
Outline

1. The current operational IASI L2 products: version 5

2. IASI L2/ Metop-B: preliminary results

3. On-going developments, towards the version 6
2. IASI L2 / Metop-B

Self-consistency checks

Cloud Fraction
22/01/2013
Metop-A & B
2. IASI L2 / Metop-B

Self-consistency checks

Inter-pixel consistency

Retrieved Temperature @500hPa :: M01 :: 18-30/01/2013

- 1; #1302464; \( <x> = 252.7; \sigma = 12.8 \)
- 2; #1314091; \( <x> = 252.7; \sigma = 12.8 \)
- 3; #1310404; \( <x> = 252.7; \sigma = 12.8 \)
- 4; #1304314; \( <x> = 252.7; \sigma = 12.8 \)
2. IASI L2 / Metop-B

IASI-B – IASI-A :: T :: Clear-sky :: 18-28/01/2013

Metop-B vs Metop-A

North Pole
North Sea
North Land

High elevation
Intertropical Sea
Intertropical Land

South Pole
South Sea
South Land

Atmospheric Pressure [hPa]

Atmospheric Temperature [K]
2. IASI L2 / Metop-B

Assessment against ECMWF

- IASI-A
- IASI-B

IASI - ECMWF Analysis :: T :: Clear-sky :: 18-28/01/2013

North Pole

North Sea

North Land

High elevation

Intertropical Sea

Intertropical Land

South Pole

South Sea

South Land
Outline

1. The current operational IASI L2 products: version 5

2. IASI L2/ Metop-B: preliminary results

3. On-going developments, towards the version 6
3. Current developments

Routine IASI L2 monitoring

- Ozone difference

Credits: Dorothée Coppens

- Time series for Temperature & Humidity departures at 200, 500, 800, 980 hPa and the surface temperature

- Temperature and humidity departures statistics

- Generation of L3 maps and daily/ weekly/ monthly departure maps (O₃, SST ...)

3. Current developments  Routine IASI L2 monitoring

Time series for Temperature & Humidity departures at 200, 500, 800, 980 hPa and the surface temperature
3. Current developments

Temperature and humidity departures statistics

Routine IASI L2 monitoring
3. Current developments

Routine IASI L2 monitoring

Generation of L3 maps and daily/weekly/monthly departure maps (O$_3$, SST ...)

Ozone difference
3. Current developments  New products: CO, O₃, SO₂, HNO₃


Implementation in the EPS ground segment of a series of atmospheric composition products developed by ULB/LATMOS.

Algorithm: FORLI (Fast Optimal Retrievals on Layers for IASI, Hurtmans et al., *JQSRT* 2012)

- CO profiles + AK (2013)
- SO₂ column
- O₃ profiles + AK
- HNO₃ profiles

Credits: ULB/LATMOS
A new cloud test
- Based on artificial neural networks (ANN)
- Inputs: IASI channels subset & AVHRR scenes analysis
- Result of external study (Brockman & Freie Univ. Berlin)
- ~25,000 IFOVs classified by visual inspections of AVHRR images
- Dedicated ANNs trained for land/sea & day/night config.
- Performs better than NWP test on the training base:
  - Accuracy ~90% vs 75% for NWP test
  - Capability ~85% vs 60% for NWP test

3. Current developments  Cloudiness & L2 quality flagging
3. Current developments  Cloudiness & L2 quality flagging

ANN test  NWP test  AVHRR test

White: cloudy  Black: clear

19/03/2010
3. Current developments  Cloudiness & L2 quality flagging

19-24 March 2010 Agreement rate: ANN vs AVHRR

- snow, Ts, T&q profiles
- ems, Tskin
- mineral dust
- q profiles

M. Crapeau

Dominant configuration

- Red: Agreement
- Green: Clear only for NNa
- Blue: Clear only for AVHRR
3. Current developments

Objectives: Relate cloudiness estimate to IASI L2 quality indicator

<table>
<thead>
<tr>
<th>Cloudiness flag in v6</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Clear-sky</td>
<td></td>
</tr>
<tr>
<td>2 Potential small cloud contamination, cloud not characterised with confidence</td>
<td></td>
</tr>
<tr>
<td>3 IFOV partially cloudy</td>
<td></td>
</tr>
<tr>
<td>4 IFOV fully cloudy</td>
<td></td>
</tr>
</tbody>
</table>
3. Current developments

Objectives: Relate cloudiness estimate to IASI L2 quality indicator

+ High confidence
- Low yield
! Some area may be systematically excluded
3. Current developments  Cloudiness & L2 quality flagging

Current clear
Q1 OEM clear
Q2 OEM clear
Current cloudy

19-24/03/2012

Southern oceans

Current clear
Q1 OEM clear
Q2 OEM clear
Current cloudy

19-24/03/2012
3. Current developments  Cloudiness & L2 quality flagging

- Quality improved/preserved in Q1
- Quality improved in Q2
- Overall yield increased

See Poster #37
Marc Crapeau
3. Current developments

Synergistic MW & IR use

Sea ice classification

<table>
<thead>
<tr>
<th>FLG_LANSEA (in v6)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Sea</td>
</tr>
<tr>
<td>1</td>
<td>Land, topography homogeneous</td>
</tr>
<tr>
<td>2</td>
<td>Land, topography variable</td>
</tr>
<tr>
<td>3</td>
<td>Mixed scene, topography homogeneous</td>
</tr>
<tr>
<td>4</td>
<td>Mixed scene, topography variable</td>
</tr>
<tr>
<td>5</td>
<td>Sea-ice</td>
</tr>
</tbody>
</table>

Ice mask: Prototype using collocated AMSU data

OSI-SAF ice edge product
NLR: Non-Linear statistical Retrieval

- Predictors: IASI radiances
- Outputs: Ts, profiles of T, q, O₃
- Retrieval methods: combination of linear regression, neural networks and support vector machines
- Training set: synthetic clear-sky IASI radiances (RTM: OSS) and climatological database (Le Chevallier, ECMWF)
- External study lead by X. Calbet (EUM), performed University of Valencia (G. Camps-Valls et al.)

!! More accurate than Linear Regression
!! Precision comparable to OE
!! Speed-up computations by 300
3. Current developments

- Predictors: **AMSU, MHS, IASI and AVHRR** measurements in PCs
- Outputs: $T_s$, profiles of $T$, $q$ & $O_3$ + error estimate
- Retrieval method: **Linear regression**
- Training set: **Real observations** & co-located ECMWF analyses.
- **36 regression classes** with specific regression coefficients, based on MHS, AMSU and IASI (band 2) radiances.

Tim Hultberg’s Talk

Thursday @ 16:00
3. Current developments MW-HR all-sky linear retrieval

MWIR Ta 20120915

Tim Hultberg’s Talk
Thursday @ 16:00
3. Current developments

MW+IR all-sky linear retrieval

Q 20120915

Tim Hultberg’s Talk
Thursday @ 16:00
3. Current developments

MW+HR all-sky linear retrieval

Regression class, 20120401
3. Current developments

Assessment of new retrievals

**Q1 PPF v5**

**Q1 NLR clear**

**Q1 MWIR**

19-24/03/2010

Southern oceans

19-24/03/2010

Intertrop. oceans
3. Current developments

Assessment of new T retrievals

19-24/03/2010 Southern oceans

Q2 PPF v5

Q2 NLR clear

Q2 MWIR

19-24/03/2010 Intertrop. oceans
3. Current developments

Assessment of new WV retrievals

19-24/03/2010
Southern oceans

Q3 PPF v5
Q3 NLR clear
Q3 MWIR

19-24/03/2010
Intertrop. oceans
3. Current developments

Assessment of new WV retrievals

**Q1 PPF v5**
- Southern oceans: 19-24/03/2010
- Intertrop. oceans: 19-24/03/2010

**Q1 NLR clear**

**Q1 MWIR**
3. Current developments  
Assessment of new WV retrievals

19-24/03/2010  
Southern oceans

Q2 PPF v5
Q2 NLR clear
Q2 MWIR

19-24/03/2010  
Intertrop. oceans
3. Current developments

Assessment of new WV retrievals

19-24/03/2010
Southern oceans

Q3 PPF v5
Q3 NLR clear
Q3 MWIR

19-24/03/2010
Intertrop. oceans
3. Current developments

- Exploration of the observation and model (RTM) subspaces
- New channel selection, use of reconstructed radiances
- Use of MWIR regression in the background terms
- Narrow down the observation error matrix
- New radiance tuning

Tim Hultberg’s Talk
Thursday @ 16:00
3. Current developments

New OEM configuration

IASI – ECMWF Analysis – Temperature profile – Clear-sky

- v5
- v6

19-24/03/2010

IASI-ECMWF Atmospheric Temperature bias and std [K]

Atmospheric pressure [hPa]
3. Current developments

New OEM configuration

IASI – ECMWF Analysis – Humidity profile – Clear-sky

- v5
- v6

19-24/03/2010
3. Current developments

Open questions

• clouds/aerosol detection/simulation from IR and impact on sounding products quality?

• What WV products references for the validation of satellite retrieved profiles with ground resolution of 12-30 km?

• Calibration instrument/RTM, esp. in WV channels and characterisation of the observation error matrix?

• Retrieving GHG with IASI?

• Validation of Land Surface Emissivity?
Summary & Outlook

- PPFv5 operational since 14/09/2010
- Significant improvements: T, LST, clouds, CO, O₃

Upcoming in 2013:

- Complete the Cal/Val IASI L2 / Metop-B
- Further validation (LSE, T & q) and algo. developments (atm. composition, aerosol detection...)
- Release the IASI L2 v6 (new algorithms & products)

- CO profiles + AK
- T, q profiles yield increased, product quality flagging
- More accurate T & q sounding in the lower troposphere, including in partly cloud-contaminated IFOVs
## Summary & Outlook

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Algorithm</th>
<th>Status</th>
<th>Plans for V6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud detection</td>
<td>NWP, AVHRR</td>
<td>Operational</td>
<td>NWP+AVHRR+ANN</td>
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<tr>
<td>Cloud fraction &amp; height</td>
<td>CO$_2$-slicing + $\chi^2$</td>
<td>Operational</td>
<td></td>
</tr>
<tr>
<td>Cloud phase</td>
<td>BT difference</td>
<td>Trial</td>
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<tr>
<td>T profiles</td>
<td>OEM</td>
<td>Operational</td>
<td>NLR, MWIR OEM(q)</td>
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<tr>
<td>q profiles</td>
<td>EOF</td>
<td>Operational</td>
<td>AK</td>
</tr>
<tr>
<td>SST / LST</td>
<td>EOF</td>
<td>Operational</td>
<td>Fix angular variation</td>
</tr>
<tr>
<td>Emissivity</td>
<td>EOF</td>
<td>Trial</td>
<td>OEM(LST &amp; ems)</td>
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<tr>
<td>O$_3$ total column</td>
<td>OEM</td>
<td>Operational</td>
<td>Profiles + AK</td>
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<tr>
<td>O$_3$ partial columns</td>
<td>OEM</td>
<td>Trial</td>
<td>Profiles + AK</td>
</tr>
<tr>
<td>CO</td>
<td>ANN</td>
<td>Operational</td>
<td>SO$_2$, HNO$_3$, ???</td>
</tr>
<tr>
<td>N$_2$O, CH$_4$, CO$_2$</td>
<td>ANN</td>
<td>Experimental</td>
<td></td>
</tr>
</tbody>
</table>
References & contacts

- **Papers**
  August et al, “IASI on Metop-A: Operational Level 2 retrievals after five years in orbit”, JQSRT 2012

- **Validation reports (SST, LST, T&Q, CO, O₃...)**
eumetsat.int/Home/Main/DataProducts/Resources/index.htm#val_reports

- **Product Generation Specification**
eumetsat.int/groups/ops/documents/document/PDF_TEN_990013-EPS-IASI L2-PGS.pdf

- **Product Guide**
eumetsat.int/Home/Main/DataProducts/Resources/index.htm#productguides

**Contact:** thomas.august@eumetsat.int

**User Helpdesk (questions, feedback, requests...):** ops@eumetsat.int