IASI measurements of short-lived species

Pierre Coheur, Lieven Clarisse, Daniel Hurtmans, Catherine Wespes
Spectroscopie de l’Atmosphère, Chimie Quantique et Photophysique, Université Libre de Bruxelles, Belgique

Cathy Clerbaux, Solène Turquety, Juliette Hadji-Lazaro
Service d’Aéronomie / CNRS, IPSL, Université Paris 6, Paris, France

IASI
- Instrument and status
- Measurements and products
- Measuring short-lived species: 4 examples
  - HNO₃
  - Trace species in biomass burning plumes
  - SO₂/Aerosols in volcanic plumes
  - Dust storms
IASI instrument and status

MetOp: First European meteorological platform on polar orbit (EPS system)

- Spectral coverage: 645-2760 cm\(^{-1}\)
- Spectral resolution: 0.5 cm\(^{-1}\)
- Radiometric noise: \(<0.1-0.2\) K

Small ground pixel size

Global coverage twice daily (1.3×10\(^6\) spectra).
Morning and evening orbits

IASI
Nadir looking FTS

- 12 km pixel \(\times\) 4 @ nadir
- 120 spectra along the swath (\(\pm 48.3^\circ\) Scan \(\rightarrow 2400\) km), each 50 km along the trace

Jun. 4, 2007 L1C Operational dissemination
Sep. 27, 2007 L2 (P, T, clouds) operational dissemination
Mar. 1, 2008 L2 (trace gases) operational dissemination

Excellent radiometric performances

Medium spectral resolution

Broad spectral coverage without gaps

Small ground pixel size

Global coverage twice daily (1.3×10\(^6\) spectra).
Morning and evening orbits

IASI
Nadir looking FTS

- 12 km pixel \(\times\) 4 @ nadir
- 120 spectra along the swath (\(\pm 48.3^\circ\) Scan \(\rightarrow 2400\) km), each 50 km along the trace

Jun. 4, 2007 L1C Operational dissemination
Sep. 27, 2007 L2 (P, T, clouds) operational dissemination
Mar. 1, 2008 L2 (trace gases) operational dissemination

Excellent radiometric performances

Medium spectral resolution

Broad spectral coverage without gaps

Small ground pixel size

Global coverage twice daily (1.3×10\(^6\) spectra).
Morning and evening orbits

IASI
Nadir looking FTS

- 12 km pixel \(\times\) 4 @ nadir
- 120 spectra along the swath (\(\pm 48.3^\circ\) Scan \(\rightarrow 2400\) km), each 50 km along the trace

Jun. 4, 2007 L1C Operational dissemination
Sep. 27, 2007 L2 (P, T, clouds) operational dissemination
Mar. 1, 2008 L2 (trace gases) operational dissemination

Excellent radiometric performances

Medium spectral resolution

Broad spectral coverage without gaps

Small ground pixel size

Global coverage twice daily (1.3×10\(^6\) spectra).
Morning and evening orbits
Measurements and Products

IASI radiance spectrum

SA/CNRS – ULB

Radiance (W / cm² sr cm⁻¹)

Wavenumber (cm⁻¹)

CO₂, HNO₃
CFC11, CFC12
CH₄
H₂¹⁶O, H₂¹⁸O, H₂O
H₂¹⁶O, H₂O
CH₄
H₂, HOD
O₃
N₂O, CH₄

Thermal + reflected solar radiation (daytime)

Noise estimation

Pre-flight estimation

On flight

Pre-flight estimation / 2

Pre-flight estimation / 2
Measurements and Products

Long-lived species (years)  
→ Climate  
+ CO, O₃ (months)  
→ Chemistry (C. Clerbaux tuesday)

Short-lived species (days/weeks) and aerosols

Inter hemispheric mixing: ~1 year  
hemispheric mixing: ~1-2 months  
PBL mixing: ~few hours
IASI measurements of short-lived species

Nitric acid
Trace species in biomass burning plumes
SO₂/aerosols in volcanic plumes
Dust storms

ULB – SA/CNRS

P.F. Coheur. 4th Hyperspectral Meeting, Darmstadt, September 2008
Profile/Column retrievals based on the Optimal Estimation Theory; NRT processing.

For HNO₃, total column mostly relevant.
$\text{HNO}_3$

Total columns

Weakly average, July 2008

$\frac{d[HNO_3]}{d[O_3]} = 4.4 \times 10^{-3}$
HNO₃

Total columns

Preliminary time series

Polar enhancements Autumn to spring

PSCs formation / denitrification during Antarctic polar night
HNO$_3$

Total columns

Preliminary time series

ULB – SA/CNRS

HNO$_3$ total column / Weakly average

May  
June  
July  
August
HNO$_3$

Towards tropospheric columns ….

\[
[HNO_3]_{tropo} = [HNO_3]^{\text{IASI}}_{\text{total}} - [HNO_3]^{\text{MLS}}_{\text{strato}(215 \rightarrow 2hPa)}
\]
IASI measurements of short-lived species

- Nitric acid
- Trace species in biomass burning plumes
- SO₂/aerosols in volcanic plumes
- Dust storms

P.F. Coheur. 4th Hyperspectral Meeting, Darmstadt, September 2008
868 252 ha burned in 14 countries (EFFIS/JRC)

Countries most affected: Greece: 270 563 ha;
Italy: 153 884 ha; Albania: 127 880 ha;
Bulgaria: 67 747 ha; Spain: 55956 ha
Fire plumes

Fires in Southern Europe in Summer 2007

Plume composition

Ammonia (NH₃)  Ethene (C₂H₄) and methanol (CH₃OH)

- Ammonia (NH₃)
- Ethene (C₂H₄)
- Methanol (CH₃OH)

Radiance (W/cm² sr cm⁻¹)

NH₃ transmittance spectrum
C₂H₄ transmittance spectrum
CH₃OH transmittance spectrum

P.F. Coheur. 4th Hyperspectral Meeting, Darmstadt, September 2008
Fire plumes

Fires in Southern Europe in Summer 2007

Plume composition

Total column retrievals for August 25

Total emitted mass:
- \( \text{NH}_3 = 40 \text{ kTons} \)
- \( \text{C}_2\text{H}_4 = 6.5 \text{ kTons} \)
- \( \text{CH}_3\text{OH} = 7 \text{ kTons} \)

\( [C_2H_4] = 7.42 \times 10^{15} + 0.14 [NH_3] \quad R^2 = 0.87 \)

\( [CH_3OH] = 1.08 \times 10^{16} + 0.07 [NH_3] \quad R^2 = 0.83 \)

\( \Rightarrow \) Chemistry in the fire plume

\( \Rightarrow \) Atmospheric budgets

P.F. Coheur. 4th Hyperspectral Meeting, Darmstadt, September 2008
Fire plumes

April/May 2008: Russia worst forest fires in 30 years

IASI short-lived species in the fire plume
NH3

MODIS fire counts (red dots) for April 18, 2008
IASI measurements of short-lived species

- Nitric acid
- Trace species in biomass burning plumes
- SO$_2$/aerosols in volcanic plumes
- Dust storms

P.F. Coheur. 4th Hyperspectral Meeting, Darmstadt, September 2008
Volcano plumes

Plume composition

Inside of plume

Outside of plume

SO$_2$

L. Clarisse, ACPD, 2008

Sensitive – highly – to high altitude plumes only → Use for aerial security

Vertical profile retrievals with 3 km height-resolution

Sensitive to high and low altitude plumes

P.F. Coheur. 4th Hyperspectral Meeting, Darmstadt, September 2008
Volcano plumes

Tracking SO$_2$ plumes

September 30 → October 11

ECMWF wind fields at 100 hPa

P.F. Coheur. 4th Hyperspectral Meeting, Darmstadt, September 2008
Volcano plumes

Tracking SO$_2$ plumes

Etna (Sicily), July 2008

May 10 → May 12, 2008

GOME-2

P.F. Coheur. 4$^{th}$ Hyperspectral Meeting, Darmstadt, September 2008
Volcano plumes

Tracking SO2 plumes
Benefit of different platforms

Etna (Sicily), May 2008

IASI ± 3 hours AIRS

July 10, 8 PM July 11, 0 AM
July 11, 9 AM July 11, 12 AM
July 11, 6 PM July 11, 9 PM
July 12, 6 AM July 12, 9 AM

One day

P.F. Coheur. 4th Hyperspectral Meeting, Darmstadt, September 2008
Volcano plumes

Tracking SO$_2$ plumes from degassing volcanoes

Use of SO$_2$ $\nu_1$ to increase sensitivity to the surface (<5 km)
Sensitivity down to less than 1 DU

Kilauea (Hawaii), May 2008
IASI measurements of short-lived species

- Nitric acid
- Trace species in biomass burning plumes
- SO$_2$/aerosols in volcanic plumes
- Dust storms

ULB – SA/CNRS
Dust plumes

IASI observation on March 3, PM

Middle East, March 2008

Broadband extinction from 800 to 1200 cm\(^{-1}\)
Sharp spectral feature between 850 and 900 cm\(^{-1}\)

Computation of $\Delta BT = BT(\bullet) - \frac{BT(\bullet) + BT(\bullet)}{2}$
Dust plumes

MODIS

March 3

March 4

IASI

Middle East, March 2008

ΔBT (K) = BT(●) - [BT(●) + BT(○)]/2

ΔBT (K) = BT(●) - [BT(●) + BT(○)]/2
Dust plumes

Dust storm (L. Clarisse)

Sand storm in China (May 27, 2008)

China, May 2008

Brightness temperature ($\Delta T$) vs. Wavenumber (cm$^{-1}$)

Beijing

SA/CNRS-ULB
Conclusions

IASI is doing great!

Small pixel size
Global Earth’s coverage twice daily
Wide spectral coverage
Low radiometric noise

NRT-identification and tracking of pollution plumes

Nominal operations since May 2007
10–15 species are monitored with applications in
• Climate (H₂O and isotopologues, CO₂, CH₄, N₂O)
• Ozone chemistry in the stratosphere (O₃, CFCs, HNO₃)
• Tropospheric chemistry (O₃, CO, CH₄, HNO₃, VOCs) including chemistry and budgets for short-lived species (NH₃, VOCs) and aerosols
• Operational monitoring (fires, volcanoes, dust storms...)

P.F. Coheur. 4th Hyperspectral Meeting, Darmstadt, September 2008
July 2008 eruptions in Alaska

Okmok

Kasatochi plume still to be seen, more than a month after the eruption