Analysis of trace gas emission and transport during biomass burning events using IASI satellite observations

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Outline

(1) IASI/METOP trace gas observations

(2) More details on retrievals in fire plumes

(3) Information on emissions?
IASI instrument – Launched Oct. 2006

Launched onboard METOP-A in Oct 2006
MetOp: First European meteorological platform on polar orbit (EPS system)
3 successive satellites: 15 years of data

MetOp

120 spectra along the swath (2400 km)
Each 50 km along the trace

> Up to $1.3 \times 10^6$ spectra/day (16Gb)

→ Oct. 19, 2006  MetOp-A launch
→ Jun. 4, 2007  L1C Operational dissemination (Eumetcast)
→ Sep. 27, 2007  L2 (P, T, clouds) operational dissemination
→ Mar. 1, 2008  L2 (trace gases) operational dissemination
IASI instrument – Launched Oct. 2006

- 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 (morning and evening orbits)

Medium spectral resolution

High radiometric performances

• 12 km pixel x 4 @ nadir
• 120 spectra along the swath (±48.3° Scan \(\rightarrow\) 2400 km), each 50 km along the trace

Broad spectral coverage without gaps
Measurements and Products

Operational L2 trace gases (EUMETCAST) : O3, CO
Main characteristics of retrievals in research groups ➔ special issue ACPD

NRT Retrievals at LATMOS/CNRS and ULB

CO, O$_3$, HNO$_3$, SO$_2$ in near real time
CO profiles, very soon O$_3$ profiles

Clerbaux et al, ACP IASI Special Issue, 2009

Carbon monoxide (ULB/LATMOS)

April 2008

July 2008

October 2008

January 2009

Clerbaux et al, ACP IASI Special Issue, 2009

Preliminary validation: George et al., ACPD, 2009
A few words about retrieval error...

→ Uncertainty on the radiances (radiometric noise): measurement error
   => only error accounted for in theoretical retrieval error

→ Uncertainty on the atmospheric and surface parameters (e.g. emissivity, temperature and water vapor profiles)

→ Lack of vertical resolution: smoothing error

characterized by the averaging kernel
and the derived degrees of freedom of signal:

$$\mathbf{A} = \frac{\partial \hat{\mathbf{x}}}{\partial \mathbf{x}}$$

$$DOFS = \text{trace}(\mathbf{A})$$

CO profile
19 levels
Degrees of freedom for signal (DOFS)
Validation against in situ observations during the POLARCAT campaign

ARCTAS: DC8
06/18-07/13/2008

POLARCAT-France:
ATR-42
06/30-07/14/2008

POLARCAT-Grace:
Falcon
06/30-07/18/2008

YAK:
07/07-07/29/2008

(M. Pommier, LATMOS)
Example of validation profile

Background air above Greenland (DLR flight)
Siberian pollution (Forest Fire): Flight YAK July 11th 2008

39 IASI pixels along the flight

only +/-1h around the aircraft position
in a box
+-0.2°around the plane

IASI CO vertical distribution vs.
YAK in situ CO measurements:
P. Nédélec, J.-D. Paris

ACE solar occultation

S. Turquety – GEIA – ACCENT
Siberian pollution (Forest Fire): YAK July 11th 2008

Enhancement in the IASI CO in the lower troposphere
BUT not able to resolve the plume shape
Enhancement in the IASI CO in the upper troposphere

**BUT**

- not able to resolve the plume shape
- too large CO?
- problem of validation:
  large correlation with CO above 12km but no in situ observation…
Case study: Greek fires August 2007

CO burden from fires = 0.321 Tg,
~40% annual anthropogenic emissions in Greece
Evaluation of CO retrievals during the 2007 Greek fires
Comparisons to MOPITT/Terra CO (v3 L2 data)

- IASI background lower
- IASI larger in BB plumes

Strong implication for inversion results!

MOPITT v4: low bias in large plumes corrected
Information on vertical transport?

Total CO, August 25, PM

CO vertical profile along the plume, August 25, PM

Turquety et al., ACP 2009
Wildfires: short lived species detection

Greece fires (August 2007)

August 25, PM

Measurements of short-lived species

Spectral signatures

NH₃

C₂H₄

CH₃OH

August 25, PM

Greece fires (August 2007)

Wildfires: short lived species detection

Coheur et al., ACP 2009
Wildfires: short lived species detection

Greece fires (August 2007)

Chemistry and transport

Slopes vs. CO give enhancements ratios $\Delta[X]/\Delta[CO]$

Enhancement ratios vs. time reveal chemistry in the fire plume

Slower decrease of CH$_3$OH during the first 12 hours

Coheur et al., ACP 2009
Next step: what constraint on BB emissions and impact?

Simulation of fire plume with regional model: need emission inventory!

Total fires in Greece = 0.33 Tg CO
⇒ Very good agreement with IASI top-down calculation

Total fires in Greece = 0.25 Tg CO
⇒ Too low but expected since algorithm was not calibrated for this region
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Evaluation of fire emissions: critical step!!!

MODIS 23-31 August 2007
Confidence level > 80%

Fire Radiative Power (mean grid 0.5°x0.5°)

⇒ Max FRP N. Africa and Balkans
more directly linked with carbon emissions?

Number of fires (total)

⇒ Max nb of fires in Greece…
Where IASI shows clear max…
Summary and Conclusions

Trace gas observations from satellite:
(+ ) Good spatial and temporal coverage allow the monitoring of plumes
(+ ) Relatively long records
(- ) Lack vertical resolution
(- ) Retrieval error often difficult to assess accurately!

Specific retrieval problems for fire plumes:
• Huge pollution: far from the a priori statistics
• Impact of aerosols (probably important for O3)
• LACK VALIDATION DATA

Next steps:
• Analyze observations with a CTM to check the available constraint
• Use model as a intermediate for validation
• Quantify the impact of fires on air quality using the CHIMERE regional model
Thank you for your attention!

Acknowledgements: