IASI contribution to chemistry(-climate)
**Key points for atmospheric composition:**

**Instrumental**
1. Broad spectral range (FTS!): 645-2760 cm\(^{-1}\), without gaps
2. Relatively high spectral resolution: 0.5 cm\(^{-1}\) apodized
3. Low noise: 0.1 – 0.2 K in the regions of interest

**Sampling**
1. Relatively small pixel size: 12 km on-ground at nadir
2. Global coverage and high sampling: global measurements twice daily
EUMETSAT, NOAA, NASA meeting on hyperspectral IR sensing
Miami March 29-31, 2011

Local-to global atmospheric concentrations

IASI species

CFC12
CFC11
N2O
CO2
CH4
OCS

years

CO
O3
HNO3
SO2
H2O +

weeks

NH3

hours

Radiative transfer
Retrievals

Weather
Atmospheric chemistry
Climate

Radiance Measurements

IASI operational and science processing

Radiance (W/cm² sr cm⁻¹)
Wavenumber (cm⁻¹)

Ts=275 K
EUMETSAT, NOAA, NASA meeting on hyperspectral IR sensing
Miami March 29-31, 2011

Highlights

- IASI
- Ozone hole
- Air quality
- Volcanic monitoring
- Climate
- Nitrogen cascade
- Acidification / eutrophication, PM formation...
- Weather
- Primary, secondary aerosols
- Chemistry
- Volcanic monitoring
- Air quality
- Ozone hole
- Greenhouse gases (direct)
- Reactive gases (indirect)
- Emissions
  - Agriculture
  - Plants
  - Urban/industrial activities
  - Volcanoes
  - Fires
  - Soil

Overview of species / processes
EUMETSAT, NOAA, NASA meeting on hyperspectral IR sensing
Miami March 29-31, 2011

Highlights

Overview of species / processes

→ Global mapping

→ Local plume chemistry

SO₂ from Merapi

2010 Russian fires
A range of applications: CO as an example

Global distributions twice per day
(ULB/LATMOS FORLI processing chains)

Long-range transport
FLEXPART  IASI

Air-quality forecast
EU MACC

Emission inventories
South East Asia
- Prior
- MOPITT
- IASI

Fire monitoring

EUMETSAT, NOAA, NASA meeting on hyperspectral IR sensing
Miami March 29-31, 2011
Contribution to climate: beyond CO₂ and CH₄

→ 3 examples

climate

- Greenhouse gases (direct)
- Reactive gases (indirect)
Contribution to chemistry-climate

Contribution to climate: beyond CO₂ and CH₄

→ 3 examples

climate

- Greenhouse gases (direct)
- Reactive gases (indirect)
Ammonia

Intensive agriculture (fertilizers, breeding)

NH$_3$ account for about 50% of all Reactive nitrogen emissions

Humans and waste water 39%
Biomass burning 13%
Fertilizers 17%
Breeding 19%
Oceans 5%
Ammonia

A word on reactive nitrogen emissions and the perturbed N cycle

Anthropogenic N-fixation

Energy $\rightarrow$ NO$_x$

Food $\rightarrow$ NH$_3$

Future trends highly uncertain

Haber-Bosch

$\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$

Today $\sim$40% the world population depends on Haber Bosch process

Today $\sim$40% the world population depends on Haber Bosch process
Ammonia

Impacts of increased Nr emissions

Reactive Nr emissions (NH$_3$ and NO$_x$ account for 90%) have increased fivefold since 1900, due to energy and food production. Future projections are highly uncertain.

→ All fluxes, including deposition have strongly been affected

Impacts are magnified through the **Nitrogen cascade** (Galloway 2003)

The same atom of Nr can cause multiple effects in the atmosphere, in terrestrial ecosystems, in freshwater and marine systems, and on human health

<table>
<thead>
<tr>
<th>Form of Nr</th>
<th>Ecosystem</th>
<th>Impacts</th>
<th>scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO$_x$</td>
<td>Atmosphere</td>
<td>Acid precipitation / AQ (BL O$_3$, PM)</td>
<td>Regional</td>
</tr>
<tr>
<td>NH$_3$</td>
<td>Atmosphere</td>
<td>AQ (PM)</td>
<td>Regional / local</td>
</tr>
<tr>
<td>N$_2$O</td>
<td>Atmosphere</td>
<td>Climate / Stratospheric ozone</td>
<td>Global</td>
</tr>
<tr>
<td>NH$_3$ + other Nr</td>
<td>Aquatic</td>
<td>Eutrophication / acidification</td>
<td>Regional / local</td>
</tr>
<tr>
<td>NH$_3$ + other Nr</td>
<td>Terrestrial</td>
<td>Acid deposition / biodiversity loss</td>
<td>Local</td>
</tr>
</tbody>
</table>
Ammonia

Impacts of increased Nr emissions

1. Increased abundance of PM.
   NH$_3$ is likely to become by 2020 the dominating primary anthropogenic source to particles in ambient air.
   *Negative radiative forcing* from nitrate aerosol would increase in importance with rising ammonia and NOx emissions and declining sulfur emissions (Shindell et al., 2009).

2. More NH$_3$-NO$_x$ emissions
   Increased abundance of N$_2$O contributes to a few percent in global warming only, but could, because it has a global warming potential 300 times superior to that of CO$_2$, have a more *profound climate influence in the future if emissions continue to grow*.

3. Perturbed N and C-cycles interactions
   The increase in reactive nitrogen emissions, followed by long-range transport and deposition, stimulates the growth of continental biomass, in particular of forests. *Theoretically enhances the uptake and storage of atmospheric CO$_2$. Large uncertainties*.
Ammonia

Mapping ammonia with IASI
Global view (1 year average)

Snake River Valley

Ammonia On Idaho’s Snake River Plain
IASI

→ 28 emission hotspots identified

Water Use On Idaho’s Snake River Plain
Landsat5 evapotranspiration

Po Valley

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Ammonia

Mapping ammonia with IASI

Since 2010: NRT global distributions daily (*NH₃ total columns, morning orbit only*) available from ULB/LATMOS FORLI processing chain

Contribution to chemistry-climate
Ammonia

Mapping ammonia with IASI

NH$_3$ is short-lived, confined in the boundary layer

→ What do we / don’t we see?

The IASI sensitivity to NH$_3$ is strongly dependent on local thermal contrast

In most agricultural valleys, a monitoring year-round is possible
Ammonia

Mapping ammonia with IASI

→ Improving on emission inventories? (Courtesy C. Heald)

Models currently underestimate most emissions in Northern hemisphere (Factor of 2 or more)
Contribution to climate: beyond CO$_2$ and CH$_4$

→ 3 examples

- Greenhouse gases (direct)
- Reactive gases (indirect)

IASI

climate

EUMETSAT, NOAA, NASA meeting on hyperspectral IR sensing
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Volcanic eruptions contribute only to 1% of total SO₂ emissions but have a significant forcing on climate.
Sulfur dioxide

Volcanic eruptions contribute only to 1% of total $SO_2$ emissions but have a significant forcing on climate.

Operational alert system
http://cpm-ws4.ulb.ac.be/Alerts/
http://sacs.aeronomie.be/
Sulfur dioxide

3 years of volcanic SO$_2$ monitoring

Time series

Contribution to chemistry-climate

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Miami March 29-31, 2011
Sulfur dioxide

3 years of volcanic SO$_2$ monitoring
A global view
Sulfur dioxide

\[
\text{SO}_2 \rightarrow \text{H}_2\text{SO}_4
\]
deployment kinetics and climate impact

*Haywood et al, JGR, 2010*
Highlights

Contribution to climate: beyond CO$_2$ and CH$_4$

→ 3 examples

climate

- Greenhouse gases (direct)
- Reactive gases (indirect)
Tropospheric ozone

Tropospheric ozone is the third most important greenhouse gas after carbon dioxide and methane.
Tropospheric ozone

Ozone vertical profiles retrieved from ULB/LATMOS processing chain in NRT
3-4 independent information → tropospheric and stratospheric columns can be separated

Ozone 0-8 km column (Preliminary)
Average for October 2010.

Large tropospheric ozone due to (fire) emissions of precursors from Africa and South-America?

Contribution to chemistry-climate
Conclusions

- By measuring routinely and globally a suite of important atmospheric species, IASI contributes, in synergy with models, in quantifying emissions and in modelling atmospheric chemistry and transport. This, in turn, is essential to understand the processes driving climate and global change.
- Operational applications in air quality forecasting (MACC EU-GMES) and aviation safety (volcanic hazard; ESA-SACS and EU-EVOSS projects) have started.

As one of the first advanced atmospheric infrared sounder, IASI helps to define a strategy for the long-term monitoring of the atmospheric composition. IASI and follow-on (IASI-NG with further improvements?) are expected to operate during decades. They are likely to become central in the Global Earth Observation System of Systems.
Monitoring our changing atmosphere
Highlights from IASI mission

SPECAT/ULB
L. Clarisse
P.F. Coheur
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CNRS/LATMOS
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M. George
J. Hadji-Lazaro
M. Pommier
C. Scannell

Collaborators worldwide
S. Turquety (LMD), F. Dentener (JRC), C. Heald (CSU), R. Martin (DU), J. Stavridou and J.F. Müller (BIRA-IASB), A. Fortems-Cheney, F. Chevallier (LMD), F. Prata (NILU)....
CO total columns from the IASI/MetOp observations (FORU-CO) from July 22 to August 22, 2010.
Data averaged over 3 days on a 0.5°x0.5° grid - only daytime with CO above $2.2 \times 10^{18}$ molecules/cm$^2$

Animation by Maya George (LATMOS)