A view on mid-tropospheric CH$_4$ and CO$_2$ in the tropics: 6 years from MetOp-A/IASI

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The IASI Instrument

• IASI (Infrared Atmospheric Sounding Interferometer) is a Fourier Transform Spectrometer that measures infrared radiation emitted from the Earth.
• It has been developed by CNES, in collaboration with EUMETSAT.

• IASI provides
  - 8461 spectral channels between 645 and 2760 cm\(^{-1}\) (15.5 - 3.63 µm)
  - with a spectral resolution of 0.5 cm\(^{-1}\) after apodisation (“Level 1c” spectra)
  - the spectral sampling interval is 0.25 cm\(^{-1}\).
  - nadir FOV: 12 km at nadir.

• 3 scientific objectives:
  - Numerical Weather Prediction.
  - Atmospheric composition: more than 25 species are observed.
  - Climate.
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Climatologies of Climate Variables from IASI
Retrieval of GHG from IASI observations in the thermal IR

- Retrieval procedure (Crevoisier et al., ACP, 2009ab):
  - Use of IASI channels around 15 µm for CO₂ and 7.7 µm for CH₄.
  - Non linear inference scheme based on neural networks (Chédin et al., 2003).
  - Based on the 4A RT code and the latest edition of the GEISA database.
  - Radiative biases are computed using the ARSA database.
  - CH₄ and T(p) are intimately correlated in the IR.
    → Use of IR (IASI) and MW (AMSU) observations to decorrelate T from gas variations.
  - The decorrelation between T/gas is easier to do in the tropics.
    ⇒ better precision in the tropical region.

- We retrieve a mid/upper-tropospheric content:
  - clear sky only (no clouds, no aerosols)
  - by day and night
  - over land and over sea

We have now ~6 years (July 2007 – August 2013) of mid-tropospheric CO₂ and CH₄ integrated content from IASI.
Mid-tropospheric CO₂ and CH₄ from IASI

Zonally averaged mid-tropospheric CO₂ / CH₄ as retrieved from IASI from July 2007 to December 2012

Crevoisier et al., ACP, 2013
Meilhac, in prep. for AMT
Mid-tropospheric CO$_2$ and CH$_4$ from IASI

Zonally averaged mid-tropospheric CO$_2$ / CH$_4$ as retrieved from IASI from July 2007 to December 2012

Crevoisier et al., ACP, 2013
Meilhac, in prep. for AMT
Comparison with aircraft measurements

Collab. H. Matsueda, T. Machida, T. Schuck

NB: IASI CH₄ ~6-16 km
aircraft CH₄ ~10 km

Over 13 CARIBIC flights, on a 4°x4° grid:
IASI – CARIBIC
= 7.2 ± 13.1 ppbv

IASI CONTRAIL MLO

IASI CONTRAIL

Bias: -9 ppbv

(a) Northern tropics

IASI

Bias: 3 ppbv

(b) Southern tropics

IASI CONTRAIL

IASI

CH₄

CH₄

0601 0701 0801 0901 1001 1101
Month

0601 0701 0801 0901 1001 1101
Month

= 7.2 ± 13.1 ppbv
Fit of IASI CH₄ (whole tropical band)

CH₄ instantaneous growth rate

Procedure (following e.g. Dlugokencky et al., 1994):

• **Fit**: Polynomial trend + 4 harmonics / filtering by low-pass filters.

• **Deseasonalized long-term trend** = polynomial trend + filtered residuals.

• **Instantaneous growth rate** = derivative of this function.

Fit of IASI CO₂ (whole tropical band)

CO₂ instantaneous growth rate

Crevoisier et al., ACD, 2013
Growth rate of mid-tropospheric $\text{CH}_4$ from IASI

GR from NOAA surface network

Very good agreement between IASI and surface tropical growth rate

IASI has the potential to follow methane trend on the long-term
Growth rate of mid-tropospheric CH$_4$ from IASI

Annual increase (ppbv yr$^{-1}$) in CH$_4$

<table>
<thead>
<tr>
<th>Year</th>
<th>20N:20S</th>
<th>20N:EQ</th>
<th>EQ:20S</th>
<th>NH</th>
<th>SH</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>9.5 ± 2.8</td>
<td>8.2 ± 1.8</td>
<td>10.7 ± 2.5</td>
<td>7.3 ± 1.3</td>
<td>9.2 ± 0.3</td>
</tr>
<tr>
<td>2008</td>
<td>6.9 ± 1.3</td>
<td>6.0 ± 1.2</td>
<td>7.9 ± 1.2</td>
<td>8.1 ± 1.6*</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>1.0 ± 0.8</td>
<td>-0.3 ± 0.5</td>
<td>2.3 ± 0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>4.2 ± 0.9</td>
<td>3.6 ± 0.5</td>
<td>4.8 ± 0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>2.2 ± 0.7</td>
<td>2.5 ± 0.7</td>
<td>1.8 ± 0.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Trend of +10 ppb.yr$^{-1}$ in 2007, which decreases throughout 2008-2009.

- The analysis of ECMWF precipitation fields reveals that precipitation has continuously decreased in wetland tropical regions over 2007-2009, the total rain fall in 2010 reaching a similar value to that of 2007.
In 2010: severe drought in Amazonia
→ Decrease in wetland emission
→ Decrease of CH$_4$ of ~10 ppbv detected by IASI.

Multivariate ENSO index

Atlantic Multidecadal Oscillation
Regional level: the Amazonian case

In 2010: severe drought in Amazonia
→ Decrease in wetland emission
→ Decrease of CH_4 of ~10ppbv detected by IASI.

The 2010 very dry conditions also induced an increase in fire activity...
... well seen on CO and CO_2 fields derived from IASI.
Impact of IASI CH$_4$ on surface flux estimation

Although IASI is sensitive to mid-troposphere, it does provide information on surface fluxes.

Good statistical consistency between CH$_4$ flux estimates from IASI, TANSO-FTS and surface network within a Bayesian inversion system.

Cressot et al., ACPD, 2013
• IASI CH$_4$ fields are now assimilated in a delayed-mode within ECMWF IFS system together with TANSO-FTS CH$_4$ fields.

• The greatest impact of IASI is in the tropics, above 700 hPa.

• Overall, the IASI-TANSO analysis is in better agreement with the HIPPO data than the TANSO alone or SCIAMACHY alone analyses, with a global difference of 12.3 ppb.

Massart et al., in prep. for AMT
Conclusion

- IASI can provide valuable information on CO₂ and CH₄ cycles:
  - Long-term evolution (IASI-1, 2, 3 + IASI-NG-1, 2, 3)
    → ESA GHG CCI.
  - Information on surface emissions (even if CH₄ is retrieved only in the mid-troposphere).
    → Assimilation within the IFS system.
    → Added value to SWIR observations: both day and night, both land and sea
  - Link to climate factors, even at regional scale.

- The simultaneous retrieval of several gases, day and night, over land and sea is a clear asset to allow monitoring local to global events.

- Perspectives:
  - Processing of IASI onboard MetOp-B and -C.
  - Higher latitudes: good enough precision to provide information for CH₄ study?

<table>
<thead>
<tr>
<th>2006</th>
<th>2012</th>
<th>2018</th>
<th>2022</th>
<th>+7?</th>
<th>+7?</th>
</tr>
</thead>
<tbody>
<tr>
<td>IASI-A</td>
<td>IASI-B</td>
<td>IASI-C Merlin</td>
<td>IASI-NG-A Sentinel5/UVNS</td>
<td>IASI-NG-B</td>
<td>IASI-NG-C</td>
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Talk Friday, 11:10
Future missions