A stand-alone retrieval of greenhouse gases: CO₂ and CH₄ from AIRS and IASI

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A stand-alone approach for $CO_2$ and $CH_4$

1. A few words on thermal infrared observation

2. The stand-alone approach

3. $CO_2$ from AIRS and IASI

4. $CH_4$ from IASI
### 1. Observations in Thermal InfraRed

<table>
<thead>
<tr>
<th></th>
<th>NOAA10-... TOVS</th>
<th>NOAAk-... ATOVS</th>
<th>Aqua AIRS/AMSU</th>
<th>MetOp IASI/AMSU</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time coverage</strong></td>
<td>1987-...</td>
<td>1999-...</td>
<td>May 2002-...</td>
<td>Oct. 2006-...</td>
</tr>
<tr>
<td><strong>Spectral resolution</strong></td>
<td></td>
<td></td>
<td>0.5 - 2 cm⁻¹</td>
<td>0.5 cm⁻¹ (apodized)</td>
</tr>
<tr>
<td><strong># IR/MW channels</strong></td>
<td>19/4</td>
<td>19/15</td>
<td>2378/15</td>
<td>8461/15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(324/15)</td>
<td>(421/15)</td>
</tr>
<tr>
<td><strong>Local time</strong></td>
<td>7.30/1.30</td>
<td>7.30/1.30</td>
<td>1.30</td>
<td>9.30</td>
</tr>
</tbody>
</table>

**CO₂:** [Chédin et al., JGR, 2003]  
[Crevoisier et al., GRL, 2004; ACPD, 2009a]
1. Observations in Thermal InfraRed

Sensitivity of IASI $T_B$ to variations of atmospheric and surface variables (simulations with the 4A RT model)

- $CO_2$ (1%)
- $H_2O$ (20%)
- $O_3$ (20%)
- $CH_4$ (20%)
- $CO$ (40%)
- $N_2O$ (2%)
- Surface
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![Graph showing sensitivity of IASI $T_B$ to variations of gases.](image-url)
1. Observations in Thermal InfraRed

Sensitivity of AIRS and IASI channels in the two CO$_2$ bands

(simulations with the 4A RT model)

\[ T_{B, \text{pert}} - T_{B, \text{ref}} (\text{K}) \]

\[ \text{wavenumber (cm}^{-1}\text{)} \]

1 % of CO$_2$ variation \(\rightarrow\) 0.04% of $T_B$ variation

$CO_2$: 3ppmv \(\rightarrow\) 0.3 K

$T$: 1 K \(\rightarrow\) 0.9 K

GreenHouse Gases Report
1. Observations in Thermal InfraRed

Jacobians of two "CO$_2$" IASI channels

Channels at 4$\mu$m peak lower in the atmosphere.
$\rightarrow$ IASI sees higher than AIRS.
2. The stand-alone approach

General features of the CO$_2$ retrieval scheme: non-linear regressions

- Simultaneous use of IR and MW channels to decorrelate T/CO$_2$.
- Retrieval limited to the tropical region.
2. The stand-alone approach

We retrieve a mid-to-upper tropospheric integrated content of $CO_2$ in clear-sky condition.

*Mean $CO_2$ averaging kernel over TIGR atmospheric dataset for nadir observation*
3. Results: tropospheric integrated content of CO₂

Seasonality and trend of CO₂: 2003-2008

Aqua/AIRS : 2003-2007
MetOp/IASI : 2007-...
IASI-2 : 2013-...
IASI-3 : 2016-...

Precision: AIRS 2.5 ppmv / IASI 2 ppmv for 1 month/5°x5°
3. Results: tropospheric integrated content of $CO_2$

AIRS - Comparison with aircraft measurements

- JAL commercial aircraft ~10km twice a month [Matsueda et al.]

- AIRS $CO_2$ (5-15km)
  Gaps in 2006 due to missing or corrupted files.
3. Results: tropospheric integrated content of $CO_2$

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  Gaps in 2006 due to missing or corrupted files.

• Instrumental problem following AIRS shutdown after a large solar flare in Nov. 2003.
• The problem was mostly corrected in mid-2004 but a remaining drift of channel frequencies was still occurring until 2005 [Strow et al., 2006].
3. Results: tropospheric integrated content of $CO_2$

IASI - Comparison with aircraft measurements

[Crevoisier et al., ACPD, 2009a]

GreenHouse Gases Report
3. Results: tropospheric integrated content of CO$_2$

IASI - Comparison with aircraft measurements

- JAL vs. surface: 1 month lag
- AIRS vs. JAL: no lag
- IASI vs. JAL: 1 month lag
- JAL vs. ~16km: 1 month lag

=time-lag of CO$_2$ while transported from the surface to the upper troposphere

[Crevoisier et al., ACPD, 2009a]

IASI 10-15 km
Tropopause 16 km
JAL 11km
AIRS 5-15km
3. Results: tropospheric integrated content of $CO_2$

A new proxy for fire detection?

Two measurements per day: one in the morning (7.30am), one in the evening (7.30pm). The difference between the two gives the DTE (Diurnal Tropospheric Excess) of $CO_2$.

[Chédin et al., JGR, 2008]
3. Results: tropospheric integrated content of CO$_2$

A new proxy for fire detection?

Linear relationship between CO$_2$ DTE and GFED fire emissions.

[Chéedin et al., JGR, 2008]
3. Results: tropospheric integrated content of $CO_2$

Conclusions on $CO_2$

- A stand-alone approach has been designed to retrieve a mid-to-upper tropospheric content of $CO_2$ from coupled IR/MW observations.
- Observations processed with one month-lag.
- Some problems encountered with AIRS and Aqua/AMSU.
- IASI vs. AIRS:
  - improvement of $CO_2$ retrievals with IASI (partly due to a better AMSU).
  - not exactly the same part of the atmosphere seen by both IR sounders.
  - two more IASI to come (MetOp B in 2013, MetOp C in 2016)…
- Thermal IR sounders can bring information on:
  - atmospheric transport (e.g. lag of seasonal cycle).
  - signals uplifted to the mid-to-upper troposphere (e.g. fire).
- Thermal IR sounders will complement the observations of total column performed by GOSAT and other satellites.
4. Results: tropospheric integrated content of CH$_4$ from IASI

Seasonality

IASI

Month

CH$_4$ (ppbv)
4. Results: tropospheric integrated content of CH$_4$ from IASI

Seasonality

IASI

Surface measurements

+10 ppbv between 2007 and 2008

+10 ppbv between 2006 and 2007

Methane starts increasing again? $\rightarrow$ MACC
4. Results: tropospheric integrated content of CH$_4$ from IASI

Latitudinal variation

(averaged over April-Sept.)

Same North-South gradient between IASI and aircraft (~30 ppbv), lower than at the surface

[Matsueda and Inoue, 1996]
4. Results: tropospheric integrated content of CH$_4$ from IASI

Geographical distribution

SON 2007

DJF 2007-8

MAM 2008

JJA 2008

All new...

I-integrated CH$_4$
4. Results: tropospheric integrated content of CH$_4$

Conclusion and perspectives on CH$_4$

- CH$_4$ retrievals from AIRS abandoned.

- The preliminary results with IASI look good:
  - compare well with in-situ data, especially aircraft.
  - seem to show interesting/realistic features.
  - give higher methane, with more seasonal variability (~15 ppbv) than MOZART-2

- Comparisons with other transport models and with SCIAMACHY over land (although not the same time period) need to be done.

- Need of validation data (in the troposphere?).

- Two more IASI to come (MetOp B in 2013, MetOp C in 2016)…