Midtropospheric CO$_2$ Concentration derived from infrared and microwave sounders.
Application to the TOVS, AIRS/AMSU, and IASI/AMSU instruments.

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### CO₂ from infrared/microwave sounders

<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>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><strong>Local time</strong></td>
<td>7.30</td>
<td>7.30</td>
<td>1.30</td>
<td>9.30</td>
</tr>
</tbody>
</table>
CO$_2$ seasonal cycle - Northern tropics [0-20°N]

- NOAA15: Very preliminary results…
Diurnal Tropospheric Excess of CO$_2$ due to biomass burning emissions

See Poster B12 [Chédin et al.]
Spectrum and sensitivity to atmospheric components

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

- CH$_4$
- CO$_2$
- CO
- N$_2$O
- O$_3$
- H$_2$O

$T_B$ pert-$T_B$ ref (K)

CO$_2$ (1%)
H$_2$O (20%)
O$_3$ (20%)
CH$_4$ (20%)
CO (40%)
N$_2$O (2%)
Surface

wavenumber (cm$^{-1}$)

15 $\mu$m  10 $\mu$m  6 $\mu$m  4 $\mu$m

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

3ppmv $\rightarrow$ 0.3 K

The full information contained in the channels is needed to extract the CO$_2$ signal!
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Spectrum and sensitivity to atmospheric components

Sensitivity of AIRS and IASI channels in the two CO$_2$ bands
(simulations with the 4A RT model)

- **CO$_2$ (1%)**
- **H$_2$O (20%)**
- **O$_3$ (20%)**
- **Surface T (1%)**
- **Surf. emissivity (5%)**

**AIRS**

<table>
<thead>
<tr>
<th>Wavenumber (cm$^{-1}$)</th>
<th>CO$_2$ noise</th>
<th>H$_2$O</th>
<th>CO$_2$ noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>650</td>
<td>-0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>670</td>
<td>-0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>690</td>
<td>-0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>710</td>
<td>-0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>730</td>
<td>-0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>750</td>
<td>-0.5</td>
<td>0</td>
<td>0</td>
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**IASI**

<table>
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<tr>
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<td>0</td>
<td>-0.5</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**TB**

- **AIRS**
  - 1.5
  - 1
  - 0.5
  - 0
  - -0.5
- **IASI**
  - 1.5
  - 1
  - 0.5
  - 0
  - -0.5

**TB** pert-T$_{ref}$ (K)

At 4 $\mu$m: Non-LTE

Only nighttime retrieval
Spectrum and sensitivity to atmospheric components

Jacobians of two "CO₂" AIRS channels

- Channel 80 - 15μm
- Channel 261 - 4μm

- Channels at 4μm peak lower in the atmosphere.
Spectrum and sensitivity to atmospheric components

Jacobians of two "CO₂" AIRS channels and AMSU weighting functions

Channel 80 - 15μm

- CO₂ Jacobian
- T Jacobian
- O₃ Jacobian

Channel 264 - 4μm

- AMSU 6
- AMSU 7
- AMSU 8
- AMSU 9
- AMSU 10

• Channels at 4μm peak lower in the atmosphere.
• AMSU channels bring the information on temperature.
**CO₂ channel selection**

- **Aqua AIRS/AMSU:**
  - 15 AIRS channels (8 in the 15 μm band - 7 in the 4 μm band).
  - 2 AMSU channels (6 and 8).

- **MetOp IASI/AMSU:**
  - 14 IASI channels (all in the 15 μm band).
  - 3 AMSU channels (6, 7, and 8).

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![Graph showing IASI sensitivity and CO₂ Jacobians](image-url)
Colocation of radiosoundings/re-analyses ERA40 with IR/MW observations

- Radiosoundings «ERA40»
  (23 Go from 1979 to 2007)
- Re-analyses ERA-40
  (79 Mo/day, 2 days/month)

Example IASI/AMSU (MetOp)
Satellite data: 14 orbits/day
900 Mo/day; 421 IR, 15 MW

The level1b validation suite at LMD

See Poster B10 [Armante et al.]

Radiative biases between calculated and observed BT

Quality control of the Radiosoundings
  Inter/extrapolation UGAMP climatology

Fixed CO₂=372 ppmv

Space and Time Colocation
  (100 Km, 3h)
AIRS Radiative biases: Monthly evolution (5 years over the tropics)

~60 situations/month over sea
~30 situations/month over land
AIRS Radiative biases: Monthly evolution (5 years over the tropics)

"CO₂" slopes (mean over 5 years):
- AIRS 80: 2.16 ppmv.yr⁻¹
- AIRS 264: 2.39 ppmv.yr⁻¹
- Mauna Loa: 2.05 ppmv.yr⁻¹

~60 situations/month over sea
~30 situations/month over land
A stand-alone approach

General features of the CO₂ retrieval scheme: non-linear regressions

- Selection of a set of CO₂ channels
- Training of Neural Networks
- Non-linear inference scheme
- Off-line
- Simultaneous use of IR and MW channels to decorrelate T/CO₂.
  - IASI
  - AMSU
- Retrieval limited to the tropical region.

[Chédin et al., JGR, 2003; Crevoisier et al., GRL, 2004]
Evaluation of the inference scheme characteristics

We retrieve a mid-to-upper tropospheric integrated content of CO₂.

Mean CO₂ averaging kernel over TIGR atmospheric dataset for nadir observation

![Graph showing CO₂ averaging kernel over TIGR atmospheric dataset for nadir observation]

5-15 km

IASI/AMSU
NOAA15
AIRS/AMSU
$\text{CO}_2$ distribution from AIRS and IASI - Monthly average
Evaluation of IASI CO$_2$

JAL commercial airliners between Australia and Japan

- Aircraft [Matsueda et al.]
  - 8-10 km
  - 1-2 points/month
  - until March 2007

- IASI CO$_2$
  - integrated content 5-15 km
  - monthly mean
  - period: July 2007-March 2008
Seasonal cycle

*Detrended CO$_2$ seasonal cycle as observed in situ by JAL aircraft for 2003-2006*
Detrended CO₂ seasonal cycle as observed in situ by JAL aircraft for 2003-2006

IASI
(07/07-08/03)
Conclusions

• We retrieve a mid-to-upper tropospheric integrated content of CO₂ from simultaneous IR/MW observations (TOVS, ATOVS, AIRS/AMSU, IASI/AMSU).

• The CO₂ signal is very low:
  The full information contained in the channels is needed (that excludes using PCA-like data).

• Good agreement of CO₂ distribution between IASI and AIRS but lower variability/uncertainty with IASI:
  - Reducing radiometric noise is as important as improving spectral resolution.
  - A “good” AMSU instrument is important.

• General good agreement with in-situ observation in terms of seasonal cycle and latitudinal gradients.