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Midtropospheric CO$_2$ Concentration
Retrieval in the Tropical Zone from
MetOp IASI/AMSU Observations

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G. Dufour, V. Capelle, A. Chédin
**CO₂ from space observation**

<table>
<thead>
<tr>
<th></th>
<th>Aqua/AIRS</th>
<th>MetOp/IASI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of launch</td>
<td>May 2002</td>
<td>Oct. 2006</td>
</tr>
<tr>
<td>Spectral coverage</td>
<td>3 IR bands</td>
<td>IR Continuous</td>
</tr>
<tr>
<td>Spectral resolution</td>
<td>0.5 - 2 cm⁻¹</td>
<td>0.5 cm⁻¹ (apodized)</td>
</tr>
<tr>
<td># IR channels</td>
<td>2378</td>
<td>8461</td>
</tr>
<tr>
<td>Local time</td>
<td>1.30</td>
<td>9.30</td>
</tr>
</tbody>
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Also onboard Aqua and MetOp: **AMSU-A** with 15 MW channels

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

- $1 \%$ of CO$_2$ variation $\rightarrow 0.04\%$ of $T_B$ variation
- At LMD: 421 IASI channels have been selected.
A stand-alone approach

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

- Selection of a set of CO$_2$ channels
- Training of Neural Networks
- Non-linear inference scheme

- Off-line
  - Training data set (TIGR)
  - Calc-obs bias removal
  - "Clear sky" detection

- Simultaneous use of IR and MW channels to decorrelate T/CO$_2$.
  - IASI
  - AMSU

- Retrieval limited to the tropical region.

[Chédin et al., JGR, 2003; Crevoisier et al., GRL, 2004]
14 channels have been selected for CO₂.

All are located in the LW band (high noise in the SW band).
CO₂ channel selection - IASI

CO₂ Jacobians of the selected IASI channels and AMSU weighting functions

IASI - CO₂ channel selection

Pressure (hPa)

CO₂ Jacobian (K.(g/g)⁻¹.km⁻¹)

AMSU 6
AMSU 7
AMSU 8
Training of the networks

Neural networks are trained using the set of selected channels.

Selection of a set of CO₂ channels

Training data set (TIGR)

Training of Neural Networks

Off-line

\[ \text{T/CO}_2 \leftarrow 14 \text{T}_B \text{ IASI} \]

\[ \text{T} \leftarrow \text{T}_B \text{ AMSU} \]

\[ \text{Inputs} \]

\[ \text{Outputs } q_{CO2} \]

- **Learning data set**: tropical atmospheric situations from the TIGR dataset (821 atmospheres out of 6000); BT simulated by the 4A RT model.
- **Training** for 10 AMSU angles of view.
Training of the networks

Neural networks are trained using the set of selected channels.

Evolution of the rms of the $CO_2$ output during training

![Graph showing the evolution of the RMS of the CO2 output during training for AIRS and IASI.]
Evaluation of the inference scheme characteristics

We retrieve a mid-to-upper tropospheric integrated content of CO$_2$.

Mean ± standard deviation of CO$_2$ weighting function over TIGR atmospheric dataset for nadir observation

5-15 km
**Cloud mask**

- Thin cirrus, low clouds and aerosols may contaminate observations.  
  → Need to detect *clear column*.

- **Use of HIRS4-AMSU observations.**
  - Differences HIRS/AMSU-A
  - Differences HIRS/HIRS (low clouds)

  - Spatial resolution = HIRS
  (mapping of AMSU-A in HIRS FOVS using AAPP)

  ➤ Use of IASI/AMSU-A: in progress

  ➤ Comparison of various detections in progress: HIRS4/AMSU-A, IASI/AMSU-A, AVHRR, AIRS/AMSU.

*July 1999 NOAA-15*

*July 2007 Metop*
Radiative Bias

The level1b validation suite at LMD: colocation of IASI observations with radiosoundings or re-analyses ERA40

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

Example IASI/AMSU (MetOp): July 2007

Satellite data: 14 orbits/day

900 Mo/day; 421 channels IR, 15 channels MWV

Fixed $CO_2=372$ ppmv

See Poster of Armante et al.
Radiative Bias

\[ T_{B,\text{sim}} - T_{B,\text{obs}} (\text{K}) \]

wavenumber (cm\(^{-1}\))

IASI (July 2007)
AIRS (2003-2006)
Radiative Bias

\[ T_{B,\text{sim}} - T_{B,\text{obs}} (K) \]

wavenumber (cm\(^{-1}\))

15 µm

IASI (July 2007)

AIRS (2003-2006)

4.3 µm
Radiative Bias

15 μm band

Mean radiative bias (K)

Standard deviation (K)

• Higher bias for IASI: \( \Delta CO_2 = +6 \text{ppmv} \iff \Delta T_B = +0.5 \text{ K} \)

• Lower IASI noise for the selected channels
Radiative Bias

4.3 μm band

Mean radiative bias (K)

Standard deviation (K)

IASI (July 2007)
AIRS (2003-2005)

• Higher noise for IASI as compared to AIRS and IASI 15μm
  ➞ IASI channels at 4.3μm are not used in the retrieval scheme
Radiative Bias

AMSU channels 6-10

Mean radiative bias (K)  Standard deviation (K)

MetOp (July 2007)
Aqua (2003-2005)

AMSU 7 is working on MetOp!!!
CO₂ field - July 2007

Blanck area = high cloudiness
Higher variability with AIRS than with IASI but similar patterns
**Evaluation of IASI CO₂**

**JAL commercial airliners between Australia and Japan**

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

- **IASI CO₂**
  - integrated content 5-15 km
  - monthly mean
  - period: July 2007

**IASI CO₂ weighting function**

Study of the **North-to-South gradient**
Study of the North-South gradients

$CO_2$ latitudinal variation in July

1 ppmv

JAL aircraft (10 km)
IASI (5-15 km)

2003
2004
2005
2006
2007

30N-25N
25N-20N
20N-15N
15N-10N
10N-05N
05N-EQ
EQ-05S
05S-10S
10S-15S
15S-20S
20S-25S
Conclusions

1. One month has been interpreted in terms of mid-to-upper tropospheric concentration of CO$_2$ in the tropics. This has required:
   - downloading of the data
   - cloud detection (HIRS4)
   - radiative biases

2. Good agreement of CO$_2$ distribution between IASI and AIRS but lower variability with IASI.

3. General good agreement with in-situ observation in terms of latitudinal gradients.

4. Next steps:
   - Extend the retrievals to the whole period...
   - Extend the retrievals to temperate regions.
   - Study of other gases: CH$_4$, CO, etc.
   - Study of related signals such as fire emission.