Midtropospheric $CO_2$ Concentration Retrieval in the Tropical Zone from MetOp IASI/AMSU Observations

C. Crevoisier, R. Armante, N. A. Scott, G. Dufour, V. Capelle, A. Chédin
**CO₂ from space observation**

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

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)

- $0.1\%$ 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

- Training data set (TIGR)
- Selection of a set of CO$_2$ channels
- Training of Neural Networks
- Non-linear inference scheme
- Off-line
- $q_{CO2}$

- 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 CO$_2$.

All are located in the LW band (high noise in the SW band).
$\text{CO}_2$ channel selection - IASI

$\text{CO}_2$ Jacobians of the selected IASI channels and AMSU weighting functions

IASI - $\text{CO}_2$ channel selection

![Graph showing CO2 Jacobians and AMSU weighting functions](image)
Training of the networks

Neural networks are trained using the set of selected channels.

- **Training data set (TIGR)**
- **Selection of a set of CO₂ channels**
- **Training of Neural Networks**

![Diagram](image)

- **Inputs**
  - \( T / CO_2 \) \( \rightarrow \) 14 \( T_B \) IASI
  - \( T \) \( \rightarrow \) \( T_B \) AMSU
- **Outputs** \( q_{CO_2} \)

- **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 \textit{rms} of the CO$_2$ output during training
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.
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

L1B Satellite Data (1979-2006)

Radiative Bias

Quality control of the Radiosoundings
Inter/extrapolation
UGAMP climatology

« Clean » radiosoundings Per month

RT model (Stransac, 4A)
Bias between calculated and observed brightness temperatures

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 2006)
AIRS (2003-2006)
Radiative Bias

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

-6 -4 -2 0 2 4 6

800 1200 1600 2000 2400

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

15 \mu m

4.3 \mu m

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

15 µm band

Mean radiative bias (K)

Standard deviation (K)

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

• Lower IASI noise for the selected channels

IASI (July 2007)
AIRS (2003-2005)
Radiative Bias

4.3 μm band

Mean radiative bias (K)

Standard deviation (K)

• 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)


AMSU 7 is working on MetOp!!!
CO\textsubscript{2} field - July 2007

Blanck area = high cloudiness
CO₂ field - July 2007

IASI - July 2007

Blanck area = high cloudiness
Higher variability with AIRS than with IASI but similar patterns
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

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

$CO_2$ latitudinal variation in July

![Graph showing $CO_2$ latitudinal variation in July with different years and altitudes.]
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.