Retrieving mid to upper tropospheric CO$_2$ columns from AIRS revisited

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

Since April 2003, LMD has stored AIRS/AMSU observations distributed by NOAA/NESDIS with the highest spatial resolution available.
Design of a new learning database (TIGR)

« SAF » tropical data set* (from one year of analyses at 60-levels): ~11,300 sit. (F. Chevallier, priv. comm.)

Fast RT algo. to compute AIRS Tb’s

Two years of daily observed AIRS Tb’s

Proximity recognition and selection of the closests: ~2,000 sit.

Final selection of ~800 situations

Analysis of their distribution in time (monthly) and in space (15° L x 5° l)

Done separately over land and over sea: two files of ~800 situations each

Improvements compared to TIGR:
- better time coverage (months, seasons)
- better space coverage (tropics)
- better coherence T(P), H2O(P), O3 (P)

To day: work completed over sea
Revised AIRS channel selection
(15 Airs and 2 AMSU)

AIRS selected channels sensitivity

CH4 10%
CO 40%
N2O 2%
O3 20%
H2O 20%
Ts 1%
Emis. 5%
CO2 1%
AIRS cloud and aerosol detection algorithm

- Aim: detect clear columns (thin cirrus, low clouds and aerosols may contaminate observations)

- 13 tests based on observed channel difference histograms

- Thresholds determined from the observations

- Dedicated tests for low clouds and/or aerosols (channels selected from simulations using “4A” and “DISORT”), mid clouds, and high clouds (cirrus)

- “Validation” using MODIS: AIRS cloud cover should be significantly larger due to lower spatial resolution
Undetected aerosols may contaminate CO$_2$ retrievals: ex. of July 2003

Dedicated AIRS cloud tests allow separating aerosols from low clouds

Infrared (10 µm) aerosol optical depths and altitude may then be calculated [Pierangelo et al., 2004]

Top left figure shows the results for AIRS AOD at 10 µm

Bottom left figure shows the results for MODIS AOD in the visible (0.55 µm)

Note the strong signature of dust aerosols crossing the Atlantic ocean
# AIRS cloud tests (night, sea, “version 8”)

<table>
<thead>
<tr>
<th>Test nb</th>
<th>Test*</th>
<th>Threshold (K)</th>
<th>W/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[93 – A6] GT</td>
<td>1.0</td>
<td>high</td>
</tr>
<tr>
<td>2</td>
<td>[264 – A6] GT</td>
<td>1.0</td>
<td>high</td>
</tr>
<tr>
<td>3</td>
<td>[280 – A6] GT</td>
<td>1.0</td>
<td>high</td>
</tr>
<tr>
<td>5</td>
<td>[284 – A5] GT</td>
<td>1.0</td>
<td>mid</td>
</tr>
<tr>
<td>6</td>
<td>[284 – A6] GT</td>
<td>1.0</td>
<td>mid</td>
</tr>
<tr>
<td>7</td>
<td>[286 – A5] GT</td>
<td>1.0</td>
<td>low</td>
</tr>
<tr>
<td>8</td>
<td>[136 – 308] GT</td>
<td>2.0</td>
<td>surf</td>
</tr>
<tr>
<td>9</td>
<td>[136 – 315] GT</td>
<td>2.0</td>
<td>surf</td>
</tr>
<tr>
<td>10</td>
<td>315 – 140 LT</td>
<td>0.7</td>
<td>low clouds</td>
</tr>
<tr>
<td>11</td>
<td>315 – 140 GT</td>
<td>3.3</td>
<td>cirrus</td>
</tr>
<tr>
<td>12</td>
<td>313 – 177 GT</td>
<td>1.8</td>
<td>high clouds</td>
</tr>
<tr>
<td>13</td>
<td>313 – 177 LT</td>
<td>0.8</td>
<td>aerosols</td>
</tr>
</tbody>
</table>

* n° on the 324 channel list ; A5-6 : AMSU channels

<table>
<thead>
<tr>
<th>Wavelength of the channels used (μm)</th>
</tr>
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<tbody>
<tr>
<td>93</td>
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<tr>
<td>136</td>
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<td>140</td>
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<td>177</td>
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<td>286</td>
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<td>313</td>
</tr>
<tr>
<td>315</td>
</tr>
</tbody>
</table>
Cloud masks from Airs and Modis …

*http://daac.gsfc.nasa.gov/data/datapool/*
Example of AIRS CO2 fields

April – July 2004
Example of AIRS CO2 fields

August – November 2004

070751 c bruit TB divs par 215  08/2004

070751 c bruit TB divs par 215  09/2004

070751 c bruit TB divs par 215  10/2004
Comparison with aircraft measurements* from April 2003 to March 2005 (Japan to Australia)

Limits of the comparison:

(a) satellite retrievals integrate the mid-to-high troposphere (max contribution between $\sim6$-$16$ km) when the aircraft flies at $10$-$11$ km.

(b) only 2 aircraft measurements per month at variable dates.

(c) the region is dominated by convection from the warm pool: large gaps due to clouds.

(d) the number of individual ($1^\circ$x$1^\circ$) retrievals to be averaged may be too small: average done over the longitudes from $120^\circ$ to $180^\circ$ E for each $5^\circ$ latitude band, when the aircraft flies at $\sim145^\circ$ E.

(e) the number of individual ($1^\circ$x$1^\circ$) retrievals to be averaged may however remain too small (see right ordinate).

*H. Matsueda, private comm., 2005
Comparison Airs– Aircraft

- Red: Aircraft 1st part of the month
- Green: Aircraft 2nd part of the month
- Blue: Airs

20N-15N

- Number of 1°x1° retrievals

« icing »

No aircraft obs
Comparison Airs– Aircraft

- Red: Aircraft 1st part of the month
- Green: Aircraft 2nd part of the month
- Blue: Airs

15N-10N

Number of 1°x1° retrievals
Comparison Airs– Aircraft

- **Aircraft 1st part of the month**
- **Aircraft 2nd part of the month**
- **Airs**

10N-5N

- Number of 1°x1° retrievals
Comparison Airs– Aircraft

- Aircraft 1st part of the month
- Aircraft 2nd part of the month
- Airs

Number of 1° x 1° retrievals

5N-0N
Comparison Airs– Aircraft

- Aircraft 1st part of the month
- Aircraft 2nd part of the month

Number of 1°x1° retrievals

0S-5S
Comparison Airs– Aircraft

- Red: Aircraft 1st part of the month
- Green: Aircraft 2nd part of the month
- Blue: Airs

5S-10S

Number of 1°x1° retrievals
Comparison Airs– Aircraft

- **Red** Aircraft 1st part of the month
- **Green** Aircraft 2nd part of the month
- **Blue** Airs

**10S-15S**

Number of 1°x1° retrievals

![Graph showing data comparison between aircraft and Airs.](image-url)
Comparison Airs– Aircraft

- **Aircraft 1st part of the month**
- **Aircraft 2nd part of the month**
- **Airs**

15S-20S

Number of 1°x1° retrievals
Problems with AIRS

- **lack of AMSU-7** due to a very large noise: its weighting function almost exactly coincides with the CO\textsubscript{2} Jacobians. This very significantly degrades the quality of the decorrelation between CO\textsubscript{2} and temperature

- **AIRS noises** degraded with respect to plans (now slightly larger than for IASI in the LW)

- **icing problems** occurred in ~ October 2003. Seem to have lasted quite long (at least at the “CO\textsubscript{2}- accuracy” !), at least looking at our present results. However, not proven

- **discontinuous** 324 channel list (what IASI list will be available ?)

- **one shot** instrument (contrary to IASI)

- **but good laboratory** for IASI and eventual forthcoming passive instruments which key characteristics should be a very significantly better S/N ratio
Noises at scene temperature* for HIRS, AIRS, and IASI

*Tropical atmosphere
Next 18-month major tasks and deliverables

Tasks

1. Refinement of the cloud and aerosol mask (completed for AIRS over sea at night) having in mind that IASI offers much larger possibilities (thin cirrus, aerosols, for ex.)

2. Selection of IASI CO2-channels (first list, Jacobians, and sensitivities sent to ECMWF)

3. Selection of IASI CH4 channels (preliminary: at most, 6-8 acceptable channels around 7.7 μm)

4. New learning data set (from Frederic "SAF" data set) : partly done for AIRS, under development for TOVS, to be done for IASI

5. Reprocessing of AIRS observations (April 2003 – now …)

6. IASI retrieval simulations and performance comparisons against both TOVS and AIRS

Deliverables

1. Final list of IASI CO2 and CH4 channels with their Jacobians and sensitivities to thermodynamic and gas variables

2. Cloud mask (night, day, land, sea) for both AIRS and IASI. Processing of all AIRS observations available

3. Reprocessing of AIRS observations in terms of tropospheric CO2 concentrations : distribution of the results

4. Results of the performance comparisons between IASI and both AIRS and TOVS on the basis of simulations