Retrievals of methane from IASI radiance spectra and comparisons with ground-based FTIR measurements

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The Infrared Atmospheric Sounding Interferometer (IASI) is a Fourier transform spectrometer onboard METOP-1 observing at nadir the radianse from the Earth’s surface and atmosphere.

Launched on 19 October 2006 into a sun-synchronous polar orbit, at 817 km altitude, with a 9:30 local equator crossing time.

Spectral range: 645-2760 cm\(^{-1}\) (15.5 – 3.62 µm); spectral resolution: 0.5 cm\(^{-1}\); radiometric resolution: 0.5 K.

Swath up to ± 48.3° off-axis; swath width: ±1200 km; each cell is analyzed simultaneously by a 2 x 2 array of detectors, with an instantaneous FOV diameter of 14.65 mrad, each pixel diameter is 12 km at nadir.

Global coverage twice daily; 1.3 106 measurements per day (day and night).

First IASI measurements available: 30 November 2006. Since May 2007 the L1c data are operationally distributed; reception at BIRA via EUMETCAST.
Pixels P1 up to P4 have a diameter of 14.65 mrad, corresponding to 12 km at nadir.
Retrievals of methane profiles from IASI

• IASI Methane retrievals are performed using the line-by-line retrieval code ASIMUT developed at BIRA.
  • ASIMUT uses OEM or Tikhonov regularisation

• The IASI retrievals are done in a two stage process:
  • first the surface temperature, H₂O profile in seven layers and the O₃ column in the following 2 windows,
    1084.0—1134.0 cm⁻¹ where mainly CO₂, H₂O and O₃ are present (noise = 0.5 10⁻⁷ W/cm²/Sr/cm⁻¹) and 1392.0—1442.0 cm⁻¹ with mainly H₂O and noise = 0.2 10⁻⁷ W/cm²/Sr/cm⁻¹.
  • The results from the first stage are used to retrieve CH₄ profile in 13 layers and the N₂O column in the following 3 windows:
    • 1175.5—1185.5 cm⁻¹ mainly H₂O and N₂O, noise = 0.4 10⁻⁷ W/cm²/Sr/cm⁻¹
    • 1228.0—1238.0 cm⁻¹ mainly CH₄ and H₂O, noise = 0.2 10⁻⁷ W/cm²/Sr/cm⁻¹
    • 1299.0—1309.0 cm⁻¹ mainly CH₄ N₂O and H₂O, noise = 0.2 10⁻⁷ W/cm²/Sr/cm⁻¹
IASI radiance spectrum

Radiance split into different contributions (ASIMUT)
Retrievals of methane profiles from ground-based FTIR instruments

- At St Denis (21°S, 55°E, Ile de La Réunion):
  - Bruker 120M
  - simultaneous fit of 13 layers of methane and columns of CO₂, H₂O, NO₂ and HDO in the following microwindows: 2613.7 — 2615.4 cm⁻¹, 2650.6—2651.3 cm⁻¹, 2835.5—2835.8 cm⁻¹, 2903.6—2904.03 cm⁻¹, 2921.0—2921.6 cm⁻¹. Measurements were taken at a resolution of 0.005 cm⁻¹.

- At Kiruna (68°N, 20°E, Sweden)
  - Bruker 120HR
  - the same microwindows were used. The first 2 to initially retrieve H₂O and HDO, and the remaining three for methane in 45 layers.
  - an L1 Tikhonov regularisation was used.
Coincidence criteria for comparison

For Saint-Denis:
- IASI observations on same day;
- Within a 100 km radius around St Denis, but only over ocean (cf. Ile de La Réunion is very mountainous)

For Kiruna:
- IASI observations on same day;
- Within a 60 km radius around Kiruna, over land
- Monthly MODIS surface emissivities on a 0.05 degree latitude/longitude grid (MYD11C1) are used for the retrievals.
The coloured horizontal dashed lines indicate the height for which the correspondingly coloured kernel is active. The sum of the rows of the averaging kernels is indicated in black. The numbers of degrees of freedom for signal (DOF) are shown in the plots.
for Saint-Denis: the averaging kernels show that one can distinguish two partial columns: one from 0 to 6 km and one above about 6 km. This is also indicated by the number of degrees of freedom for signal (DOF). The ground-based (gb) retrievals show DOF of about 2.5 whereas the IASI retrievals have DOF of about 2.

For Kiruna: the DOF is lower than for Saint-Denis (2.4 for gb and 1.7 for IASI). This is also seen in the averaging kernels where the 2 columns cannot be distinguished as good as for Saint-Denis.

The sensitivity curve shows where the measurements contribute for at least 50% to the signal at each height. It covers a wider range for the ground-based retrievals (0 to about 28 km for Saint-Denis and 0 to 40 km for Kiruna) than for IASI retrievals (0 to about 16 km for Saint-Denis and 0 to about 14 km for Kiruna).
Time series of total vertical columns (VCD) of methane and percent differences

Saint-Denis, Réunion
June to September 2007

Kiruna, Sweden
May to September 2007

Daily means of methane VCD, the error bars represent the total random error.

Percent differences between the daily means. The differences are calculated with respect to the ground-based measurements.

The horizontal yellow lines indicate ±10% in all panels.
Comparison

- **at Saint-Denis:**
  - The comparison between IASI and ground-based VCD retrievals shows a negative bias for the IASI retrievals. The mean bias is about -4.4% with a standard deviation $\sigma=4.0\%$.
  - The random errors are about 5.9% for the IASI retrievals and 4.8% for the ground-based retrievals.

- **at Kiruna**
  - The mean bias for the IASI retrievals is also negative, namely -0.4%.
  - The standard deviation is $\sigma=3.1\%$. 
Future work: Validation at NDACC sites

Validation of IASI atmospheric chemistry products (CO, CH4 and HNO3) using ground-based FTIR network from the Network for the Detection of Atmospheric Composition Change (NDACC)
CONCLUSION

• Retrieval of IASI trace gas products and their validation has started.

• For methane:
  • There is a difference between the sensitivities of the ground-based and the IASI retrievals.
  • Comparisons of the ground-based and IASI methane time series show reasonable agreement.

• Comparisons at different sites and for different chemical species (CO, HNO3) are under way.