Processing system for analyzing IASI Level 1C data to retrieve trace gases concentrations

J. Hadji-Lazaro[1], M. George[1], S. Turquety[1], C. Clerbaux[1,2], D. Hurtmans[2], P.-F. Coheur[2]

1) Service d'Aéronomie, CNRS/IPSL, Paris, France

2) Service de Chimie Quantique et de Photophysique, Université Libre de Bruxelles, Brussels, Belgium

2 complementary tools

Near real-time: *SA-NN*

→**Total columns** of CO, CH_4, O_3
→**Partial columns** of O_3
(0-6 km, 0-12km 0-16km)

Neural network (NN) based techniques

Very efficient to treat huge quantity of IASI data

Hadji-Lazaro et al., JGR, 1999; Clerbaux et al., JGR, 2001; Turquety et al., GRL, 2002; Turquety et al., JGR, 2004.

Research: *Atmosphit*

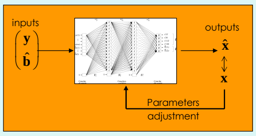
→ **profiles** of any (IR absorbing) species
→ errors
→ averaging kernels

Constrained retrieval: Optimal Estimation theory

More precise and possible profiles retrieval
Complete characterization of the retrievals

Coheur et al., JGR, 2005; Barret et al., ACP, 2005; Wespes et al., JGR, 2007; Herbin et al., ACP, 2007.

NN training



Supervised learning with a database including simulations of IASI spectra calculated from three-dimensional chemical-transport model (MOZART[1] + climatology) trace gases simulations and temperature extracted from the ECMWF analysis coupled with a high resolution radiative transfer code (LBLRTM[2] + HITRAN). The simulated high resolution spectra were convoluted with the instrument spectral response function for IASI Level 1C data[3]. Only cloud-free and aerosol free conditions are considered, nadir viewing geometry, and the emissivity was fixed to constant mean values for each spectral range. The dataset spanned all seasons and locations but did not include situations with surface height higher than 2 km.

[1]Brasseur et al., 1998; Hauglustaine et al., JGR, 1998.
[2]Clough et al., JQSRT, 2004.
[3]Camy-Peyret et al., technical report, CNES, 2001.

Inputs

- Radiances (IASI L1C) at selected spectral channels for each constituent : O_3 (148), CO (30), and CH_4 (53);
- Estimated surface temperature;
- Atmospheric temperature (IASI L2) at selected vertical levels for each constituent : O_3 (25), CO and CH_4 (18).

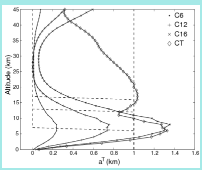
Outputs

Columns of each constituent : O_3 (total and 3 partial : 0-6 km, 0-12 km, and 0-16 km), CO and CH_4 (total).

Characterization of the retrievals and statistical validation of the NN training

For each constituent, averaging kernels peak at different altitudes :
- O_3 : 6-8 km in the free troposphere, secondary peak near 15-20 km, large sensitivity up to 35-40 km;
- CO : 6-10 km in the free troposphere;
- CH_4 : 8-10 km in the free troposphere.

The sensitivity in the boundary layer increases with the surface temperature.



Averaging kernels characterizing the retrieval of the O3 columns for the standard atmosphere US 1976 conditions. The dashed lines correspond to the ideal sensitivity profiles.

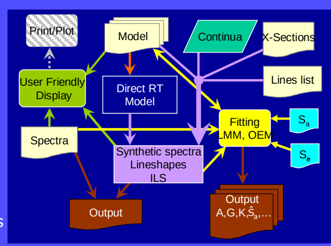
To test NN performance, we used a dataset similar to the training one but including independent examples. The RMS errors estimated on this dataset were estimated to :
- O_3 : <30% for 0-6 km column, 15% for 0-12 km column, 9% for 0-16 km column, and 1.5% for total column;
- CO : 6% for total column;
- CH_4 : 2% for total column.

Data selection before inversion (whatever the inversion tool used)

The following data are not treated:
- Flagged "bad" IASI L1C data;
- When the flag IASIBAD of IASI L2 data indicate degradation preventing temperature retrieval;
- When IASI L2 data indicate a cloud cover higher than 25% and IASI L2 temperature profile is not complete.

Atmosphit

Atmosphit was developed at ULB in order to make retrievals of atmospheric trace species out of spectra recorded from onboard instruments as well as from ground based instruments; thus implementing ray tracing of nadir, zenith and occultation geometries and a radiative transfer as complete and as precise as possible (without compromising computation time).
The software is developed under the Windows environment in order to allow benefiting of the user friendly visual interface used to monitor the retrieval process and to make its usage by end users as smooth as possible.



Inputs

- Model: P(z),T(z), base VMR(z);
- Spectra (Multiple spectra and multiple μ-windows per spectrum);
- Instrument(s) and geometry(ies) definitions (*e.g.*: ILS, altitudes, angles,…);
- *A-priori* matrices and profiles for molecular species to be retrieved;
- Databases (lines parameters, absorption cross-sections – Hitran 2005 and Geisa formats);
- User defined emissivity or solar absorption spectrum.

Outputs

All data convenient for posterior characterization, among others:
- Profiles (isotopologues separation possible) + error (posterior covariance);
- Partial columns at user defined altitudes;
- Averaging kernels matrix (**A**);
- Ray-tracing results (<*Pj*>,…);
- Calculated and residual spectra; derivatives relative to the retrieved parameters.

Major points

Lineshapes
- «Fast» and precise Voigt profile based on Wells numerical method[1].
- Dicke narrowing (soft collision model) in the Varghese and Hanson[2] formalism.

Cross-sections
- User's data from databases with HITRAN-like format. {T,P} quadric, planar interpolation scheme using the closest points for regions with a sufficient density.

ILS
- Standard FTIR ILS (SINC) and apodisations, as well as user defined ILS (ACE operational function, IASI, or user defined modulation efficiency functions) are convolved to the synthetic spectra.
- Field of view effects (straight and tilted) are also accounted for.

Continua

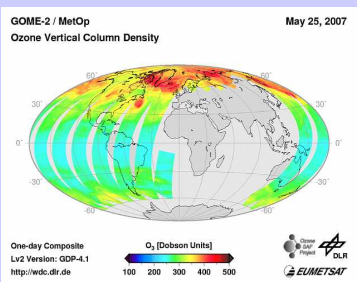
Sub-set of MT_CKD[3] V1.0 for H2O and CO2 continua, and for N2 (4.3µm) and O2 (6.2µm) CIA. Lookup tables interpolated by a piecewise cubic spline instead of the 4-points interpolation.
Overall agreement is better than 0.3% even if some interpolation discrepancies are observable.

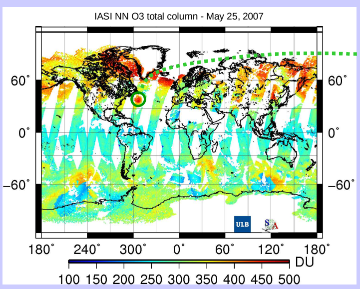
[1]Wells RJ, J. Quant. Spectrosc. Radiat. Transfer 1999;62:29–48.
[2]Varghese PL, Hanson RK, Appl. Optics. 1984;23:2376–2385.
[3]Mlawer EJ, Tobin DC, Clough SA, in preparation

Coupling of the complementary tools

- Near-real time NN treatment of the IASI Levels 1C and 2 data to estimate global distributions;
- Selection of areas to be studied in details;
- Detailed and precise studies of special events and areas of interest with Atmosphit.

Total columns from SA-NN





Vertical profiles from Atmosphit