Application of KLIMA/G-POD algorithm to CO_2 retrieval from IASI/METOP-A observations and comparison with TANSO-FTS/GOSAT products

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Introduction

We investigated the ultimate capabilities of the KLIMA algorithm to retrieve CO_2 total column from nadir sounding observations acquired in the thermal infrared by the IASI spectrometer onboard the METOP-A satellite, for the purpose of comparison and cross-validation with CO_2 values retrieved from the TANSO-FTS instrument onboard the GOSAT mission.
Here we present the consolidated results of the following tasks:

- **Development of a non-operational radiative transfer code,** indicated as KLIMA-IASI, for processing IASI/METOP-A Level 1 data.
- **Integration of the KLIMA-IASI Accelerated Retrieval Model** (optimized version of the retrieval code, as resulting from a sensitivity study) **into the ESA Grid Processing On-Demand** (G-POD) system for bulk processing of IASI data**.**
- **Preliminary outcomes** from the on-going activities for testing the capabilities and the performances of the KLIMA-IASI inversion code: the capability to process IASI L1b and L1c data and the comparison and cross-validation of KLIMA-IASI and TANSO-FTS data.

The KLIMA algorithm

The KLIMA algorithm consists of two distinct modules: the **Forward Model** and the **Retrieval Model**, optimized for inverse processing of IASI measurements.
The **Forward Model** is a line-by-line radiative transfer model, with capability to simulate wideband spectral radiances acquired by IASI. The adopted spectroscopic database is HITRAN 2008. Dedicated spectroscopic database and line shape are implemented for CO_2, to take into account the line-mixing effect (Niro et al., 2005).
The **Retrieval Model** uses a constrained Non-linear Least Square Fit approach and the cost function to be minimized takes into account the a priori information (Optimal Estimation Method) and the Marquardt parameter. To reduce the impact of systematic uncertainties, this module implements a multi-target retrieval (more than one species is simultaneously retrieved) and a complete variance-covariance matrix (VCM), including both the measurement errors and the errors in the estimate of FM parameters.
Main requirements established for the cross-validation with GOSAT/TANSO-FTS products and for the integration on G-POD environment are:

- *Target accuracy* of 0.3% (1 ppm out of 370 ppm) on regional scales (1000 x 1000 km) at monthly intervals (consistent with the requirement of GOSAT CO_2 products)
- *Program size* not exceeding 1 Gbyte and *running time* aimed at processing 1 orbit of IASI data in 1 day using G-POD computing resources.

The KLIMA-IASI Reference and Accelerated Retrieval Model

A sensitivity study was conducted on the KLIMA-IASI retrieval code, indicated as the **KLIMA Reference Retrieval Model** (**RRM**) and on a version implementing a series of forward model approximations, named the **KLIMA Accelerated Retrieval Model** (**ARM**):

- **KLIMA RRM** is capable to retrieve the CO_2 total column, with total error of –1.0% and no bias, but it does not meet the program size and running time requirements for integration on G-POD.
- **KLIMA ARM** achieves the program size and running time requirements, with slight degradation of the performances in terms of total retrieval error w.r.t. the RRM. The CO_2 retrieval error is less than 1.5%. A small bias in the retrieved CO_2 total column (when using the full IASI spectral range) can be corrected by including the errors due to FM approximations in the VCM of the observations or performing a band selection, in order to mask the FM approximations needed for the optimization of the code.

Integration of KLIMA-IASI in G-POD

The KLIMA-IASI ARM algorithm has been successfully integrated in the ESA G-POD for Earth Observation Application. ESA G-POD is a GRID based-operational environment, accessible using a dedicated Web portal (http://gpod.eo.esa.int/). It hosts more than 350 local computing nodes, more than 500 TB of EO data coming from ESA and non-ESA satellites.
The full capacity of G-POD computing resources, that can be made available for KLIMA-IASI bulk processing, are currently under evaluation; morover the upload of the full set of IASI data acquired in one year (march 2010 - march 2011) shall be completed (3 months are available at the moment).

Validation of KLIMA-IASI Reference Forward Model

A validation of the KLIMA-IASI Reference Forward Model (RFM) was conducted. We compared synthetic IASI measurements generated by the KLIMA RFM and by the forward model of the LBLRTM code (from the night-time measurements acquired by IASI over the Southern Great Plains in Oklahoma, USA, on 19 April 2007, during the Joint Airborne IASI Validation Experiment JAIVEx).

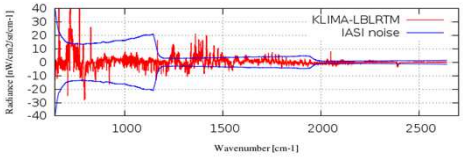

Figure 1 - Residual difference between KLIMA simulation and LBLRTM simulation, compared with the nominal values of IASI radiometric noise.

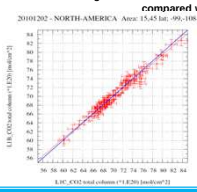

Figure 2 – Inverse processing of IASI L1B and L1C data using the KLIMA algorithm

A first processing of IASI data was carried out, to test the capability of the KLIMA algorithm to retrieve CO_2 total column from IASI Level 1B and Level 1C data.

The figure 2 shows the linear best fit of the dataset (red line, y = Ax+B, with A = 0.954 and B = 3.128 10^{20}) and the good correlation of the two sets of retrieved values (correlation coefficient = 0.9795).

KLIMA-IASI spectral band selection

For the analysis of the retrieved CO_2 total column, we selected 3 bands within the IASI spectral coverage where CO_2 features is present: (1) 645-800 cm^{-1} (2) 2000-2380 cm^{-1} (3) 2400-2500 cm^{-1}. Band 3 contains only little information so it was discarded. Two areas were selected over Nord America and Asia between 25-45°N, where was performed a comparison between CO_2 total column retrieved from KLIMA-IASI algorithm using band 1 and band 1+ band 2 and IASI operational level 2 products. The results of this comparison are shown in figures 3-4.

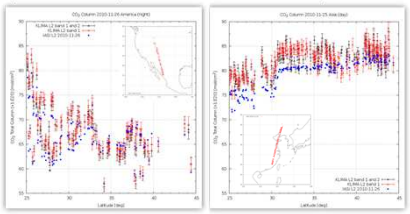

Figure 3, 4 - Comparison of KLIMA CO_2 total column band 1, KLIMA band 1+band 2 and IASI L2 over America and Asia

The comparison show that band 1 and band 1 + band 2 retrieval give comparable results, even if the band 2 can carry additional information. At the moment, we can only use the computing resources available at IFAC-CNR, so we chose to use only band 1 for the comparison with GOSAT.

First comparison with GOSAT TANSO-FTS data

The KLIMA-IASI ARM was used for the retrieval of CO_2 total column from a series of test cases for comparison with GOSAT TANSO-FTS SWIR L2 data.
Retrieved values from measurements acquired by the two instruments in February 2011 in two selected areas between 25-45°N over Nord America and Asia are shown in figures 5-6, along with maps of the footprints of IASI (red crosses) and GOSAT (green crosses) Field of Views. Due to the limited dataset available and the few coincidences between IASI and TANSO-FTS, we considered the GOSAT passage over the selected areas in a period of ±5 days from the measurements acquired by IASI. For the cross-validation, we compared CO_2 total column retrieved from KLIMA-IASI (using only band 1) with the operational product of IASI L2 and the TANSO-FTS L2 data. Preliminary results of the comparison show substantially good agreement, especially between TANSO-FTS and KLIMA-IASI, for what concerns the observed trend as a function of latitude.

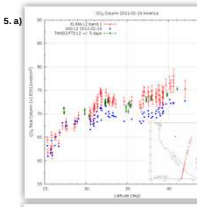

**Figure 5 - Comparison of CO_2 total column retrieved from KLIMA (red), the operational product of IASI L2 (blue) and CO2 total column from TANSO-FTS (green) over America for a) 02/19/2011 and b) 02/25/2011.
Small box: footprints of IASI (red crosses) and TANSO-FTS (green crosses) Field of Views**

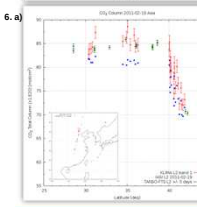

**Figure 6 - Comparison of CO_2 total column retrieved from KLIMA (red), the operational product of IASI L2 (blue) and CO2 total column from TANSO-FTS (green) over Asia for a) 02/19/2011 and b) 02/20/2011.
Small box: footprints of IASI (red crosses) and TANSO-FTS (green crosses) Field of Views**

Summary

- ✓ The capability to process IASI L1B and L1C data was tested and consistent results were obtained from the two datasets, thus we decided to retrieve CO_2 total column from IASI L1C.
- ✓ The KLIMA-IASI ARM algorithm has been successfully integrated in the ESA G-POD; G-POD will soon be available for bulk processing of IASI level 1C data.
- ✓ The comparison between CO_2 total column retrieved from KLIMA-IASI using band 1 and band 1+ band 2 and IASI L2 products shows a good agreement. Moreover, it is possible to see that band 1 and band 1 + band 2 retrieval give comparable results, even if the band 2 can carry additional information.
- ✓ A first set of inter-comparison and cross-validation between TANSO-FTS SWIR and KLIMA-IASI CO_2 total column was carried out: it is possible to see a substantially good agreement between TANSO-FTS and KLIMA-IASI for what concerns the observed trend as a function of latitude.
- ✓ Studies will be carried out to further improve the results of the cross-validation on a larger IASI-GOSAT dataset.

References

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