Carbon dioxide observation from IASI and comparison with TANSO-FTS

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INTRODUCTION

The ESA research project "Application of **KLIMA** Algorithm to CO_2 Retrieval from IASI/METOP-A Observations and Comparison with TANSO-FTS/GOSAT Products" aimed to develop a dedicated software, based on the KLIMA inversion algorithm (originally proposed by IFAC-CNR for the 6 cycle of ESA Earth Explorer Core Missions), suited for CO_2 retrieval and integrated into the ESA grid-based operational environment Grid Processing On-Demand (**G-POD**) to process Level 1 data acquired by the Infrared Atmospheric Sounding Interferometer (**IASI**) and to perform a comparison with Thermal And Near-infrared Sensor for carbon Observation Fourier Transform Spectrometer (TANSO-FTS), on board of the Greenhouse gases Observing SATellite (GOSAT), Level 2 data.

In order to obtain a reasonable capacity to bulk processing IASI data, we choose to integrate the KLIMA code into the G-POD system. For this reason, we investigated an optimized version of the KLIMA algorithm, aiming at developing a non-operational retrieval code with adequate features for the integration on the G-POD system. The optimized version of KLIMA retrieval code has been completed and integrated on the G-POD operational environment and is available for bulk processing of IASI data. Using the KLIMA inversion code integrated into the ESA G-POD, it was possible to perform an extensive comparison of a selected set of IASI measurements collocated with **SWIR TANSO-FTS** observations.

As part of an extension of the collaboration between IFAC-CNR and the GOSAT team in response to the second Research Announcement, we performed a comparison over a temporally reduced dataset of collocated IASI and **TIR TANSO-FTS** observations over land and ocean. In this work, we present first results and preliminary conclusions from this activity.

ANALISYS OF IASI DATA WITH KLIMA ALGORITHM

We analyzed a total of **240.000** IASI spectra using G-POD computing resources, retrieving the CO_2 both on **land** and on **water** and during **day** and **night** for a global geographical coverage.

The coverage is given in **Fig. 1** where the global map of CO_2 averaged over the full year on a grid of 2°×2° pixels is shown. In the retrievals, the forward model calculations fit well the spectra observed by IASI with residual differences comparable with the spectral noise. The residuals are generally much smaller than the spectral noise. Few isolated atmospheric features show average residuals that are larger than the spectral noise. The χ^2 values show a correlation with Earth's surface temperature and are close to unity at low temperatures, while increase monotonically up to 3 at the highest temperatures. Values greater than 3 occasionally occur, but being mostly located in desert areas are probably associated to sand storm scenarios.

The retrieval error of CO_2 varies as a function of the surface temperature with values of 2 ppm at high temperature and up to 20 ppm at low temperature. Best precision of IASI observations is obtained in warm seasons and at low latitudes and the worst precision is obtained in the cold seasons and at high latitudes. A conservative estimate of the total retrieval error is obtained by multiplying the retrieval error with the square root of the χ^2 (see **Fig. 2**).

Fig. 3 shows the average of all retrieved CO_2 values as a function of surface temperature. Over land (**red points**) a higher surface temperature is correlated with plant growth when a CO_2 sink is expected, on the other hand over ocean (**blue points**) a lower surface temperature increases the solubility of CO_2 into the sea and produces a sink.

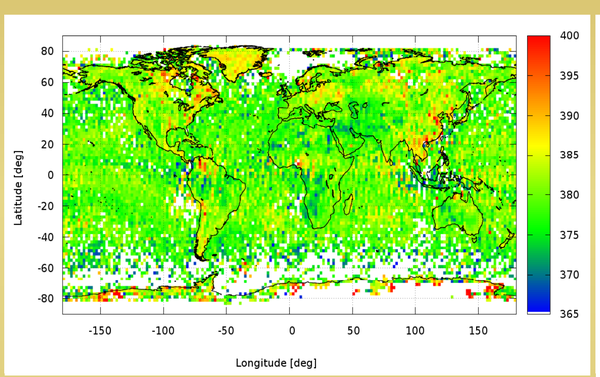


Figure 1: Global map of CO_2 averaged over the full year on a grid of 2°×2° pixels

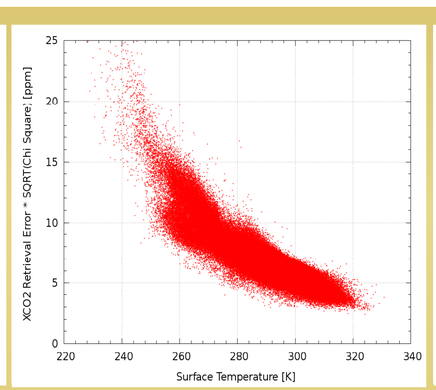


Figure 2: Total error of KLIMA-IASI CO_2 multiplied by the square root of the χ^2 plotted as a function of the surface temperature

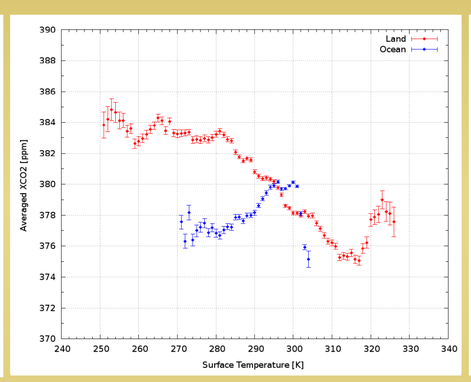


Figure 3: Averaged CO_2 as a function of the surface temperature binned over 1 K

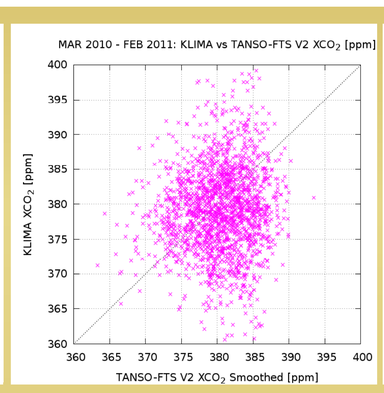


Figure 4: Scatter diagrams of the CO2 KLIMA vs TANSO-FTS v.2 comparison on a 2°x2° pixel grid related to the whole year

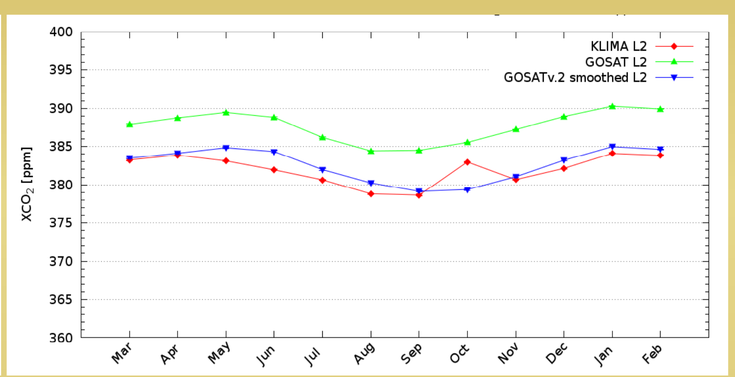


Figure 5: Seasonal variation of the CO_2 from March 2010 to February 2011 in Northern Hemisphere. The average on the Hemispheres of the CO_2 retrieved by KLIMA-IASI (red points) is compared with the Hemisphere average of SWIR TANSO-FTS CO_2 products; green points refer to L2 TANSO-FTS v.2 original products while blue points refer to v.2 smoothed

COMPARISON ACTIVITIES

KLIMA IASI L2 vs. EUMETSAT IASI L2 products

A perfect coincidence in time and space exists with respect to operational data delivered by EUMETSAT. The comparison between KLIMA and EUMETSAT datasets is difficult because straightforward correlations do not emerge and the absence of an error estimate for one of the two results prevents a clear conclusions [Cortesi et al., 2013].

KLIMA IASI L2 vs. SWIR TANSO-FTS GOSAT L2 products

Three different strategies have been used:

- Co-located comparison: comparison of the CO_2 total column retrieved from observations of IASI and TANSO-FTS made in contiguous locations in time and space [Cortesi et al., 2013];
- Averaged comparison: comparison of the CO_2 total column averaged on a suitable spatial and time interval (**Fig. 4**);
- Seasonal variation comparison: comparison of the seasonal variations of CO_2 from March 2010 to February 2011 (**Fig. 5**).

In the case of the averaged comparison the distribution of the differences between the two datasets shows a negative 7,3 ppm bias of KLIMA-IASI, with a standard deviation of 7 ppm and an un-accounted error of KLIMA-IASI of about 6 ppm with respect to the retrieval error and to the CO_2 atmospheric variability. Taking into account the different Averaging Kernels , the negative bias is reduced to 1,17 ppm, as showed in **Fig. 4**.

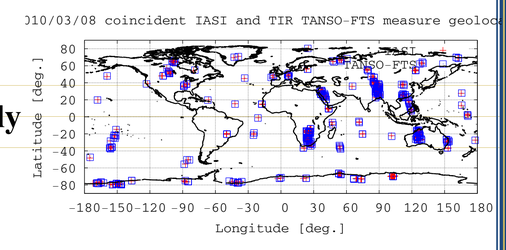
KLIMA IASI L2 vs. TCCON products

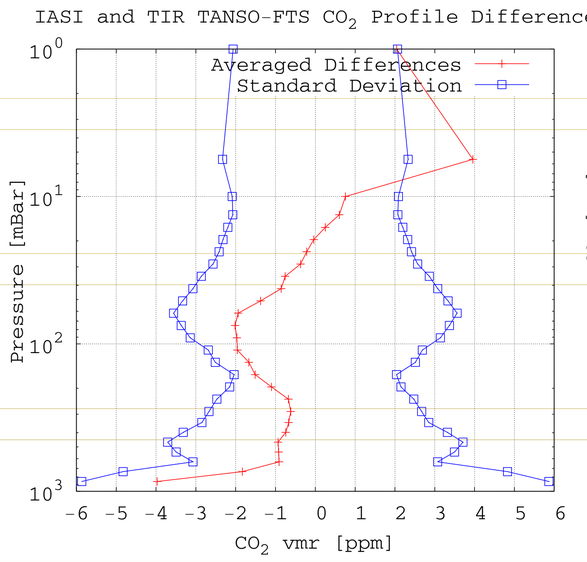
As in the previous case, the comparison with TCCON stations shows a negative bias [Cortesi et al., 2013].

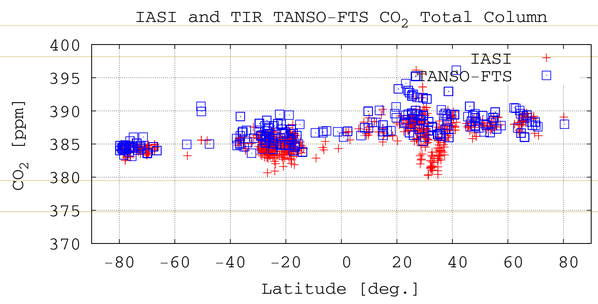
KLIMA IASI L2 vs. TIR TANSO-FTS GOSAT L2 products

A different retrieval set-up has been adopted in this comparison:

- Retrieval of CO_2 profile
- Use of the same vertical retrieval grid
- **Un-accounted continuum retrieved simultaneously**







The un-accounted continuum retrieval removes the un-accounted error in the KLIMA results. The new retrieval settings will be applied in the comparison with **SWIR TANSO-FTS GOSAT** and **TCCON L2 products**.

CONCLUSIONS

The main outcomes of the project can be summarized in terms of the results we have already consolidated and of the open and new issues we are investigating at present or plan to address in future activities:

- Development and implementation of a non-operation inverse model for the retrieval of CO_2 profile and total column from IASI/MetOp-A observations
- Fits of good quality obtained from KLIMA wide-band and multi-target analysis; observed geographical and seasonal variability often in good agreement with expectations
- On average, negative bias of KLIMA retrieved CO_2 relative to other instruments; the averaged comparison with SWIR TANSO-FTS shows a bias of -7,3 ppm
- The comparison with SWIR TANSO-FTS showed an un-accounted error of KLIMA-IASI of about 6 ppm with respect to the retrieval error and to the CO_2 atmospheric variability
- **The un-accounted continuum retrieval adopted for the comparison with TIR TANSO-FTS products removes the un-accounted error in the KLIMA results**
- **The new retrieval settings used for the TIR will be applied in the comparison with SWIR TANSO-FTS GOSAT and TCCON L2 products**

The authors wish to thank Dr. Naoko Saitoh of Chiba University for the collaboration in providing the used dataset of TANSO-FTS TIR data.

U. Cortesi et al. (2013) Finale Report of the Project 'Sensitivity analysis and application of KLIMA algorithm to GOSAT and OCO validation' (ESA-ESRIN/Contract n. 21612/08/I-OL).