Main results of Carbon Dioxide comparison between IASI, TANSO-FTS and HIPPO products

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A great effort is undertaken by the scientific community to investigate carbon dioxide amounts and vertical distribution and to characterize its sources and sinks. In this context, the development of CO2 retrieval models in the Thermal InfraRed (TIR) spectral range is effective for the characterization of the CO2 distribution in the mid-to-upper troposphere because of the profiling capabilities of the TIR with peak sensitivity in these altitudes. The research project “Application of KLIMA Algorithm to CO2 Retrieval from IASI/METOP-A observations and Comparison with TANSO-FTS/Global Products” has the main purpose to investigate the performances of the KLIMA algorithm applied to the Infrared Atmospheric Sounder Interferometer (IASI) observations. The Thermal And Near infrared sensor for Carbon Observation (TANSO)-FTS on board of the Greenhouse gases Observing SATellite (GOSAT) can measure CO2 column amounts from the ShortWave infrared band (SWIR) and CO2 profiles from the TIR band, simultaneously. SWIR observations are more sensitive to CO2 near the earth surface, but they have a lower capability to resolve the vertical profile than TIR observations. Thus, the use of the SWIR and TIR combined data provides the possibility to estimate the amounts of CO2 in the boundary layer accurately and consequently may produce a useful dataset for the study of CO2 sources and sinks. The main goal of the HIPPER Pole-to-Pole Observations (HIPPO) project is to provide the first high-resolution vertically resolved global survey of trace gases and aerosols investigating the Carbon Cycle and greenhouse gases annual cycle throughout various altitude in the western northern hemisphere by aircraft measurements. In order to provide additional evidence on the ongoing discussion on the measurement of carbon dioxide from space, we performed a comparison between temporally reduced dataset of IASI CO2 retrievals and SWIR retrievals. The objectives of Phase 2, pursued in cooperation with JAXA, NIES and the Met Office of Japan and completed beyond the end of the ESA project, were the procurement of a consolidated version of the KLIMA-IASIG-Pod retrieval code, the processing of IASII CO2 spectra and the comparison with TANSO-FTS SWIR and TIR products.

For the SWIR products we have analyzed 240000 IASI spectra acquired in the period from March 2010 to February 2011 using the KLIMA retrieval code developed by the IFAC group on the Grid Processing On Demand (GPOD) system at ESA/ESRIN both on land and on water and during night and day for a global geographical coverage.

The overall activity of the research project "Application of KLIMA algorithm to CO2 retrieval from IASI/METOP-A observations and comparison with GOSAT/TANSO-FTS products" aimed at the application of the KLIMA inversion algorithm, integrated into the ESA G-POD (Grid Processing On-Demand) operational environment, to processing of IASI/METOP-A spectra and at the retrieval of carbon dioxide profiles and products for comparison and cross-validation with GOSAT-TANSO SWIR and TIR products. According to the original planning, the activities of the project have been developed in two phases. In Phase 1 a prototype software for the retrieval of CO2 from IASI data with performance suitable for the comparison with TANSO-FTS products and with basic features matching the requirements of the integration on G-POD has been developed. The objectives of Phase 2, pursued in cooperation with JAXA, NIES and the Met Office of Japan and completed beyond the end of the ESA project, were the procurement of a consolidated version of the KLIMA-IASIG-Pod retrieval code, the processing of IASII CO2 spectra and the comparison with TANSO-FTS SWIR and TIR products.

Comparisons ACTIVITIES

KLIMA IASI L2 vs. SWIR TANSO-TFS HIPPO L2 products Three different strategies have been used:

- Co-located comparison: comparison of the CO2 column total 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 CO2 column total averaged on a suitable spatial and time interval (negative 7.3 ppm bias of KLIMA-IASI, with a standard deviation of 7 ppm and an unaccounted error of KLIMA-IASI) of about 6 ppm with respect to the retrieval error of the CO2, according the results found. Taking into account the different Averaging Kernels, the negative bias is reduced to 1.17;
- Seasonal variation comparison: comparison of the seasonal variations of CO2 from March 2010 to February 2011

KLIMA IASI L2 vs. TCONC products In as the previous case, the comparison with TCONC shows a negative bias of the IASII measurements

Global mean of CO2 averaged over the year (Mar 2010-Feb 2011) on a grid of 2° × 2° pixels

One coincidence case selected for the comparison between CO2-KLIMA and TANSO-FTS CO2 products and HIPPO data (IASI over land, GOSAT over sea) (top: IASI CO2, bottom: HIPPO data). The left map shows the acquisition locations (red line: HIPPO, black square: IASI - flight path lower point) and the relative HIPPO flight path.

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MetOp-A/IASI – GOSAT/TANSO-FTS – HIPPO3 (TIR)

The KLIMA-IASI inversion code was used for processing IASI L1-C data to retrieve CO2 profiles with the aim of comparison with TANSO-FTS band 4 data. The GOSAT/TANSO-FTS CO2 TIR operational products were obtained with the retrieval algorithm described in Saltz et al. (2009, 2015). In order to validate the comparison results between IASI and HIPPO products, we considered CO2 merged 10-second data product retrieved in the HIPPER Pole-to-Pole Observations (HIPPO) 3 aircraft campaign as reference to evaluate the results. The CO2 profiles from IASI and HIPPO products have been compared with HIPPO 3 measurements for the coincidence cases April 2010 (274 coincidence cases).

- We selected coincidences between HIPPO 3 campaign and both GOSAT TIR and IASI products, separately, considering the same criteria: 72 hours as time difference, IASI TIR and HIPPO time space distance (Δs) between the centre of the GOSAT (or IASI) satellite acquisition and the location of the lowest HIPPO measurement point. We considered IASI and HIPPO passes over both land and on water and during day and night.
- A quantitative analysis of the differences between IASI and HIPPO Band 4 products and HIPPO TIR measurement described IASI satellite, the vertical sensitivity of the remote-measuring soundings from space, using the associated averaging kernel matrices, has been finally performed to derive strong retrieval results. 

We calculated the differences between the CO2TIR (or HIPPO) real and retrieved CO2 profile xij and xij to evaluate the differences with the HIPPO CO2 measurements: ΔCO2TIR (i,j) = xij − xij where xij = xij + Aij (Eij − xij) is the HIPPO or (or IASI) retrieved state as if they observed the air mass described by the aircraft profile (Rodgers et al., 2000). xij is the HIPPO profile, xij Aij and Aij are the apriori state and averaging kernel matrix of IASI (or HIPPO), respectively.

Every coincidence case has been considered singularly and then the results have been evaluated to determine the dependence on the different variables considered about the satellite measurements: overpass time (day or night), overpass surface (land or water), and temperature profile.

Conclusions

- The ΔCO2 values range between 0 to 2 ppm from 3.2 to 0.5 ppm for IASI data over land and water, respectively, while the range for GOSAT products is between 0.5 and 0.5 ppm, considering the complete dataset.
- IASI data over water (59 cases) demonstrate a different vertical trend in comparison with aircraft profiles, in these cases the mean difference between the two CO2 datasets varies from -0.5 ppm (upper troposphere and near the surface) to -3.5 ppm (400 hPa).
- IASI daytime measurements overestimate HIPPO CO2 data in the pressure levels near the surface (pressure levels grater than 700 hPa), while the behaviour is exactly reversed for nighttime overpasses.
- For GOSAT/TANSO-FTS data, the mean ΔCO2 trends for daytime and nighttime measurements are similar, with an increased underestimation of GOSAT CO2 pressures from 600 to 800 hPa for the nighttime overpasses.
- The definition of more strict coincidence criteria in time and space did not improve the comparison results, there is no relationship between ΔCO2 values and Δs and Δt.
- The IASI and TANSO-FTS total retrieval error close to 9.5 ppm, while the ΔCO2 values vary from 3 to 3 ppm, considering all coincident cases. So, the differences in CO2 profiles between the two couples of TANSO-FTS-HIPPO and IASI-HIPPO measurements are within the total retrieval errors.
