Results of the comparison among IASI/METOP-A, TANSO-FTS/GOSAT Band 4 and HIPPO 3 Carbon Dioxide products

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The research project "Application of KLIMA algorithm to CO_2 retrieval from IASI/METOP-A observations and comparison with TANSO-FTS/GOSAT products" has been conducted in response to the Second Research Announcement on GOSAT for the research field "Calibration/Validation", to support the activities of the KLIMA-IASI project funded by the European Space Agency (ESA-ESRIN, Frascati, Italy) and lead by the Institute for Applied Physics "Nello Carrara" of the Italian National Research Council (IFAC-CNR, Sesto Fiorentino, Firenze, Italy). The overall activity 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 columns and profiles for comparison and cross-validation with TANSO-FTS/GOSAT SWIR and TIR products. The activities of comparison and cross-validation were pursued in cooperation with JAXA, NIES and the MoE of Japan. The latter continued beyond the end of the ESA project to exploit the availability of GOSAT operational products from TANSO-FTS measurements in the TIR region. In this work, we present the main results from the final activity of comparison and cross-validation between CO_2 retrieval products obtained from IASI/MetOp-A observations processed by the consolidated version of the KLIMA-IASI/G-POD retrieval code and the operational Level-2 products from Band 4 of TANSO-FTS. We performed a comparison between temporally reduced dataset of collocated IASI, TANSO-FTS TIR and HIAPER Pole-to-Pole Observations (HIPPO) 3 campaign data. We considered CO_2 merged 10-second data retrieved in the HIPPO 3 campaign as reference to evaluate the satellite products. A quantitative analysis of the differences of KLIMA-IASI and TANSO-FTS Band 4 products and HIPPO 3 measurements, taking into account the vertical sensitivity of the remote-sounding measurements from space, has been completed to obtain stringent comparison results.

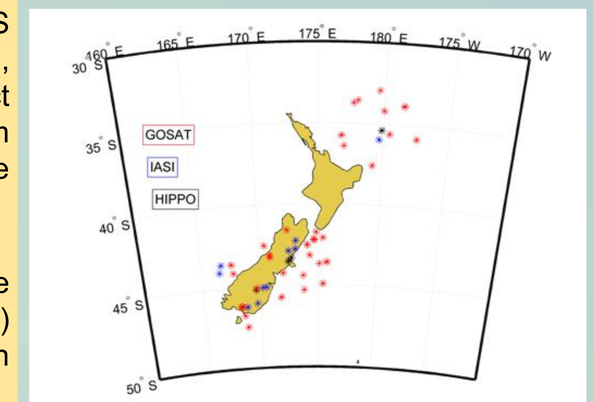
IASI/MetOp-A –TANSO-FTS/GOSAT – HIPPO3 CO_2 COMPARISON (TIR)

The KLIMA-IASI inversion code was used for processing IASI L1C data to retrieve CO_2 profiles with the aim of comparison with TANSO-FTS band 4 data. The TANSO-FTS/GOSAT CO_2 TIR operational products were obtained with the retrieval algorithm described in Saitoh et al. (2009, 2015). In order to validate the comparison results between IASI and TANSO products, we considered CO_2 merged 10-second data product retrieved in the HIAPER Pole-to-Pole Observations (HIPPO) 3 aircraft campaign as reference to evaluate the results. The CO_2 profiles from TANSO-FTS and IASI products have been compared with HIPPO 3 measurements for the coincidence cases of April 2010 (274 coincidence cases).

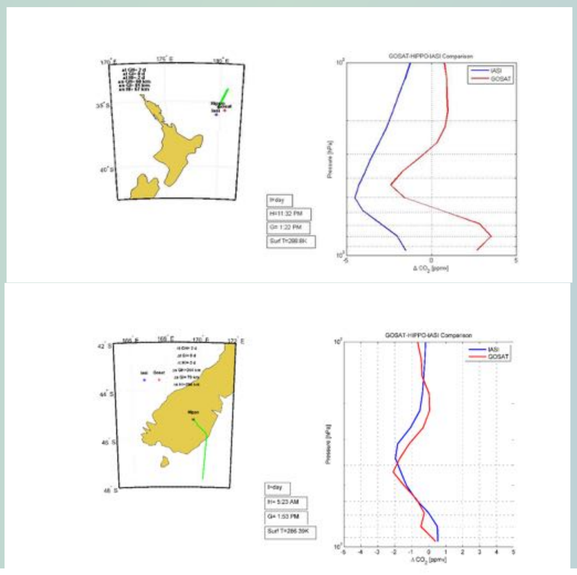
- We selected coincidences between HIPPO 3 campaign and both TANSO-FTS TIR and IASI products, separately, considering the same criteria: 72 hours as max. time difference (Δt_{max}) and 300 km as max. space distance (Δs_{max}) between the centre of the TANSO-FTS (or IASI) satellite acquisition and the location of the lowest HIPPO measurement point. We considered IASI and TANSO-FTS overpasses both on land and on water and during day and night.

- A quantitative analysis of the differences between IASI and TANSO-FTS Band 4 products and HIPPO 3 data taking into account the vertical sensitivity of the remote-sounding measurements from space, using the associated averaging kernel matrices, has been finally performed to obtain stringent comparison results.

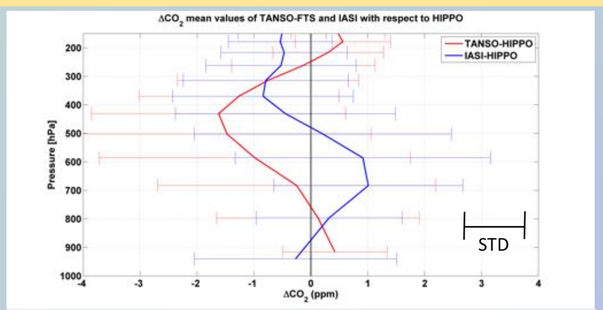
Every coincidence case has been considered singularly and then the resulting ΔCO_2 have been averaged to evaluate the dependence on the specific features of the satellite measurements scenarios: i.e overpass time (day or night), overpass surface (water or land), and IASI thermal contrast between the surface and the lowermost atmospheric layer.



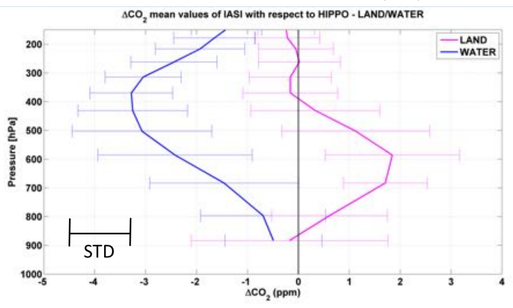
Geolocations of measurements aquired by TANSO-FTS/GOSAT (red stars), IASI/METOP-A (blue stars) and HIPPO 3 (black stars).



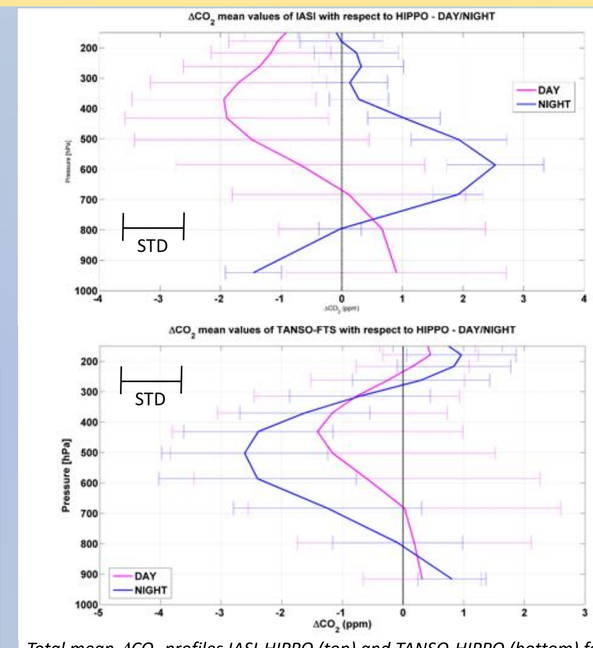
Two coincidence cases selected for the comparison between CO_2 KLIMA and TANSO-FTS TIR products and HIPPO3 data. On the left: a map with the acquisition locations (red star: TANSO-FTS, blue star: IASI, black star: HIPPO flight path lower point) and the relative HIPPO flight path. On the right: $\Delta CO_{2\,(I,T)}$ profiles for IASI-HIPPO (blue line) and TANSO-HIPPO.



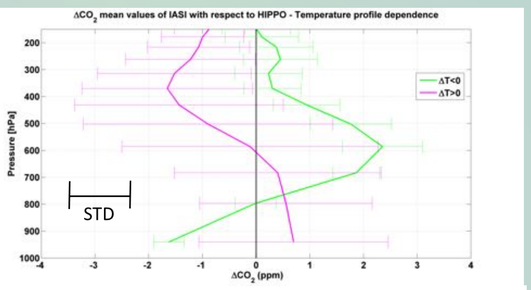
Total mean $\Delta CO_{2\,(I,G)}$ profiles (IASI-HIPPO and TANSO-HIPPO) for the 274 coincident cases and associated standard deviation (STD)



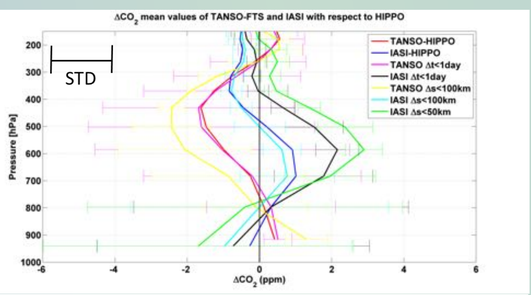
Total mean ΔCO_2 profiles IASI-HIPPO for the coincident cases relative to overpass over land (215 cases; magenta) and over water (59 cases; blue)



Total mean ΔCO_2 profiles IASI-HIPPO (top) and TANSO-HIPPO (bottom) for the coincident cases relative to IASI and TANSO-FTS daytime (magenta) and nighttime (blue) overpasses.

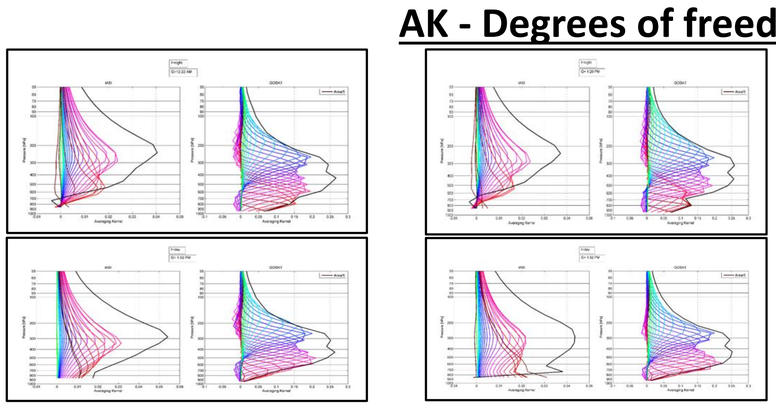


Total mean ΔCO_2 profiles IASI-HIPPO for the coincident cases characterized by ΔT <0 (green) and ΔT >0 (magenta), where ΔT=surface temperature - lowermost atmospheric layer temperature).



Comparison of total mean $\Delta CO_{2\,(I,G)}$ profiles (IASI-HIPPO and TANSO-HIPPO) obtained averaging all coincident cases with ds<dsmax e dt<dtmax or selecting more strict coincidence criteria (time difference Δt< 1 day, spatial difference Δs <100 km for both sensor, Δs <50 km for IASI, no cases for TANSO-FTS).

AK - Degrees of freedom



Averaging kernels for IASI (left) and TANSO-FTS (right) for four coincidence cases selected. Top left: IASI nighttime and TANSO-FTS nighttime overpass over land. Bottom left: IASI daytime and TANSO-FTS daytime overpass over water. Top right: IASI nighttime and TANSO-FTS daytime overpass over land. Bottom right: IASI daytime and TANSO-FTS daytime overpass over land. The selected cases are representative of the AK mean values behaviour relative to the four specific overpass time and surface.

IASI measurements seem to provide information in the atmospheric layer around 250-400 hPa and in a layer near 700-800 hPa for daytime cases, while TANSO-FTS kernels seems to define a higher information content in the layers between 250 and 600 hPa.
The difference in the kernels values is probably due to the radiometric error that is lower for TANSO-FTS data (<0.1 Kelvin) than for IASI (0.2 Kelvin).

The mean number of degree of freedom (DOF, trace of AK) are:

- for IASI: 0.264 (over water) and 0.189 (over land), 0.168 (nighttime) and 0.240 (daytime)
- for TANSO-FTS: 1.72 (nearly no difference for overpass time and surface)

	DOF IASI (MEAN)					DOF TANSO-FTS (MEAN)				
Atmospheric layer	TOT	W	L	D	N	TOT	W	L	D	N
0 – 5 km	0.04	0.05	0.03	0.02	0.02	0.64	0.66	0.57	0.65	0.71
5 – 10 km	0.08	0.10	0.07	0.09	0.07	0.71	0.71	0.72	0.71	0.71
10 – 15 km	0.06	0.07	0.06	0.07	0.06	0.27	0.31	0.26	0.31	0.30
15 - 20 km	0.01	0.02	0.01	0.02	0.01	0.02	0.03	0.02	0.03	0.03

CO2 Partial Columns

IASI and TANSO-FTS CO_2 partial columns have been calculated for four atmospheric layers (0-5 km, 5-10 km, 10-15 km, 15-20 km) considering a common pressure grid. HIPPO3 partial columns have been calculated for the layers 0-5 km and 5-10 km using the higher vertical resolution grid of the aircraft measurements. CO_2 partial column values are expressed in Dobson Units and derived from:

ATMOSPHERIC LAYER	IASI Partial Column (DU)	TANSO Partial Column (DU)	Mean Ratio IASI/TANSO	Std/$N^{1/2}$ (Ratio)
0-5 km	1.34e+05	1.26e+05	1.0655	5.95×10^{-4}
5-10 km	5.18e+04	5.17e+04	1.0017	4.77×10^{-4}
10-15 km	2.90e+04	1.22e+03	1.0014	1.72×10^{-4}
15-20 km	1.33e+04	1.20e+03	1.0071	1.98×10^{-4}

$$Partial\ Column\ (PC) = 10 \cdot \frac{RT_0}{g_0 p_0} \cdot \sum_{i=1}^{N} 0.5 \cdot (VMR(i) + VMR(i+1))(P(i) - P(i+1))$$

- The mean ratio between IASI and TANSO-FTS CO_2 partial column values differs from 1 more than the associated uncertainty (std/$N^{1/2}$).
- Nearly no differences are evident for ratios and standard varying overpass surface and time.
- Also for the comparison with HIPPO partial columns for the layers 0-5 and 5-10 km shows IASI/HIPPO and TANSO-FTS/HIPPO mean ratio values that differs from 1 more than the associated uncertainty.

ATMOSPHERIC LAYER	Mean ratio IASI/ HIPPO	Mean ratio TANSO /HIPPO	Std/$N^{1/2}$ (Ratio) IASI/HIPPO	Std/$N^{1/2}$ (Ratio) TANSO/HIPPO
0-5 km	1.0749	1.0096	5.88×10^{-4}	7.36×10^{-4}
5-10 km	1.1181	1.1171	0.02	0.02

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

- The ΔCO_2 values range from 0 to 2 ppm for IASI data and from -2 and 0.5 ppm for TANSO-FTS products, considering the complete dataset.
- IASI data over water (59 coincidence cases) demonstrate a different vertical behaviour in comparison with aircraft profiles, in these cases the mean difference between the two CO_2 datasets varies from -0.5 ppm (upper troposphere and near the surface) to -3.5 ppm (400 hPa).
- IASI daytime measurements overestimate HIPPO CO_2 data in the pressure levels near the surface (pressure levels greater than 700 hPa), while the behaviour is exactly reversed for nighttime overpass cases.
- For TANSO-FTS/GOSAT data, the mean ΔCO_2 values for daytime and nighttime measurements are similar, with an increased underestimation of TANSO-FTS CO_2 for pressures from 600 to 800 hPa for the nighttime overpasses.
- The adoption of more strict coincidence criteria in time and space did not improve the comparison results, no definite relationship emerges between ΔCO_2 values and Δs and Δt selection.
- The mean DOF value for TANSO-FTS is 1.72, with nearly no dependence on overpasses surface and time. The DOF are lower for IASI (0.264 (over water) and 0.189 (over land), 0.168 (nighttime) and 0.240 (daytime))
- The mean ratio between IASI and TANSO-FTS CO_2 partial column values differs from 1 more than the associated uncertainty. The same result is found from the comparison of CO_2 partial columns of HIPPO measurements, compared with IASI and TANSO-FTS values for the layers 0-5 km and 5-10 km.
- In the CO_2 partial columns analysis, we did not observe significant differences for mean ratios and associated standard deviations for different overpass surface and time.

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