Validation of TROPOMI NO_2 and HCHO vertical columns with UV-Vis DOAS and FTIR instruments

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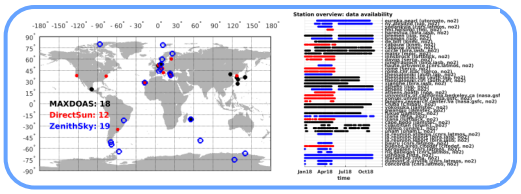
Abstract

Within the **S5P Validation Team**, the **NIDFORVal project AO 208607** (S5P NItrogen Dioxide and FORmaldehyde VALidation using NDACC and complementary FTIR and UV-Vis DOAS ground-based remote sensing data) aims at assessing the quality of nitrogen dioxide (NO_2) and formaldehyde (HCHO) operational S5P products. Both Fourier Transform Infrared (FTIR) and UV-Visible Differential Optical Absorption Spectroscopy (UV-Vis DOAS) are recognized as independent techniques which can routinely provide total NO_2 (DirectSun DOAS), tropospheric NO_2 (Multi-AXis (MAX-) DOAS), and HCHO total column (FTIR and MAXDOAS) reference data sets for the long-term validation of satellite observations.
High-quality measurements from **over 60 ground-based stations and 80 instruments** will be gathered over the whole S5P mission timeline (10/2017-2023) from NDACC and other complementary networks, covering a large range of observation conditions including **high, mid, and low latitudes, as well as remote, sub-urban, and urban polluted sites**. About 50 stations were operational with data submission in rapid delivery mode during the commissioning and pre-operational phase and about 25 UV-vis DOAS stations were involved in the validation of the first TROPOMI total and tropospheric NO_2 column operational products released last June. Data from 16 FTIR sites and 13 UV-vis stations were also used for the preliminary validation of the HCHO S5P vertical columns. The level of agreement varies from station to station, but globally and for both products, **comparison results show negative biases (i.e. TROPOMI smaller than ground-based) which are within the accuracy requirements (50% for NO_2 and 40-80% for HCHO).**
Updates of NO_2 and HCHO comparison results will be reported in this presentation, as well as the validation plan for the routine operations phase during which large TROPOMI data records will be accumulated.

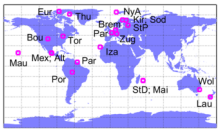
UV-vis DOAS data

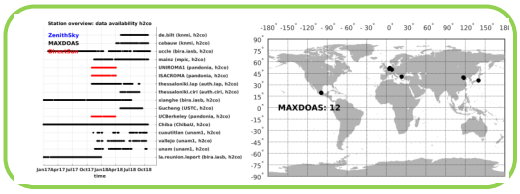
Collection of Uv-vis NO_2 and HCHO VCDs covering November 2017 to November 2018.
ZenithSky: stratospheric NO_2 VCD from 19 stations.
MAXDOAS: tropospheric NO_2 VCD from 16 stations and tropospheric HCHO VCD from 12.
DirectSun: total NO_2 VCD from 10 stations and total HCHO from 3 stations (3 pandonia instruments).



FTIR data

Vigouroux et al., AMT, 2018: 21 stations provide HCHO time series using harmonized retrieval parameters.
Collection of HCHO VCDs for this study: 9 stations provided data up to 1st Nov.; 5 up to 1st Sept.; 5 up to Aug.





TROPOMI data

Comparisons have been performed with **TROPOMI data from ESA Expert HUB**:
- NO_2 data: processor v1.0.2 RPRO (Feb-May 2018) + OFL (May-Sept 2018) - data publicly available since 6/2018
- HCHO data: processor v01.01.02 RPRO (May-Aug 2018) + OFL (Aug-Nov). For FTIR comparisons, also NRT (Aug-Nov) - NRT data publicly available since 10/2018

Data Filtering using QA values:
NO_2: QA>0.75 , HCHO: QA>0.5

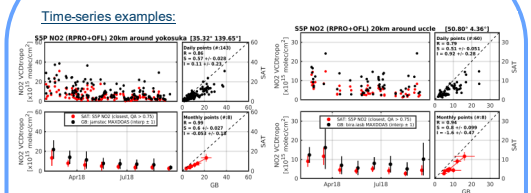
Colocations: (NO_2/HCHO) Use for each day the closest/average of TROPOMI valid pixels within 20km of the station; use the value only if at least 10 good pixels are provided. Use the interpolated/average over ±1h value of gb measurements around TROPOMI overpass for Uv-Vis and daily mean (~ ±2.5h) for FTIR.

Validation results

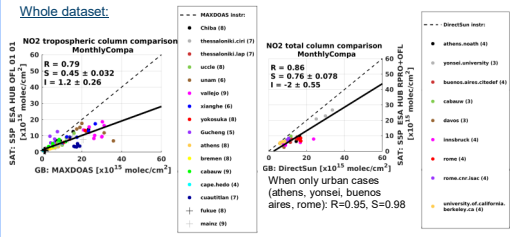
Comparisons have been performed on a daily and monthly basis.

tropo and total NO_2

Time-series examples:

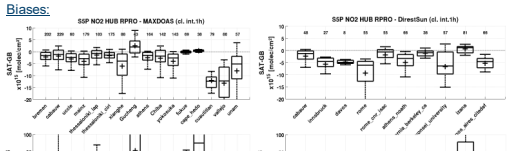


Whole dataset:

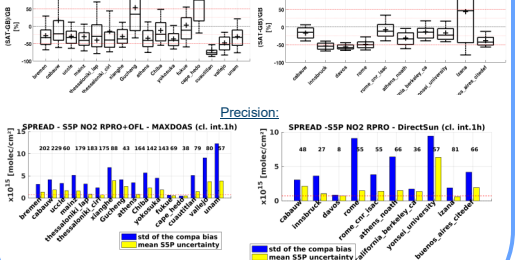


When only urban cases (athens, yonsei, buenos aires, rome): R=0.95, S=0.98

Biases:



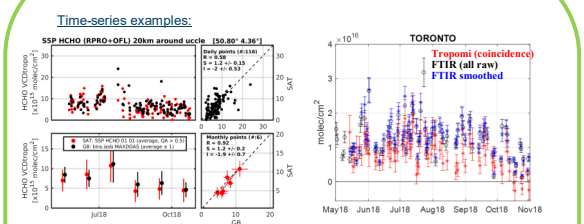
Precision:



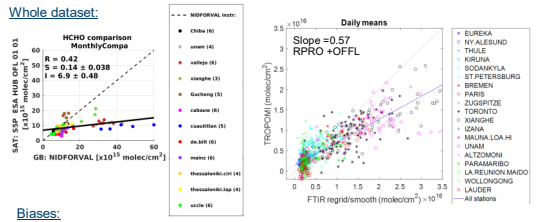
TROPOMI within the bias requirements, but generally smaller than ground-based. Most cases, std> expected precision. Structural comparison errors?

HCHO

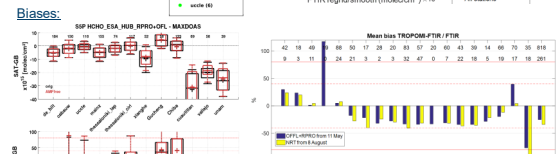
Time-series examples:



Whole dataset:

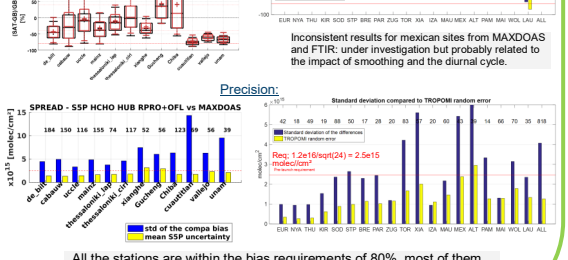


Biases:



Inconsistent results for mexican sites from MAXDOAS and FTIR: under investigation but probably related to the impact of smoothing and the diurnal cycle.

Precision:



All the stations are within the bias requirements of 80%, most of them within 40%. Usually std > expected precision. Structural comparison errors? Some random error in syst_SAT_error ?

Conclusions

	Daily ovp ALL sites			
RPRO+OFL	Bias	Stand. Dev. (% and molec/cm^2)	Slope	Corr
HCHO (MAXDOAS)	-33%	34%	0.2	0.4
HCHO (FTIR)	-25%	62%; 4.1x10^{15}	0.57	0.84
HCHO (FTIR) NRT	-31%	56%; 4.4x10^{15}	0.56	0.85
NO2 (tropo)	-34%	35%	0.48	0.71
NO2 (total)	-29%	30%	0.68	0.83

- Ground-based data collection is efficient and the NIDFORVAL results have been used for the validation of the S5P NO_2 and HCHO products for their public release.
- Validation results are very promising, with very good correlation, but a S5P general tendency to underestimate the ground-based columns (within requirements). The standard deviation of the comparisons usually exceed the precision, which points to structural comparisons errors or underestimation of the satellite errors.
- Separation of the results per station type (urban, suburban, remote) is ongoing and shows very good comparisons for direct-sun urban cases.
- Preliminary comparisons at stations where both MAXDOAS and FTIR are present show coherent agreement in Xianghe while for Mexico City the results need to be further investigated.
- Smoothing need to be applied to MAXDOAS to remove the a-priori profile uncertainty.
- More in depth validation is performed at some of the sites by NIDFORVAL partners, eg Uccle with 3D MAXDOAS (Dimitropoulou et al., poster 191), Thessalonikli (Koukouli et al. Thursday), ...

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FTIR: C. Bauer Aquino, C. Becker, T. Blumenstock, M. De Mazière, O. Garcia, M. Grutter, C. Guarin, J. Hannigan, F. Hase, C. Hermans, N. Jones, R. Kivi, D. Koshelev, E. Lutsch, M. Makarova, J.-M. Metzger, J. Notholt, I. Ortega, M. Palm, C. Paton-Walsh, A. Poberovskii , M. Rettinger, J. Robinson, D. Smale, W. Stremme, K. Strong, R. Sussmann, Y. Té
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