Assessment of the S-5P tropospheric NO2 product based on coincident airborne APEX observations over polluted regions

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Sentinel-5 Precursor (S-5P), launched in October 2017, is the first mission of the Copernicus Programme dedicated to the monitoring of air quality and climate. Its characteristics, such as the fine spatial resolution, introduce many new opportunities and challenges, requiring to carefully assess the quality and validity of the generated data products by comparison with independent reference observations.

In the presented study, the S-5P/TROPOMI tropospheric nitrogen dioxide (NO2) L2 product (3.5 x 7 km² at nadir observations) has been validated over strongly polluted urban regions based on comparison with coincident high-resolution airborne remote sensing observations (~100 m²).

Airborne imagers are able to map the horizontal distribution of tropospheric NO2, as well as its strong spatio-temporal variability, at high resolution and with high accuracy. Satellite products can be optimally assessed based on airborne observations as a large amount of satellite pixels can be fully mapped in a relatively short time interval, reducing the impact of spatiotemporal mismatches. Additionally, such data sets allow to study the TROPOMI subpixel variability and impact of signal smoothing due to its finite satellite pixel size, typically coarser than fine-scale gradients in the urban NO2 field.

In the framework of the S5PVAL-BE campaign, the Airborne Prism EXperiment (APEX) imaging spectrometer has been deployed during four mapping flights (26-29 June 2019) over the two largest urban regions in Belgium, i.e. Brussels and Antwerp, in order to map the horizontal distribution of tropospheric NO2. Per flight, 15 to 20 TROPOMI pixels were fully covered by approximately 5000 APEX measurements for each TROPOMI pixel. Mapping flights and ancillary ground-based measurements (car-mobile DOAS, MAX-DOAS, CIMEL, ceilometer, etc.) were conducted in coincidence with the overpass of TROPOMI (typically between noon and 2 PM UTC). The TROPOMI and APEX NO2 vertical column density (VCD) retrieval schemes are similar in concept. Retrieved NO2 VCDs were georeferenced, gridded and intercompared. As strongly polluted areas typically exhibit strong NO2 vertical gradients (besides the strong horizontal gradients), a custom TROPOMI tropospheric NO2 product was computed and compared as well with APEX by replacing the coarse 1° x 1° a priori NO2 vertical profiles from TMS-MP by NO2 profile...
shapes from the CAMS regional CTM ensemble at 0.1° x 0.1°.

Overall for the ensemble of the four flights, the standard TROPOMI NO\textsubscript{2} VCD product is well correlated (R = 0.94) but biased low (slope = 0.73) with respect to APEX NO\textsubscript{2} retrievals. When replacing the TM5-MP a priori NO\textsubscript{2} profiles by CAMS-based profiles, the slope increases to 0.88. When calculating the NO\textsubscript{2} VCD differences, the bias is on average -1.3 ± 1.2 x 10\textsuperscript{15} molec cm\textsuperscript{-2} or -16% ± 11% for the difference between APEX NO\textsubscript{2} VCDs and the standard TROPOMI NO\textsubscript{2} VCD product. The bias is substantially reduced when replacing the coarse TM5-MP a priori NO\textsubscript{2} profiles by CAMS-based profiles, being -0.1 ± 1.1 x 10\textsuperscript{15} molec cm\textsuperscript{-2} or -0.1% ± 11%. Both sets of retrievals are well within the accuracy requirement of a maximum bias of 25-50% for the TROPOMI tropospheric NO\textsubscript{2} product for all individual compared pixels.