Comprehensive validation of the QA4ECV OMI NO$_2$ climate data record with a harmonized MAXDOAS data set, and first TROPOMI NO$_2$ operational validation results

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The QA4ECV NO$_2$ 1.1 tropospheric column climate data record (CDR) is one of three quality assured, atmospheric Essential Climate Variable (ECV) CDRs produced within the EC's FP7 QA4ECV project, available on several sensors. In this work we report on the comprehensive quality assessment and validation of this product on the OMI sensor. The generic building blocks —developed or refined within the projects QA4ECV and EC's H2020 GAIA-CLIM and integrated in BIRA-IASB's Multi-TASTE system and the QA4ECV validation server- are (i) a harmonized list of standard terms and definitions, relevant to the quality assurance of ECV Climate Data Records, (ii) a generic validation protocol, virtually applicable to all atmospheric ECVs, and (iii) error classification in the comparison, distinguishing between satellite errors, reference errors and comparison errors. The QA4ECV validation server and Multi-TASTE components are the dedicated validation tools. As reference data sets, we use (i) a harmonized NDACC MAXDOAS data set at 10 sites established within the QA4ECV project (QA4ECV MAXDOAS), providing column measurements, and (ii) a separate processing based on optimal estimation, bePRO MAXDOAS, available at 3 sites, providing profile measurements.

Application of the validation protocol results in the following conclusions regarding QA4ECV NO$_2$ OMI 1.1.

Data content study. The recommended quality filter causes a negative sampling bias in the satellite product at the MAXDOAS sites, mainly due to the exclusion of clouded scenes which are associated with higher tropospheric NO$_2$ concentrations.

Information content study. A priori profile assumptions are quite different for MAXDOAS and satellite, and this has a significant impact on the retrieved column values.

Co-location, harmonization and comparison. The QA4ECV NO$_2$ CDR displays a negative, seasonally varying bias with respect to the MAXDOAS reference, and -depending on the site- a high comparison dispersion. Harmonization of the a priori profiles does not resolve the discrepancy. Part of the bias and comparison dispersion can be accounted for by the ex-ante satellite and reference uncertainties and comparison errors (i.e., temporal/horizontal/vertical smoothing and sampling difference errors). Some types of comparison error, like the horizontal smoothing difference error, likely contribute to the negative bias at some sites but not all. For some sites, part of the bias and comparison dispersion remains unexplained.

While the QA4ECV and GAIA-CLIM projects have ended, experience and tools developed within are re-used in the ongoing validation of S5p TROPOMI. For example, the validation server from the Validation Data Analysis Facility of the S5p Mission Performance Centre (S5p-MPC-VDAF) is an extended and automated evolution of the QA4ECV validation server. S5p TROPOMI NO$_2$ validation results, both from S5p-MPC-VDAF and from the S5PVT project NIDFORVal (S5P NItrogen Dioxide and FORmaldehyde Validation using NDACC and complementary FTIR and UV-Vis DOAS ground-based remote sensing data) are presented here, using as reference data NDACC MAXDOAS, ZSL-DOAS and direct sun DOAS to validate respectively tropospheric, stratospheric and total NO$_2$ column.