Tropospheric NO$_2$ retrieved from OMI, GOME(-2), and SCIAMACHY within the Quality Assurance For Essential Climate Variables (QA4ECV) project: retrieval improvement, harmonization, and quality assurance

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One of the prime targets of the EU-project Quality Assurance for Essential Climate Variables (QA4ECV, www.qa4ecv.eu) is the generation and subsequent quality assurance of harmonized, long-term data records of ECVs or precursors thereof. Here we report on a new harmonized and improved retrieval algorithm for NO$_2$ columns and its application to spectra measured by the GOME, SCIAMACHY, OMI, and GOME-2(A) sensors over the period 1996-2016. Our community ‘best practices’ algorithm is based on the classical 3-step DOAS method. It benefits from a thorough comparison and iteration of spectral fitting and air mass factor calculation approaches between IUP Bremen, BIRA, Max Planck Institute for Chemistry, KNMI, WUR, and a number of external partners.

For step 1 of the retrieval, we show that improved spectral calibration and the inclusion of liquid water and intensity-offset correction terms in the fitting procedure, lead to 10-30% smaller NO$_2$ slant columns, in better agreement with independent measurements. Moreover, the QA4ECV NO$_2$ slant columns show 15-35% lower uncertainties relative to earlier versions of the spectral fitting algorithm. For step 2, the stratospheric correction, the algorithm relies on the assimilation of NO$_2$ slant columns over remote regions in the Tracer Model 5 (TM5-MP) chemistry transport model. The representation of stratospheric NO$_2$ in the model is improved by nudging towards ODIN HNO$_3$:O$_3$ ratios, leading to more realistic NO$_2$ concentrations in the free-running mode, which is relevant at high latitudes near the terminator. The coupling to TM5-Mass Parallel also allows the calculation of air mass factors (AMFs, step 3) from a priori NO$_2$ vertical profiles simulated at a spatial resolution of 1°×1°, so that hotspot gradients are better resolved in the a priori profile shapes. Other AMF improvements include the use of improved cloud information, and a correction for photon scattering in a spherical atmosphere. Preliminary comparisons indicate that the new QA4ECV tropospheric NO$_2$ columns are ±10% lower than operational products, and provide more spatial detail on the horizontal distribution of NO$_2$ in the troposphere.

Our comparisons provide more insight in the origin and nature of the retrieval uncertainties. The final QAECV NO$_2$ product therefore contains overall uncertainty estimates for every measurement, but also information on the contribution of uncertainties of each retrieval sub-step to the overall uncertainty budget. We conclude with a presentation of the data format and a verification of the QA4ECV NO$_2$ columns using the traceable quality assurance methodologies developed in the QA4ECV-project, and via validation against independent measurements (using the online QA4ECV Atmospheric Validation Server tool).