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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

K. Folkert Boersma (1,2) and the QA4ECV NO_2 Team

(1) Royal Netherlands Meteorological Institute, Climate Observations Department, De Bilt, The Netherlands (boersma@knmi.nl), (2) Wageningen University, Meteorology and Air Quality Group, Wageningen, The Netherlands, (3) Belgian Institute for Space Aeronomy, Brussels, Belgium, (4) University of Bremen, Institute of Environmental Physics, Bremen, Germany, (5) Max Planck Institute for Chemistry, Mainz, Germany, (6) Science [&] Technology Corporation, Delft, The Netherlands

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_y 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 $1^\circ \times 1^\circ$, 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 $\pm 10\%$ 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).