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Impact of 3D cloud structures on tropospheric NO_2 column measurements from UV-VIS sounders

Huan Yu[1], Arve Kylling[2], Claudia Emde[3], Bernhard Mayer[3], Michel Van Roozendael[1], Kerstin Stebel[2], and Ben Veihelmann[4]

[1]Belgian Institute for Space Aeronomy, UV-Vis Team, Brussels, Belgium (yuhuan@aeronomie.be)
[2]Norwegian Institute for Air Research (NILU), Kjeller, Norway
[3]Ludwig Maximilians-University (LMU), Meteorological Institute, Munich, Germany
[4]ESA-ESTEC, Noordwijk, the Netherlands

Operational retrievals of tropospheric trace gases from space-borne spectrometers are made using 1D radiative transfer models. To minimize cloud effects generally only partially cloudy pixels are analysed using simplified cloud contamination treatments based on radiometric cloud fraction estimates and photon path length corrections based on oxygen collision pair (O2-O2) or O2A-absorption band measurements. In reality, however, the impact of clouds can be much more complex, involving unresolved sub-pixel clouds, scattering of clouds in neighbouring pixels, and cloud shadow effects, such that 3D radiation scattering from unresolved boundary layer clouds may give significant biases in the trace gas retrievals. In order to quantify this impact, we use the MYSTIC 3D radiative transfer model to generate synthetic data. The realistic 3D cloud fields, needed for MYSTIC input, are generated by the ICOsahedral Non-hydrostatic (ICON) atmosphere model for a region including Germany, the Netherlands and parts of other surrounding countries. The retrieval algorithm is applied to the synthetic data and comparison to the known input trace gas concentrations yields the retrieval error due to 3D cloud effects.
In this study, we study NO2, which is a key tropospheric trace gas measured by TROPOMI and the future atmospheric Sentinels (S4 and S5). The work starts with a sensitivity study for the simulations with a simple 2D box cloud. The influence of cloud parameters (e.g., cloud top height, cloud optical thickness), observation geometry, and spatial resolution are studied, and the most significant dependences of retrieval biases are identified and investigated. Several approaches to correct the NO2 retrieval in the cloud shadow are explored and ultimately applied to both synthetic data with realistic 3D clouds and real observations.