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Comparison of two profile retrieval algorithms for MAX-DOAS: tropospheric profiles of NO_2, HCHO and aerosols obtained from four years of observations in China

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Spectral measurements (UV/VIS) of scattered sunlight with a Multi-Axis Differential Optical Absorption Spectroscopy (MAX-DOAS) instrument can be used for the detection of trace gases and aerosols in the troposphere. Many studies in the last decade have demonstrated that tropospheric columns can be retrieved with relatively high accuracy ($\sim$10%). The quality of retrieved vertical profile estimates is less well known, partly because profile retrieval is more challenging (the information content is limited, a-priori assumptions play an important role), but also because long term data sets which could serve as reference (golden standard) in a comparison do not exist.

In order to quantify the uncertainties related to the MAX-DOAS profile retrieval, we compared two very different profile retrieval algorithms. The first (method A, BIRA) describes tropospheric profiles with 13 layers and uses the optimal estimation approach in combination with on-line radiative transfer simulations. The second (method B, KNMI) uses a profile shape parameterization with between 2 and 4 free parameters (depending on circumstances), a look-up table and least-squares optimization.

Both algorithms are applied to a four year data set of MAX-DOAS observations done in China (Beijing and Xianghe). By comparing results for different atmospheric constituents (NO_2, HCHO, aerosols) it is possible to discriminate between effects which are general (and possibly related to the retrieval method) and effects which are more specific to one particular constituent. For example: we find systematic differences for tropospheric HCHO columns (10%) but not for NO_2 (constituent-specific results); with method A no profiles are found with a height(*) above 1.5 km (general result).

The dynamic range of profile heights retrieved with method B is larger than with method A, especially for HCHO. This reflects the fact that the information content is higher in the Vis (NO_2) than in the UV (HCHO). The finding that profile heights retrieved with method B are systematically lower in the morning than in the afternoon (not only for HCHO, but also for NO_2 and for aerosols) suggests that the variations are not completely random, but roughly in agreement with the expected dynamics of the cloud free boundary layer. It is interesting to note that the dynamic range of near-surface concentrations is much more in agreement between the two methods.

A general conclusion is that method A is more stable (precise) than method B, which is a consequence of the optimal estimation approach in combination with a relatively low estimate for the a-priori uncertainty. This stability is especially advantageous for tropospheric columns (and aerosol optical thickness) and near-surface concentrations, which are relatively independent of the a-priori. A disadvantage of method A is that the profile height is more dependent on the a-priori, especially in the UV. Profile heights obtained with method B are generally less precise, but could on average have a higher accuracy. This is however to be confirmed by independent observations in future (preferably long-term) validation campaigns.

(*) footnote:
With profile heights, we mean the height below which 75% of the integrated tropospheric column resides.