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Development of a cloud-screening method for MAX-DOAS measurements

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In recent years, ground-based multi-axis differential absorption spectroscopy (MAX-DOAS) has shown to be ideally suited for the retrieval of tropospheric trace gases and deriving information on the aerosol properties. These measurements are invaluable to our understanding of the physics and chemistry of the atmospheric system, and the impact on the Earth's climate.

Unfortunately, MAX-DOAS measurements are often performed under (partially) cloudy conditions, causing data quality degradation and higher uncertainties on the retrievals. A high aerosol load and/or a strong cloud cover can introduce additional photon absorption or multiple scattering. The first effect strongly impacts the retrieved differential slant columns (DSCDs) of the trace gases, leading to an underestimation of the atmospheric column density. Multiple scattering, on the other hand, becomes important for low clouds with a high optical depth, and cause a strong increase in the retrieved trace gas DSCDs.

The presence of thin clouds can furthermore introduce a degeneracy in the retrieved aerosol optical depth, since they will have similar effect on the MAX-DOAS measurements. In this case, only information on the trace gas DSCDs can be successfully retrieved. If the cloud cover consists of broken or scattered clouds, the MAX-DOAS method becomes very unstable, since the different elevation angels will probe regions of the sky with strongly deviating properties.

Here we present a method to qualify the sky and cloud conditions, using the colour index and O_4 DSCDs, as derived from the MAX-DOAS measurements. The colour index is defined as the ratio of the intensities at the short- and long-wavelength part of the visible spectral range, typically at 400 nm and 670 nm. For increasing optical thickness due to clouds or aerosols, the colour index values decrease and values for different elevation angles converge. In the case of broken clouds, the colour index shows a strong and rapid temporal variation, which is easily detectable.

Additional information is derived from the O_4 DSCD measurements, since they are quite sensitive to the change of the light paths due to scattering at different altitudes. For example, thick clouds at low altitude show a very strong increase in the DSCD values due to scattering, combined with a low colour index value due to the intensity screening.

In general, our method shows promising results to qualify the sky and cloud conditions of MAX- DOAS measurements, without the need for other external cloud-detection systems such as Brewer instruments or pyrheliometers.