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Improving the detection limit of airborne NO_2 remote sensing by using DOAS in a wide spectral window

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Airborne imaging spectrometers such as the Airborne Prism Experiment (APEX) instrument can be used for mapping the spatial distribution of air pollutants such as nitrogen dioxide (NO_2) with a high spatial resolution of a few tens of meters. The detection limit of the NO_2 retrieval is limited by the signal-to-noise ratio (SNR) and other characteristics of the sensor. For airborne imaging spectrometers the SNR can be small, because the radiance signal obtained for a combination of small ground pixel and short observation time is small. As a result, NO_2 fitting errors can be large and the detection limit correspondingly low.

Here we demonstrate that the detection limit for NO_2 can be improved if the DOAS fit is applied to a wide spectral window from 410 to 510 nm. However, retrieving over such a wide window required several modifications of the standard DOAS approach. In particular, we replaced the standard low-order polynomial with a cubic spline and computed wavelength-dependent air mass factors instead of a single air mass factor with the SCIATRAN radiative transfer model. The algorithm was implemented with a new custom-made library flexDOAS which allows for flexible development of DOAS retrievals in Python and supports non-linear parameter fitting and integration of a priori information.

The retrieval was tested both with synthetic spectra and applied to real observations from an APEX campaign conducted over Zurich. For the retrieval with wide spectral window (410-510 nm), the fitting error was significantly reduced by about 20% compared to a retrieval with a narrow window (470-510 nm).

In conclusion, fitting over a wider spectral window has the potential to significantly reduce the fitting error and thereby improve the detection limit but requires a more advanced treatment of the smooth background radiance and the application of wavelength-dependent air mass factors.