AIRBORNE IMAGING DIFFERENTIAL OPTICAL ABSORPTION SPECTROSCOPY: TRACE-GAS MEASUREMENT FROM THE SUBURBS TO THE SUB-CONTINENT

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1. INTRODUCTION

The satellite instruments SCIAMACHY, OMI and GOME-2 show high time-averaged tropospheric NO_2 vertical column densities over the South African Highveld, a region with a high density of coal-fired power generation facilities and other heavy industries. In order to further investigate this feature of the satellite record, a nadir-viewing UV-Visible passive imaging spectrometer was constructed and flown on board an aircraft. The wavelength range of the spectrograph includes differential absorption structures of trace gases relevant to air quality such as SO_2, NO_2, HCHO, O_4, O_3, H_2O.

2. INSTRUMENT

The instrument operates in the so-called pushbroom geometry, imaging one across-track line of pixels simultaneously. The sunlight entering the instrument is dispersed by a Czerny-Turner imaging spectrograph and recorded on a CCD. Spectral dispersion occurs in one dimension of the CCD; the perpendicular direction of the CCD represents the across-track spatial dimension. Spectral resolution is determined by the spectrograph optics, and by the pixel spacing on the CCD relative to the wavelength range. Across-track resolution is determined by the optical system. Along-track spatial resolution is determined by the aircraft's ground speed and the integration time of the instrument. Spatial resolution under typical flight conditions is less than 100 metres in both the across-track and along-track directions.

3. RETRIEVAL ALGORITHM

Trace gas slant columns are retrieved from spectral data using the differential optical absorption spectroscopy (DOAS) technique[1]. Differential absorption structures are broad-band absorption features, unique to each trace gas. A Levenberg-Marquhart non-linear least-squares fitting algorithm fits the known differential absorption structures of the trace gases to the measured spectra from the instrument. The scaling factor of each differential structure determines the so-called slant column density.

4. RADIATIVE TRANSFER

Owing to multiple scattering effects in the atmosphere, the actual light path from the sun to the instrument is longer than the geometric light path. A reverse Monte-Carlo spherical-shell radiative transfer model is used to determine the ratio of the true light path to the geometric light path. This ratio is called the air-mass factor (AMF). The shell AMF's are used to determine the the more useful vertical column density from the slant column density. The radiative transfer model accounts for vertical profiles of aerosols and trace gases in the atmosphere.

5. RESULTS

Three measurement campaigns were flown over the South African Highveld between 2006 and 2008[2]. Flights were planned to validate satellite measurements, to measure trace-gas distributions on a regional scale, and to investigate emissions from point, area, and line sources. Direct comparison of the airborne instrument to the satellite data indicates that the satellite instruments can be used to make an accurate assessment of the NO_2 over the Highveld, provided their various limitations are understood.

Simple flux estimates are made of emissions from individual industies, from the city of Johannesburg and of the Highveld as a whole. Despite their lack of sophistication, these estimates appear to give reasonable results.

The high spatial resolution of the instrument combined with the mobility of the aircraft platform allows measurement on spatial scales from street level to the sub-continent. This allows identification of plumes from individual stacks, from line sources such as roads, and direct observation of trace-gas distributions at high spatial resolution.

6. OUTLOOK

Future developments of the technology include improvements to the optics and CCD detector, refinement and validation of flux estimates and modifications to the viewing geometry.

7. REFERENCES

[1] U. Platt and J. Stutz, *Differential Optical Absorption Spectroscopy*, Springer-Verlag, Berlin, Heidelberg, 2008.

[2] K.-P. Heue, T. Wagner, S.P. Broccardo, D. Walter, S.J. Piketh, K.E. Ross, S. Beirle, and U. Platt, "Direct observation of two dimensional trace-gas distributions with an airborne imaging DOAS instrment," *Atmos. Chem. Phys.*, vol. 8, pp. 6707–6717, 2008.