GOME measurements of SO_2

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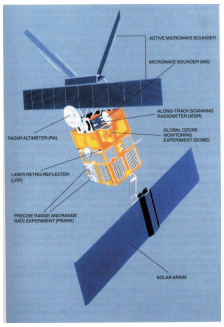
Introduction

Sulphur Dioxide (SO2) is an important trace species in the atmosphere, both under background conditions and in polluted areas. It is released to the troposphere mainly by fossil fuel combustion, volcanic emissions and oxidation of organic material in soils as well as biogenic emissions over the oceans (DMS, H2S). In the last years, anthropogenic emissions in Europe and the US have been reduced through switching to cleaner fuels and reductions in coal use. At the same time, economic decline in Eastern Europe has also reduced SO2 emissions. However, burning of "dirty" coal in China has significantly increased and now is a major source of tropospheric SO2.

SO2 can be monitored from the ground by absorption spectroscopy, and also from space with the TOMS instrument. Using data from the Global Ozone Monitoring Experiment (GOME), a much more sensitive retrieval for atmospheric SO2 can be performed, and SO2 from volcanic eruptions, continuous outgasing and anthropogenic emissions can be monitored. in this paper, the sensitivity of GOME measurements to SO2 is stud-

GOME Instrument



The *Global Ozone Monitoring Experiment* (GOME) is a grating spectrometer observing light scattered back by the atmosphere and reflected from the ground in a near nadir viewing geometry. GOME covers the spectral range of 240 to 790 nm with 0.2 - 0.4 nm resolution. The spatial resolution is 320 x 40 km2, resulting in a global coverage every three days. The instrument has been launched on ERS-2 in a polar sun-synchronuous orbit in April 1995, and is operational since fall of that year.

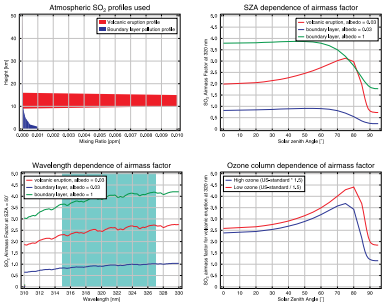
Using the *Differential Optical Absorption Spectroscopy* (DOAS) technique, a number of atmospheric trace gases can be retrieved from the spectra, including O_3, NO_2, BrO, OClO, SO_2, HCHO, and H_2O. In the absence of clouds, a large part of the photons observed by GOME have penetrated down to the troposphere, and global maps of tropospheric concentration fields can be derived from the measurements.

Due to the large pixel size, the spatial resolution of the data sets is limited, and also only (local) mid-morning measurements are available as a result of the ERS-2 orbit. To overcome these limitations, a geostationary observing platform is required as recently proposed in the GEOSCIA-project.

Sensitivity Studies

The sensitivity of the GOME measurements towards absorptions by a species are usually given as an airmass factor (AMF) that in first approximation gives the ratio between the column integrated along the light path and the vertical column. Large AMF correspond to high sensitivity, small AMF to small sensitivity. Here, for two different vertical profiles representing a volcanic SO2 plume and anthropogenic pollution the dependence of AMF on wavelength, surface albedo and O3 column has been explored.

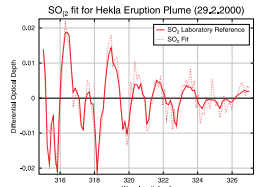
As shown in the figures, volcanic eruptions can usually be observed with much higher sensitivity than SO2 in the boundary layer.



Sensitivity to the boundary layer depends strongly on surface albedo and can be large over snow and ice. As a result of strong Rayleigh scattering and increasing O3 absorption, the AMF depends strongly on wavelength, even within the selected fitting window. It also depends on the stratospheric O3 column, in particular at large SZA.

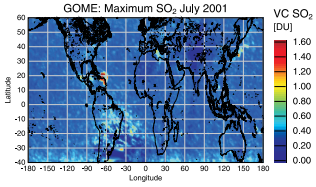
Analysis Procedure

SO2 is retrieved using the Differential Optical Absorption (DOAS) technique. GOME earth shine spectra are fitted relative to the solar irradiance measurements using the fitting window 315 - 327 nm. In addition to SO2, Ozone at two temperatures and the Ring effect are included in the analysis. An example of the fit results for a volcanic SO2 plume is shown in the upper figure.

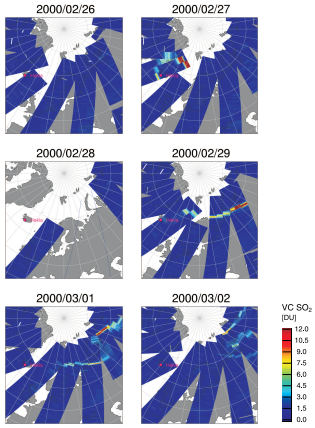


As ozone absorptions are large in this spectral region, the largest error is introduced by residual structures from the ozone fit. As a result, GOME SO2 retrieval is difficult at low sun found in measurements at high latitudes in winter. The SO2 retrieval is also sensitive to perturbations in the SAA region over Southern America.

An example of a global GOME SO2 retrieval is shown in the lower plot. Please note, that not the average value, but the largest value measured during the whole month is plotted. This is also true for all other GOME plots shown on this poster.



Eruption of Hekla, Feb. 2002



In February 2002, the Hekla volcano on Island erupted, emitting large quantities of SO2 into the atmosphere. The SO2 plume first moved towards Greenland, then turned and extended towards Russia. Interestingly, it then turned again to the North and was last detectable by GOME on March 2nd, in good agreement with preliminary results from the FLEXTRA model (A. Stohl, private communication).

The eruption was also monitored by TOMS (Krueger et al., private communication), giving a much better spatial resolution but losing track of the plume after three days as a result of the lower sensitivity. Measurements from both instruments are currently being compared to establish the degree of agreement.

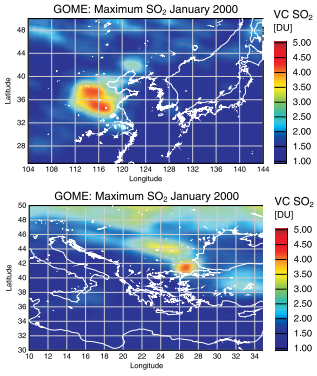
In the GOME data analysis, the simple "volcanic eruption" airmass factor has been used as discussed above, neglecting changes in altitude and the possible influence of the ash in the plume on the light path. This first estimate is currently being refined.

SO_2 from pollution

SO2 from tropospheric pollution is much more difficult to detect than volcanic SO2 as in the UV only a small part of the photons collected by the satellite instrument have actually probed the boundary layer. Therefore, anthropogenic SO2 can mainly be retrieved if the concentrations are high or if surface albedo is large, for example over snow.

In the figures, two examples are shown for anthropogenic SO2, one over China in spring and the second one over Eastern Europe. In both cases, burning of coal is probably the source of the observed SO2.

In GOME data, the SO2 columns above China in winter are always largest, but SO2 can sometimes also be observed above the US, the Arabian Peninsula, parts of Russia and South Africa..



Conclusions

GOME measurements of SO2 can be used to monitor both volcanic activity and anthropogenic pollution on a global scale with high sensitivity. Some more work needs to be done to account for the dependence of the sensitivity on layer height and surface albedo.

Acknowledgements

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see also: www.iup.physik.uni-bremen.de

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