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# SCIAMACHY Measurements of tropospheric $SO_2$

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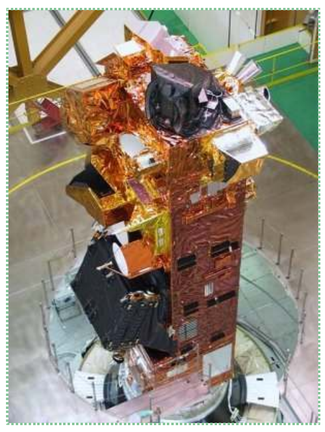
## Introduction

In the last years, more and more measurements of atmospheric species from space have become available. The Global Ozone Monitoring Experiment (GOME) launched on ERS-2 in April 1995 has been one of the most successful instruments of this kind. Although primarily designed to deliver total ozone columns, measurements from the GOME instrument have been used to determine columns of $NO_2$, BrO, OClO, $SO_2$, HCHO, $H_2O$ and also vertical profiles of $O_3$.

In March 2002, the SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) was launched on board of ENVISAT. This instrument is in many respects an extended version of GOME, providing better spatial resolution, a wavelength range that extends into the NIR and most importantly the ability to measure alternatingly vertical profiles in the stratosphere and nadir columns.

In this poster, global tropospheric $SO_2$ columns derived from SCIAMACHY nadir measurements are presented, some aspects of the sensitivity of the measurements are discussed and illustrated for the eruption of the Sierra Negra volcano in October 2005.

## SCIAMACHY Instrument

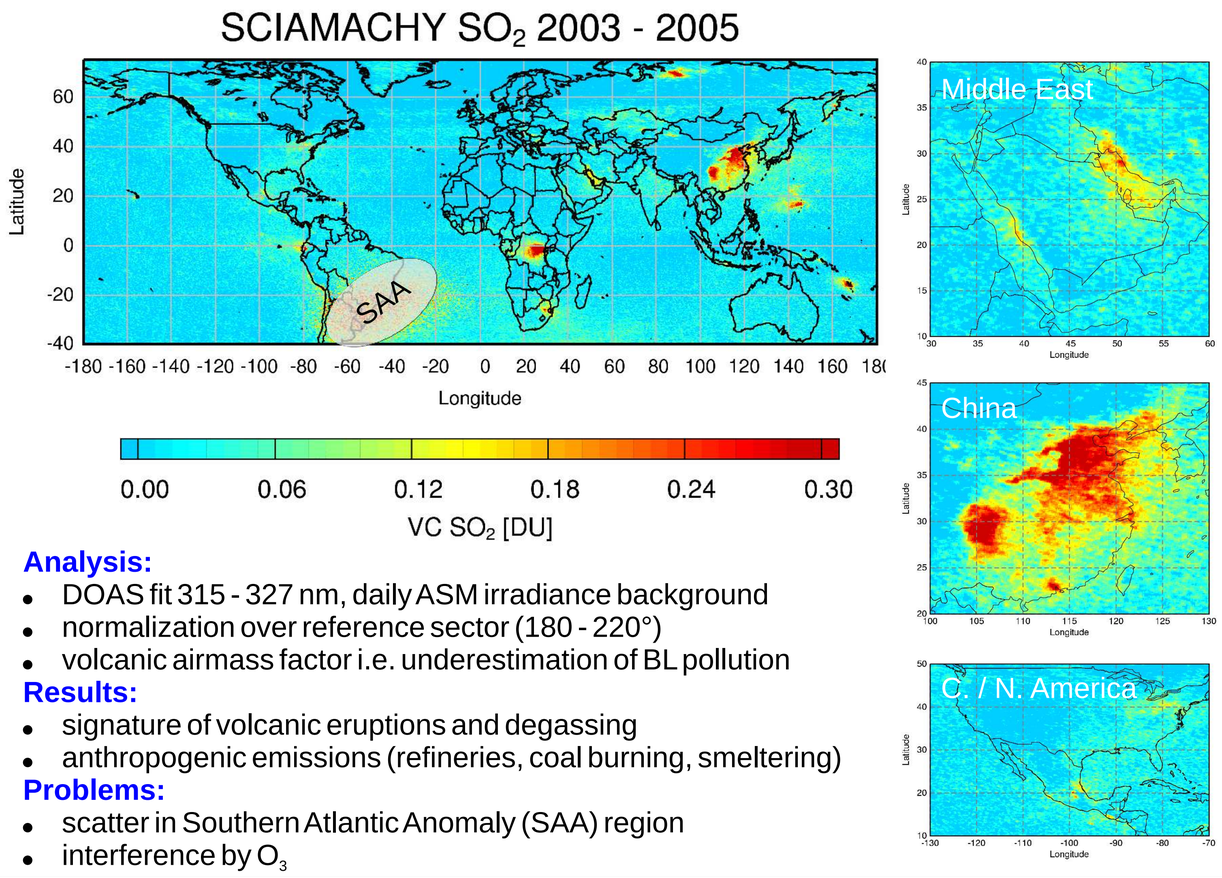


The SCIAMACHY instrument is a 8 channel grating spectrometer measuring in nadir, limb, and occultation (both solar and lunar) geometries. SCIAMACHY covers the spectral region from 220 to 2400 nm with a spectral resolution of 0.25 nm in the UV, 0.4 nm in the visible and less in the NIR. The size of the nadir ground-pixels depends on wavelength range and solar elevation and can be as small as 30 x 30 $km^2$. The instrument was launched on ENVISAT in a sun-synchronuous orbit on March 1st, 2002 and is in nominal operation since August 2002.

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 SCIAMACHY in the nadir have penetrated down to the troposphere, and global maps of tropospheric concentration fields can be derived from the measurements.

Compared to GOME, the SCIAMACHY instrument has improved spatial resolution and the ability to measure stratospheric profiles. At the same time, nadir coverage is reduced by a factor of two as result of the time sharing between nadir and profile measurements.

## $SO_2$ - The Global Picture




**Analysis:**

- DOAS fit 315 - 327 nm, daily ASM irradiance background
- normalization over reference sector (180 - 220°)
- volcanic airmass factor i.e. underestimation of BL pollution

**Results:**

- signature of volcanic eruptions and degassing
- anthropogenic emissions (refineries, coal burning, smeltering)

**Problems:**

- scatter in Southern Atlantic Anomaly (SAA) region
- interference by $O_3$

## The Sierra Negra Eruption

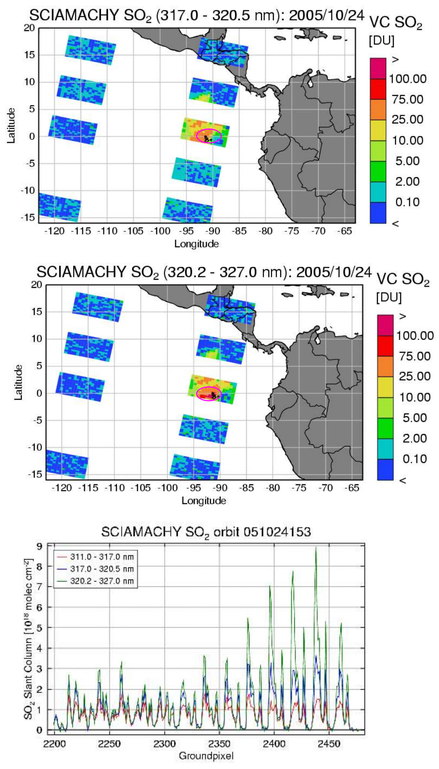
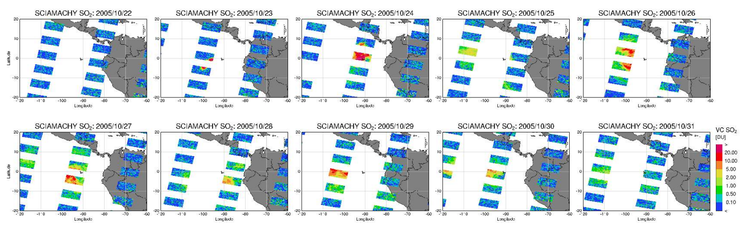



**Figure:** Wavelength dependence of retrieved $SO_2$ columns. Note the missing plume in the upper plot



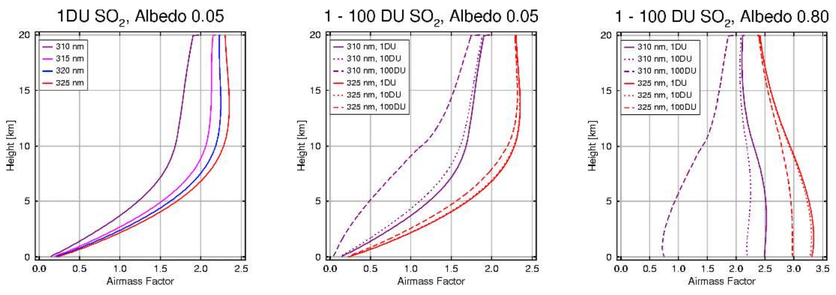

**Observations**

- Sierra Negra Volcano, Galapagos Islands
- large eruption on October 22nd, 2005
- largest $SO_2$ columns ever observed in the GOME / SCIAMACHY record
- more than 100 DU maximum column
- many scenes at least partially cloud contaminated

**Analysis**

- fit in standard fitting window (315 - 327 nm) fails as absorption structures have different depth at different wavelengths
- observed slant column depends strongly on wavelength
- region with largest $SO_2$ columns not resolved in UV fit
- from the observed ratio, one can estimate that a large fraction of the $SO_2$ was located below 5 km altitude

## Measurement Sensitivity




**Settings:**

- nadir viewing
- 1 / 10 / 100 DU $SO_2$ well mixed in lowest 10 km
- no aerosols
- surface albedo> 5% / 80%
- 40° SZA

- As result of the strong Rayleigh scattering in the UV, measurement sensitivity decreases strongly towards the surface over dark scenes.
- For the same reasons, sensitivity decreases towards the UV.
- For large column amounts of $SO_2$, absorption by $SO_2$ itself becomes important and the sensitivity decreases for the lower atmospheric layers.
- This effect is independent of surface albedo, although the absolute sensitivity is much larger over bright surfaces (or clouds).
- By looking at the ratio of $SO_2$ columns retrieved at different wavelengths, some information on the vertical distribution can be obtained in the case of large $SO_2$ columns.

## Conclusions

- $SO_2$ column retrieval from SCIAMACHY measurements is possible.
- The resulting maps show a wealth of details on both volcanic eruptions and boundary layer pollution from coal burning, refineries and smeltering.
- The vertical sensitivity of the measurements depends critically on surface albedo.
- At very large $SO_2$ columns, penetration depth in the UV is strongly reduced, providing some profile information.
- The Sierra Negra eruption on October 22nd, 2005 produced the largest $SO_2$ signal measured so far by GOME and SCIAMACHY.
- The wavelength effect is clearly visible in the data withstrongly reduced columns in a fitting window shifted to the UV.
- Preliminary analysis of the data indicates that the bulk of the $SO_2$ was located below 5 km.
- For atmospheric applications, the lack of coverage in space and time by SCIAMACHY nadir measurements is the largest obstacle. This can be solved by using geostationary platforms.

## Acknowledgements

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