COMPARISONS OF SCIAMACHY SULFUR DIOXIDE OBSERVATIONS

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ABSTRACT

First results from two algorithms for the retrieval of SO_2 total columns from SCIAMACHY nadir measurements are presented. The algorithms, which were developed at the Belgian Institute for Space Aeronomy (BIRA) and the Institute of Environmental Physics (IUP) at the University of Bremen, respectively are both able to detect volcanic emissions and strong pollution events. Comparison with results from applying the same methods to SCIAMACHY's precursor instrument GOME show good agreement.

Key words: SCIAMACHY, SO2 column, DOAS.

1. INTRODUCTION

The largest anthropogenic source of sulfur dioxide is the combustion of fossil fuels. Strong, but localised and episodic natural sources of sulfur dioxide are volcanic eruptions. In the troposphere, SO_2 has a limited lifetime of a few days due to chemical reaction mainly with OH. Clean continental air contains less than 1 ppb SO_2. In the lower stratosphere, the lifetime is in the order of several weeks (Eisinger, 1998).

The SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY) instrument onboard EnviSat measures the sunlight reflected, backscattered or transmitted by the Earth's atmosphere in the ultraviolet, visible and near-infrared spectral regions (Bovensmann, 1999). Sulphur dioxide is a minor trace gas having absorption lines in the ultraviolet region between 315 nm and 326 nm. The Differential Optical Absorption Spectroscopy-Method (DOAS) (Richter, 1998; Van Roozendael, 1999) can be used to determine the column of SO_2 in the atmosphere from SCIAMACHY nadir measurements. The current operational implementation of the SCIAMACHY Near-Real-Time (NRT) processor (Ver. 5.01) is not able to provide reliable retrievals of SO_2, mainly because a cluster (virtual channel) boundary lying in the SO_2 fitting window cannot be handled. The offline processor (OL) which does not suffer from this limitation is not yet operational for SO_2.

Instead, two scientific implementations for a SO_2 retrieval are used, developed at the Institute of Environmental Physics (IUP) at the University of Bremen, and at the Belgian Institute for Space Aeronomy (BIRA/IASB). Both are using the DOAS method. The fitting interval is 315 nm to 326 nm; as cross-sections for SO_2, ozone and NO_2, the ones measured with SCIAMACHY during the on ground calibration Bogumil (1999) are used. Calculated Ring cross-sections (Vountas, 1998) are also fitted, and a polynomial of fourth order. Both algorithms have additional terms to handle calibration issues which are currently not fully corrected in the SCIAMACHY spectra.

The standard solar spectra measured by using SCIAMACHY's Elevation Scan Mirror Diffuser (ESM Diffuser) cannot be used as reference spectrum for the DOAS fit because they introduce spectral artifacts in the SO_2 fitting window. The BIRA/IASB algorithm uses instead a radiance spectrum taken over the Indian Ocean, where the SO_2 content is supposed to be negligible. The IUP algorithm uses the solar spectra measured with SCIAMACHY's Azimuth Scan Mirror Diffuser (ASM Diffuser). This diffuser was a last minute addition to the SCIAMACHY instrument after discovering the spectral features of the ESM Diffuser.

2. OBSERVATION OF STRONG POLLUTION EVENTS

An unusual and large, anthropogenic source for SO_2 pollution is a fire in a sulphur plant. On June, 25th 2003, a huge fire at the sulphur plant in Qayyarah, Iraq started and continued to burn for most of July. Emissions from this fire lead to severe pollution in the region and were detectable as far as in Iran according to press reports. Figure 1 shows an image composed from SCIAMACHY SO_2 observations from June, 26th to July, 25th 2003, calculated with the IUP algorithm. The plumes along the two main wind directions are clearly visible.

The Nyamuragira volcano, a shield volcano in the

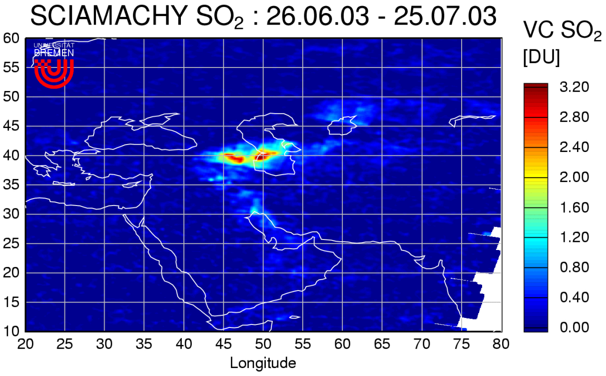

Figure 1. SCIAMACHY observations of the SO_2 emissions from a fire in a sulphur plant (IUP retrieval).

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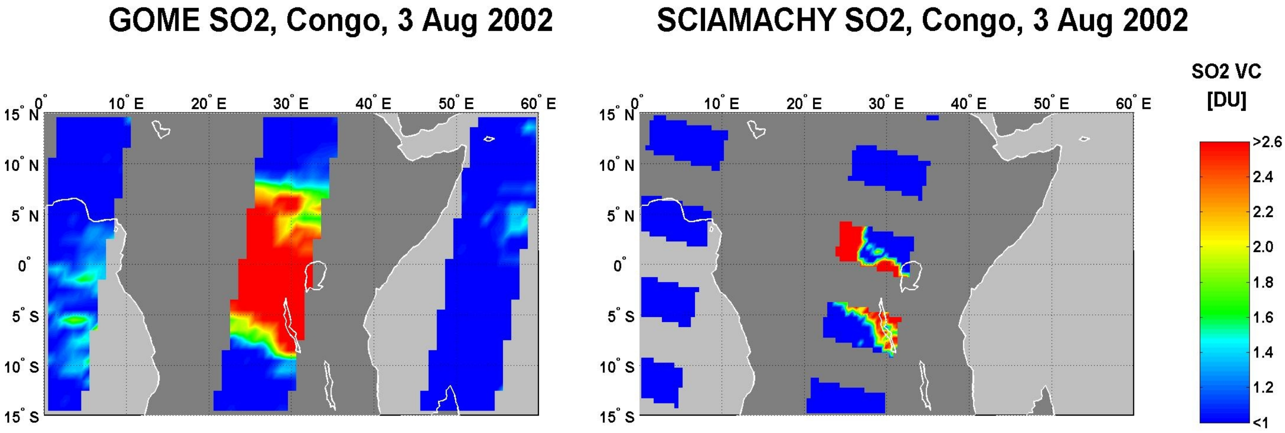

Figure 2. *SO_2 plume of the Nyamuragira volcano (1.4° S, 29.2° E, Congo), observed by GOME (left plot) and SCIAMACHY (right plot) August, 3rd 2002. The BIRA/IASB algorithm was used to determine the SO_2 columns from both instruments. The results are gridded to 1.0° × °. The large ground-pixels (320 km × 40 km) of GOME lead to an overestimation of the affected area compared to the SCIAMACHY image based on smaller ground-pixels (60 km × 30 km).*

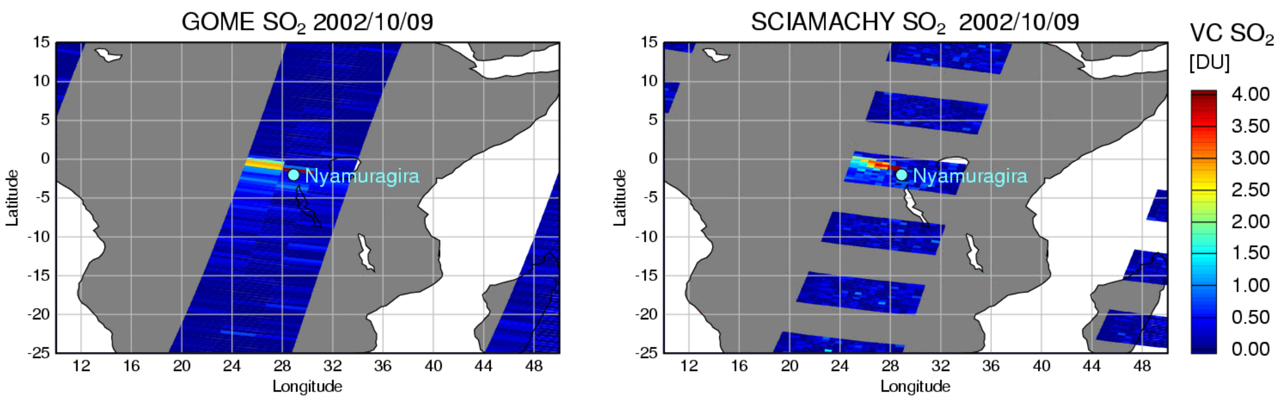

Figure 3. *SO_2 plume of the Nyamuragira volcano (1.4° S, 29.2° E, Congo), observed by GOME (left plot) and SCIAMACHY (right plot) October, 9th 2002. The IUP algorithm was used to determine the SO_2 columns from both instruments. The values for the individual ground-pixels are plotted. While only about three of the large GOME pixels show the SO_2 enhancement, the SCIAMACHY plot gives an impression of the shape of the plume.*

Virunga volcano field, Zaire / Democratic Republic of Congo was active from end of July until September 2002 according to the reports of the *Global Volcanism Network*. Figure 2 shows the SO_2 plume of the volcano on August, 3rd 2002, an very active phase of the volcano as observed by GOME (Burrows, 1999) and SCIAMACHY using the BIRA/IASB algorithm. A large area around the volcano is polluted with SO_2. The large GOME ground-pixels of 320 km × 40 km in conjunction with the interpolation used for the gridded data leads to an overestimation of the polluted area, whereas the SCIAMACHY plot which is based on smaller ground-pixels of 60 km × 30 km gives a more accurate impression of the SO_2 distribution. At the same time, also the disadvantage of SCIAMACHY nadir observations, the gaps between the nadir states used for the limb measurements is obvious.

This eruptive episode of the volcano ended in September. But the observation by GOME and SCIAMACHY still show a SO_2 plume from the volcano area. Figure 3 shows the plume for September, 9th 2002, calculated with the IUP algorithm. The SO_2 columns are much smaller than the ones observed in August. Here, the actual ground-pixels are plotted. Only four GOME pixels show values over 2 DU, whereas the high resolution SCIAMACHY plot gives an impression of the shape of the plume.

Figure 4 shows a composite map (BIRA/IASB) for June 2003, where some SO_2 polluted areas can be identified. Volcanic eruptions can be observed in Ecuador, Congo, and the Indian Ocean. Anthropogenic pollution is observed in China in the region around Beijing and Shanghai and in the northeast of the United States. Also the effect of the South Atlantic anomaly is clearly visible as scattered values over the South Atlantic and South America.

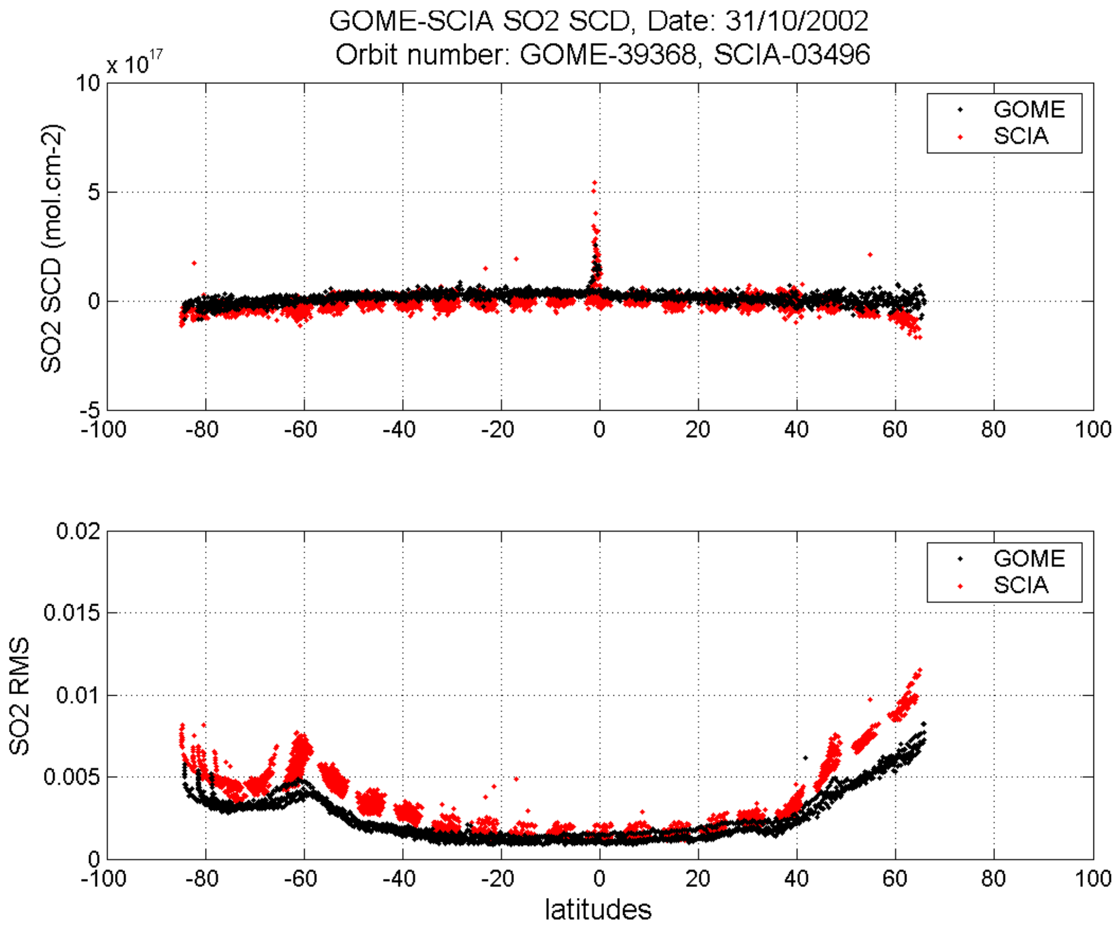

Figure 5. Slant column density of SO_2 and root mean square (RMS) of the fit residual for the corresponding orbits 36368 (GOME) and 3496 (SCIAMACHY).

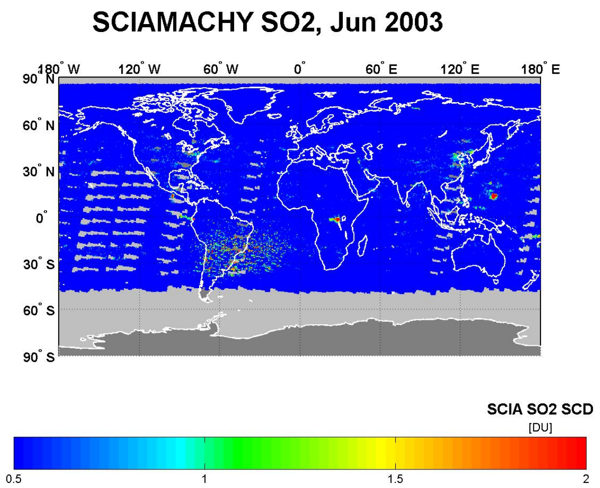

Figure 4. SO_2 column collected from June 2002, as calculated by the BIRA/IASB algorithm. Plumes of volcanos in Ecuador, Congo, and the Indian Ocean are visible. Polluted areas show up in China around Beijing and Shanghai and in the northeast of the United States.

3. COMPARISON WITH GOME

Figure 2 and 3 both show the results for GOME and SCIAMACHY for the corresponding orbit, e.g. with a time difference of 30 minutes between the two instruments. The results are qualitatively the same, if the improved spatial resolution of SCIAMACHY is taken into account. Figure 5 gives a more quantitative insight. Shown is the calculated SO_2 column and the root mean square (RMS) of the DOAS fit residual for corresponding orbits of GOME and SCIAMACHY. Chosen are the GOME orbit 39368 and the SCIAMACHY orbit 3496 from October, 31th 2002. For most of the orbit, both algorithms show values around zero as expected. Near the equator, a peak of up to 5 DU for SCIAMACHY and up to 2.5 DU for GOME can be observed. This is again the SO_2 plume of the Nyamuragira volcano. The smaller ground-pixel size of SCIAMACHY leads to higher values, because the volcano is a small, localised source and covers only a small part of the large GOME ground-pixel. The mean SO_2 column of the most polluted GOME ground-pixel is therefore smaller as for the most polluted SCIAMACHY ground-pixel.

The RMS of the fit is in general higher for SCIAMACHY than for the corresponding GOME calculations indicating that there are still more problems in the SCIAMACHY spectra than in the GOME spectra. This is related to both poorer signal to noise from photon statistics (shorter integration times for smaller ground-pixels) and calibration issues that will hopefully be resolved in future lv1-data products.

Figure 5 is based the BIRA/IASB algorithm, but using the IUP algorithm leads to similar results. Averaged SO_2 columns from corresponding GOME and SCIAMACHY orbits are similar, but the fit residuals from SCIAMACHY are higher.

4. CONCLUSIONS

The two implementations of the DOAS method to retrieve SO_2 columns from SCIAMACHY nadir measurements presented here are able to detect strong pollution events and emissions from volcanic eruptions. This demonstrates the high potential of SO_2 retrieval from SCIAMACHY measurements. Both methods show good agreement with results from GOME, the precursor of SCIAMACHY. Nevertheless, a fully independent validation has not been performed yet because of the lack of independent measurements during strong emission events. GOME results are not fully independent, because they are basically retrieved from the same algorithms.

After optimisation of the settings, similar quality can be expected for the operational products.

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