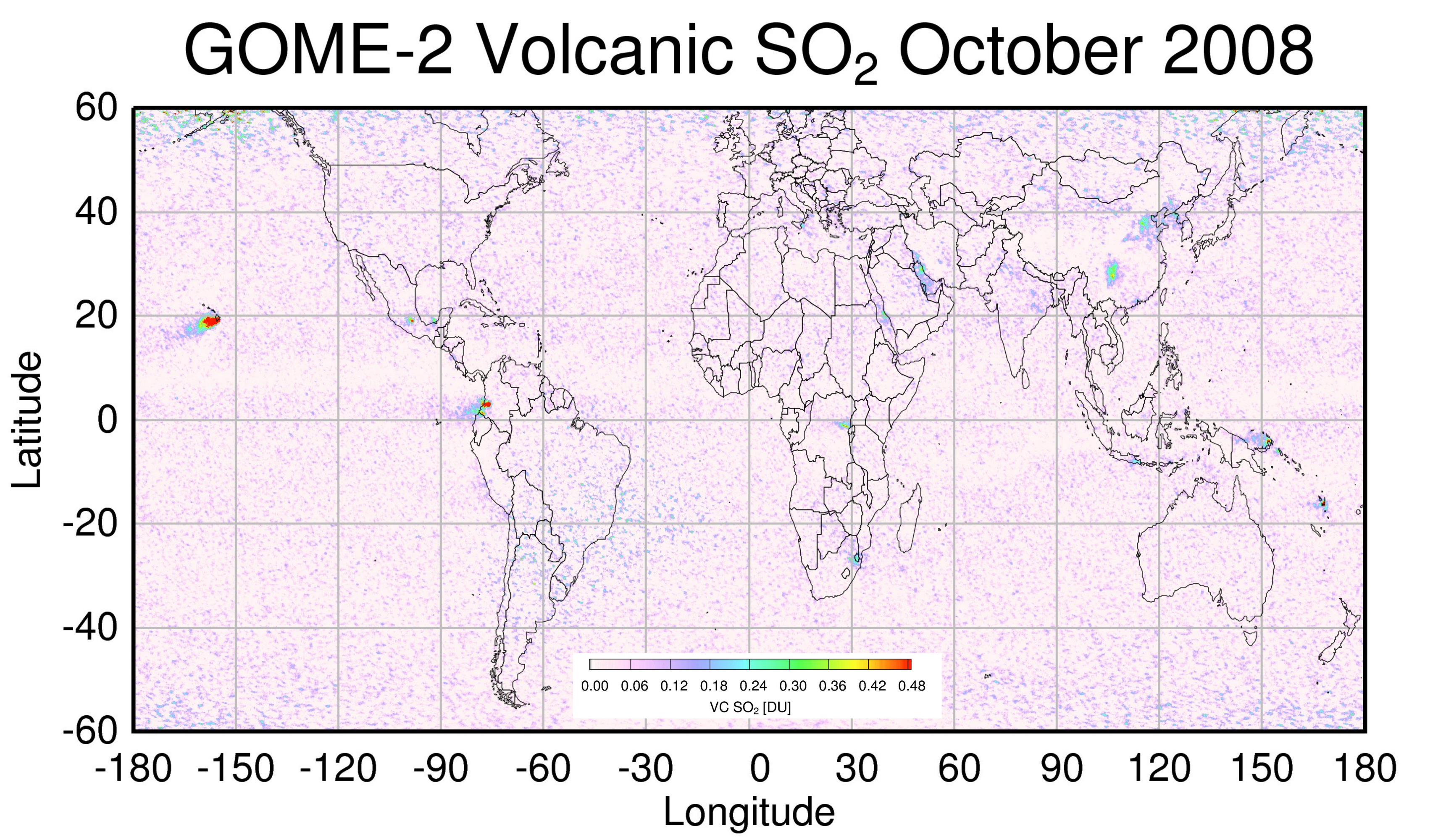
Quantifying volcanic SO_2 emissions using GOME-2 measurements

EGU2009-7679
AS3.15
XY247

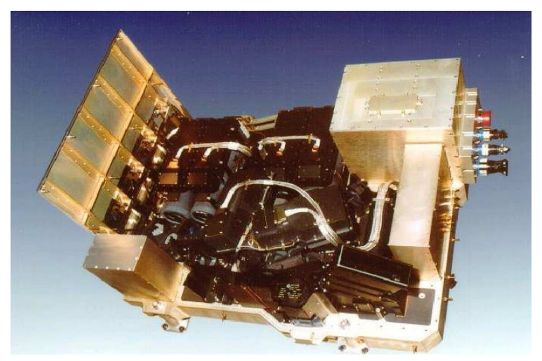
A. Richter, F. Wittrock, A. Schönhardt, and J. P. Burrows
Email: Andreas.Richter@iup.physik.uni-bremen.de
Institute of Environmental Physics/Remote Sensing, University of Bremen, FB 1, P.O. Box 330440, D-28334 Bremen, Germany

Introduction

- volcanoes emit large quantities of ash and trace gases into the atmosphere, including SO_2
- volcanic emissions occur both during eruptions and as degassing albeit at different altitudes
- volcanic eruptions are dangerous for local population
- volcanic SO_2 can lead to acid rain in the troposphere and to aerosol formation in both the troposphere and for high injection altitudes the stratosphere
- this has effects on radiation budget and cloud formation
- ash and sulphuric acid from volcanic eruptions are a hazard for air traffic and early knowledge of plume positions and strengths is relevant for air traffic control
- satellite observations are the only way to provide continuous global data sets for monitoring of volcanic SO_2
- they also can provide important input for air traffic control if delivered in NRT



Instrument and Retrieval



GOME-2 Instrument:

- launched on MetOp-A in October 2006
- data since January 2007
- 4 channel nadir viewing UV/visible spectrometer
- similar to GOME and SCIAMACHY
- first in a series of three identical instruments
- 80 x 40 km^2 pixel size
- global coverage in 1.5 days
- 09:30 LT equator crossing

Analysis:

- **D**ifferential **O**ptical **A**bsorption **S**pectroscopy (DOAS)
- 312.5 - 327 nm fitting window
- offset removal with moving median of values not identified as volcanic peaks
- retrieval using SO_2 slant optical depths computed for different atmospheric SO_2 amounts is iterated until closure to account for nonlinearities at large SO_2 absorption

Results:

- clear signature of volcanic eruptions and degassing in daily maps
- noise level for individual pixels better than 0.5 DU for SZA < 60°
- some anthropogenic signals also discernible (e.g. from coal burning, smeltering, oil production) but fitting window is not optimised for lower troposphere

Problems:

- increasing scatter at SZA > 60°
- scatter in Southern Atlantic Anomaly (SAA) region

Acknowledgements

Funding by ESA under project SAVAA and the University of Bremen is gratefully acknowledged.

Kasatochi Eruption August 2008

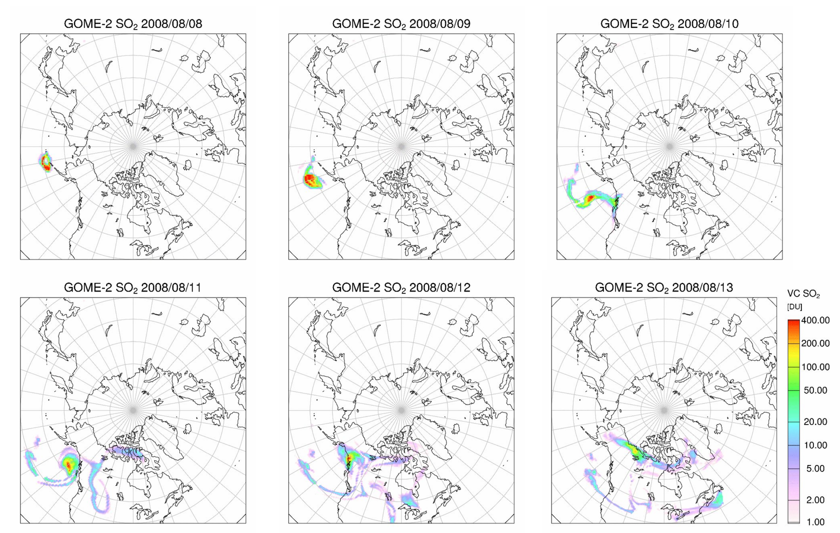


Figure 1: Daily GOME-2 maps of SO_2 after the Kasatochi eruption

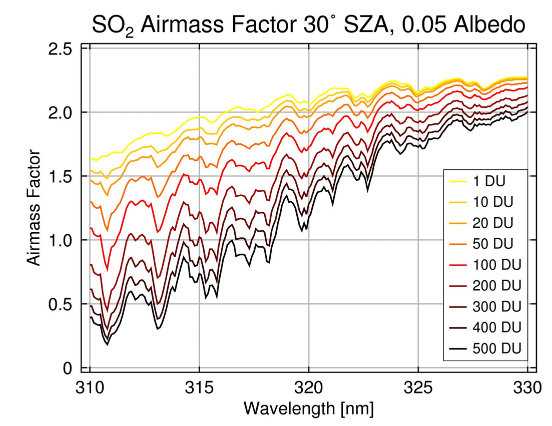


Figure 2: Airmass factors for SO_2 computed for different SO_2 columns located in a layer between 10 and 11 km

- After some weaker activity in the weeks before, on August 8, 2008, the Kasatochi volcano erupted
- Very large amounts of SO_2 were emitted in the upper troposphere and lower stratosphere
- The SO_2 plume travelled over the entire Northern hemisphere with signals still visible after 5 weeks
- Due to the large SO_2 column, a strong non-linearity in the absorption and light path occurred (see Fig. 2)
- Iterative correction of the nonlinearity in the retrieval strongly increased the columns (Fig. 4)
- Estimated total SO_2 mass is 2.5 Tg, larger than reported from OMI measurements (N. Krotkov, personal comm.)

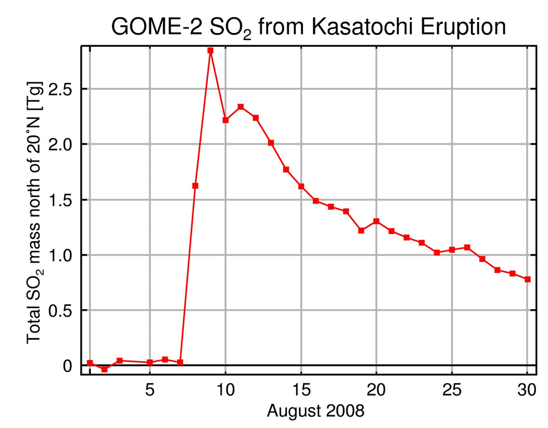


Figure 3: Integrated SO_2 abundance North of 20°N after the Kasatochi eruption. The estimated total SO_2 mass is 2.5 Tg, more than from other estimates.

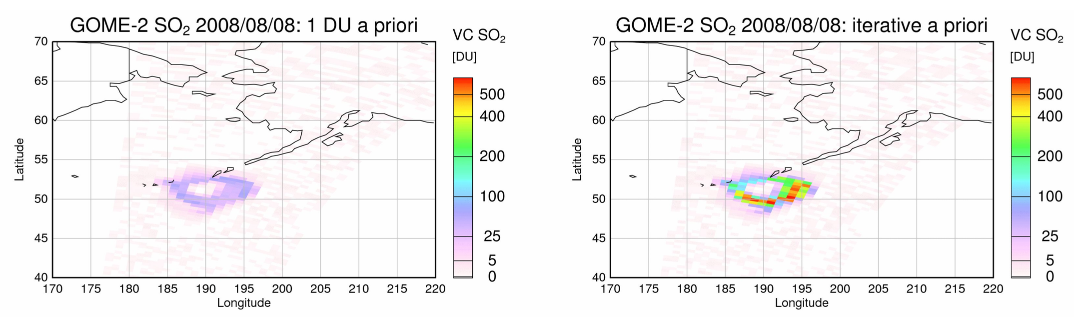


Figure 4: Effect of saturation correction on columns of the first day of observation of the Kasatochi eruption on August 8, 2008. Note the nonlinear colorscale. The estimate of the total SO_2 mass changes from 0.3 Tg to 1.7 Tg.

SO_2 above Hawaii

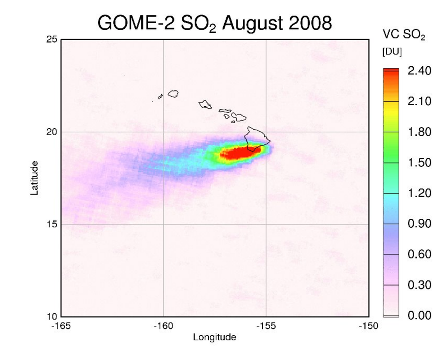


Fig. 5. Average of GOME-2 SO_2 amounts above Hawaii for August 2008

- In 2008, volcanic activity in Hawaii increased significantly leading to enhanced SO_2 emissions and problems for local population
- The SO_2 signal is clearly visible in the GOME-2 data series
- Nonlinearities in the retrieval are small as result of the small columns
- Incomplete sampling of the plume introduces artificial variations which are reduced by selecting only cases with good coverage of the plume
- Conversion of SO_2 amounts to SO_2 emissions depends on atmospheric lifetime of SO_2 and has not yet been performed

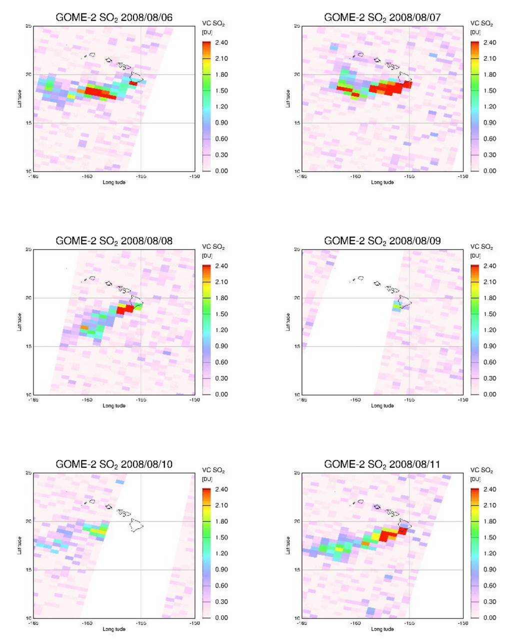


Fig. 6: Daily images of GOME-2 SO_2 measurements above Hawaii illustrating the varying coverage which leads to uneven sampling of the volcanic plume

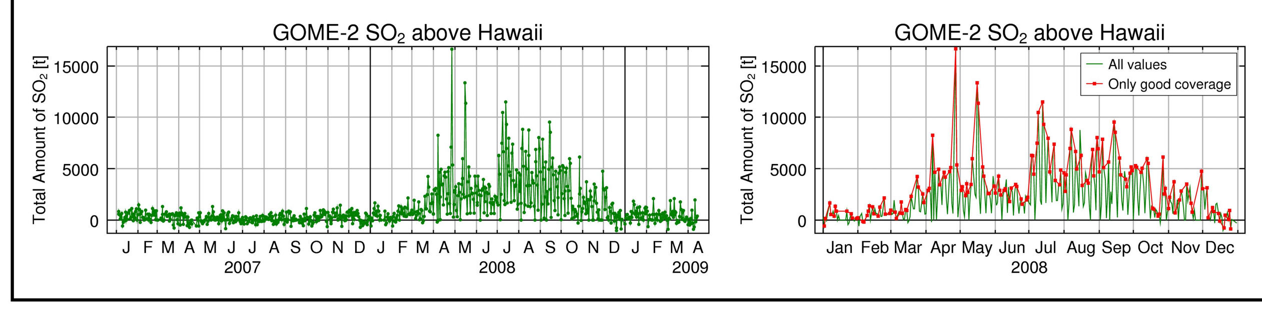


Fig. 7: Daily GOME-2 SO_2 amounts above Hawaii for all data (left figure) showing intense activity in 2008. Right figure: Comparison with those data having good sampling of the plume (in red).

Conclusions

- GOME-2 measurements provide good coverage and low noise data on volcanic SO_2
- For large SO_2 columns, nonlinearities in the absorption and light path have to be taken into account for improved fits and correct columns
- SO_2 from the Kasatochi eruption in August 2008 could be tracked for many weeks in the entire NH
- The total amount of SO_2 emitted is estimated to be 2.5 Tg after correction for nonlinearity, more than reported in other studies
- Analysis of data above Hawaii shows much increased SO_2 emissions in 2008
- Even the relatively small gaps in coverage of GOME-2 lead to artificial variation in estimated SO_2 burden which has to be taken into account
- For more GOME-2 SO_2: **http://www.doas-bremen.de/gome2_so2_alert.htm**

Selected References

Afe, O. T. et al., BrO Emission from Volcanoes - a Survey using GOME and SCIAMACHY Measurements, *Geophys. Res.Lett.*, **31**, L24113, doi:10.1029/2004GL020994, 2004
Eisinger, M., and J. P. Burrows, Tropospheric Sulfur Dioxide observed by the ERS-2 GOME Instrument, *Geophys. Res. Lett.*, No. **25**, pp. 4177-4180, 1998.
Khokhar, M. F., et al., Satellite Observations of Atmospheric SO_2 from Volcanic Eruptions during the Time Period of 1996 to 2002, *Advances in Space Research*, **36**(5), 879-887, 10.1016/j.asr.2005.04.114, 2005
Krotkov, N. A et al., (2006), Band residual difference algorithm for retrieval of SO_2 from the Aura Ozone Monitoring Instrument (OMI), *IEEE Transac. Geosci. Remote Sensing*, 44, 5, 1259-1266.
Krueger, A. (1983), Sighting of El Chichon sulfur dioxide clouds with the Nimbus 7 total ozone mapping spectrometer, *Science*, **220**, 13771379.
Yang, K. et al., (2007), Retrieval of large volcanic SO_2 columns from the Aura Ozone Monitoring Instrument: Comparison and limitations, *J. Geophy. Res.*, 112, D24S43, doi:10.1029/2007JD008825