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Observations of volcanic SO_2 using GOME-2 measurements

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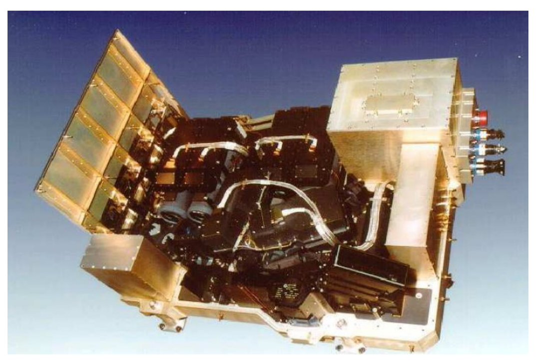
Why measure SO_2?

- volcanoes emit large quantities of ash and trace gases into the atmosphere, including SO_2
- volcanic emissions occur both during eruptions and as degassing
- 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 with 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

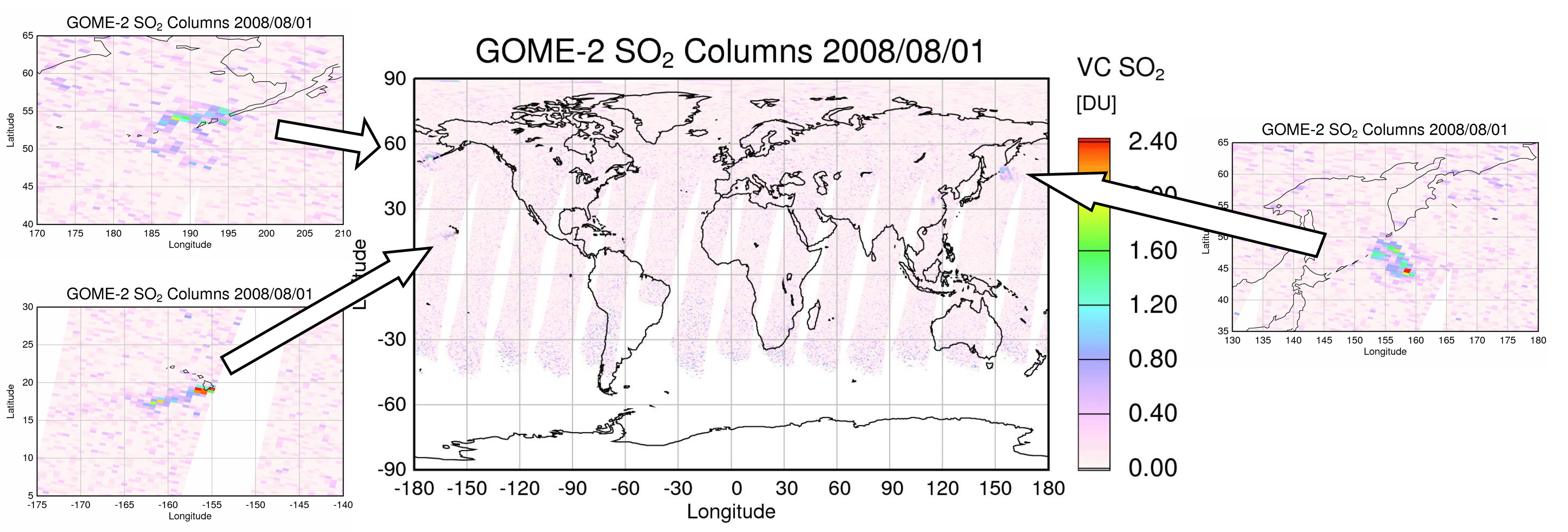
GOME-2 Instrument



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

Retrieval of SO_2



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
- airmass factor appropriate for weak volcanic signal (1DU)
- correction needed for large SO_2 columns (see box to the right)

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)

Problems:

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

Quantification of volcanic emissions

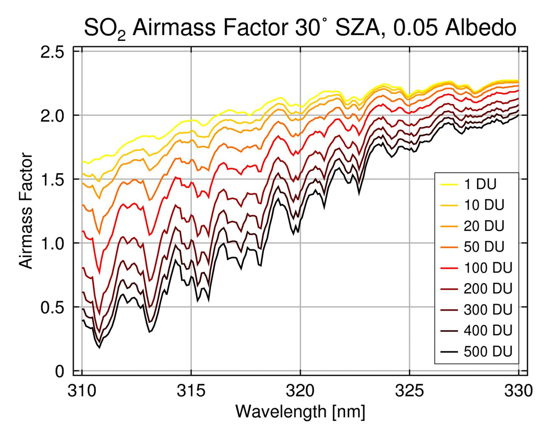


Figure: Airmass factors for SO_2 computed for different SO_2 columns located in a layer between 10 and 11 km

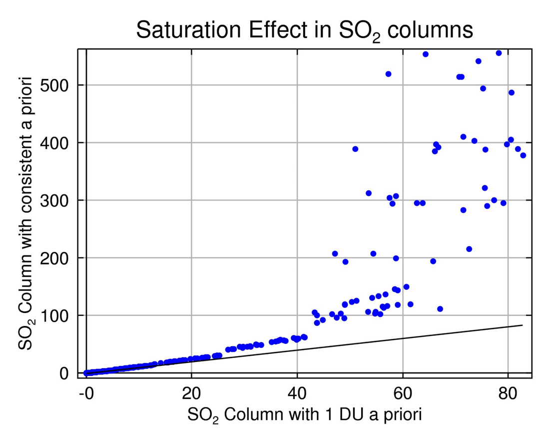


Figure: Effect of saturation correction on columns for one GOME-2 overpass. The step-wise appearance is a result of the limited number of scenarios used

Problem

- as result of strong absorption by SO_2 itself, the light path and thus the airmass factor depends on the SO_2 amount present in the atmosphere
- both the absolute values and the wavelength dependence of the AMF change with SO_2 column
- this needs to be accounted for in the fit

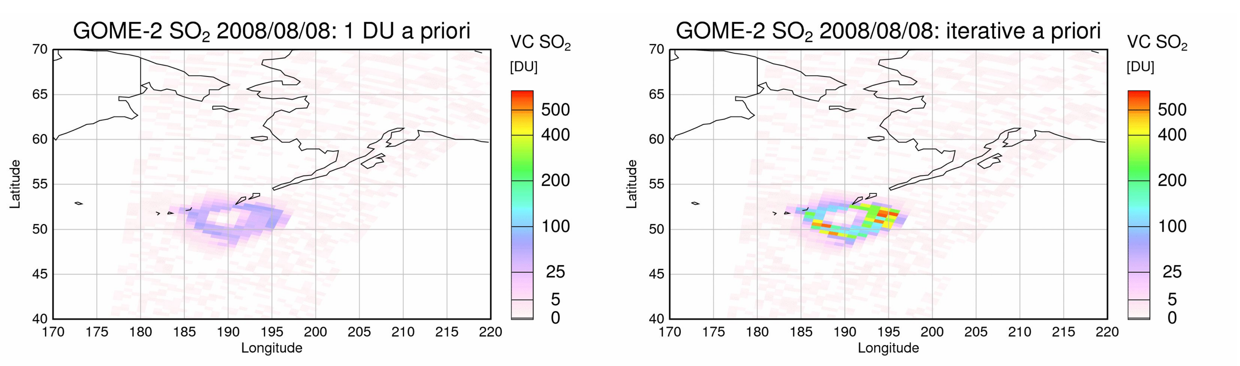
Approach

- starting from the initial guess of the SO_2 column derived using the 1 DU a priori, a more appropriate scenario is selected and a new SO_2 retrieval started
- the retrieval with the best match between a priori and retrieved column is used for the final column

Results

- the fitting quality is much improved (up to factor of 10 smaller residuals)
- the absolute columns are much larger for high SO_2 loading, resulting in more realistic columns
- for some pixels, the scenario with the best residuals has a much larger column than the retrieved column for unknown reasons

Figure: 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 1.35 Tg.



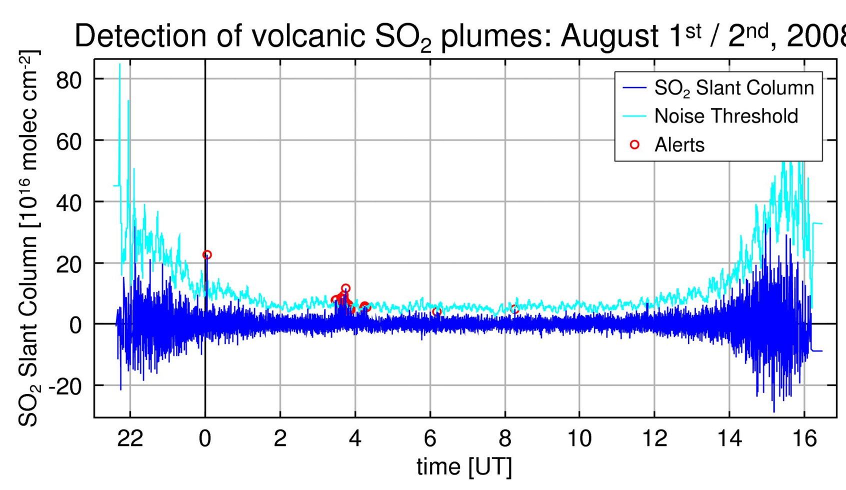
Identification of volcanic Emissions

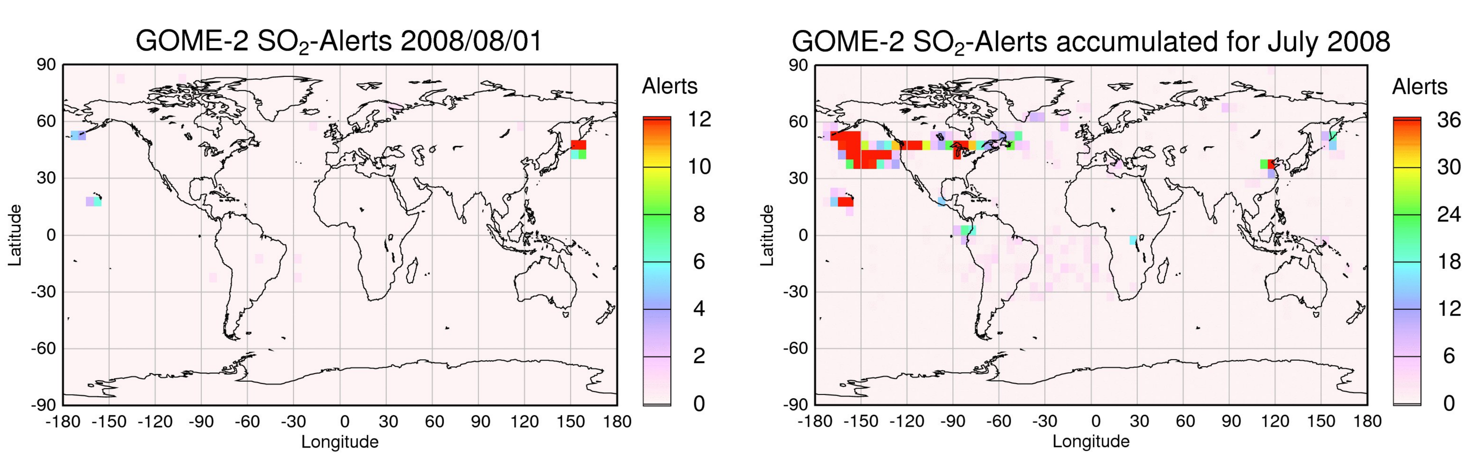
Task:

- identification of volcanic hot-spots
- separation from noise
- identification of even weak signals
- minimisation of false alerts

Approach:

- selection of values which are above 6 x RMS of negative (= noise) signals
- limitation to SZA < 80°
- filtering for low fit quality
- counting number of alerts in 5° x 5° box





Results:

- All relevant signals are detected
- some false alerts over China (pollution) and in the region of the SAA (noise)

Conclusions and future work

Conclusions

- GOME-2 SO_2 columns have excellent signal to noise and good coverage
- volcanic emissions can be easily detected in an automated way
- quantification of volcanic emissions is complicated by the strong non-linearity of the SO_2 signal for large columns
- using individual a priori columns for the SO_2 references used in the retrieval for each pixel improves the fitting quality and the retrieved columns for large signals

Future work

- creation of better resolved data base of slant optical thicknesses for SO_2
- inclusion of the effect of ozone variations on the SO_2 sensitivity
- inclusion of the effect of variable albedo on the SO_2 sensitivity
- validation of satellite SO_2 columns with ground-based observations

Acknowledgements

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Selected References

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