Satellite retrievals and inverse modeling of volcanic SO_2 clouds: Implications for accurate transport modeling of volcanic emissions

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Introduction

To accurately predict the transport and fate of volcanic emissions, the vertical profile of the emissions is essential. An analytical inverse modeling method has been developed to estimate the vertical emission profile of sulphur dioxide (SO_2) emitted during a volcanic eruption. The method has been applied to the eruption of Jebel at Tair (Red Sea) in September 2007 and the eruption of Kasatochi (Alaska) in August 2008.

Inverse modeling

The analytical inversion method used to estimate the emission height profile makes use of satellite-observed SO_2 columns from various satellite instruments (e.g., AIRS, OMI) together with modeled SO_2 columns from an atmospheric transport model FLEXPART. On the basis that particles are transported to different directions due to vertical wind shear, the modeled emissions from certain height levels will give a best match to the satellite observations, thus the method finds the emission profile with which the model can optimally reproduce the shape and horizontal position of the observed SO_2 plume. By minimizing the total difference between the simulated and observed SO_2 columns and also consider a priori information, the inversion method estimates the vertical emission profile.

Emission Height Profile and transport

Jebel at Tair

The height emission profile of SO_2 for the eruption of Jebel at Tair on 30 September 2007 was obtained using satellite data from the first 24 h after the eruption. The profile (*fig 1*) shows emission maximum near 16 km above sea level, and secondary maxima near 5, 9, 12 and 14 km. 60% of the emission occurred above the tropopause. The inversion result is robust against various changes in both the a priori and the observations. Even when using only SEVIRI data from the first 15 h after the eruption, the emission profile was reasonably well estimated.

Acknowledgements

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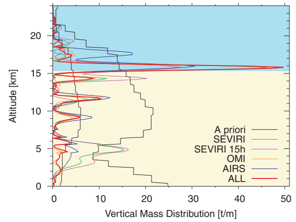

Figure 1 *Emission height profile of SO_2 (tons pr metre) for the eruption of Jebel at Tair (Red Sea) 30 September 2007.*

The transport of the SO_2 emissions was simulated by FLEXPART using the estimated emission profile from figure 1. The overall plume dispersion over the following week as observed by OMI could be simulated very well (fig 2). Also, the altitude of the simulated plume is in agreement with CALIPSO observations of stratospheric aerosol.

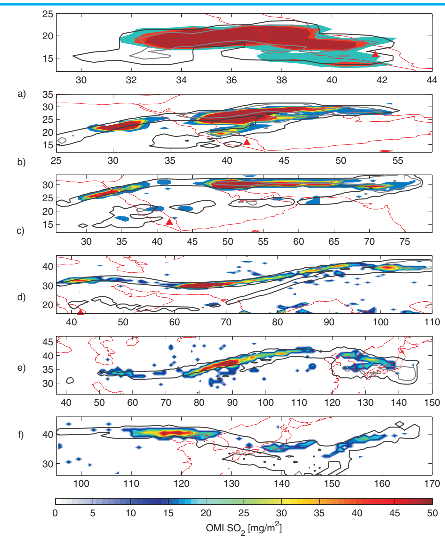

Figure 2. *Jebel at Tair emissions. Comparison of SO_2 columns measured by OMI and simulated by FLEXPART using the emission profile from figure 1, for (a) 1 October, (b) 2 October (c) 3 October (d) 4 October (e) 5 October, (f) 6 October. The satellite data are shown by the color shading and the FLEXPART results are shown as isolines for 1 mg m^{-2} (thick black line) and 30 mg m^{-2} (thick grey line).*

Kasatochi

Using AIRS satellite data for 72 h after the eruption of Kasatochi 7 August 2008, the inversion method estimates SO_2 emission maxima near 5 km, 9 km and 12 km (fig 3). Emissions reached 20 km height.

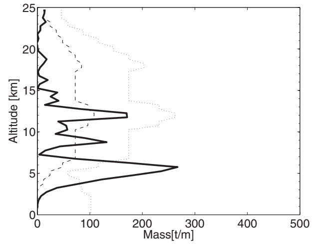

Figure 3 *Emission height profile of SO_2 (tons pr metre) for the eruption of Kasatochi (Alaska) 7 August 2008.*

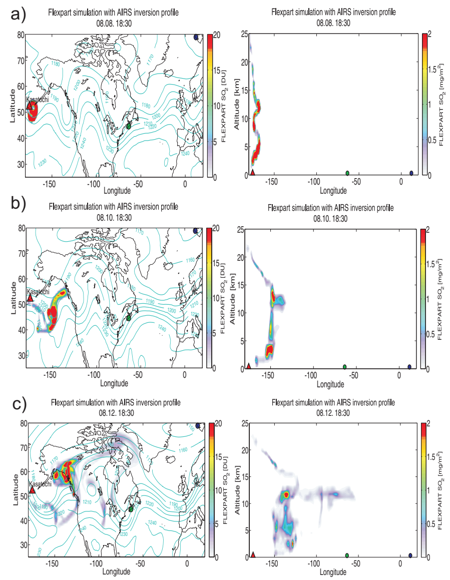

Figure 4 *General transport of the SO_2 plume from Kasatochi (a) 8 August (b) 10 August (c) 12 August, simulated by FLEXPART using the emission profile from figure 3. Left: the horizontal dispersion and 200hPa potential height [dkm]. Right: vertical zonal plots where mass is integrated over all latitudes.*

The transport of the SO_2 cloud was reconstructed with FLEXPART (*fig 4*) based on the estimated emission profile. The emissions reached Greenland 5 days after the eruption and the emissions were transported quickly with the jet stream at 10-12 km altitude. The height of the simulated plume agrees very well with LIDAR observations of aerosols at Nova Scotia (*Eastern Canada, marked with a green dot on fig 4*) on 21 August, 14 days after the eruption (*fig 5*).

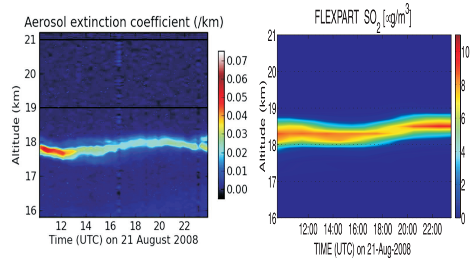

Figure 5 *Left: LIDAR measurements from Nova Scotia on 21 August. Right: SO_2 levels simulated by FLEXPART for the location of the LIDAR, on the same day. Emissions according to the emission profile from figure 3 are used for the model simulation.*

The inversion method can estimate the emission altitudes of volcanic eruptions with great accuracy, and is suitable for real time predictions of the threat posed by volcanic ash for commercial air traffic.

This system is presented:
Friday 24. Apr, 11:30-11:45 Room 29
Support for Aviation for Volcanic Ash Avoidance: SAVAA
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References

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