The eruption of Kasatochi Volcano;

Remote sensing and transport modeling of the emitted sulfur dioxide cloud

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Introduction

Volcanic eruptions release gases, e.g. sulfur dioxide (SO_2), and particles to the atmosphere which can affect the global climate. Volcanic ash is a great danger to airline traffic as aircrafts that fly into a cloud of ash can experience damage to the aircraft and even engine failure.

Satellite observations can be used to observe the emission clouds and track them as they are transported around the globe. Recent improvements in satellite retrievals of e.g. SO_2 and ash have made this even more feasible.

To predict the fate and transport of volcanic emissions, **numerical transport simulations** are used. For dispersion models, certain input parameters are needed, e.g. the time of the eruption onset, and also to which heights the material is emitted – **the emission height profile.**

Inverse Modeling

Inverse modeling can be used to estimate the emission height profile of a volcanic eruption by comparing **model simulations** and **satellite observations** of the emissions. By releasing particles in stacked heights above the volcano and comparing the individual transport patterns with the satellite observations, it is possible to subtract the emission heights which best fit with the observations and in that way estimate an emission height profile.

When the profile is obtained a **long-range transport simulation** of the eruption may be performed and used to predict where to the emissions are transported, and warn air line traffic of areas that should be avoided.

Mt. Kasatochi Eruption

The Kasatochi Volcano is a small island volcano located at the Aleutian Arc in Alaska. The volcano erupted suddenly on **7. August 2008** and emitted a huge amount (~1.5 Tg) of $\mathbf{SO_2}$ into the atmosphere. This was the largest SO_2 amount observed since Chile's Hudson volcano erupted in 1991. Also significant amounts of **volcanic ash** were emitted which forced the Alaskan Airlines to cancel 44 flights in the days after the eruption.

Figure 1: Kasatochi caldera two weeks after the eruption. Photo credit: Chris Waythomas/AVO/USGS

Satellite Observations

Several satellites were able to observe the SO_2 emitted by Kasatochi. Observations from 2 days after the eruption as seen from the **GOME-2, OMI and AIRS satellite instruments** are shown in Figure 2. The observed transport patterns are similar, but there are differences in the total amount of SO_2 due to the satellites detection limits and different retrieval procedures. These data are used in the inversion algorithm to estimate the SO_2 profile.

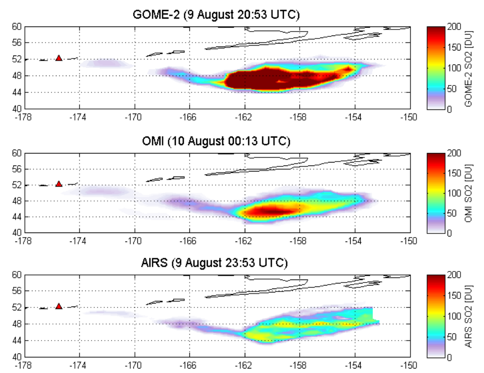

Figure 2: SO_2 columns retrieved from UV satellite measurements (GOME-2 and OMI) and from IR measurements (AIRS). The measurements are from ~2 days after the eruption. The Kasatochi Volcano is marked by a red triangle.

SO_2 Emission Height Profile

The inversion result (Fig. 3) for Kasatochi yields an emission profile with two **large emission maxima near 7 km and 12 km** above sea level with smaller emissions up to 20 km. The total mass of SO_2 injected into the atmosphere was estimated to 1.7 Tg, with ~1 Tg reaching the stratosphere (>10 km).

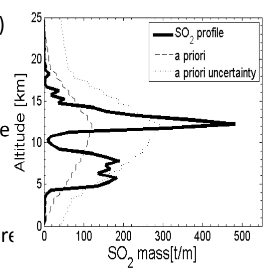

Figure 3: Vertical SO_2 profile for the eruption of Kasatochi estimated by the inversion algorithm.

Transport Modeling of Volcanic SO_2

A long-range transport simulation of the emitted SO_2 was performed using the LPDM **FLEXPART** (Stohl et al, 2005, http://transport.nilu.no/flexpart)., see Fig. 4. The model uses the estimated SO_2 profile and meteorological parameters from the ECMWF model as input.

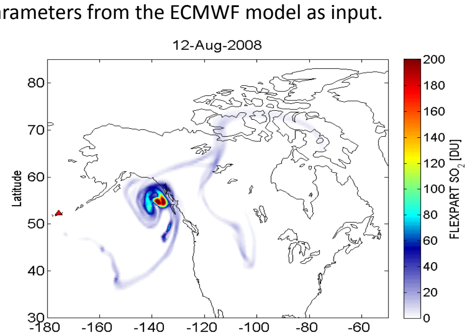

Figure 4: FLEXPART model simulation of the SO_2 plume emitted by the eruption of Kasatochi (red triangle) for 12 August, 5 days after the eruption.

Validation of Model Simulation

Comparison with CALIPSO

The model successfully recaptures the shape of the SO_2 plume as observed by the satellite-based lidar instrument CALIPSO (Fig. 5).

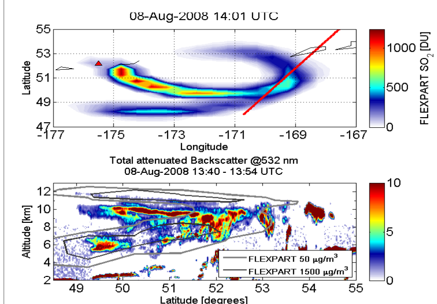

Figure 5: Comparison of CALIPSO attenuated backscatter with SO_2 concentrations simulated by FLEXPART on 8 August, 15 hours after the eruption. The map (upper panel) shows total columns of SO_2 simulated by FLEXPART. The red line indicates the location of the CALIPSO nadir track. In the lower panel, the CALIPSO data are shown by the color shading and the FLEXPART results are plotted as isolines (black and grey lines).

Comparison with ground-based LIDAR

Observations on 21. August from a lidar instrument located at Halifax, Canada, show an aerosol layer at 18 km altitude which the model can recapture very well (Fig. 6).

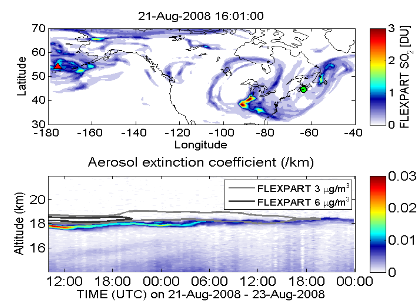

Figure 6: Comparison of aerosol extinction coefficient measured at Nova Scotia, ~2 weeks after the eruption, and FLEXPART model simulated SO_2 concentrations. (Panels similar to Fig.5)

Conclusion / Summary

A vertical SO_2 profile for the 2008-eruption of Kasatochi volcano was estimated and used to successfully perform a long-range transport simulation of the emissions.

Future Work

- Implementation of volcanic ash and estimation of vertical ash profiles.
- Investigate the potential for improvement of the retrieved satellite data when using the modeled height distributions of SO_2 as input.

References

Kristiansen, N. I., et al. (2009) Remote sensing and inverse transport modeling of the Kasatochi eruption sulfur dioxide cloud, *J. Geophys. Res.*, Special Issue, Submitted Sept 2009

Stohl, A. et al. (2005), Technical note: The Lagrangian particle dispersion model FLEXPART version 6.2, *Atmos. Chem. Phys., 5(9)*, pp. 2461–2474.

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