Determination of time- and height-resolved volcanic ash emissions for quantitative ash dispersion modeling: The 2010 Eyjafjallajökull eruption

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Summary

At the example of the April-May, 2010 volcanic eruptions of Eyjafjallajökull, Iceland, we demonstrate for the first time that dramatic improvements can be made in quantitative predictions of the fate of volcanic ash emissions, by using an inversion scheme that couples a priori source information and the output of a Lagrangian dispersion model with satellite data to estimate the volcanic ash source strength as a function of altitude and time. From the inversion, we obtain a total fine ash emission of the eruption of 8.3±4.2 Tg for particles in the size range of 2.8—28 μm diameter and extrapolate this to a total ash emission of 11.9±5.9 Tg for the size range of 0.25–250 μm m.

We evaluated the results of our a posteriori model using independent ground-based, airborne and space-borne measurements both in case studies and statistically. Subsequently, we estimate the area over Europe affected by volcanic ash above certain concentration thresholds relevant for the aviation industry. We find that during three episodes in April and May, volcanic ash concentrations at some altitude in the atmosphere exceeded the limits for the "Normal" flying zone in up to 14% (6--16%), 2% (1--3%) and 7% (4--11%), respectively, of the European area. For a limit of 2 mg m^{-3} only two episodes with fractions of 1.5% (0.2--2.8%) and 0.9% (0.1--1.6%) occurred, while the current "No-Fly" zone criterion of 4 mg m^{-3} was rarely exceeded. Further details can be found in Stohl et al. (2011).

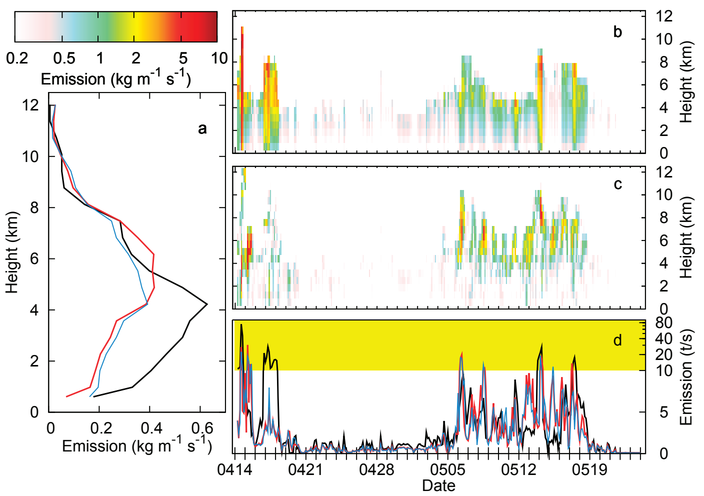

Figure 1: A priori and a posteriori ash emissions. (a) Comparison of temporally-averaged vertical profiles of ash emissions used a priori (black line) and obtained a posteriori by the inversion when using ECMWF meteorological data (red line) and GFS meteorological data (blue line). (b) A priori emissions as a function of altitude and time. (c) A posteriori emissions, averaged for the two inversions using alternative meteorological data sets, as a function of altitude and time. (d) Vertically integrated a priori (black line) and a posteriori emissions (red and blue lines) as a function of time. Notice the switch from a linear to a logarithmic scale above 10 t s^{-1} (yellow area).

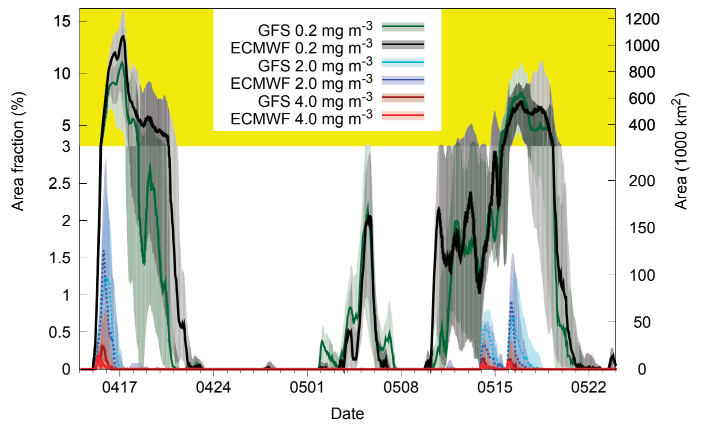

Figure 2: Area of Europe affected by volcanic ash. Area in the domain 10ºW-30ºE and 36ºN-60ºN, expressed in relative (left axis) and absolute numbers (right axis) and shown as a function of time, where modeled ash was present somewhere between the surface and 13 km altitude at concentrations higher than 0.2, 2 or 4 mg m^{-3}. Results are shown for model runs using two different meteorological data sets (ECMWF and GFS). Lines show reference model values and transparent areas indicate the span for a model uncertainty of ±50%. Notice the change in ordinate scale at 3% (yellow area). For clarity, 2 mg m^{-3} lines are dotted.

Method

The analytical inverse method to determine volcanic ash emissions merges a priori information on the ash emissions, satellite observation data (SEVIRI and IASI volcanic ash retrievals) and simulations with a dispersion model to derive improved a posteriori ash emissions. The emissions were determined every 3 hours and with a 650 m height resolution, optimizing the agreement between satellite data and observations as well as a priori and a posteriori emissions. The a priori emissions were determined with a 1-D column eruption model nudged towards observed plume heights.

The results were evaluated based on independent satellite (CALIPSO) data, ground-based lidar data as well as with aircraft measurements. It was shown (Stohl et al., 2011) that the inversion improved the results consistently, leading to good quantitative agreement between measured and modeled data.

Reference:

Stohl, A., A. J. Prata, S. Eckhardt, et al. (2011): Determination of time- and height-resolved volcanic ash emissions for quantitative ash dispersion modeling: The 2010 Eyjafjallajökull eruption. *Atmos. Chem. Phys. Discuss.* **11**, 5541-5588.