Surface air quality implications of volcanic injection heights

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Summary

* Air quality implications of volcanic eruptions have gained increased attention since the 2010 Icelandic eruption that resulted in the shut-down of European airspace. The extent of the impact depends on the emission amount, injection height and prevailing weather conditions.

* To understand the maximum impact an Icelandic volcanic eruption can have on the air quality over Europe, the major eruption of 1783-1784, Laki that had a significant impact over Europe is simulated. Europe was under the influence of a high pressure system during that eruption.

* Previous studies has often argued that in the case of such an eruption, the pollutants injected high into the atmosphere led to substantially increased concentrations of pollutants over continental Europe via long range transport in the jet stream and eventual large-scale subsidence in a high pressure system. Using the state-of-the-art simulations, we show that the air quality impact of Icelandic volcanoes is highly sensitive to the emission injection height.

This is the first study showing that the major impact on European surface air quality from such eruptions during anticyclonic conditions occur by long range transport of emissions which are taking place at lower levels, especially below 5 km. A long lasting high pressure system can then trap large amounts of these pollutants resulting in atmospheric haze.

Design of Experiments

* Laki eruption (64°N, 17°W) is considered as the emission source point and the emissions are similar to what was emitted during Laki eruption (Thordarson and Self, 2003) .

* Simulations are carried out for the period from 20 July until 30 October 2015 (103 days) and this period was influenced by intermittent periods of high and low pressure periods over Europe.

* As the plume height from volcanic eruptions can vary largely, we define three emission heights which are combined to three different scenarios.

Type of emission	**Duration of emission**	**Plume height above volcanic top**	**SO_2 emissions (ton/s)**	**Total SO_2 emissions (Mt)**
1. Degassing	Continuous (103 days)	0-2 km	3.15	27.6
2. Explosive eruption - low	Continuous (77 days)	2-8 km (~3-9 km a.s.l)	14.75	98.4
3. Explosive eruption - high	Continuous (77 days)	8-12 km (~9-13 km a.s.l)	14.75	98.4
Scenarios	**Emission type(s) included**		**Total SO2 emissions (Mt)**	
De-gassing	Type 1		27.6	
Lo-cont	Type 1+2		126	
Hi-cont	Type 1+3		126	

MATCH Model:

- Eulerian chemistry transport model, MATCH (Multiple-scale Atmospheric Transport and Chemistry) developed at SMHI (Robertson et al., 1999).

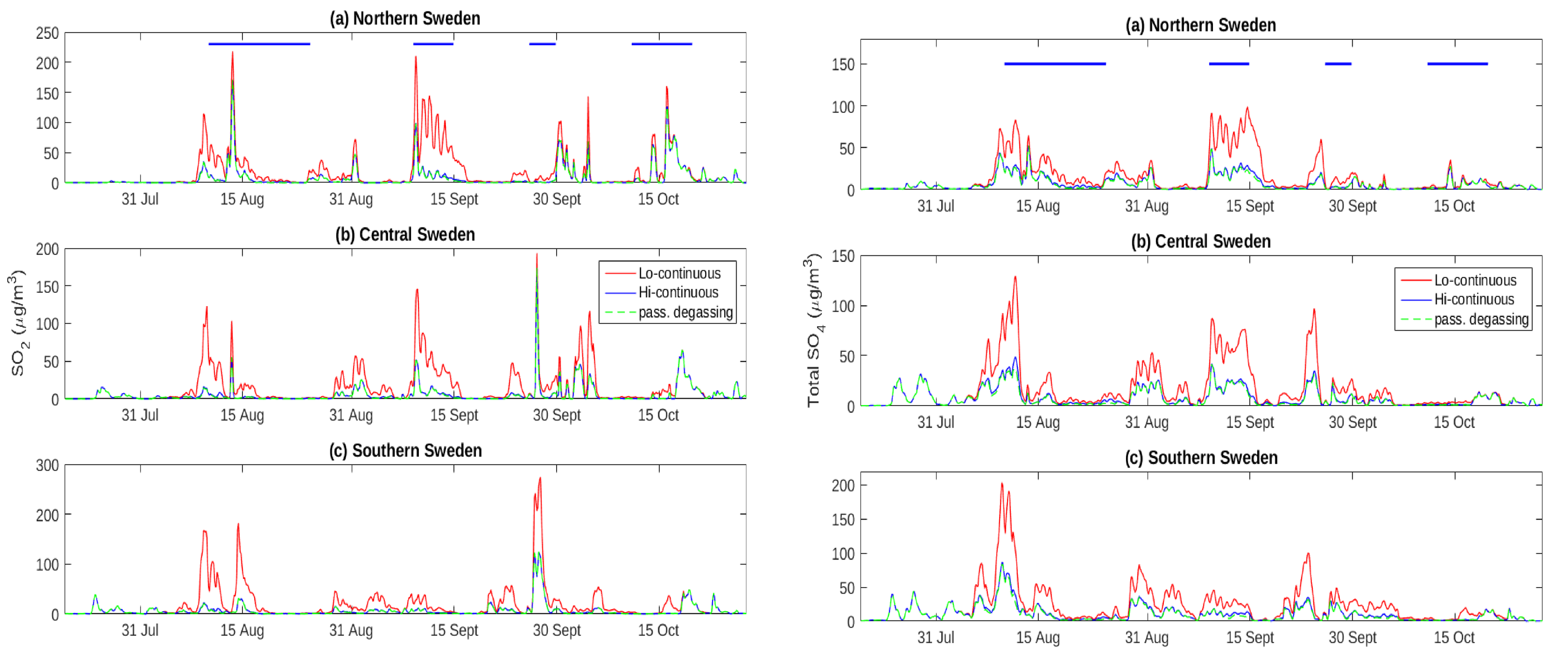
- Meteorological boundary conditions are taken from the SMHI's forecast model, HIRLAM at 3 hourly intervals and run at 22 km² resolution and up to 30 km height.

The surface concentrations of both SO_2 (left) and sulfate (total SO_4) (right) over Sweden.

- Irrespective of the region, the concentrations are substantially higher in the Lo-cont scenario where the emissions are below 9km a.s.l compared to the Hi-cont.

- The periods of anticyclonic conditions are marked by blue lines and it coincides with increased concentrations over Sweden.

-The similarity between Hi-cont scenario and de-gassing scenario is remarkable implying that the high altitude injections do not significantly contribute to the pollutant levels over Sweden.



Thordarson, T., Self, S.. Atmospheric and environmental effects of the 1783-1784 Laki eruption: A review and reassessment. J Geophys Res 2003;108(D1).
Robertson, L., Langner, J., Engardt, M.. An Eulerian limited-area atmospheric transport model. J Appl Meteor 1999;38:190–210.

PELLO Model:

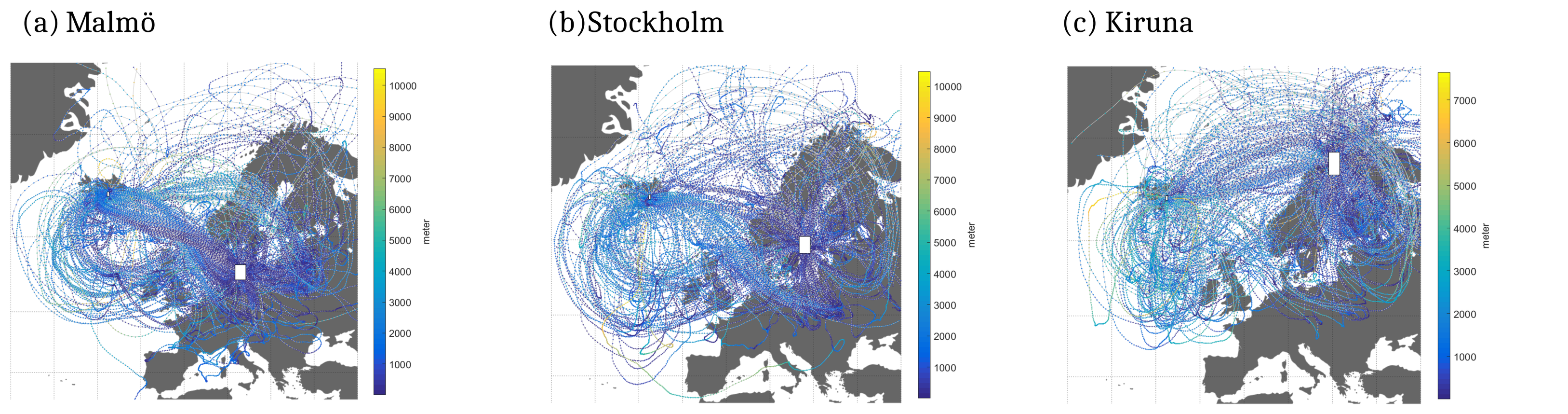
- Lagrangian random displacement model, PELLO is developed by the Swedish Defence Research Agency (Lindqvist, 1999).

-A combined scenario is used here with Type 1 + 10% Type 2+ 90% Type 3.

- Meteorological conditions are taken from the IFS model from ECMWF at 0.1o resolution and up to 11 km height at 3 hourly intervals.

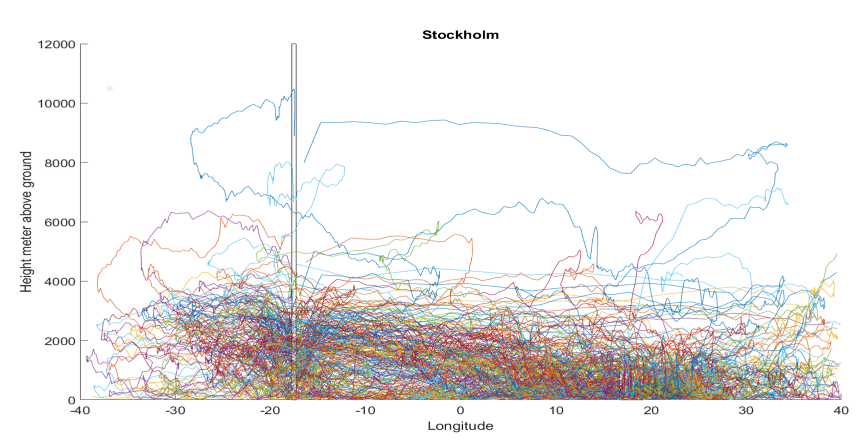
All trajectories arriving at (a) Malmö (b) Stockholm and (c) Kiruna from the source of origin

- it is apparent that the vast majority of model particles reaching these cities have never strayed above 5 km.



To show the altitude of the trajectories more clearly, all trajectories reaching Stockholm viewed as if standing at the ground level looking north is presented below.

- Only a fraction of one percent of the trajectories reaching Stockholm start higher than 5km above the volcano despite nearly 80% of the total emission is above 5 km.



Lindqvist, J.. En stokastisk partikelmodel i ett ickemetriskt koordinatsystem. FOI-R-99-01086-862-SE, ISSN 1107-9154 1999.

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