Modeling of SO2 dispersion from the 2014 Holuhraun eruption in Iceland using WRF-Chem

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Introduction

The fissure eruption in Holuhraun in central Iceland is the country's largest lava and gas eruption since 1783 but has produced very little volcanic ash. The eruption started in late August 2014 and lasted until end of February 2015. The main threat from this event was the atmospheric pollution of SO_2 that was carried by wind to all parts of the country and produces elevated concentrations of SO_2 that have frequently violated National Air Quality Standards (NAQS) in many population centers.

The Volcanic Ash Research (VAR) group in Iceland is focused on airborne measurement of ash contamination to support safe air travel, as well as various gas concentrations. In relation to the Holuhraun eruption the VAR group has organized an investigation campaign including 10 measurement flights and performed measurements of both the source emissions and the plume distribution. SO_2 concentrations measured at the source showed clear potential for creating pollution events in the toxic range and contamination of surface waters.

The data obtained in the measurement campaign was used for calibration of the WRF-Chem model [1] of the dispersion of SO_2 and volcanic ash concentration. The model has both been run in operational forecast mode (since mid October) as well as in a dynamical downscaling mode, to estimate the dispersion of SO_2 from the plume.

Model setup

The WRF-Chem model is an extension of the widely used AR-WRF atmospheric model [2]. WRF-Chem has the capabilities of simulating, both online and offline, the coupling between dynamics, radiation and chemistry. Studies have shown that this interaction can be of considerable importance [3,4].

To simulate the dispersion of SO_2 and volcanic ash the WRF-Chem was installed on a horizontal grid of 95x90 points with 9 km resolution. Number of vertical levels is 41 with model top at 5 hPa. Based on airborne in-situ observation, the height of the stroke was set as 1200 meters a.g.l. and the daily amount of SO_2 was set to $40x10^6$kg. These values were kept unchanged for the duration of the eruption. Values of SO_2, volcanic ash, snow cover and various soil parameters where cycled between forecasts.

Comparison with observations

In general the model captured the general distribution of the pollutants, cf. Figs. 1 and 2. However, events did occur where the model failed to simulate the observed strength of the SO_2 (cf. Fig. 3).

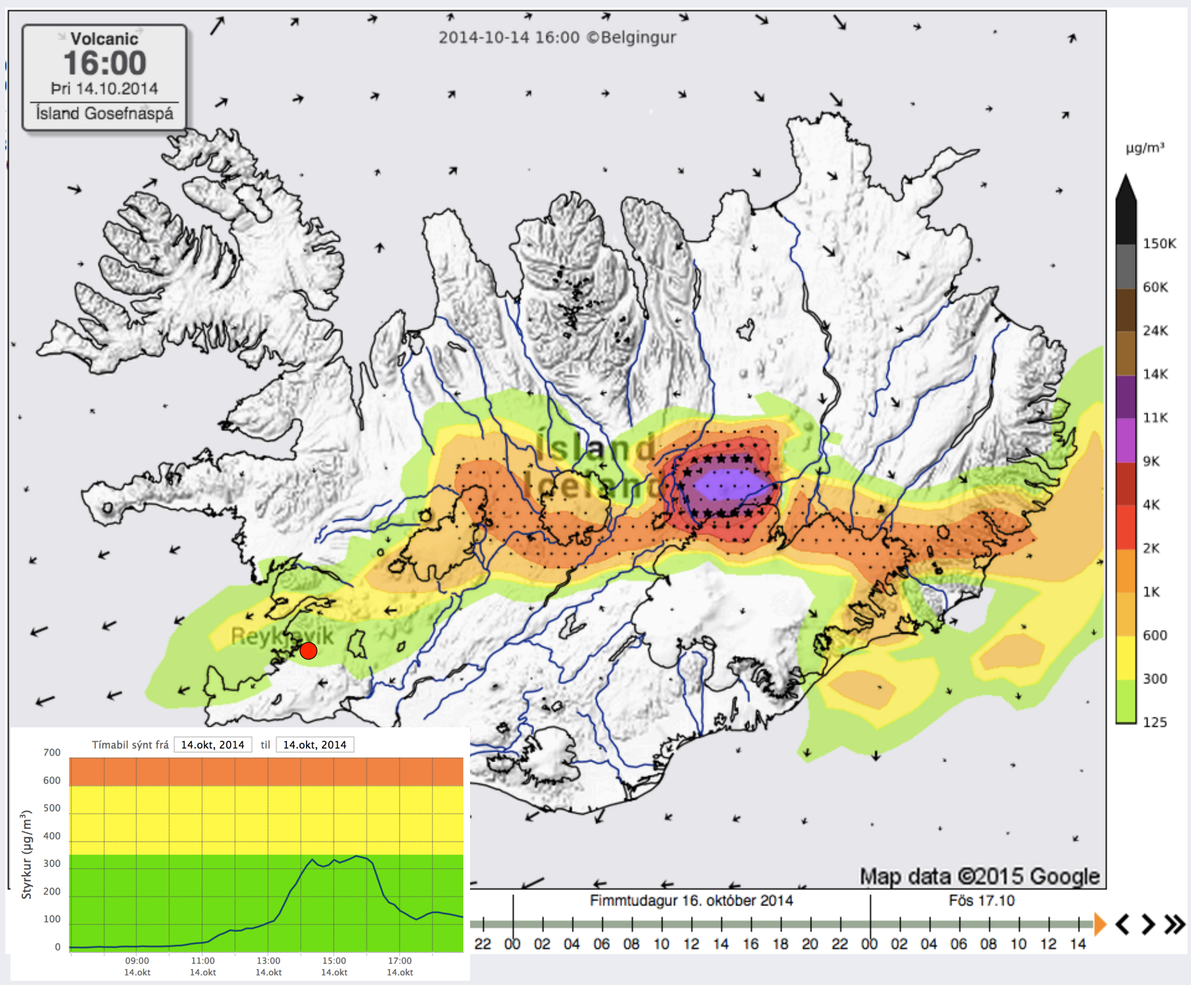

Figure 1: Twelve hour forecast of SO_2 concentration [µg/m³] valid at 16 UTC 10 November 2014. Increased strength of SO_2 was observed in the afternoon (cf. graph in lower left corner). Red dot indicates the location of the observation site. Observations are from the Environment Agency of Iceland (www.ust.is).

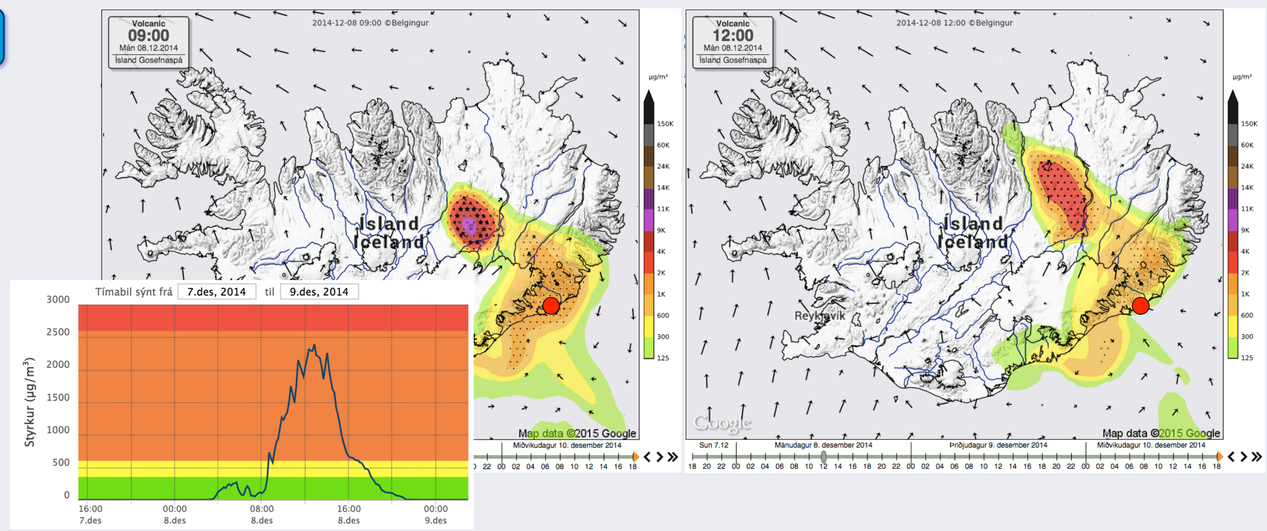

Figure 2: Eighteen hour forecasts of SO_2 concentration [µg/m³] valid at 09 (left) and 12 (right) UTC 8 December 2014. Maximum forecast strength was at 9 in the morning but observed maxima was at noon (cf. graph in lower left corner). Red dot indicates the location of the observation site. Observations are from the Environment Agency of Iceland (www.ust.is).

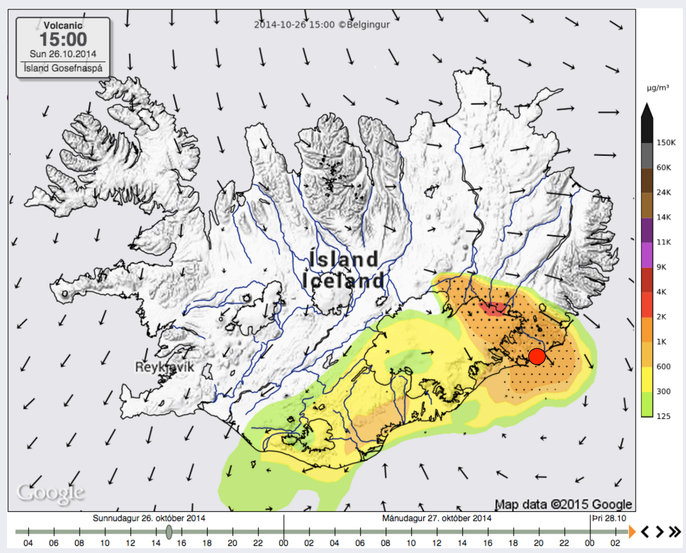

Figure 3: Twelve hour forecast of SO_2 concentration [µg/m³] valid at 15 UTC 26 October 2014. Maximum forecast strength at location Höfn í Hornafirði (red dot) was between 1.000 and 2.000 µg/m³ but observed values were in the range of 3.000 to 7.000 µg/m³.

Discussions and future research

Due to the sparseness of observations, in particular upper air observations of pollutants and reliable estimates of the temporal evolution of the plume height and source strength of SO_2, it is difficult to identify the source of discrepancies between simulations and observations. Most likely, the uncertainty of the forecast is due to combining factors such as the model not being able to resolve important flow features due to too coarse resolution, and errors in the source terms of pollutants.

As spring approaches the first melt waters are likely to contain acid sulfur compounds that can be harmful for vegetation, with the highland vegetation being the most vulnerable. Hence, it is important to simulate the conversion of SO_2 to sulfur in order to try an map the most vulnerable ares. The results could then be compared to values taken from snow samples from the ice caps and highlands of Iceland.

Acknowledgements

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