Geophysical Research Abstracts
Vol. 18, EGU2016-301, 2016
EGU General Assembly 2016
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Satellite detection, long-range transport, and air quality impacts of volcanic sulfur dioxide from the 2014–2015 flood lava eruption at Bárðarbunga (Iceland)

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The 2014–2015 Bárðarbunga-Veiðivötn fissure eruption at Holuhraun produced about 1.5 km3 of lava, making it the largest eruption in Iceland in more than 200 years. Over the course of the eruption, daily volcanic sulfur dioxide (SO_2) emissions exceeded daily SO_2 emissions from all anthropogenic sources in Europe in 2010 by at least a factor of 3. We present surface air quality observations from across Northern Europe together with satellite remote sensing data and model simulations of volcanic SO_2 for September 2014. We show that volcanic SO_2 was transported in the lowermost troposphere over long distances and detected by air quality monitoring stations up to 2750 km away from the source. Using retrievals from the Ozone Monitoring Instrument (OMI) and the Infrared Atmospheric Sounding Interferometer (IASI), we calculate an average daily SO_2 mass burden of 99 ± 49 kilotons (kt) of SO_2 from OMI and 61 ± 18 kt of SO_2 from IASI for September 2014. This volcanic burden is at least a factor of 2 greater than the average SO_2 mass burden between 2007 and 2009 due to anthropogenic emissions from the whole of Europe. Combining the observational data with model simulations using the United Kingdom Met Office's Numerical Atmospheric-dispersion Modelling Environment model, we are able to constrain SO_2 emission rates to up to 120 kilotons per day (kt/d) during early September 2014, followed by a decrease to 20–60 kt/d between 6 and 22 September 2014, followed by a renewed increase to 60–120 kt/d until the end of September 2014. Based on these fluxes, we estimate that the eruption emitted a total of 2.0 ± 0.6 Tg of SO_2 during September 2014, in good agreement with ground-based remote sensing and petrological estimates. Although the volcanic air pollution episodes were transient and lava-dominated volcanic eruptions are sporadic events, the observations suggest that (i) during an eruption, volcanic SO_2 measurements should be assimilated for near real-time air quality forecasting and (ii) existing air quality monitoring networks should be retained or extended to monitor SO_2 and other volcanic pollutants.