Inverting for hourly volcanic SO_2 flux using plume satellite imagery and chemistry-transport modelling: application to the 2010 Eyjafjallajökull eruption

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Depending on the magnitude of their eruptions, volcanoes impact the atmosphere at various temporal and spatial scales. The volcanic source remains the major unknown to rigorously assess these impacts. At the scale of an eruption, the limited knowledge of source parameters, including time-variations of erupted mass flux and emission profile, currently represents the greatest issue that limits the reliability of volcanic cloud forecasts. However, various satellite and remote sensing observations of distant plumes are available today and indirectly bring information on these source terms. Here, we develop an inverse modeling approach combining satellite observations of the volcanic plume with an Eulerian regional chemistry-transport model (CHIMERE) to better characterise the volcanic SO_2 emissions during an eruptive crisis. The 2010 Eyjafjallajokull eruption is a perfect case-study to apply this method as the volcano emitted substantial amounts of SO_2 during more than a month. We take advantage of the SO_2 column amounts retrieved from a vast set of observations by the IASI (Infrared Atmospheric Sounding Interferometer) instrument on board the METOP-A satellite to reconstruct retrospectively the time-series of the SO_2 flux emitted by the volcano with a temporal resolution of about 2 hours, spanning the period from 1 to 12 May 2010. The initialisation of chemistry-transport modelling with this reconstructed source allows a reliable simulation of the evolution of the long-lived tropospheric SO_2 cloud over thousands of kilometres. Heterogeneities within the plume, which result from the temporal variability of the emissions, are also correctly tracked over a time scale of a few days. The robustness of our approach is also demonstrated by the broad similarities between the SO_2 flux history determined by this study and the ash discharge behaviour estimated by other means during the phases of high explosive activity at Eyjafjallajokull in May 2010. Finally, we show how a sequential IASI data assimilation allows for a substantial improvement in the forecasts of the location and concentration of the plume compared to an approach assuming constant flux at the source. As the SO_2 flux is a good indicator of the volcanic activity, this approach is also of interest for volcanologists to monitor from space poorly instrumented volcanoes.

