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Modelling the evolution of the bromine chemistry in the plume of Mount Etna during the Christmas 2018 eruption using WRF-Chem Volcano

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Volcanic eruptions emit bromine-containing species in varying quantities, with their emission ratio to tracer species such SO_2 varying between volcanoes, eruptions, and even phases of an eruptive event.

Although primarily emitted as HBr, bromine within volcanic plumes cycles between species in a series of low temperature chemical reactions which include heterogenous and photolysis steps. Some bromine exists as BrO, a species which can be observed spectroscopically from ground- and satellite-based instruments.

We present modelling results from WRF-Chem Volcano (WCV), a modified version of the three-dimensional regional atmospheric chemistry and transport model WRF-Chem and associated utilities. We have simulated the Christmas 2018 eruptive event of Mount Etna using a nested implementation the model at maximum lateral resolution of 1km. The plume of this eruption was observed remotely by the TROPOMI instrument.

WCV is able to reproduce the bromine explosion and the major features of the satellite observation –including a cross-plume variation in the BrO/SO_2 column ratio. We find that variations in the BrO/SO2 ratio are primarily caused by variations in the concentration of ozone. Ozone is consumed by bromine chemistry and is replenished by the mixing in of ozone-rich background air. This creates a zone of low ozone in the core of the plume which is consequently low in BrO and surrounded by a higher-ozone edge with a higher BrO/SO_2 ratio.

For the temporal evolution of the plume, we find that the bromine-chemistry of a concentrated emission plume can be divided into four phases, also governed by ozone availability. In the last phase ozone limitation is minimal and the proportion of bromine in the form of BrO (and the BrO/SO_2 ratio) is approximately stable. We find this stable regime also with a simulation of a weaker emission plume. These results could facilitate the use of remote-sensing BrO measurements as a means of quantifying total bromine emissions from volcanoes.

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