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Modelling halogen chemistry of volcanic plumes with WRF-Chem Volcano

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The halogen species HBr and, to a lesser extent, HCl, emitted by volcanoes are known to be transformed efficiently into radicals by heterogeneous chemical processes within plumes. Two of these transformation products, BrO and OClO, have distinct spectroscopic signatures allowing ground and satellite-borne measurements of these species to be made within volcanic plumes.

Changes in halogen emissions can indicate changes in volcanic activity, and may provide information useful for hazard forecasting. Earth-observing satellites provide a global coverage in monitoring. In particular, the TROPOMI instrument aboard Sentinel-5P has been able to resolve BrO within volcanic plumes at spatial resolution of 3.5x7 km2. However, BrO is a secondary product formed within the plume through non-linear processes and it represents only a variable fraction of the total bromine available within the plume. Therefore, making use of BrO observations requires an assessment of the in-plume chemical processes which are variable between, and even within plumes, due to a variety of factors.

Numerical modelling is highly applicable for this purpose. The high resolution of the new satellite observations, notably TROPOMI, is well suited to 3D regional chemistry-transport models.

In this presentation, we present preliminary results from WRF-Chem Volcano (WCV), our development of the WRF-Chem community chemistry-transport model to simulate halogen chemistry within volcanic plumes. The chemistry scheme includes heterogeneous reactions that allow the model to simulate the "bromine explosion". WCV is able to reproduce the main halogen-related phenomena which have been observed within plumes, including BrO formation, ozone depletion, and differences in chemical regime between plume edges and core.

The simulated plume can be investigated in far greater detail than is practical or possible by measurements in a real-world case. We investigate various aspects of the halogen chemistry including the partitioning between bromine species. Additionally, we demonstrate how, by changing model inputs, WCV can be used to investigate and quantify the non-linear response of plume chemistry to various factors such as emissions strength.