

EGU24-9973, updated on 18 Jul 2024

<https://doi.org/10.5194/egusphere-egu24-9973>

EGU General Assembly 2024

© Author(s) 2024. This work is distributed under the Creative Commons Attribution 4.0 License.



## A novel model of volcanic plume evolution from high-temperature chemistry to reactive plume chemistry in the atmosphere

Alexander Nies<sup>1</sup>, Tjarda Roberts<sup>1,2</sup>, Guillaume Dayma<sup>3</sup>, Tobias Fischer<sup>4</sup>, and Jonas Kuhn<sup>5</sup>

<sup>1</sup>Laboratoire de Physique et de Chimie de L'Environnement et de l'Espace, CNRS/Université Orleans, Orleans, France

(alexander.nies@cnrs-orleans.fr)

<sup>2</sup>LMD/IPSL, ENS, Université PSL, École Polytechnique, Institute Polytechnique de Paris, Sorbonne Université, CNRS, Paris, France

<sup>3</sup>Institute de Combustion Aérothermique Réactivité Environnement, CNRS/Université Orléans, Orléans, France

<sup>4</sup>Center for stable Isotopes, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM, USA

<sup>5</sup>Department of Atmospheric and Oceanic Sciences, University of California, Los Angeles, CA, USA

The first seconds of the interaction of volcanic gases with the atmosphere have so far often been drastically simplified, e.g., by assuming thermochemical equilibrium. In this period, hot and reduced magmatic gases mix with ambient air and undergo rapid cooling. The in-mixture of atmospheric oxygen triggers fast oxidation processes which depend on the dynamic interplay of chemical kinetics, mixing and cooling.

We present a novel chemical box model, which can capture rapid chemical kinetics alongside cooling and mixing of the early plume. The model combines a chemical combustion mechanism with atmospheric chemistry mechanisms and includes sub-mechanisms for halogens, sulfur, reactive nitrogen and mercury, respectively. It is fast and flexible to test many different emission temperatures, mixing scenarios, eruption styles, and gas compositions.

Here, we focus on the formation of reactive halogen species (e.g. bromine oxide (BrO), bromine chloride (BrCl), hypobromous acid (HOBr), and atomic bromine (Br)) during the first seconds, minute to hours of plume evolution, which significantly influence atmospheric chemistry on a regional scale. We study the impact of the high-temperature initializations on ambient-temperature plume chemistry to capture for example the catalytic destruction of ozone by bromine chemistry in the cooled plume. The simulations show that up to 40% of the emitted bromine can be converted into reactive forms within seconds. It promotes fast formation of BrO in the early evolution of the volcanic plume, at magnitudes consistent with UV-remote sensing measurements.

We further assess the presence of reduced species (e.g. molecular hydrogen (H<sub>2</sub>) and carbon monoxide (CO)) in the cooled plume and potential implications for the interpretation of observations of redox pairs in the plume. Our kinetic model contrasts to previous thermochemical equilibrium assumptions of near-complete oxidation of H<sub>2</sub> and CO. We identify emission temperatures and plume cooling conditions that allow these reduced species to persist whilst

reactive bromine is formed, as well as conditions where the reduced species become oxidized.

The combustion-atmospheric model is a unique tool for analyzing volcanic plume composition measurements as it provides the link to the original composition of the magmatic gas by a kinetic treatment of the magma-atmosphere interface. Future applications include the study of aerosol formation by SO<sub>2</sub>-sulfate transformation, mercury and NO<sub>x</sub>-nitrate chemistry.