Chemical processing of volcanic ash within eruption plume and cloud: a numerical modeling approach

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Volcanic ash is recently identified as an active chemical agent in the Earth system. Generated mainly through lithospheric processes and magma fragmentation, it can pose significant impacts upon different components of the Earth system for e.g. atmosphere and hydrosphere on various temporal and spatial scales. While airborne in the atmosphere, transition metals contained in the ash can catalyze the sulfur oxidation cycle thereby indirectly affecting the volcanic radiative forcing. Moreover, upon deposition on the surface ocean, ash can release soluble iron that fertilizes Fe-limited areas of the ocean and stimulate the marine productivity and CO_2 drawdown. Such impacts are provoked through interfacial processes and thus, are mainly induced by the ash surface composition. Recent studies suggest that in-plume and in-cloud processing of volcanic ash primarily control its surface composition. Direct evidences concerning such processes are, however, lacking.

Here we present the results of our recent investigations on in-plume and in-cloud processing of volcanic ash. A 1D numerical model is developed that simulates the gas-ash-aerosol interactions in volcanic eruption plume and cloud at temperatures between 600 ˚C and 0 ˚C focusing on iron, sulfur and halogen chemistry. Results show that sulfuric acid and water vapor condense at 150 ˚C and 50 ˚C, respectively, generating a liquid coating at the ash surface that scavenges the surrounding gases (>95% of HCl, 12-62% of HF and 3-20% of SO_2) and becomes extremely acidic (pH<2). The low pH conditions of the aqueous film promote acid-mediated dissolution of the ash that can for e.g. mobilize 0.1-33% of the total iron available at the ash surface before the freezing point is reached.

Sensitivity studies revealed that the efficiency of the gas scavenging and ash dissolution are controlled by various chemical and physical parameters. For e.g., elevated halide concentrations and presence of Fe^{2+}-carrying phases lead to the highest ash dissolution efficiency. Size distribution of the ash particles is another important factor: finer distributions tend to show up to one order of magnitude higher scavenging and dissolution efficiency. Therefore, processes that control the size distribution (e.g., particle aggregation) need to be considered in more details in the model.