Solid-gas interactions in the eruption plume can both depress and enhance volcanic ash ice-nucleating activity

Funded by the Horizon 2020 Framework Programme of the European Union

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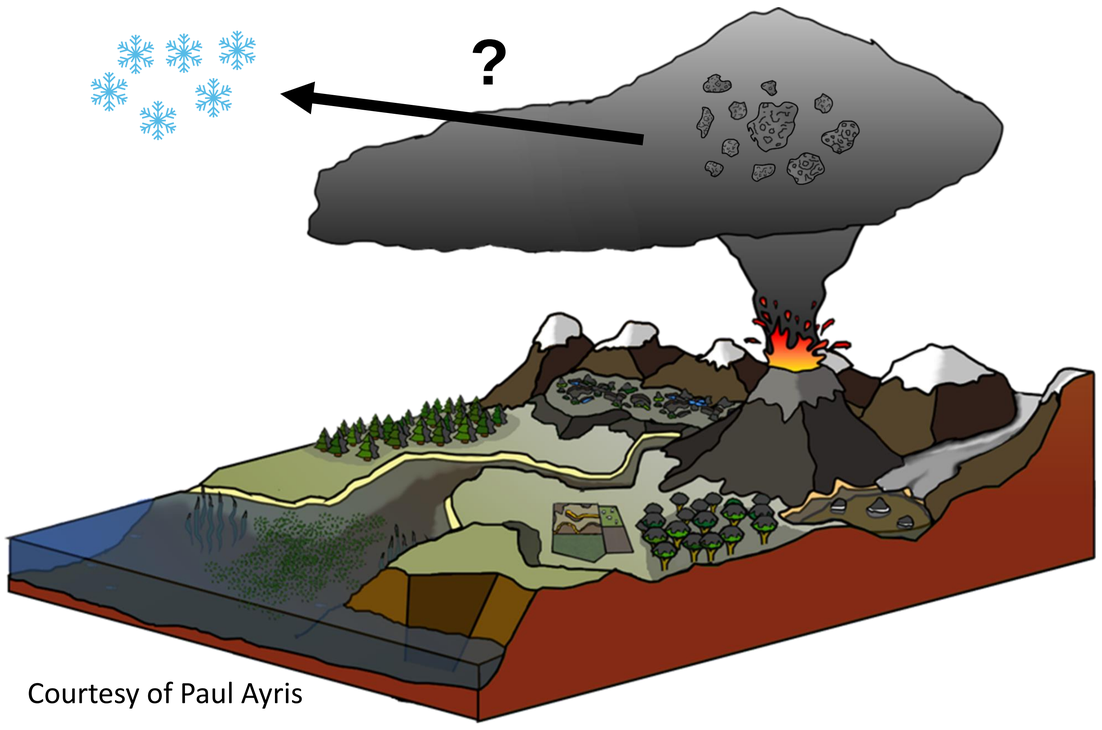

Courtesy of Paul Ayris

Background

Volcanic ash can act as ice-nucleating particles, promoting freezing of supercooled water in the eruption plume and cloud and the atmosphere[1]

It remains unclear what drives the large variation in ice-nucleating activity (INA) of ash reported in previous field and laboratory measurements

Our first study of a range of ash and glass samples suggests that crystalline phases (e.g., feldspar minerals) likely play an important role[2]

However, ash surface properties can be modified by interactions with magmatic gases in the hot eruption plume,[3-5] and it is not known how such interactions might affect the INA of ash

Materials and Methods

Five silicate materials studied: Tungurahua tephra (TUN), Astroni tephra (AST), Etna tephra (ETN), K-feldspar (FELD), Smoky quartz (QRTZ)

Samples were exposed in an Advanced Gas-Ash Reactor[6] at 800/400 °C to water vapour on its own (H_2O) or mixed with $SO_{2(g)}$ (H_2O-SO_2) or $HCl_{(g)}$ (H_2O-HCl) for 1200 seconds

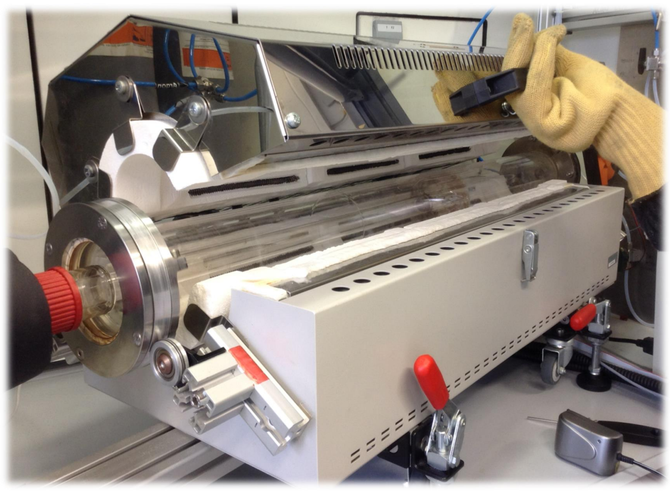

Figure 1. Photo of the Advanced Gas-Ash Reactor showing the working tube within a three-stage furnace

Soluble compounds formed on samples were assessed by leaching in water, filtration and analysis by ICP-OES and IC

Ice-nucleating activity of samples was assessed by cold stage droplet assays using a microlitre Nucleation by Immersed Particles Instrument[7]

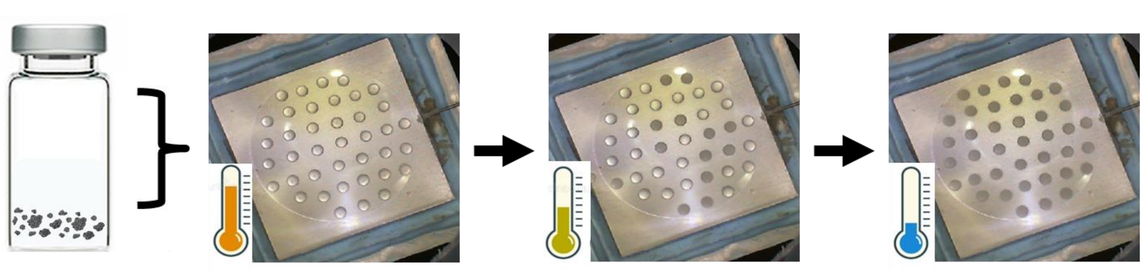

Figure 2. Schematic of a droplet assay experiment showing water droplets containing 1 wt.% sample suspension freezing as temperature decreases

Ice-nucleation active site density per unit solid surface area ($\boldsymbol{n_s}$) as a function of temperature was calculated as:

$$n_{ice}(T)/n = 1\text{-}\exp(-\boldsymbol{n_s}(T)A)$$

$n_{ice}(T)$ = number of droplets frozen at temp (T)
n = total number of droplets
A = total solid surface area per droplet

Results Summary Figure

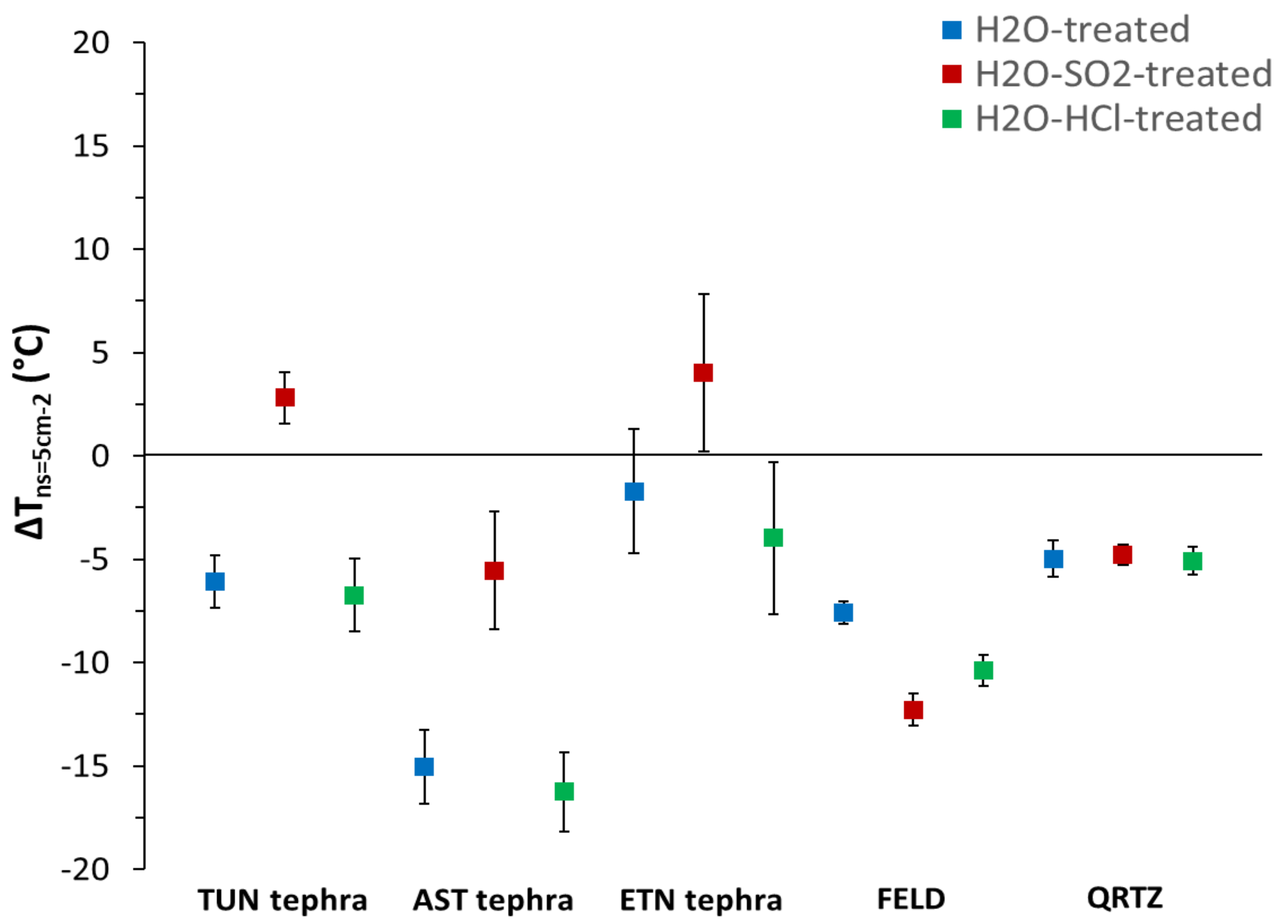

Figure 3. Difference in INA ($\Delta T_{ns \approx 5\ cm\text{-}2}$) between the H_2O-treated, H_2O-SO_2-treated, or H_2O-HCl-treated and the non-treated silicate materials. Values above or below the horizontal black line indicate that the INA of the treated samples is higher or lower, respectively, than the INA of the non-treated samples. The error bars reflect the ranges of values based on the standard deviations of mean $T_{ns \approx 5\ cm\text{-}2}$ values for the treated and non-treated samples from replicate ice nucleation experiments.

H_2O and H_2O-HCl *decreased* INA relative to the non-treated material

H_2O-SO_2 either *increased* INA relative to the non-treated material (TUN and ETN) or *decreased* INA to a lesser extent (AST), to a greater extent (FELD), or to the same extent (QRTZ) as the other treatments

Differing effects of treatments likely reflect contrasting reactivities of the silicate materials towards H_2O and $SO_{2(g)}$ or $HCl_{(g)}$

Changes in tephra INA do not relate to a 'solute effect'[8,9] of sulphate or chloride salts formed by reaction with $SO_{2(g)}$ or $HCl_{(g)}$ at high temperatures

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