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The role of volcanic particle thermal conductivity, density, and porosity in influencing ice melt.

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Volcanoes can generate pyroclastic material that is deposited on ice and snow surfaces. However, a range of particle properties and spatial distribution of layer thicknesses are associated with deposition of volcanic material[1]. This can modify the thermodynamic behaviour and optical properties of clean ice. Typically, thin layers of particles (i.e. in 'dirty' ice conditions) can increase ice ablation, whilst thick layers of particles (i.e. in 'debris-covered' conditions) can hinder ablation[2]. Therefore, the state of ice is an important control on the energy balance of an ice system. 20.4% of Earth's known Holocene volcanoes are associated with glacier or permanent snow cover[3], and so it is crucial to understand how volcanic material interacts with ice systems to (1) better understand the evolution of debris-covered and dirty ice in general and (2) forecast future ice-melt scenarios at individual ice-covered volcanoes.

We present laboratory experiments that systematically reviewed the impact of volcanic particles of a range of compositions and properties (e.g. thermal conductivity, diameter, density, and albedo) on ice. Experiments assessed single particles and a scattering of particles on optically transparent and opaque ice, subjected to visible light illumination from a light emitting diode in a system analogous to dirty ice. Automated time-lapse images and in-person observations captured the response of particles and ice to radiation. Particles investigated included trachy-andesitic cemented ash particles from Eyjafjallajökull (Iceland), basaltic-andesitic scoria from Volcán Sollipulli (Chile), and rhyolitic pumice from Mount St. Helens (USA).

The experiments provided insight into some of the processes associated with volcanic particle interaction with ice. Results demonstrated that all volcanic particles with varying albedos induced ice melt and drove convection systems within the meltwater. This convection resulted in indirect heating beyond the immediate margins of the particles. The particles additionally lost finer grained fragments to meltwater, further driving ice melt through the addition of multiple absorbing surfaces within the ice system. This demonstrated that volcanic particles have the capability to melt ice very effectively in dirty ice conditions. In all experiments, the particles had a low thermal conductivity (relative to ice), although the density differed between particle types. Our experiments showed that the porosity and density of a volcanic particle can dictate the behaviour of particle-ice interaction; a dense particle can melt downwards through the ice (in similarity with the behaviour of iron-based meteorites[4]), whilst a less dense particle can become buoyant in

meltwater, resulting in an extensive area of surface melt.

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