EGU21-6821
https://doi.org/10.5194/egusphere-egu21-6821
EGU General Assembly 2021

Modelling the formation and evolution of glaciovolcanic caves and chimneys.

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Localised elevated subglacial or subnivean geothermal activity has the potential to influence the morphology and flow of glaciers. Under conditions where the meltwater produced by these glaciovolcanic interactions is effectively drained away from the geothermal source, glaciovolcanic voids may form. These voids can only exist if the influx of geothermal vapours/gases provides more heat for melting than can be compensated by the inflow of ice. We identify two distinct glaciovolcanic void morphologies: horizontal passageways or chambers beneath the ice/snow, termed *caves*, and vertical shafts, termed *chimneys*. Both transient and long-lived caves and chimneys have been observed, with their formation sometimes being precursory or concurrent expressions of volcanic unrest. A better understanding of these features can therefore aid volcano monitoring programs and volcanic hazard assessments. Here we investigate the relationships between glaciological and geothermal conditions and their effects on the formation and evolution of glaciovolcanic caves and chimneys. We adapt existing analytical models, originally developed to describe subglacial hydrology, to derive and balance expressions for the radial melt-opening and creep-closure to find steady-state solutions for cave and chimney geometries. The effects of localised geothermal heat fluxes on fully drained glaciovolcanic voids are further investigated using a numerical full-Stokes ice-flow model. Idealised voids, subject to a prescribed geothermally induced mass balance, are inserted within synthetic glaciers of variable bed slope and thickness. Transient simulations are then used to map out the parameter space that influences the formation and evolution of glaciovolcanic caves and chimneys.