Geophysical Research Abstracts
Vol. 19, EGU2017-1100, 2017
EGU General Assembly 2017

An experimental investigation of ice melting and heat transfer from submerged warm water jets upward impinging into ice-blocks, implications for subglacial volcanic eruptions

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The rates and processes of energy transfer in water-filled cavities formed under glaciers by geothermal and volcanic activity has been investigated using an experimental setup with a hot water jet impinging on an ice block. A systematic set of experimental runs typically lasting 60-90 seconds with water jet temperatures in the range 10° - 90°C has been performed with initial ice block temperatures ranged from 0°C to –33°C. It is found that heat flux from flowing water to ice is linearly dependent on temperature of the jet flow. The hot water jets melted out cavities into the ice. The cavities had steep to vertical sides with a doming roof. Flow visualizations have been attempted to capture the important events. Some of the ice blocks used had trapped air bubbles. In these cases melting of the ice lead to the trapping of air at the top of the cavity, partially insulating the roof from the hot water jet. Such cavities had lower aspect ratios (height/width) and flatter and less dome shaped roofs than did cavities in ice blocks with little or no air bubbles. The overall heat transfer rate in cavity formation varied with jet temperature from <100 kW m-2 to ∼900 kW m-2 while melting rates in the vertical direction yield heat transfer rates of 200-1200 kW m-2. The observed experimental heat transfer rates can be compared to data on subglacial melting observed for ice cauldrons in various settings in Iceland. For the lowest experimental temperatures the numbers are comparable to those found for geothermal water in cool, subglacial water bodies and above subglacial flowpaths of jökulhlaups. However, the highest experimental rates for 80-90°C jets are 3-10 times less than inferred from observations of recent subglacial eruptions (2000-4000 kW m-2). This can indicate that single phase liquid water convection alone may not be sufficient to explain the rates seen in recent sub-glacial eruptions in Iceland, suggesting that during such eruptions forced two-phase (liquid and steam) or three phase (liquid, steam and pyroclasts) convection can be common or of importance.