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Variations in geothermal heat flux at Grímsvötn, Iceland

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Thermal signals from sub-surface magmatic sources are difficult to quantify, as the measurement of fluxes from the ground to the atmosphere is subject to large uncertainties. Ice cauldrons are depressions which form on the surface of glaciers due to basal melting as a result of geothermal flux from the bedrock beneath, often generated by volcanic sources. The monitoring of ice cauldrons provides a unique opportunity to quantify heat flux to a much improved accuracy, as the melting ice acts as a calorimeter.

Time series data of ice surface elevation at cauldrons above Grímsvötn volcano are presented over a 14 year period, with estimates of the melt volume and surface heat flux required for this melting to have occurred. Three volcanic eruptions took place at Grímsvötn during the study period, the effects of which are visible in ice surface elevation data. However, separate thermal anomalies are observed in areas unaffected by erupted products. A peak in surface heat flux is observed following the 1998 eruption, several kilometres east of the vent, with a maximum rise of $\sim$200 $W{\cdot}m^{-2}$. The anomalous signal lasts for approximately three years. Possible explanations include the intrusion of a dyke beneath this area during the eruption, or increased permeability from greater dilatational strain due to regional stress, both of which would significantly increase heat flux.

We investigate possible scenarios which could produce such a thermal anomaly, using finite element modelling. The effects of cooling magmatic intrusions and changes to the parameter space for country rock conductivity and permeability are considered, in relation to heat flux and the timescales and spatial extent of associated surface anomalies. Our results advance the understanding and interpretation of thermal signals observed at ice-covered volcanoes.