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Full stokes ice models as a tool to estimate heat source properties underneath ice

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Subglacial geothermal areas of various magnitude occur in glaciated volcanic regions. Such spots of elevated heat flow are common in Iceland, e.g. under the Vatnajökull and Mýrdalsjökull ice caps, but they are also found elsewhere, including the West Antarctic Ice Sheet and several ice-filled calderas around the world. A heat source at the base of an ice stream will change the basal sliding properties by providing water to lubricate the basal layer and therefore can be seen as a major part of the ice stream process, possibly even control ice-stream formation in areas with basal heat sources. The heat sources underneath the Icelandic glaciers produce meltwater at the base, which drains along the bedrock towards the glacier rims. When this meltwater accumulates near the thermally active site or along the flowpath, as in the Grimsvötn caldera, this collected water will drain after overcoming the hydrostatical boundary (ice dam) as jökulhlaup. Such jökulhlaups can pose a threat to man made infrastructure. Estimating the properties of heat sources underneath ice where direct observation is not possible can be achieved by studying the depressions formed at the ice surface. A simple calorimetric estimate of heat output can be carried out from ice volume changes but ice flow is then ignored. This, however, is unsatisfactory in areas where significant ice flow occurs. Full Stokes Ice models allow the modeling of ice flow above basal heat sources in such detail that differences between the modeled and the measured surface evolution can be used to infer the heat source properties. Through forward modeling it is possible to estimate the strength of the heat source, identifying variations in the heat flux as well as infer the spacial variations of the strength of the heat source. This method of estimating basal heat source properties underneath ice and glaciers is evaluated through synthetic models. The heat fluxes used in the forward models are of order $10^2\ Wm^{-2}$, a magnitude considered applicable to hydrothermal activity. It is

found that for this magnitude of heat sources, ice flow becomes increasingly important in the process of estimating the heat source properties. This implies that as the heat source becomes stronger, the error incurred from not including ice flow effects becomes larger. This method is applied to an elongated subglacial geothermal area in the eastern part of Grimsvötn in Vatnajökull. It is found that the model can reproduce the characteristics and magnitude of the observed surface evolution in this area.