

# STUDIES OF THE SKAFTÁRKATLAR SUBGLACIAL LAKES, VATNAJÖKULL ICE CAP, ICELAND

Monday 15 September 2025 15:05 (5 minutes)

In the western part of the Vatnajökull ice cap, two subglacial geothermal systems cause steady melting of the overlying ice and collection of meltwater in subglacial lakes that empty out in jökulhlaups (glacier lake outburst floods) every 2 years (on average). Release of the meltwater, which contains a geothermal fluid component, leads to subsidence of the surface and the formation of 50–150 m deep, nearly circular cauldrons, the Skaftárvatn (Skaftá cauldrons), which are 1–3 km wide (Björnsson, 2010; Einarsson et al., 2016).

In the years 2006–2015, we conducted several hot-water drilling, sampling and logging projects in both the western and the eastern Skaftá cauldrons. A drill with built-in sterilization (Thorsteinsson et al., 2007) was used to penetrate the 230–300 m thick ice cover seven times at five different locations within the cauldrons. The program included the following efforts:

**June 2006:** First drilling in the Western Skaftá cauldron. Successful sampling of the subglacial lake for geochemical and microbiological analysis, demonstration of a biological habitat in this extreme environment (Gaidos et al., 2008). Measurement of the temperature profile in the 115 m deep lake, modelling of circulation within the water body and estimation of ice-melting rates at the ice-shelf base (Jóhannesson et al., 2007).

**June 2007:** Drilling into the lake beneath the Eastern Skaftá cauldron, at 3 locations. Continued sampling program and microbiological studies (Marteinsson et al., 2013). Deployment into the lake of a thermistor string with 15 temperature sensors at different depths and collection of data over 12 months. Installation of a GPS-receiver to record vertical movement of the ice shelf at the start of a jökulhlaup and deliver early warning.

**2008–2010:** Smaller reconnaissance projects in Skaftárvatn and Kverkfjöll (N-Vatnajökull).

**March 2014:** Successful drilling into the eastern cauldron during wintertime conditions. Continued sampling and temperature profile logging.

**June 2015:** Successful drilling into both cauldrons, sampling at different depth levels in the subglacial lakes. Temperature profile measurements.

Results obtained and lessons learned during these projects include:

**Hot-water drilling.** Under favourable conditions within the cauldrons, the 230–300 m thick ice cover could be penetrated in less than 10 hours. Minimal problems were encountered in penetrating volcanic tephra layers, but englacial crevasses and water bodies were sometimes encountered. This caused difficulties which could be alleviated by drilling a new hole a few tens of meters away. Sterilization of the drilling water was successful.

**Sampling method.** A commercial sampler produced by Mt. Sopris Instruments, with an opening and closing mechanism operated from the surface, worked without problems.

**Temperature profiles.** We used Starmon mini and Geokon temperature sensors to measure the lake temperatures. In the western lake, the water temperature was at 3.5–4.7°C in June 2006 and large-scale circulation in the lake body was inferred from the observed stratification (Jóhannesson et al., 2007). In June 2015, lake temperatures were at 4.0–4.5°C throughout most of the water column. The eastern lake displayed a more stable temperature profile close to 4°C in 2007 and limited change in the vertical profile was observed over the 12-month period during which the deployed thermistor string survived. In 2015, the temperature was stable at 3.5°C in an 86 m water column.

**Jökulhlaup mechanisms.** The subglacial lake studies have allowed determination of the initial temperature of jökulhlaup water released from these water bodies. Moreover, estimation of lake volumes during the onset of outburst floods has greatly improved since the start of the program and in related work (Magnússon et al., 2021). Combining data on lake properties with GPS-measurements of vertical and horizontal movement of the glacier surface at locations downstream, a new picture has emerged of the mechanisms of water flow along the 40 km long subglacial flow path, where alternating sheet flow and tunnel flow is the most plausible explanation of the observed flow behaviour (Einarsson et al., 2017).

During drilling in the western cauldron in 2015, the drill stem hit an englacial water body and water was rapidly released through the borehole into the subglacial lake. This sudden influx of water probably triggered a jökulhlaup from the lake two days later (Gaidos et al., 2020).

**Early warning systems.** A GPS-station delivering data on vertical and horizontal surface movement was operated in the Eastern Skaftá cauldron for several years. The station recorded lowering of the cauldron surface when the lakes emptied out in jökulhlaups. This allowed early warning to be given to civil protection

authorities at least 20 hrs before emergence of the floodwaters from beneath the western margin of Vatnajökull.

## References

- Björnsson H (2010). Understanding jökulhlaups: From tale to theory. *Journal of Glaciology* 56 (200):1002–1010. doi:10.3189/002214311796406086
- Einarsson, B, Magnússon E, Roberts MJ, Pálsson F, Thorsteinsson Th, Jóhannesson T (2016). A spectrum of jökulhlaup dynamics revealed by GPS measurements of glacier surface motion. *Annals of Glaciology* 57 (72), 4–61. doi: 10.1017/aog.2016.8
- Einarsson B, Jóhannesson T, Thorsteinsson Th, Gaidos E, Zwinger T (2017). Subglacial flood path development during a rapidly rising jökulhlaup from the western Skaftá cauldron, Vatnajökull, Iceland. *Journal of Glaciology* 63 (240) 670–682. doi: 10.1017/jog.2017.33.
- Gaidos EJ, Marteinsson V, Thorsteinsson Th, Jóhannesson T, Rúnarsson ÁR, Stefánsson A, Glazer B, Lanoil B, Skidmore M, Han S, Miller M, Rusch A, Foo W (2008). An oligarchic microbial assemblage in the anoxic bottom waters of a volcanic subglacial lake. *The ISME Journal* 3, 486–497, doi:10.1038/ismej.2008.124
- Gaidos E, Jóhannesson T, Einarsson B, Thorsteinsson Th, Amend J, Skidmore M (2020). Après nous, le déluge: A human-triggered jökulhlaup from a subglacial lake. *Geophysical Research Letters* 47 (22). doi.org/10.1029/2020GL089876
- Jóhannesson T, Thorsteinsson Th, Stefánsson A, Gaidos E, Einarsson B (2007). Circulation and thermodynamics in a subglacial geothermal lake under the Western Skaftá cauldron of the Vatnajökull ice cap, Iceland. *Geophysical Research Letters* 34, L19502, doi:10.1029/2007GL030686.
- Magnússon E, Pálsson F, Gudmundsson MT, Högnadóttir Th, Rossi C, Thorsteinsson Th, Ófeigsson BG, Sturkell E, Jóhannesson T (2021). Development of a subglacial lake monitored with radio-echo sounding: Case study from the Eastern Skaftá Cauldron in the Vatnajökull ice cap, Iceland. *The Cryosphere* 15, 3731–3749. doi.org/10.5194/tc-15-3731-2021.
- Marteinsson V, Rúnarsson Á, Stefánsson A, Thorsteinsson Th, Jóhannesson T, Magnússon SH, Reynisson E, Einarsson B, Wade N, Morrison HG, Gaidos E (2013). Microbial communities in the subglacial waters of the Vatnajökull ice cap, Iceland. *The ISME Journal* 7, 427–437, doi:10.1038/ismej.2012.97.
- Thorsteinsson Th, Elefsen S, Gaidos E, Lanoil B, Jóhannesson T, Kjartansson V, Marteinsson V, Stefánsson A, Thorsteinsson, Thr (2008). A hot water drill with built-in sterilization: Design, testing and performance. *Jökull* 57, 71–82.

**Primary author:** THORSTEINSSON, Thorsteinn (Icelandic Meteorological Office)

**Co-authors:** STEFÁNSSON, Andri (University of Iceland); ÓFEIGSSON, Benedikt (Icelandic Meteorological Office); BERGSSON, Bergur (Icelandic Meteorological Office); EINARSSON, Bergur (Icelandic Meteorological Office); LANOIL, Brian (University of Alberta); GAIDOS, Eric (University of Hawaii); AMEND, Jan (USC Dornsife); SKIDMORE, Mark (Montana State University); JÓHANNESSON, Tómas (Icelandic Meteorological Office); MARTEINSSON, Viggó (MATÍS); KJARTANSSON, Vilhjálmur (Icelandic Meteorological Office)

**Presenter:** THORSTEINSSON, Thorsteinn (Icelandic Meteorological Office)

**Session Classification:** Poster sessions oral introduction

**Track Classification:** Subglacial drilling and sampling