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Application of novel DNA-based dye tracers to determine the subglacial drainage system structure and morphology of Storglaciären, Sweden

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Storglaciären, Sweden, is a 3.22km2 polythermal valley glacier. Its extensive datasets provide a unique prospect for assessing cryospheric response to climate change over recent years and into the future. Storglaciären has predominantly temperate thermal regime ($\sim$85% temperate ice) with a cold surface layer of mostly $\sim$20m thickness, but $\sim$60m thickness at the terminus and margins (Gusmeroli et al., 2012, Journal of Glaciology). Subglacial hydrology exerts important controls on a glacier. Modelling future ice-mass dynamics needs sound understanding of glaciers' subglacial drainage systems, especially the variety of potential structures and morphologies adopted over time and space. Proglacial-runoff changes may result from shifts in subglacial drainage systems over time; these changes have important implications for glacierised catchments' populations. Moreover, knowledge acquired from valley glaciers can be applied to ice sheets. In most studies, subglacial water pressure (Pw) is assumed to equal ice-overburden pressure, yet recent studies suggest a lower long-term value may be more appropriate (e.g. Willis et al., 2008, 2012, Hydrological Processes). Research to date using Shreve's (1972, Journal of Glaciology) hydraulic-potential theory and comparing modelled drainage systems with empirical observations ascertained that Storglaciären's steady-state subglacial Pw is likely adjusted to 70-80% of ice-overburden pressure (Williamson, unpublished undergraduate thesis). Further work using an alternative modelling approach is necessary to determine Storglaciären's spatiotemporal Pw variations.

Dye tracing is widely employed to determine subglacial drainage systems' structure and morphology through analysing breakthrough curves and through delimiting the extent of proglacial streams' watersheds. 25 dye-tracing experiments using conventional synthetic tracers (Rhodamine WT and Uranine) were conducted from 12 injection sites during summer 2012. As with all present dye-tracing experiments, a limitation was the finite number of tracers available for simultaneous use due to tracer interference if $\geq$2 identical tracers are employed. In resolving this problem, 10 synthetic DNA-based dye tracers were tested on Storglaciären during summer 2013. The DNA sequences can be randomly merged, meaning lots of unique tracers can be developed and injected simultaneously. Higher spatial concentration of injection points can therefore be used in a single experiment conducted at a discrete instance in the melt season, allowing previously unobtainable glacial-hydrology information to be collected, including drainage-morphology variations at different areas beneath a glacier. Modelling is conducted in conjunction with dye tracing. The model of Arnold et al. (1998, Hydrological Processes) is applied to Storglaciären, only formerly applied to a temperate glacier. Meltwater volumes (modelled with 2013 meteorological-station data using an energy-balance approach) are routed to the bed at known conduit locations extending from the surface, producing better models of drainage system structure than when meltwater is routed to the bed in situ (e.g. Gulley et al., 2012b, Journal of Glaciology).

Subglacial drainage system morphology and spatiotemporal Pw variations are determined with these methods. 2013 data are compared with those from 2012 and the 1980s to determine temporal developments to subglacial drainage, including how well englacial drainage becomes connected with the subglacial system in differing climatic years. DNA-based tracers have promising future applications for valley glaciers and ice sheets.