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Simulating hydrology and tracer dynamics in a subglacial environment underneath the Greenland ice sheet

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The Greenland ice-sheet surface melt has increased substantially in intensity and spatial extent over the recent decades. The rapid migration of melt towards upstream areas of Greenland ice sheet is expected to incur major changes in hydrological behaviour of the ice-sheet and outlet glaciers along with changes in export fluxes of carbon, methane, and other nutrient fluxes, which, in turn, will further affect the downstream ecosystem of rivers, fjords and oceans. Subglacial environments are emerging as ecological hotspots, urging detailed understanding of interaction between subglacial-hydrology and biogeochemistry. However, due to their inaccessibility, the hydrology and biogeochemistry of subglacial environment thus far lacks a detailed understanding. Numerical models are, in combination with observational data, ideal tools to advance our understanding.

Here, we developed a novel process-based model to investigate the interplay between subglacial-hydrology and (passive and active) tracer dynamics underneath the rapidly changing Greenland ice sheet on seasonal, inter-annual and climate warming relevant timescales. We set up the subglacial-hydrology model GlaDS (Glacier Drainage System model) to simulate seasonal and interannual evolution of distributed and channelized subglacial water flow for Leverett glacier (Southwest Greenland) to explore the geometry, connectivity, and flow dynamics in the seasonally evolving drainage system.

We then use the GlaDS results to inform a reaction-transport model (RTM) of Leverett's subglacial system following the GlaDS set-up. The RTM is run to conduct a series of idealized tracer experiments with the aim of disentangling the transport and reaction controls on subglacial tracer distribution and outflow. Tracers are injected to the system through moulins with the surface meltwater and are either passively transported (passive) or also consumed/produced (active) during their transit through the system. Model results are validated with long-term measurements in this area. Results show that the tracer transport is primarily controlled by subglacial drainage system efficiency, which is regulated by discharge magnitude, topography and moulin locations. The spatial and temporal variation in tracer concentration is further dependent on hydrological interaction between different subglacial components (cavities and channels), location and type of branching of channels, and bed properties.

In the future, we will extend the model to wider area of Greenland ice sheet and couple it to multi-component biogeochemical reaction networks with the. aim to understand the evolution of biogeochemical process along with the evolution of hydrology in warming climate.