Combined Modeled and Explored Moulin Shape Informs Subglacial Pressure Dynamics in Western Greenland

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Abstract

Ice motion in land terminating regions of the Greenland Ice Sheet is controlled in part by meltwater input into moulins. Moulins, large near-vertical shafts that deliver supraglacial water to the bed, modulate local and regional basal water pressure and ice flow by influencing subglacial drainage efficiency on daily to seasonal timescales. Our previous modeling work found that the geometry of a moulin near the water line has substantial effect on subglacial water pressure variations. Here, we develop a new physically based moulin model which can help constrain moulin shape across the ice sheet and its influence on hydraulic head oscillation, and inform the englacial void parameter used in glacier hydrology modeling. The Moulin Shape (MouSh) model (in Matlab and Python) provides new insight into the evolution of subsurface moulin size and shape at hourly to multi-year timescales. The modeled moulin is initialized as a vertical cylinder. The moulin walls melt back above and below the water line due to the dissipation of turbulent energy, open or close due to viscous and elastic deformation, and freeze inward in winter when cold air temperatures and an absence of meltwater allow refreezing. We combine MouSh modeling results with geometric data from two moulins in Pâkitsoq, western Greenland, which we mapped to the water line. The moulins have heterogeneous shapes and volumes in the top 100 m. This suggests that the size and shape of the upper portion is controlled by local and regional pre-existing fractures, which provide preferential paths for water flow and melting, creating stochastic karst-like conduit shapes. Modeling results show that moulin geometry below the water line is influenced by the hydraulic head, which controls the depth-dependent elastic and viscous closure rates, and by the roughness of the walls, which enhances melt-out rates that oppose moulin closure. We show that subglacial water pressure across the ice sheet is likely influenced by moulin geometry, underscoring the need for including moulins in subglacial models.

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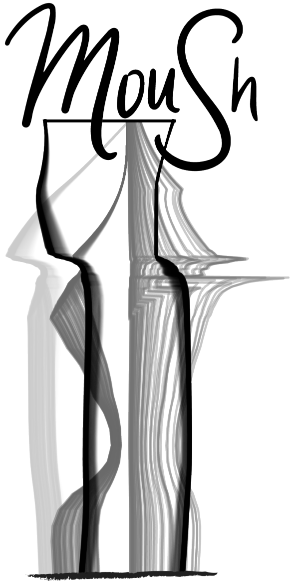

Moulin Shape Model

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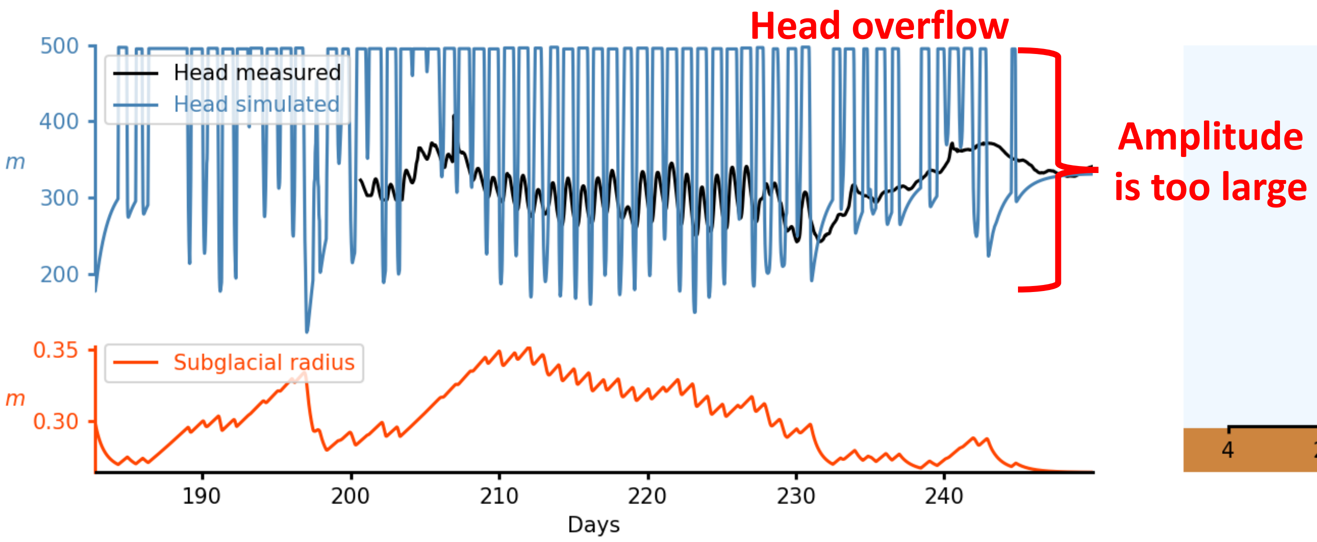
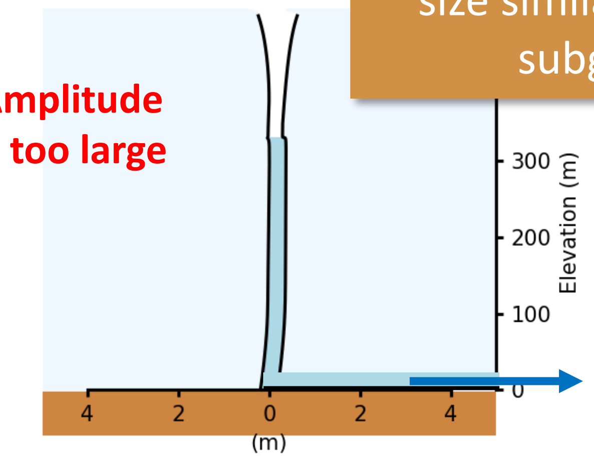
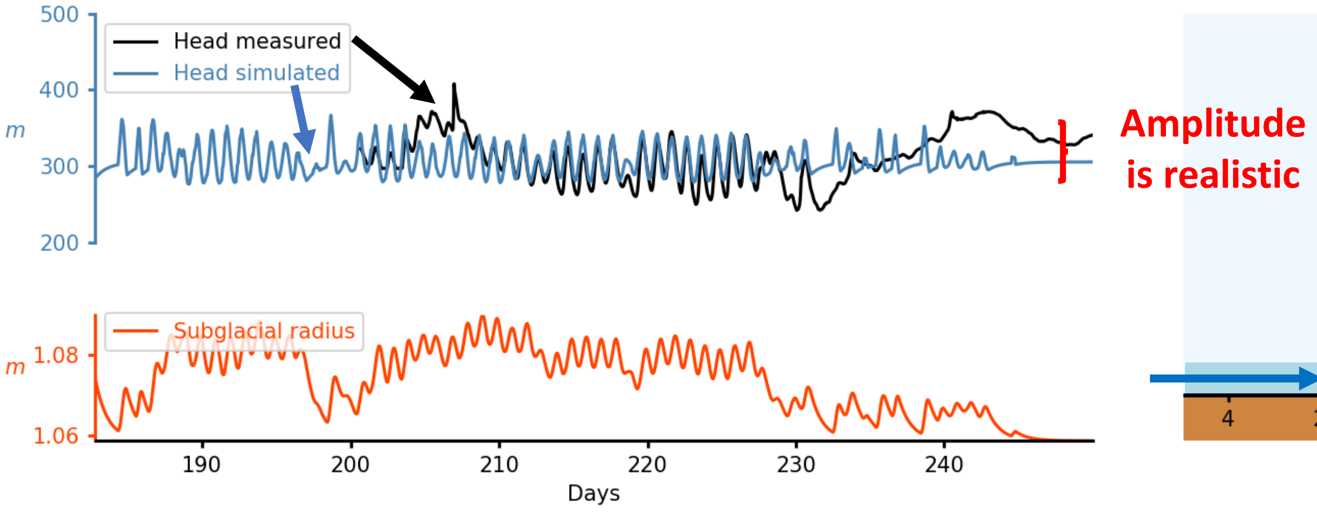
Current models require very large moulin volumes to generate realistic head variations

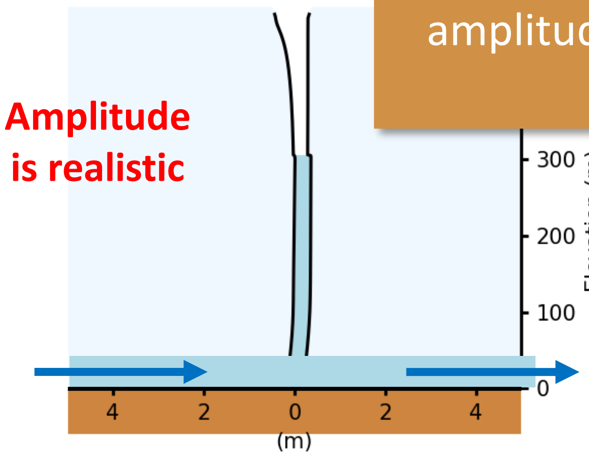


MouSh predicts a moulin size similar to the associated subglacial channel

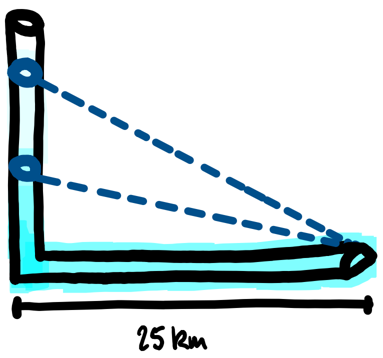


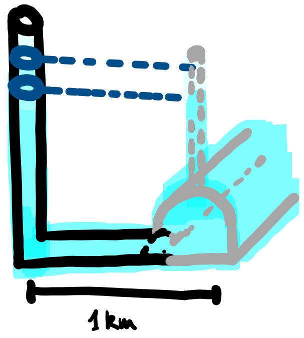


A subglacial baseflow makes the amplitude of head oscillations more realistic

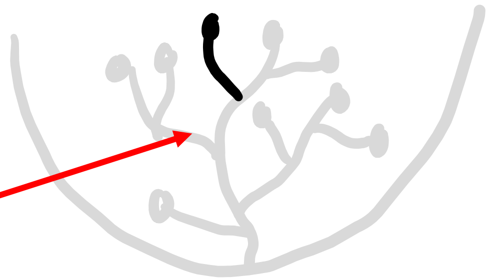


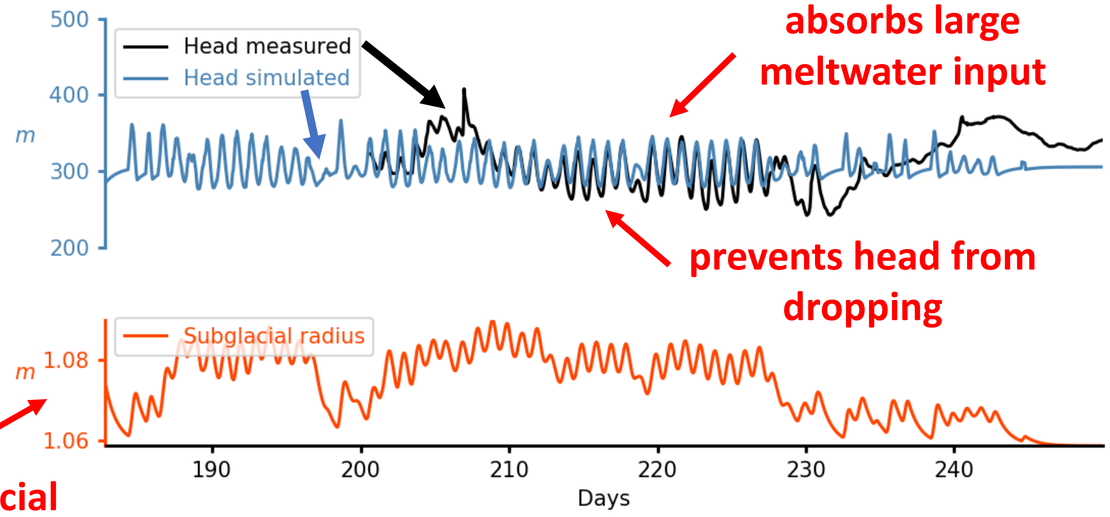
There is more water in the subglacial system than simulated with a single channel





More water in the subglacial drainage

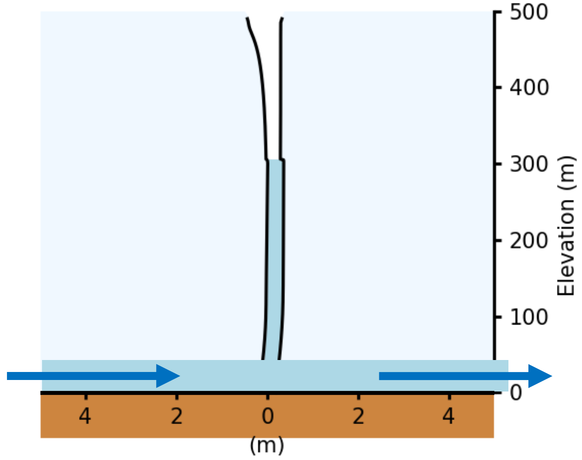




absorbs large meltwater input

prevents head from dropping

keeps subglacial channel larger



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