Modeling subglacial meltwater runoff and associated sediment transport

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Meltwater runoff from the Greenland ice sheet and its impacts on the ocean have drawn increasing interest. The surface meltwater is drained through englacial channels called moulins that reach the bedrock, and hence it is discharged to the ocean at the grounding level of marine-terminating glaciers [Chu, 2014]. Therefore, meltwater runoff may contain substantial amount of terrestrial sediments. Although several observational and modeling studies have been performed on the subglacial discharge events recently, few have focused on such sediment transport induced by the meltwater plume.

In the present study we have developed a numerical model to quantitatively assess the subglacial plume driven by the turbid meltwater discharge and associated sediment transport. To explicitly simulate the dynamics of turbidity current, a non-hydrostatic ocean model is coupled with a built-in Lagrangian particle tracking system that trace a huge number of sediment particles. The model domain is an idealized rectangular fjord of 10 km long, 3 km wide and 300 m deep. The initial stratification is set to idealize the typical summertime Greenland fjord where the cold and less-saline Polar water layer exists over the warm and saline Atlantic water, while the surface is covered by the warm and fresh surface water. We set a tunnel-like englacial channel at the grounding line (280 m depth) of the glacier front and the freshwater runoff is applied into this tunnel with various discharge flux from 100 to 1000 m^3/s. We also imposed a sediment particle supply corresponds to 1000 kg/s inside the tunnel.

Figure 1 is the result of CTRL experiment (discharge flux Q = 500 m^3/s, particle diameter d = 1 μm) where the color shows the concentration of sediment particles (corresponds to the turbidity of seawater). Since the discharged fresh water is significantly less dense than seawater, strong vertical motion is induced at the exit of the tunnel and an upwelling plume is formed along the side of the glacier front. The major portion of sediment particles is captured inside this upwelling plume and reach the surface, and then it forms the similar high-turbidity sub-surface layer as observed in Greenland fjords. The upwelling plume induces overturing circulation inside the fjord where the upper layer flows offshore and compensating onshore current exists below. Some portion of sediments are transported offshore by this overturning circulation. The higher concentration of suspended sediments are found along the right-hand-side wall because of the Coriolis force. The distance of offshore sediment transport highly depends on the particle size; sediment particles of less than 10 μm diameter tend be transported to the end of the domain while the particles of greater size tend to deposit near the glacier front.

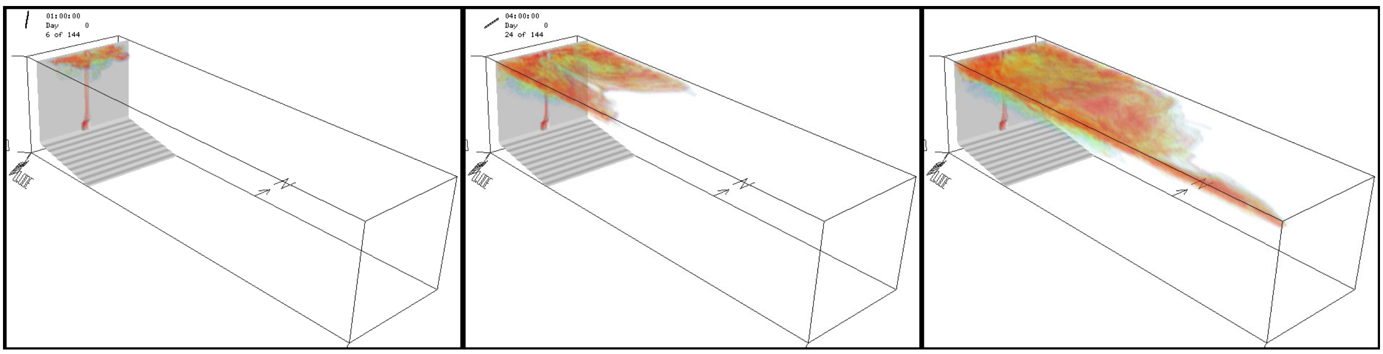

Figure 1. 3D volume-rendering images of the simulated turbidity at t = 1, 4, and 8 hours of CTRL experiment (discharge flux Q = 500 m^3/s, sediment diameter d = 1 μm).

Reference

Chu, V. W., Greenland ice sheet hydrology: A review. Progress in Physical Geography, 38(1), 1-54, 2013.