Dissolved organic matter export from the Greenland Ice Sheet: quantity, age and source

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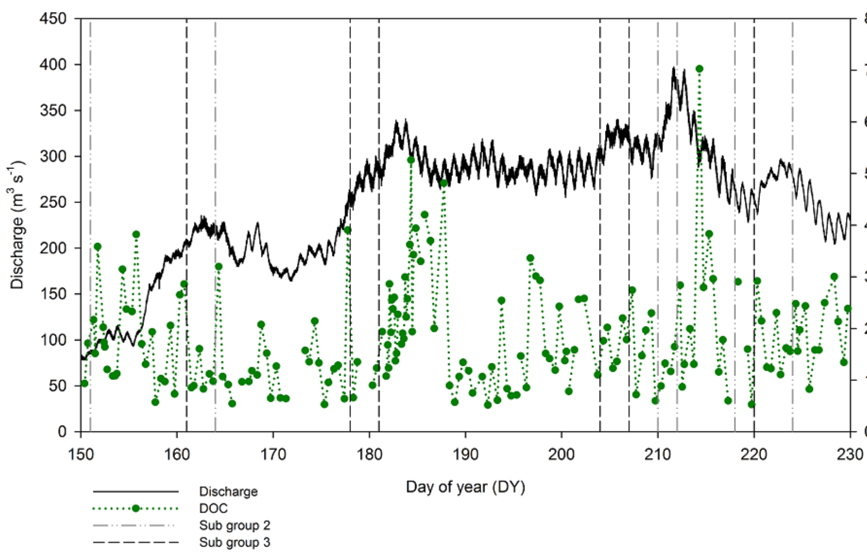
The Greenland ice sheet (GrIS) is the largest expanse of glacial ice in the Northern Hemisphere and is capable of contributing significant quantities of meltwater and associated material to the surrounding North Atlantic and Arctic Oceans. Surface-derived meltwater drains to the bottom of the ice-sheet and interacts with overridden soils, vegetation and bedrock. This meltwater fuels biogeochemical processes beneath the ice initiated by subglacial microbial communities prevalent in glacial systems with water at their base. Funding from an earlier Clark Arctic Research Initiative grant supported a PhD graduate student (Maya Bhatia, PhD 2011). Her thesis showed that microbial communities have a particularly significant impact on the composition of dissolved organic matter exported from GrIS in the early melt-season. This signature was diluted relative to plant-derived organic matter later in the season as the flux of surface-derived meltwater increased.

In this project, we expanded our initial dataset to a larger glacier from the same general region of Greenland. In this case, we collaborated with Dr. Jemma Wadham and her student, Emily Lawson, from the Glaciology Centre at the University of Bristol (UK), who conducted a field season in 2010 at the Leverett Glacier on the southwestern margin of the GrIS. This glacier had a catchment area of 2000 km^3, approximately 400X the size of our initial glacier. Supraglacial and subglacial water samples were collected throughout the meltseason to ascertain organic matter age (radiocarbon content) and organic matter source and character (compositional assessment by mass spectrometry).



Discharge (black) and dissolved organic carbon (green) concentrations during the meltseason at Leverett Glacier. Vertical lines indicate subglacial sampling points for DOM compositional analysis. These samples were compared to point samples taken from the glacier surface (supraglacial).

We analyzed subglacial samples from different discharge levels (see figure) throughout the melt season by ultrahigh resolution mass spectrometry. The two dominant results from our work are that subglacial organic matter is very different from supraglacial organic matter and that subglacial organic matter is dominated by nitrogen-rich molecules throughout the meltseason. In the first case, our results are consistent with our earlier ARI-funded work and suggest that organic matter on the surface of the GrIS has a very different source than subglacial organic matter. The source appears to be primarily microbial with additional material derived from atmospheric deposition of continental organic matter. In the second case, our results were consistent with our earlier work only in the initial stages of the melt-season. At the smaller glacier, a significant terrestrial component from over-ridden vegetation, which contains very little nitrogen, dominates the DOM in later stages of the meltseason. In contrast, at the large Leverett Glacier, the nitrogen-rich component remains large throughout the meltseason. It is possible that this material is derived from subglacial microbial activity but further work is needed to ascertain the exact source of this material. If the source is indeed microbial, our results may indicate that DOM in waters under larger glaciers are less affected by shifts in discharge throughout the meltseason than DOM under small glaciers. This is an important result because large glaciers deliver significant meltwater to downstream ecosystems and nitrogen-containing molecules are highly susceptible to bacterial degradation in these systems. If this source increases as the region of liquid water increases in areal coverage beneath the GrIS, downstream ecosystems may receive increasingly labile organic matter. Further work is needed to constrain the role of hydrology and microbial metabolism in organic matter composition underneath the GrIS.

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