The impacts of tidewater glacier retreat on functioning of Arctic fjords: observations and modeling

Pedro Duarte, Philipp Assmy, Haakon Hop and Sebastien Moreau

The main goals of this study are to discuss the effects of tidewater glacier retreat on fjord biogeochemistry based on observational and modeling evidence collected in Kongsfjorden, Svalbard, and on published studies. We here present a fjord conceptual model, including a benthic compartment, to visualize the biogeochemical fluxes between the sediments and the water column.

The effects of tidewater glaciers on fjords are conveyed through: (i) the heat exchanges between the glacier fronts and the calving icebergs, on one hand, and the water column with advection of Atlantic water on the other hand, and (ii) the physical and biogeochemical interactions between the glacier melt water and the sea water, strongly dependent on flow type - surface or subglacial. The effects of subglacial discharges have been discussed in the literature, with emphasis on local upwelling caused by the rising meltwater plumes, entraining deep, nutrient-rich, sea water to the surface.

Our observational evidence suggests that subglacial water has higher ammonia concentrations, when glaciers are moving over an “old” seabed with high loads of organic matter available for bacterial degradation. This provides a glimpse into the expected changes resulting from the retreat of tidewater glaciers and the newly exposed organic-rich sediments with mobilization of nutrients and organic matter to the water column. It also emphasizes the need for fjord biogeochemical models to include a benthic compartment to simulate sediment-water biogeochemical interactions. Such a model should include diffusion, adsorption-desorption, mineralization, nitrification, denitrification, and uptake and release fluxes by most relevant benthic organisms. Some of the mentioned fluxes depend on oxygen and temperature and may be represented without the explicit inclusion of bacteria for the sake of simplicity. Another argument for inclusion of a benthic compartment in such biogeochemical models is the increasing biomass of macroalgae and their spread to shallower waters in Arctic fjords. However, their relative importance on fjord primary production and nutrient sinking needs to be established. We argue that sediment-water interactions are key to properly quantifying the impact of ice sheet and glacier retreat, in the Arctic and in Antarctica, on the global biogeochemical cycles of carbon and nitrogen within a framework of climate change. Thus, our conceptual model may serve as a “template” for application in larger scale models.