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Insights into the supraglacial ecosystem of the Greenland ice sheet using process-based ecosystem modelling

Marek Stibal (1), James Bradley (2), Christopher Williamson (3), and Jason Box (4)

(1) Department of Ecology, Faculty of Science, Charles University, Prague, Czechia (marek.stibal@natur.cuni.cz), (2) Department of Earth Sciences, University of Southern California, Los Angeles, CA, USA, (3) Bristol Glaciology Centre, School of Geographical Sciences, University of Bristol, Bristol, UK, (4) Department of Glaciology and Climate, Geological Survey of Denmark and Greenland, Copenhagen, Denmark

The surface of the Greenland ice sheet (GrIS) is the largest supraglacial ecosystem on Earth, and the ongoing climate warming and resulting increased surface melting make it one of the fastest-changing ecosystems. It is now widely recognised that biological processes occurring in supraglacial ecosystems contribute to surface melting, thus changing the physical behavior of glaciers and ice sheets, and to local and regional carbon and nutrient cycling through primary production, recycling both allochthonous and autochthonous organic substrates, and meltwater export to downstream ecosystems.

Insights into the supraglacial ecosystem have been driven mostly by empirical approaches relying on field sampling and laboratory measurements. Despite increasing data on sources, sinks, and transformations of carbon and nutrients in the GrIS supraglacial ecosystem, few attempts of linking them together into an ecosystem model have been made to date. As a result, estimates of microbial activity and associated carbon and nutrient transformations on an ice sheet scale are highly uncertain, and predictions of future ecosystem change are virtually impossible.

Here we present a new process-based zero-dimensional (0-D) ecosystem model of the GrIS surface based on organic carbon (OC). The model comprises four state variables: dissolved OC, particulate OC, autotrophic biomass, and heterotrophic biomass, linked via physical and biological OC fluxes. To test the model, we forced it by irradiation and surface melt data from 2008-2013 from the southwestern part of the ice sheet. Results show that dynamic ecological equilibria can be reached relatively fast (within two years), and that different melt seasons in terms of temperature and irradiation may result in great differences in ecosystem production. Autotrophs (mostly ice algae) are likely to drive carbon cycling in the ecosystem, controlled primarily by light conditions. The model output suggests that our understanding of the supraglacial ecosystem is still far from complete, and that some key parameters (e.g. microbial death rates, flushability of OC) and processes (microbial activity in winter) need to be quantified.