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Modelling ice algal growth and its impact upon Greenland Ice Sheet albedo

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Greenland Ice Sheet albedo is an Essential Climate Variable that critically influences ice sheet surface mass balance. It varies substantially both over the course of a melt season which has significant implications for meltwater generation.

There is increasing evidence that ice algae growing on the ice sheet surface are a highly important albedo reducer. Over regional scales, observations of the inter-annual dynamics of 'dark ice' areas show that the extent, duration and intensity of darkening in these areas vary significantly between years, driven by synoptic climatic conditions controlling the size of the ice algae population and hence the darkening signal that they contribute.

Here we use a novel ice algal growth model which is driven by surface melting status, photosynthetically-active radiation and snowpack thickness to determine growth as a function of optimal growth rates determined from productivity incubation experiments. This is a substantial advance on existing approaches where in-situ measurements of actual growth rates specific to a given melt season have been used together with a simple time-since-snowline-retreat dependency. The ice algal model is implemented as a module of the regional climate model MAR. We compare the performance of ice algal growth model against melt seasons for which we have field measurements of algal biomass. We further use it as an input to the two-stream Snow, Ice and Aerosol Radiative (SNICAR) 2-stream model also coupled to MAR in order to determine the impact of ice algae upon ice surface albedo. We show that both direct and indirect (i.e. physical changes to ice weathering crust structure) albedo effects of ice algae have to be considered in order to determine the full impact on Greenland ice sheet melting. Finally, we run model hindcast experiments corresponding to the full duration of the MODIS remotely-sensed albedo record to assess the ability of this new ice albedo modelling approach to capture observed inter-annual variability.