Down the cryoconite hole: An interdisciplinary investigation of biogeochemical dynamics at glacier and ice sheet surfaces

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Project description: Once considered inhospitable masses of ice, the biological diversity and activity of glaciers and the biogeochemical consequences of such activity are now attracting attention. Life on glaciers and ice sheets is mostly associated with airborne debris, so-called cryoconite material. Cryoconite holes form when the cryoconite material binds to inorganic minerals, settles on to the ice, absorbs heat and thus causes the ice to melt. These holes are individual ecosystems with distinct boundaries, energy flows, and nutrient cycling that emerge in a hostile environment subject to fluctuating environmental conditions. They provide important information about life under extreme conditions and can serve as analogues for life on other icy terrestrial planets in our solar system. It has also been speculated that they accelerate the melting of glaciers and provide labile organic matter and macronutrients to downstream environments.

However, the main source of organic carbon that accumulates at the surface of glaciers and provides the substrate for these intriguing ecosystems is still a matter of debate. There are two different potential sources of carbon: microbiologists and biogeochemists tend to focus on the importance of positive net primary production in promoting organic matter (OM) accumulation at the surface of the ice; while glaciologists tend to regard black carbon and other aeolian, allochthonous inputs of carbon as the main significant contributor. The presence of allochtonous and autochtonous organic carbon at the surface of the ice has a number of consequences. First, accumulation of allochthonous dark-coloured OM promotes further absorption of solar radiation and thus enhances glacial melting. Microbial fixation of CO_2 at the glacier surface and subsequent export of organic matter during the summer melt season on the other hand may be important for sustaining microbial life in downstream ecosystems, including subglacial environments, proglacial lakes and coastal waters.

This project aims at assessing the interplay between external inputs, photosynthetic productivity and respiration of organic matter and the associated biogeochemical dynamics in cryoconite holes on different timescales (daily, seasonally, annually) by means of an interdisciplinary approach. For this purpose, the first numerical, biogeochemical model of a cryoconite hole will be developed within the framework of this project. Model development and validation will be informed by field and lab-based experiments. Key model assertions will be modelled in the laboratory using cryoconite obtained from current subglacial sampling expeditions to Antarctica and Greenland. In addition, biomarker and δ13C analysis will elucidate the sources of organic matter accumulating in the hole. This highly interdisciplinary approach, combining microbial, biogeochemical and numerical modelling techniques, will for the first time allow an quantitative assessment of the biogeochemical dynamics of cryoconite holes on time and spaces scales that are not accessible to field observations.

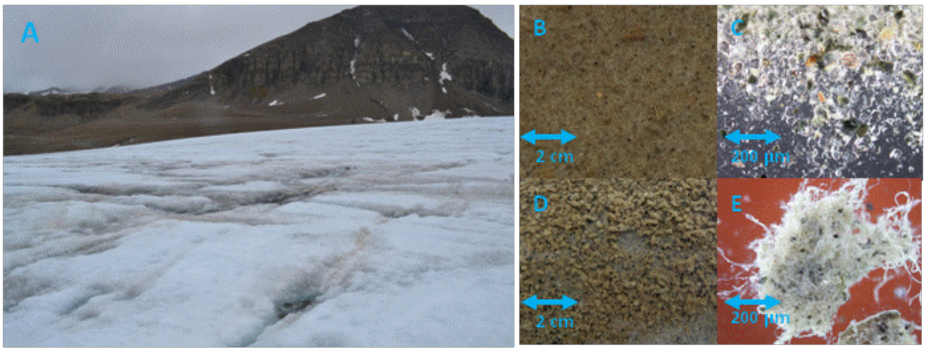

Figure 1: A) Organic debris loading on a typical Arctic glacier with a strongly negative mass balance. Here, very dark material, largely composed of cyanobacteria and other algae trapped within structural features on the ice surface, reduces the albedo by more than 50%. B, C, D and E: The development of microbial granules in samples with nutrient additions and light exposure during the simulation experiment. Initially there was only a mixture of inorganic dust with a minimal microbial inoculum (B and C), which then developed into samples rich in granules and filamentous cyanobacteria (D and E).