Geophysical Research Abstracts
Vol. 14, EGU2012-7479, 2012
EGU General Assembly 2012

Carbon and Nitrogen fixation at the surface of Glaciers and Ice Sheets

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Microbial activity on the surfaces of glaciers and ice sheets is associated with surface sediment, which may be found in the form of dispersed sediment grains, layers of sediment melted into the ice to form holes filled with glacial water, or stream washed deposits. Debris covers between 1 and 15% of the ablation zone of glaciers and ice sheets and contains a wide range of prokaryotic and eukaryotic microorganisms, including photosynthetic cyanobacteria and algae, heterotrophic bacteria and viruses. The debris at the surface of the ice is primarily composed of inorganic particles, derived either from aeolian dust deposition or locally derived debris from moraines or basal ice. The origin of the organic matter within debris is unclear since locally derived debris usually has low organic carbon concentration compared to the high concentration of organic carbon at the surface of the ice. In this study, we demonstrate that the majority of organic matter is autochthonous (i.e. produced in situ at the surface of glaciers by photosynthesis and other microbial interactions). The autochthonous organic matter is then an important source of organic carbon and nutrients for in situ and downstream ecosystems, including glacial forefield. Further, organic matter produced by photosynthesis may cause a decrease in the albedo of the ice, either directly by the production of dark pigments, or indirectly through the trapping and agglutination of dark mineral via the production of exopolysaccharides as well as the merging and coalescing of more debris. In this study, we also show that microbial communities at the surface of glaciers and ice sheets can fix N from the atmosphere, particularly at the margins during the summer as a result of N limitation. Viruses most probably play an important role in controlling microbial mortality and hence biogeochemical cycling on glaciers. Such processes are relevant to researchers interested in the transport of organic matter from glaciers and ice sheets to their forefields. We predict that the fluxes of C and N from ice to forefield are likely to substantially change in response to glacial retreat.