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Implementing high-latitude biogeochemical processes into Earth System Models

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Projections of future climate changes suggest that air temperatures in the Arctic could rise to the levels unprecedented in the last million years. Sensitivity of carbon storages on land and shelves to climate change of that scale is highly uncertain. Earth System models (ESMs), consisting of atmosphere, ocean, land, and cryosphere components are the main tools to understand interactions between carbon cycle and climate. However, ESM representation of ecological and biogeochemical processes in the Arctic is extremely simplistic. For example, all ESMs agree that tree cover in the future warming scenarios will move northwards to the Arctic coast, but they ignore interactions between vegetation, permafrost, and disturbances such as fires, which are critical for vegetation dynamics in this region. Improving modeling of interactions between model components and their evaluation against growing observational evidence is a promising research area.

The first attempts to account for the permafrost carbon dynamics in the ESM framework suggest that CO_2 and CH_4 emissions from high-latitude regions in the 21^{st} century are relatively small, but they become much more significant afterwards due to committed climate changes. Therefore, extension of ESM simulations beyond 2100 is essential to estimate a proper scale of frozen carbon pool response to human-induced climate change. Additionally, inclusion of sub-sea permafrost component into ESMs is an active research area that brings together terrestrial and marine biogeochemical communities, as well as geologists analyzing climate proxies on glacial timescales.

Another challenging aspect of biogeochemical interactions in Arctic is an extreme land surface heterogeneity. A mixture of wetlands, lakes, and vegetation-covered surfaces on fine local scale is not properly reflected in the model structure. A promising approach of dealing with scaling gaps in modeling high-latitude biogeochemical processes in ESMs will be presented.