Geophysical Research Abstracts
Vol. 14, EGU2012-12778-1, 2012
EGU General Assembly 2012

Numerical modeling of subglacial erosion and sediment transport beneath the Laurentide Ice Sheet

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Present-day sediment distribution offers a potentially strong constraint on past ice sheet evolution. However, glacial system models (GSMs) cannot address this while lacking physically-based representations of subglacial sediment generation and transport. Incorporation of these elements in GSMs is also required in order to understand the impact of changing sediment cover on glacial cycle dynamics.

Towards this goal, we present a subglacial process model that incorporates mechanisms for sediment production, entrainment, transport, and deposition. An abrasion law based on Hallet's model and a quarrying law dependent on basal water pressure and bed roughness are used to calculate bedrock erosion. The incorporation of loose debris in the basal ice is modeled by regelation intrusion and basal freeze-on, depending on the thermal condition and the availability of water at the base. The entrained debris is subsequently transported along the ice sheet's internal velocity field and vertically mixed through a diffusion equation that accounts for folding and thrust faulting. The inclusion of vertical mixing lowers the basal debris concentration and allows more regelation entrainment. Soft bed deformation is included as an advective component within the subglacial sediment, the rheology of which is assumed to be weakly non-linear. Deposition occurs whenever the basal ice is debris-laden and the melting rate exceeds the entrainment rate.

The model is coupled to the MUN 3D GSM, which includes a newly developed subglacial hydrology module. The GSM itself has been subject to Bayesian calibration for North American and Eurasian deglaciation and thus a probabilistic ensemble of deglacial chronologies is available. With this calibrated ensemble, we compare the range of calculated sediment thickness fields and cumulative erosion over the last glacial cycle against the present-day pattern of glacigenic sediment and the geological estimates of glacial erosion over North America, respectively.