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

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Short-term goals

- Successfully model glacial erosion rates over the last glacial cycle (120kyr).
- Identify key variables and parameters for modeling subglacial erosional and transport processes.
- Allow Glacial System Models (GSMs) to properly address the impact of soft-bed deformation on ice dynamics.

Long-term goals

- Allow GSMs to predict glacial landform development.
- Expand the range of GSM constraint data to include glacial geological observations.

Model description : erosion laws

Physically-based

Abrasion

- Proportional to sliding velocity and basal debris concentration.

Hallet's model

- Controlled by basal melting rate.

Boulton's model

- Controlled by effective normal pressure.

Quarrying

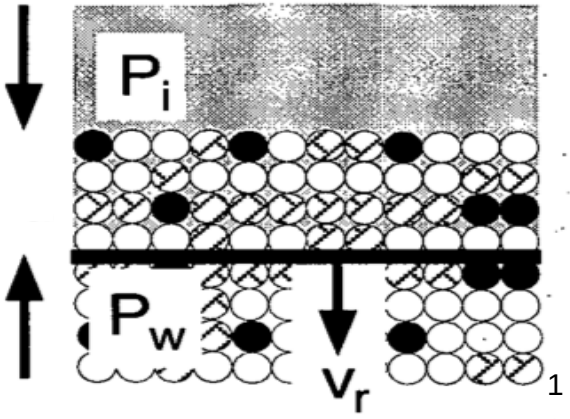
- Proportional to sliding speed and presence of cavities.
- Inversely proportional to ice overburden pressure and basal roughness

Empirical

- Assumes that erosional processes need not be modeled separately.
- Erosion rate is proportional to the product of basal shear stress and sliding velocity (basal power).
- Field studies provide estimates of the ratio between basal power and erosion rates.

Model description : sediment entrainment, transport and deposition

- Sediment is incorporated in the basal ice by regelation entrainment.
- Deposition occurs where the basal melting rate is greater than the calculated entrainment rate.
- Transport by subglacial sediment deformation is calculated from a weakly non-linear rheology[2].
- The model is driven by the data-calibrated **MUN 3D GSM**[3], and the **MUN basal hydrology solver**[4], which provide key variables such as ice thickness, sliding velocities, basal melting rate and water pressure.



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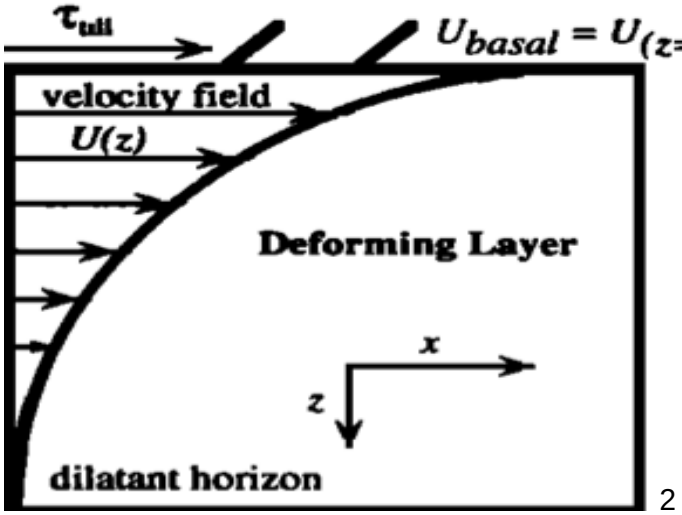

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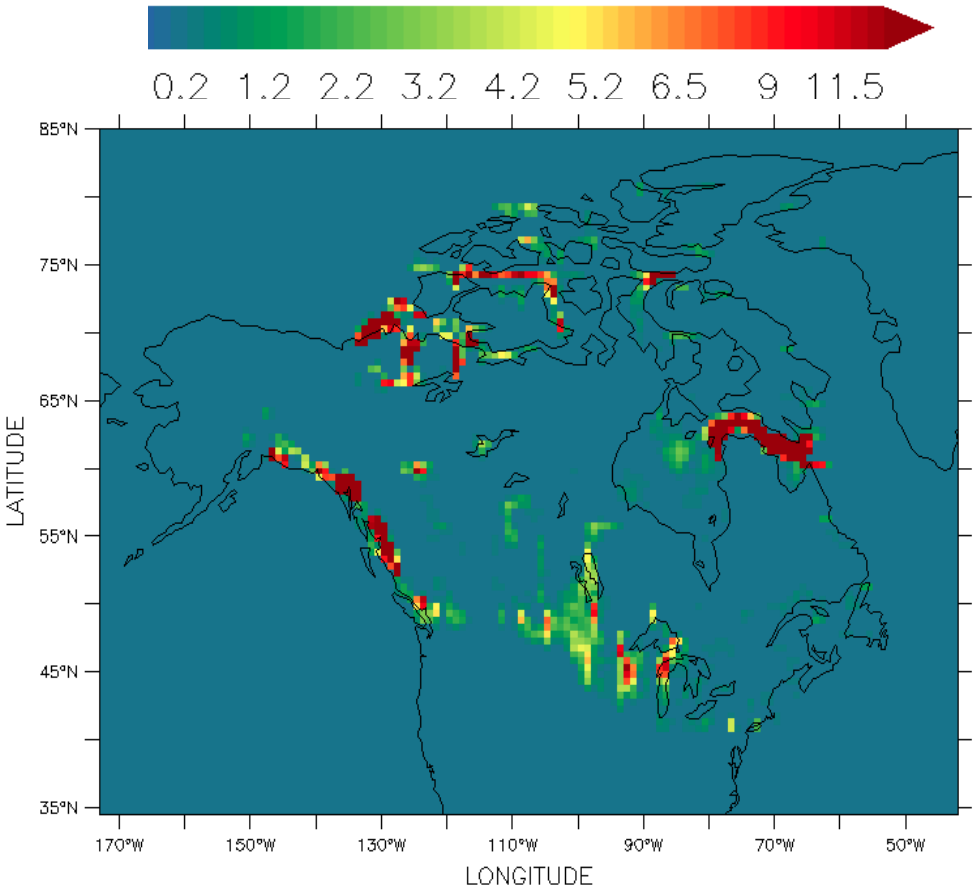
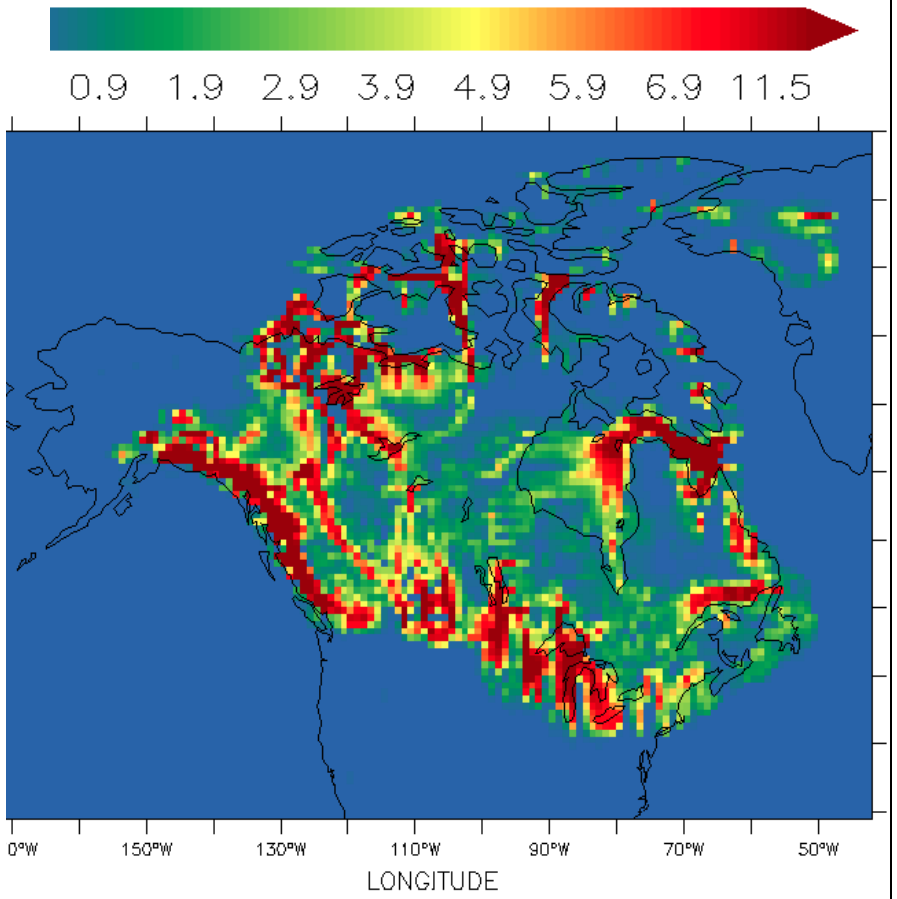
1: Hildes, 2001 2: Jenson et al. 1996 3: Tarasov et al. 2012 4: CR5.40 Poster session

Results: Comparison between erosion laws



Physically-based erosion law:
Cumulative erosion (m)

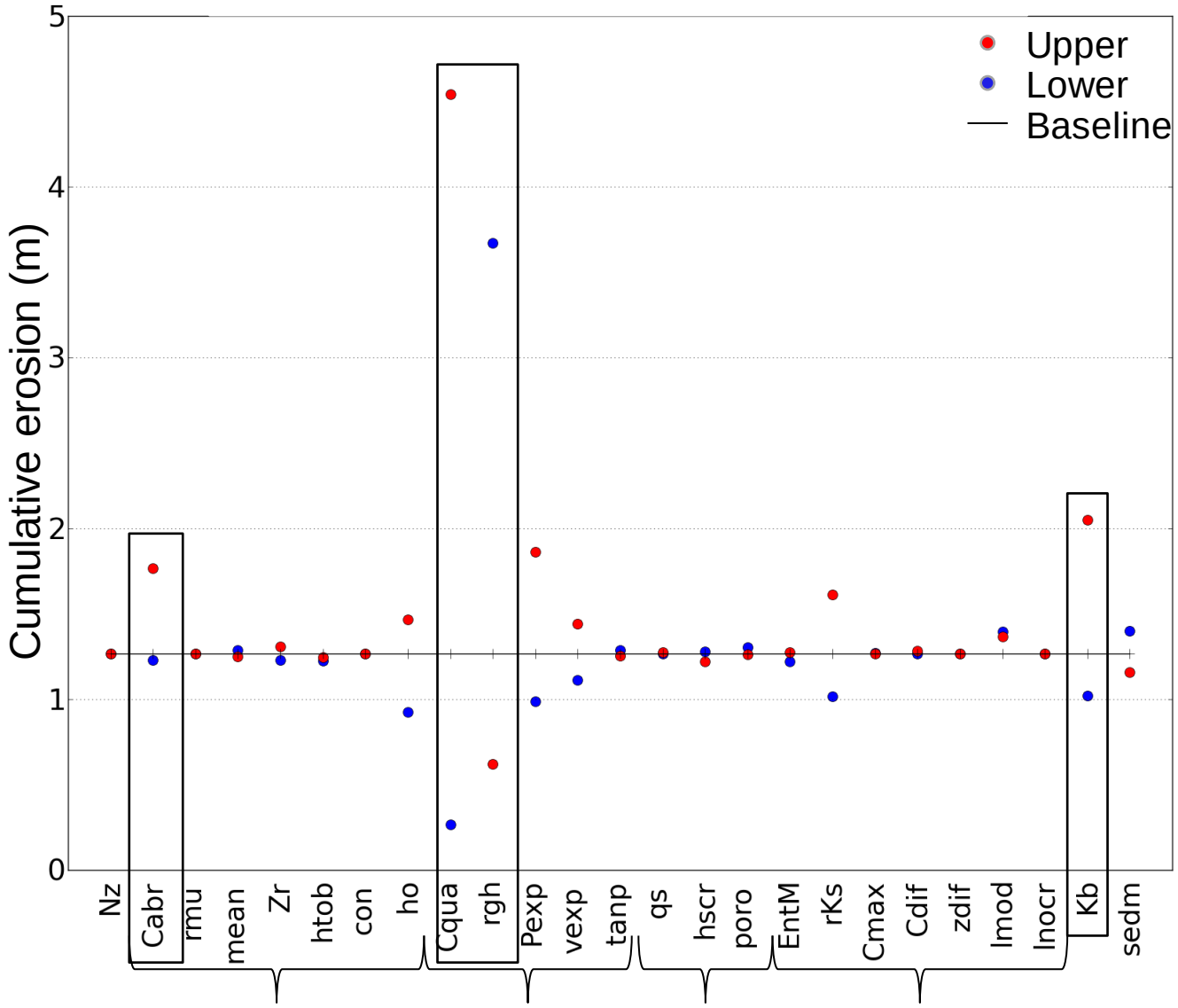
Total **abrasion**= 0.05m Total **quarrying** = 1.21m
Local maximum = 189m



Empirial erosion law :
Cumulative erosion (m)

Total erosion = 3.24m
Local maximum = 127m

Results: Sensitivity analysis for the physically-based erosion law



Key model parameters

Cabr: abrasion coef.
Cqua: quarrying coef.
rgh: basal roughness
rKs: entrainment coef.
Pexp: water pressure exponent for quarrying
Kb: hydraulic conductivity coef.
ho: erosion shielding coef.
Vexp: sliding vel. exponent for quarrying

Conclusions

- Incorporating sub-grid scale lithological and topographic information is likely to have a strong impact on modeled erosion patterns.
- The two modeling approaches fall within the range of geological estimates for Laurentide erosion[1,2,3].
- Limited validation data precludes further assessment of the two approaches.

Data needs

- Relative contribution of abrasion and quarrying to total glacial erosion pattern
- Assessment of the regional variability of glacial erosion, in order to justify the use of isolated, local data.

1: Bell and Laine, 1985 2: Hay et al., 1989 3: Kaszychi, 1996

Future work

- Active coupling with ice dynamics and hydrology models, and applying the model to Quaternary time-scales to evaluate the long-term influence of a changing sediment cover on ice dynamics and other feedbacks between subglacial sediment and hydrology.
- Include sub-grid scale lithological and topographic information.
- Quantify model uncertainty.