Paleo-ice sheet reconstructions constrained by GIA and geological data for use in climate models

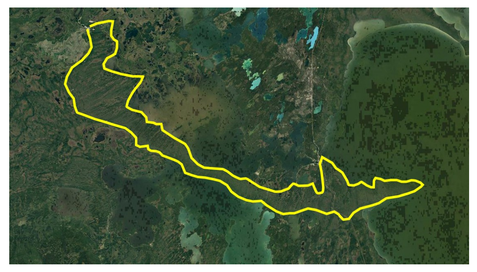
Evan J. Gowan[1], Xu Zhang[1], Sara Khosravi[1], Gerrit Lohmann[1] and Klaus Grosfeld[1]

[1]Alfred Wegener Institute, Bremerhaven, Germany

Ice sheet reconstructions based on geological and geophysical information

- Geophysical modelling of glacial-isostatic adjustment (GIA) processes has long been used to reconstruct paleo-ice sheets (e.g. Tarasov et al 2012, Peltier et al 2015, Gowan et al 2016a, Lambeck et al 2017). In order to do this efficiently, it is necessary to have strict control on the geometry of the ice sheet.
- These data have limitations due to the spatial distribution (i.e. sea level indicators are only located in coastal regions, so other geological information need to be used, such as flow direction.
- Ultimately, the reconstruction should have at least a minimal amount of glaciological realism. This can be achieved using our model, ICESHEET (Gowan et al 2016b), which uses perfectly plastic rheology.

Radiocarbon dated raised beaches (such as these along southern Hudson Bay, near the center of the Laurentide Ice Sheet), can be used to assess past ice sheet volume based on the rate of fall through time.



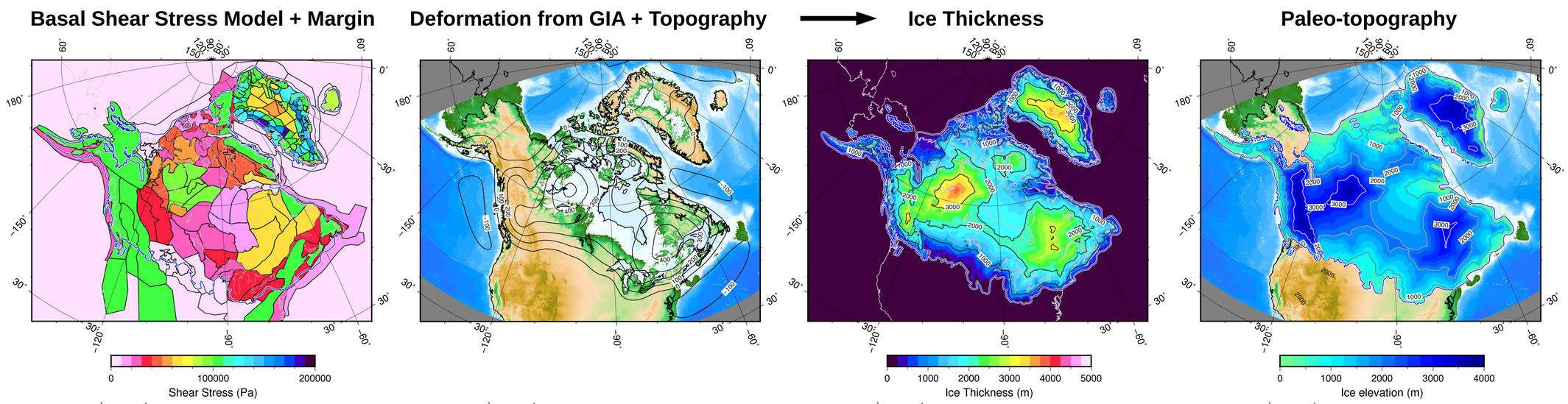
End moraines, such as the The Pas moraine in Manitoba (above, outlined in yellow) can be used as direct constraints on past ice sheet extent

Methodlogy to make ice sheet reconstructions using ICESHEET

- Inputs for ICESHEET include the margin at discrete time periods, and a temporal variable basal shear stress model which controls the ice surface profile.
- Can include iterations of GIA to account for changes in basal topography from loading and sea level change. We use SELEN (Spada et al., 2012) to compute this.
- At present, we have setups for North American and Eurasian ice sheets.

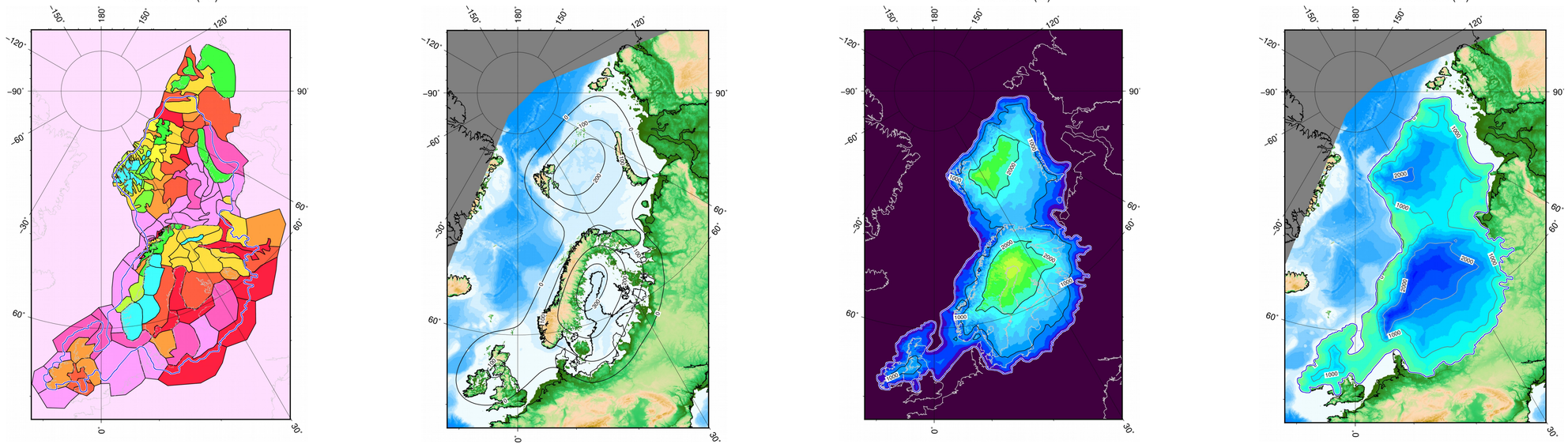
North American Ice sheets at 20000 yr BP

(blue line is the margin reconstruction from Dyke, 2004 and Gowan et al. 2016a)



Eurasian Ice sheets at 20000 yr BP

(blue line is the margin reconstruction from Hughes et al. 2016)



Refining the ice sheet reconstruction

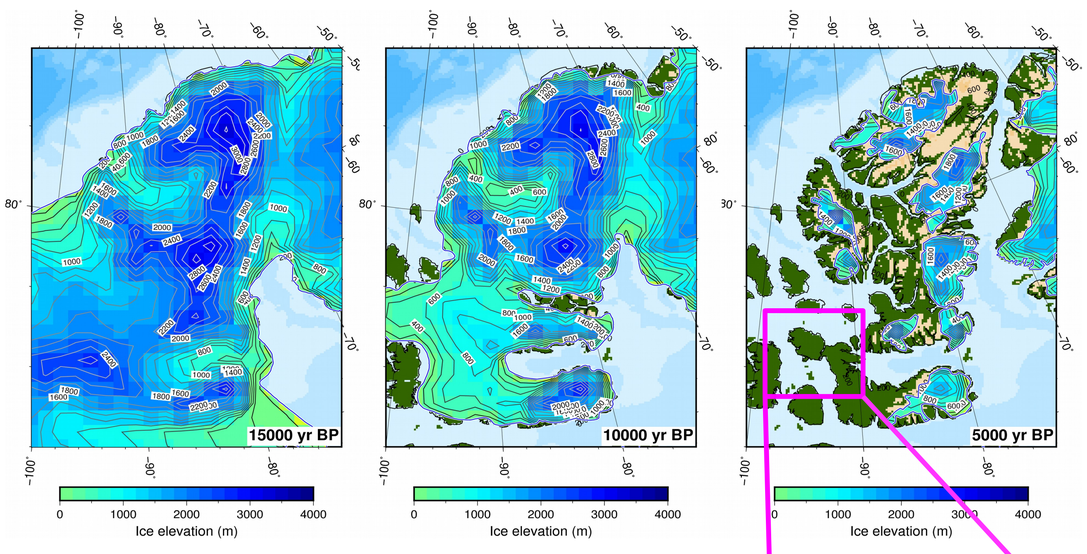
Currently, we are refining the ice sheet reconstruction for the Innuitian Ice Sheet in Northern Canada. We are revising margins and sea level indicators using updated reservoir corrected radiocarbon dates (Butzin et al 2017).

The Sea level data are classified based on whether they indicate that sea level was above (*minimum*) or below (*maximum*) the sample elevation, or intermediate of the sample and the local highstand position (*bounded*).

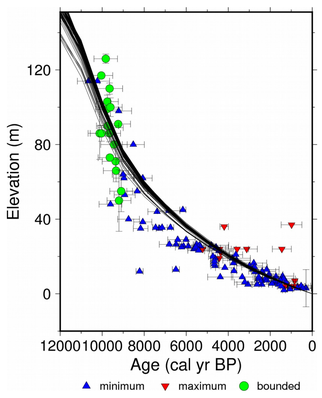
Sea level is calculated at the location of each sample, and a score is assigned based on the discrepancy between the observation and model (zero if there is no discrepancy). This score is used to assess the ice sheet reconstruction.

The basal shear stress or margin models are adjusted if there is a discrepancy in calculated sea level.

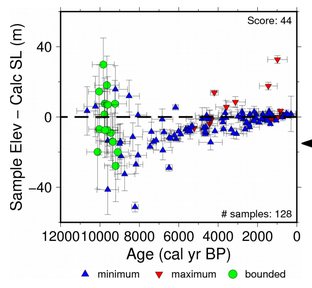
Paleo-topography – Innuitian Ice Sheet



Calculated Sea Level and data



Sample Elevation – Calculated Sea Level



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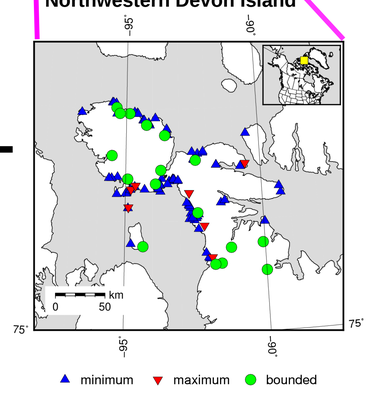
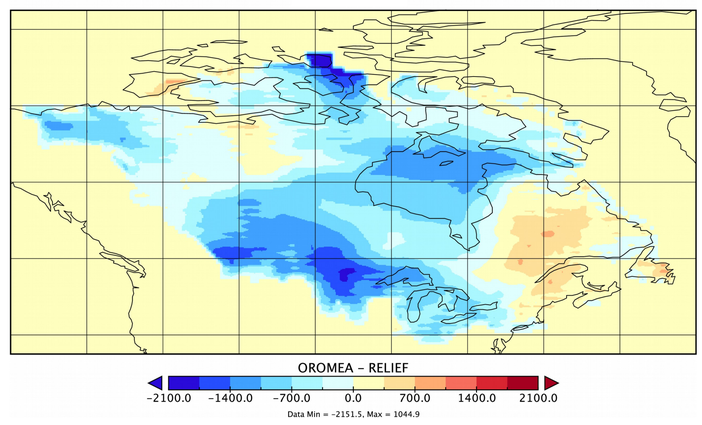
Northwestern Devon Island



Ice Sheet Topography and climate modeling

Difference between Gowan et al (2016) reconstruction and the PMIP4 Laurentide reconstruction



Refinement of western Laurentide Ice Sheet by Gowan et al (2016a) resulted in a ice sheet geometry that has a substantially lower profile from the reconstruction used by PMIP. The cause of this discrepancy is a result of the inclusion or exclusion of specific data in this region, and a different choice of Earth rheology for glacial-isostatic adjustment.

One of the main differences is a result of fitting sea level data from southern Hudson Bay, which has been difficult to reconcile in other reconstructions (i.e. Tarasov et al, 2012 and Lambeck et al 2017). Another difference is the inclusion of Glacial Lake Agassiz strandline tilt data. A lower profile ice sheet has profound effects on modelled climate (see concurrent poster by Zhang et al.).

Use of ICESHEET and additional datasets can be used to test different hypotheses on the role of ice sheet topography and paleo-climate.

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References
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Basal Shear Stress Model + Margin | **Deformation from GIA + Topography** → **Ice Thickness** | **Paleo-topography**

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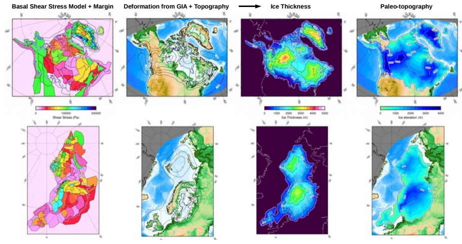

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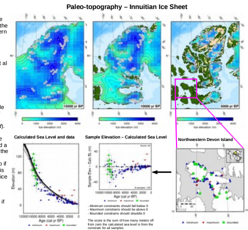

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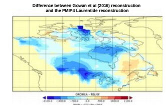

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