Self-Consistent Regolith Hypothesis: Removal of Soft Beds in an Ice Sheet Model

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MUN Physics & Physical Oceanography

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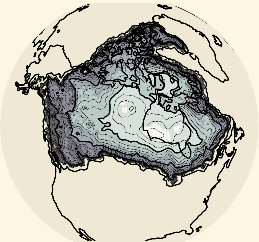
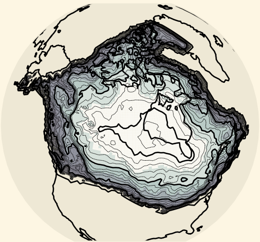
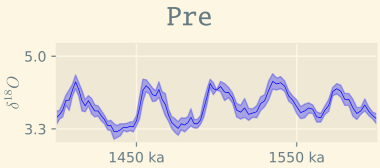
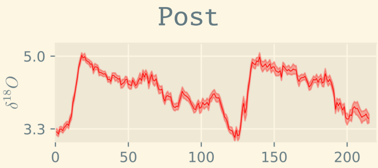




1 Myr ago: Small 41 kyr Glaciations to Large 100 kyr With Similar Extent





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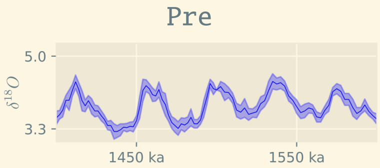

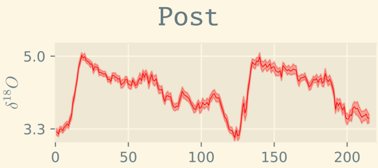

Roy et al., 2004 Early Pleis till spots

Dalton et al., 2020 LGM margin

How could a smaller early Pleistocene ice sheet have similar extent to a bigger late Pleistocene ice sheet?

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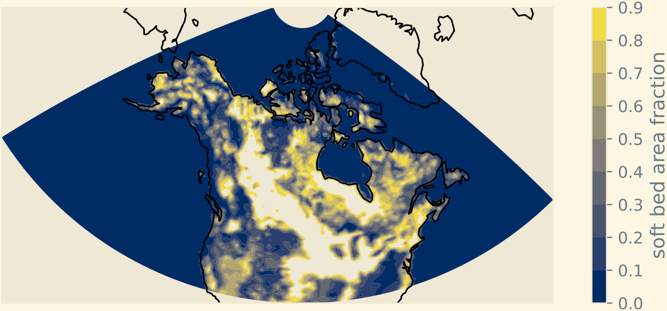
A change in basal friction

Regolith Hypothesis: Soft bedded early Pleistocene, hard bedded late



Soft sediment cover calculated from dataset of Pelletier et al., 2016

Is the regolith hypothesis consistent with glacial sediment removal and wide bounds on Pliocene regolith?

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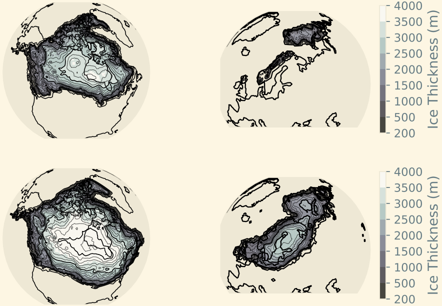
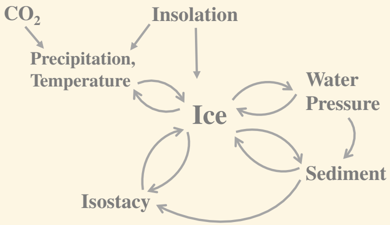
To test this, we need a model which couples all of the relevant physics

Fully Coupled Glacial Systems Model, State of Art Sediment & Hydrology





Climate

- weighted EBM/glacially indexed PMIP fields
- forced with CO_2 and insolation only

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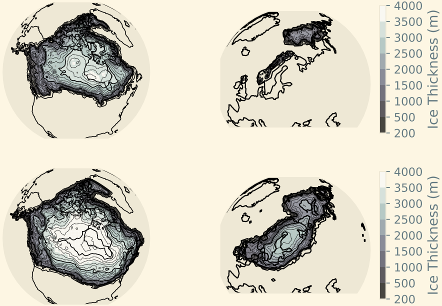

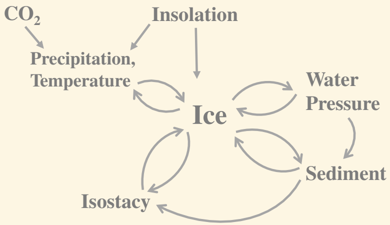

Ice

- Shallow shelf/shallow ice dynamics
- 3D, thermomechanically coupled

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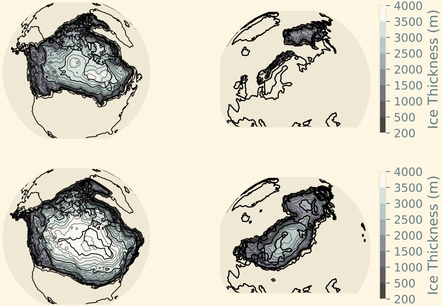

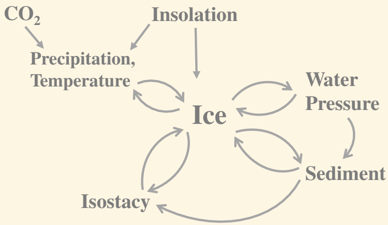

Basal Drag

- Dynamic subglacial water pressure
- Dynamic soft/hard bedded mask

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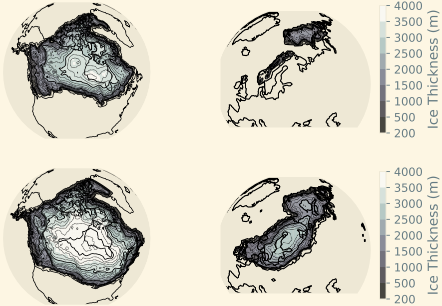

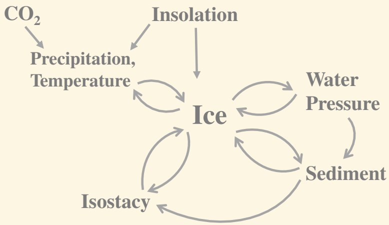

Sediment

- Transport: entrainment, deposition, and soft deformation
- Production: quarrying and abrasion

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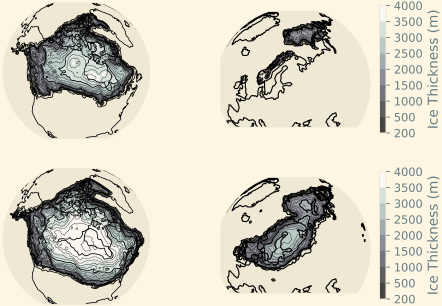
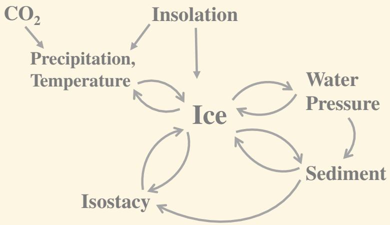
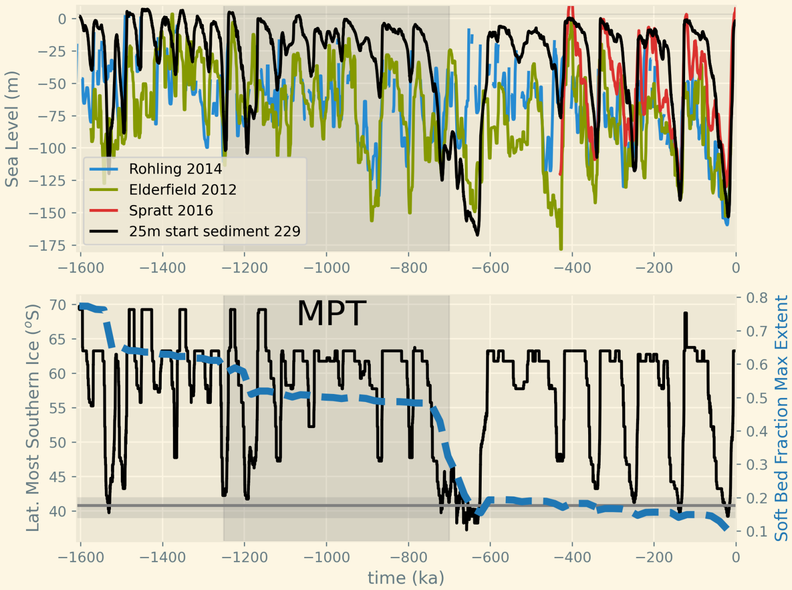




Isostatic Adjustment

- Visco-elastic
- Accounts for ice, water, and sediment changes

E.G. MODEL RUN CAPTURES TRANSITION: 41-100 KYR, SMALL TO LARGE, SOFT TO HARD BED



Model Captures MPT, Removes Sediment, Uncertainty Assessment Needed

Model Captures:

- Ice volume increase
- 41 and 100 kyr glacial cycles
- Min latitude before and after MPT similar
- Sediment is removed within inferred timing of MPT

Next steps

- Bound sediment removal rates
- Larger ensemble to probe uncertainties

References I

Dalton, April S. et al. (2020). “An updated radiocarbon-based ice margin chronology for the last deglaciation of the North American Ice Sheet Complex”. In: *Quaternary Science Reviews* 234, p. 106223. ISSN: 0277-3791. DOI: 10.1016/j.quascirev.2020.106223. URL: http://dx.doi.org/10.1016/j.quascirev.2020.106223.

Elderfield, H. et al. (2012). “Evolution of Ocean Temperature and Ice Volume Through the Mid-Pleistocene Climate Transition”. In: *Science* 337.6095, pp. 704–709. ISSN: 1095-9203. DOI: 10.1126/science.1221294. URL: http://dx.doi.org/10.1126/science.1221294.

References II

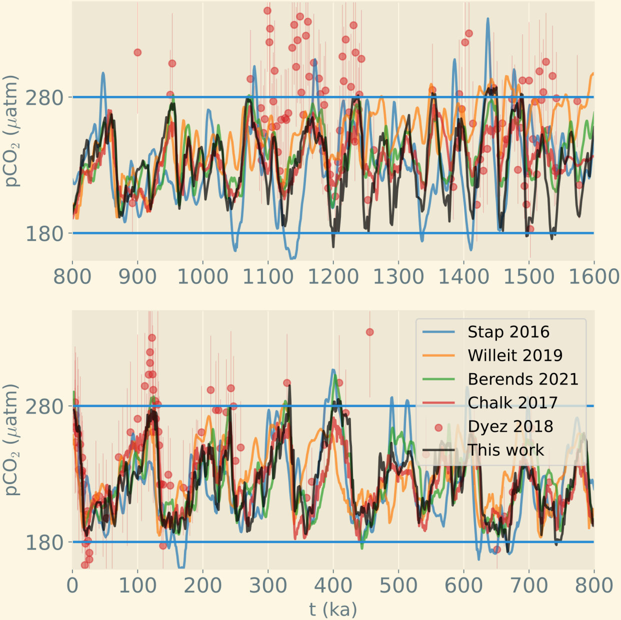
- Pelletier, Jon D. et al. (2016). "A gridded global data set of soil, intact regolith, and sedimentary deposit thicknesses for regional and global land surface modeling". In: *Journal of Advances in Modeling Earth Systems* 8.1, pp. 41–65. ISSN: 1942-2466. DOI: 10.1002/2015ms000526. URL: http://dx.doi.org/10.1002/2015MS000526.
- Rohling, E. J. et al. (2014). "Sea-level and deep-sea-temperature variability over the past 5.3 million years". In: *Nature* 508.7497, pp. 477482. ISSN: 1476-4687. DOI: 10.1038/nature13230. URL: http://dx.doi.org/10.1038/nature13230.

References III

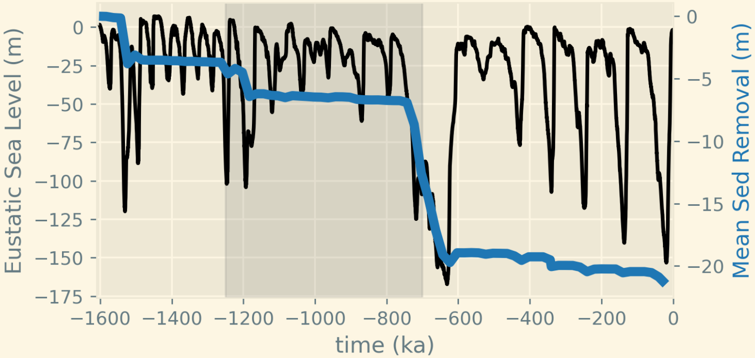
Roy, Martin et al. (2004). "Geochemical constraints on the regolith hypothesis for the middle Pleistocene transition". In: *Earth and Planetary Science Letters* 227.3-4, pp. 281–296. ISSN: 0012-821X. DOI: 10.1016/j.epsl.2004.09.001. URL: http://dx.doi.org/10.1016/j.epsl.2004.09.001.

Spratt, Rachel M. and Lorraine E. Lisiecki (2016). "A Late Pleistocene sea level stack". In: *Climate of the Past* 12.4, pp. 1079–1092. ISSN: 1814-9332. DOI: 10.5194/cp-12-1079-2016. URL: http://dx.doi.org/10.5194/cp-12-1079-2016.

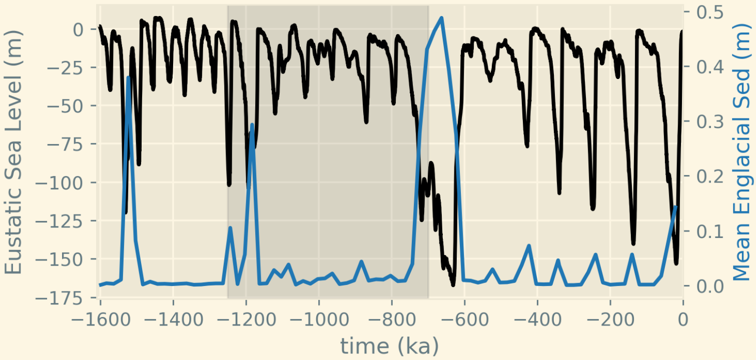
1.6-0.8 Ma: $CO_2 \propto$ LR04; 0.8 Ma-PD $CO_2 =$ EPICA



Mean Sediment Removal Within Central Domain of Ice Sheet



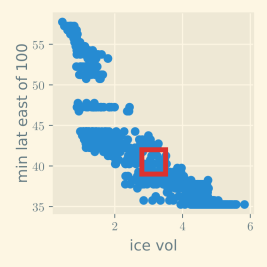
Mean Englacial Sediment Thickness (m)



Successive Ensembles Sieved to Get Suitable Parameters for Long Run

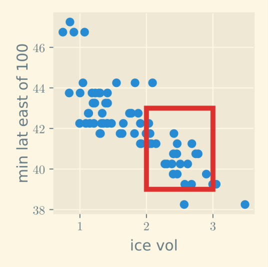
I. MIS 5 to PD

Control: LGM ice volume, Dyke 2004 margins, time of Hudson bay deglaciation



II. MIS 55 to 45

Control: Ice volume<LGM, Southern extent from tills, sea level change



III. Incl. sediment and hydrology for time frames I+II

Control: same as step I. and II. Choose representative subset (via PCA of metrics)

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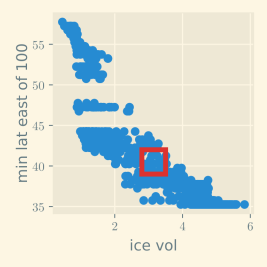

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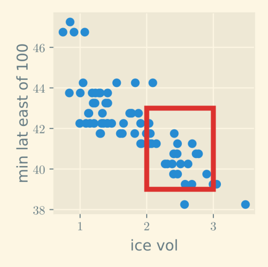

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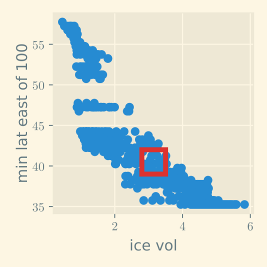

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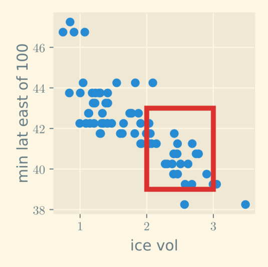

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