3 Approaches to Reconstructing North American Deglaciation

Lev Tarasov[1] and W. R. Peltier[2]

(1) Memorial University of Newfoundland, (2) University of Toronto, Canada

(1) Approach 1: calibrated glaciological modelling

• Data: Relative Sea Level (RSL), geodetic (surface uplift), ice margin chronology, (and marine limits, strand-lines for scoring)

• Model: MUN/UofT Glacial Systems Model (GSM): 3D thermo-mechanically coupled shallow ice-sheet model, visco-elastic bedrock response, fully-coupled surface drainage solver,...

• Challenges: 32 ensemble parameters, non-linear system, large diverse noisy data set, many assumptions within climate forcing

•Advantages: Bayesian, glaciologically-self-consistent, large set of constraint data, meaningful error bars

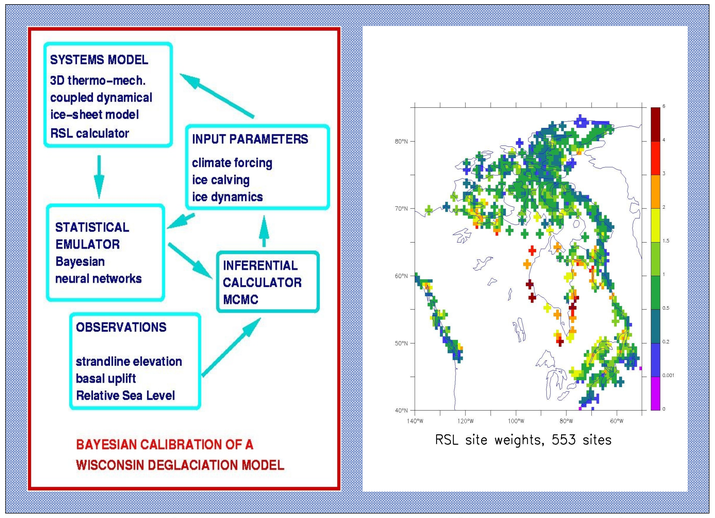


Figure 1. Calibration procedure and RSL site weights for calibration

App. 2: hand-tuned geophysical inversion: ICE5-G

•Data: RSL, geodetic, and ice margin chronology
•Method: ice history created by hand with conceptual Lego blocks
•Advantage: Allows localized tuning. Has been the defacto standard for geophysical and paleomodel intercomparisons
•Disadvantages: No error bars, no glaciological self-consistency, pain-staking hand tuning, no ice velocities,...

App. 3: physically bounded nudging of glaciological model towards ICE5-G

•Adjust surface mass-balance up to 0.5 m/yr in net accumulation and up to 4* increase in ablation rate (Note does not create ablation where there is no melt)
•Applied in accumulation zone or for the case of extremal forcing throughout ice-sheet (but not beyond it)

(3) Results, fit to constraints

•Calibration results based on 2700 GSM runs, 443 of which pass primary cut-off constraints (marginally sufficient mwp-1a event, -40kyr/-30kyr/LGM ice volume,...) .

•Overall best calibrated model (nn3170), weighted ensemble mean, best nudged model, and ICE5-G are displayed below (caveat: "best" depends on metric choice)

•All models use the same VM2 L90km earth rheology

•Nudged 10 best runs from calibration, repeated with 4 levels of nudging

• Comparison against GRACE observations for rate of mass change offers an independent test of the reconstructions

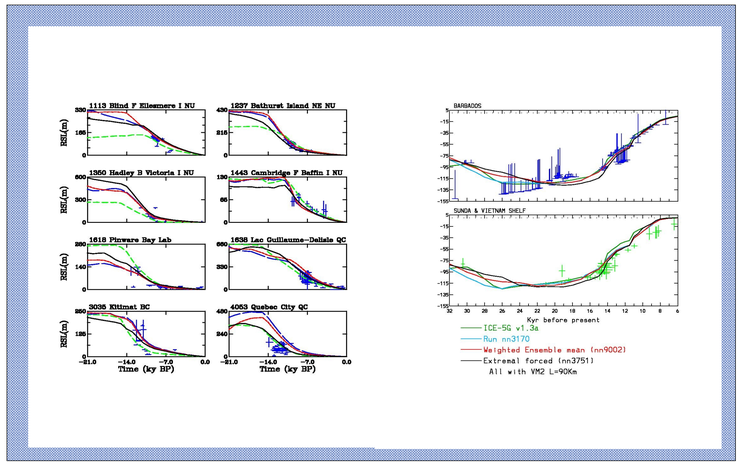


Figure 3a. RSL predictions. For calibrated models, a preliminary calibrated model is used for Eurasia, ICE5-G for Antarctica

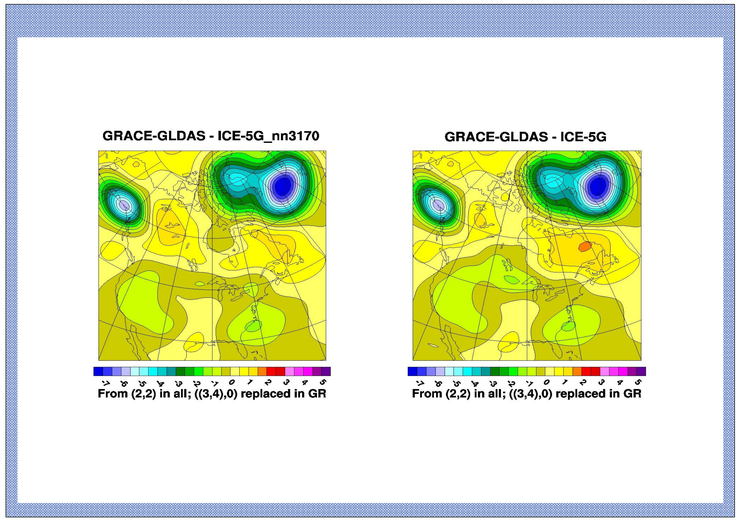
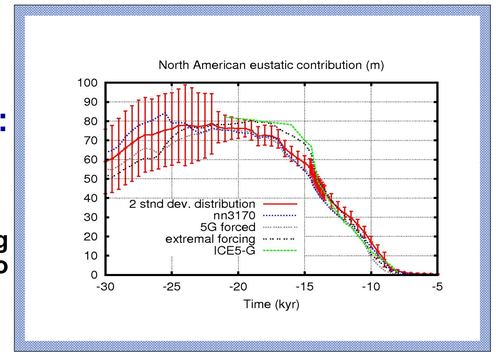


Figure 3b. - comparison against GRACE observations for mass rate

(4) Results: ice chronology

•extremal nudging is required to approach ICE5-G



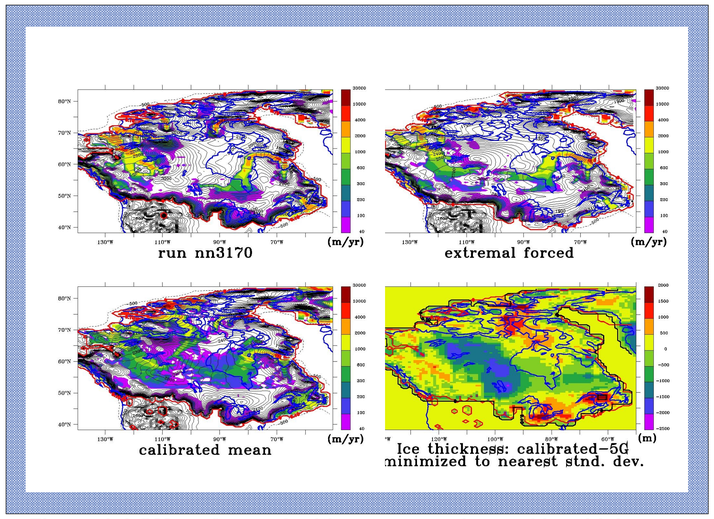


Figure 4. LGM surface velocities, topography, and ice thickness difference

(5) Conclusions

• within physical bounds and parameter limits of the glaciological model, nudging to ICE5-G can improve regional RSL fits, but at the cost of poorer fits to other constraints

•ICE5-G ice fields are significantly different than the calibrated glaciological model & appear to be unattainable within the parameter bounds of the calibration model

•Overall, the calibrated glaciological model is able to attain a near similar level of fits to RSL observations as that of ICE5-G and also validates to a similar level with MassRate observations from GRACE

•The full magnitude of meltwater-pulse 1-a is barely attainable with the calibrated glaciological models of the Northern Hemisphere as currently configured

References

Neal, R.M. (2003), Slice sampling, Ann. of Statis., 31, 705-767

Peltier, W.R. (2004), Global Glacial Isostasy and the Surface of Ice-Age Earth: the ICE-5G (VM2) Model and GRACE, Ann. Rev. Earth Plan. Sci,, 32, 111-49

Tarasov, L., and W. R. Peltier (2005), Arctic freshwater forcing of the Younger Dryas cold reversal, Nature, 435, 662-665