Conceptual Model of Global Ice Volume during the Quaternary for the Mid-Pleistocene Transition

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1. Motivation

The Quaternary (past 2.6 Myr) climate was characterized by alternating glacial and interglacial states. Glacials are linked to colder global mean temperatures and extended glaciation in the polar and mid-latitudes, while the interglacials are linked to periods of warmer climate [2]. The Mid-Pleistocene Transition (MPT) occurred between 1.2–0.8 Myr ago and marks the shift from low-amplitude ∼41-kyr glacial-interglacial cycles towards high-amplitude ∼100-kyr cycles (Fig. 1). The cause and the drivers of the MPT are still discussed and whether the MPT occurred due to an abrupt or a more gradual change in the climate system is still unclear [5]. It has been shown that conceptual models, which are low-dimensional models of the climate system, can yield a valuable contribution to answering these questions [3, 4].

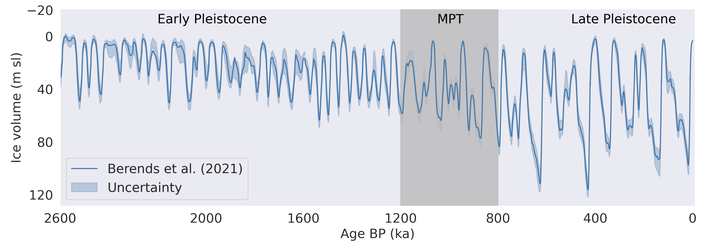


Figure 1. Global ice volume changes over the past 2.6 Myr. The grey-shaded area marks the MPT.

2. 2-State Conceptual Model

- **Original model:** Based on model by Parrenin et al. (2012), later adapted by Legrain et al. (2023) for the MPT
- **2-state model:** Glaciation + Deglaciation state with different ODEs
- **External forcing:** Orbital forcing by obliquity and precession cycles
- **Internal forcing scenarios:** ORB (=orbital), GRAD (=gradual), ABR (=abrupt), RAMP (=ramp-like)

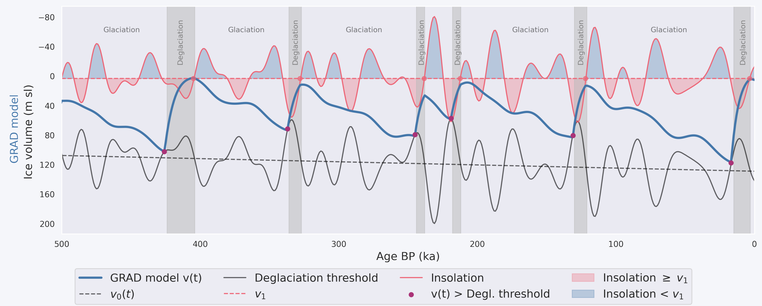


Figure 2. 2-state conceptual model. State changes depend on two thresholds: the deglaciation threshold (black line) and the current insolation (red line). The simulated ice volume v(t) is depicted by the blue line.

3. Results

- Abrupt change from 41-kyr to 100-kyr world, even with a gradual scenario for internal forcing
- Gradual and ramp-like internal forcing yield the best results and can reproduce the MPT
- RAMP experiment: MPT has started very early (> 2 Myr ago) and ended a few 100 kyr ago
- Prediction (RAMP): Onset next glaciation: 1 kyr ago. Duration: 105 kyr. Amplitude: 112 m sl

3.1 Which model is most likely to reproduce the MPT?

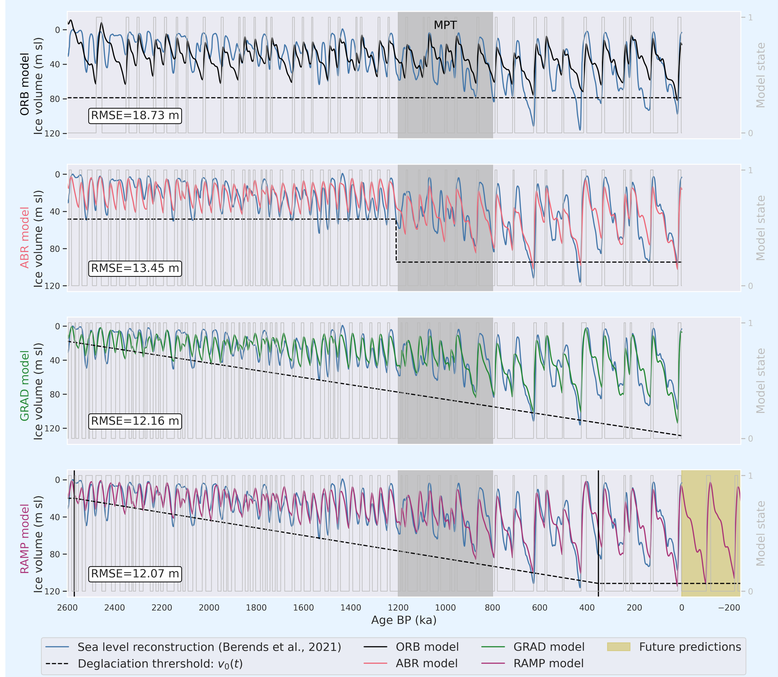


Figure 3. The four different model configurations. The orbital model (ORB) is solely externally forced, while the ABR model is abruptly-, the GRAD model is gradually-, and the RAMP model is ramp-like internally forced.

3.2 Model Validation: Does the tuning work with gaps?

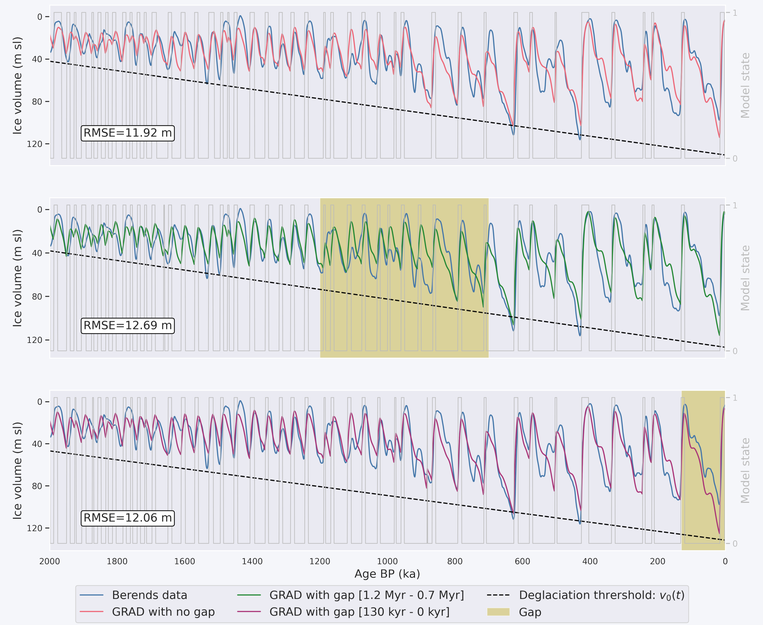
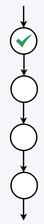


Figure 4. Gradual (GRAD) model tuned on full 2 Myr sea level data from Berends et al. (upper panel), with a gap for the interval 1.2-0.7 Myr (middle panel), and with the gap for the last glacial cycle 130-0 kyr (lower panel).

4. Outlook



- Numerical speedup of the code
- Implementation of new optimization algorithm for the parameter tuning
- Integration of other proxy records into the model
- Tuning of the model not just wrt global sea level, but additionally onto other climate variables (e.g. CO_2, CH_4, Antarctic temperatures, etc.)
- Reconstruction of paleo records for further climate variables, e.g. generating CO_2 curve for past 2.6 Myr

References

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