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Modeling rapid flow of the Antarctic Ice Sheet using continental-scale models

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1. The hybrid models

The Stokes equations describe the dynamics of ice bodies. For **long, continental-scale simulations**, they are commonly simplified using the **Shallow Ice Approximation** (SIA, for grounded ice) and the **Shallow Shelf Approximation** (SSA, for floating ice).

However, the SIA is inapplicable to rapid flow regions where basal sliding operates and some of the neglected terms become important. Since these terms are included in the SSA, recent studies have introduced heuristic, **"hybrid" combinations of both approximations.**

2. The goal

Here, we compare the performance of four different **hybrid schemes** (HS) during an automated calibration procedure that uses modern observational data of ice thickness to infer spatial variations in the **highly uncertain** basal sliding parameters.

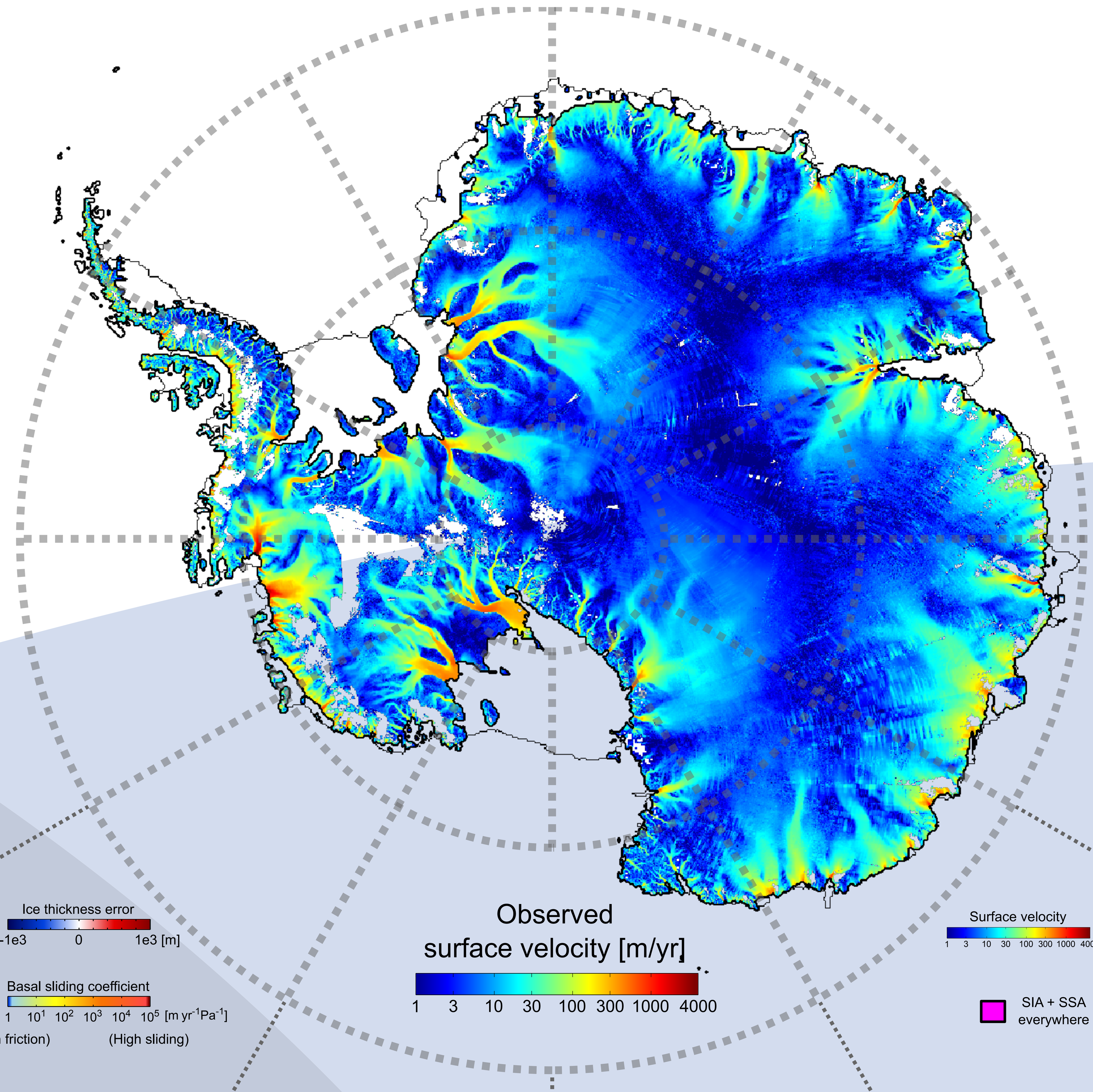
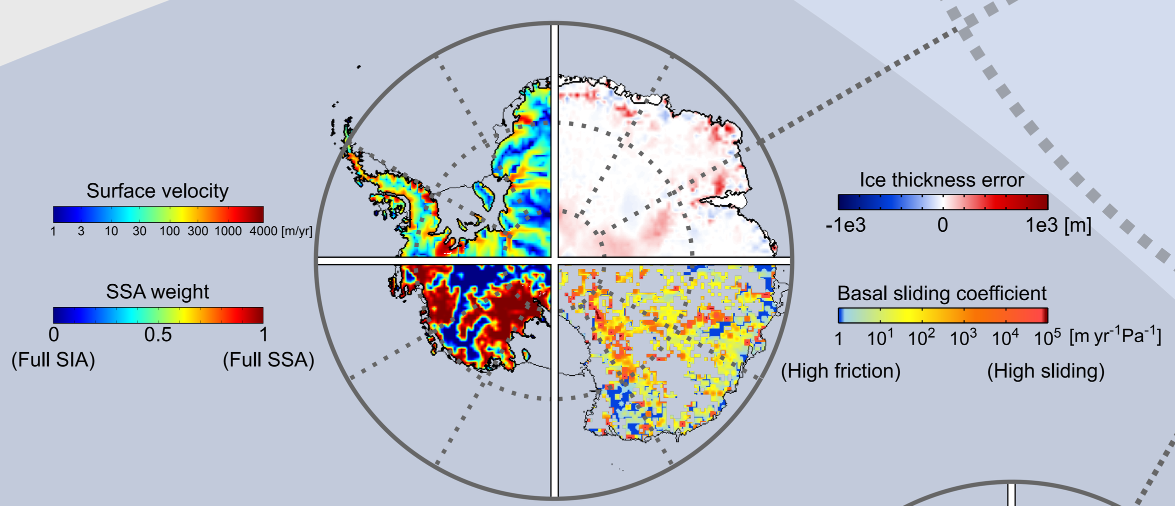
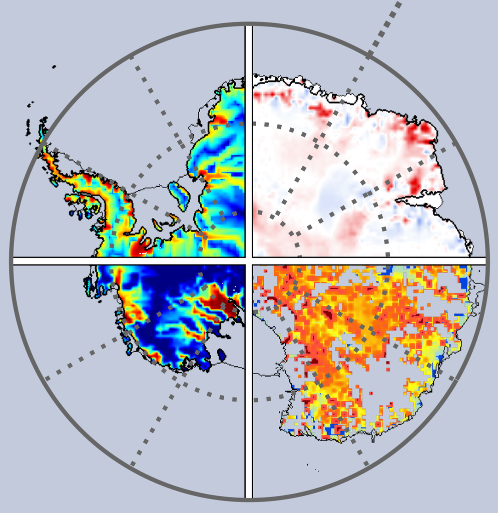
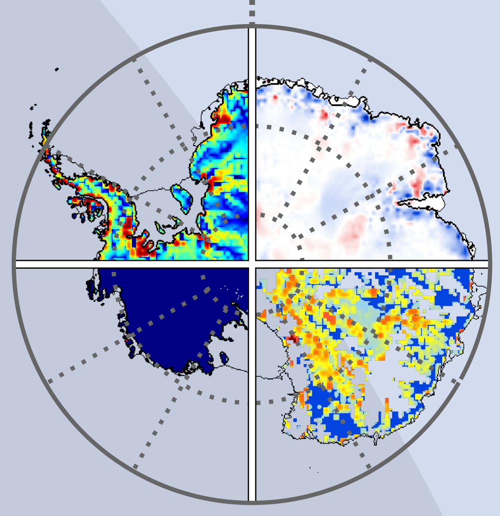
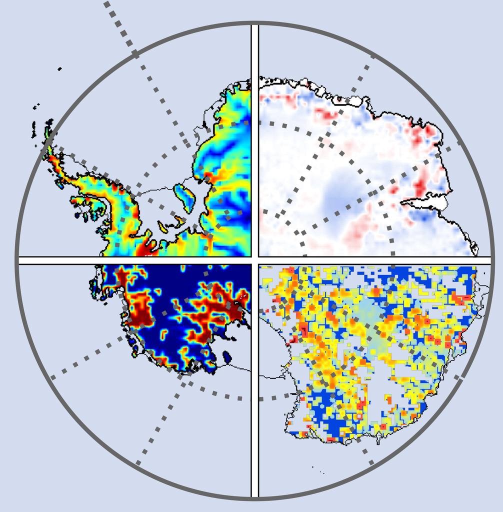


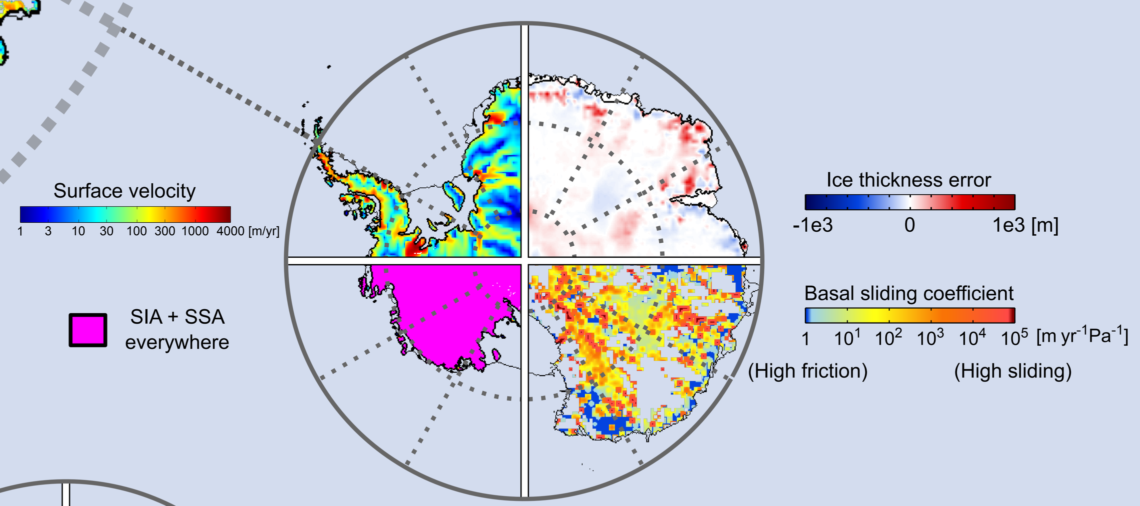
Fig. 1: Top: Observed surface velocities from Rignot et al. (2011). Bottom: Equilibrium ice sheet configurations. The modeled surface velocity, ice thickness error, SSA weights for the hybrid combination, and the inferred basal sliding coefficients are shown for each scheme.











HS-1

Uses the ratio of basal and surface SIA velocities to compute a weighted average of the SIA and SSA: A high ratio implies sliding, thus the average is weighted towards the SSA.

HS-2a

Prescribes a no-sliding condition for the SIA. Where the SSA velocities are high, the average is weighted towards the SSA, using it as the sliding component.

SIA

Non-hybrid, SIA-only solution.

HS-2b

As HS-2a, but keeps the basal velocities from the SIA solution. SIA velocities are increasingly replaced by the SSA solution as the SIA basal velocity becomes higher.

HS-3

Simply adds the SIA and SSA velocities. To avoid a double contribution of basal velocities, a no-basal-slide condition is prescribed for the SIA.

3. Evaluating the performance of the schemes

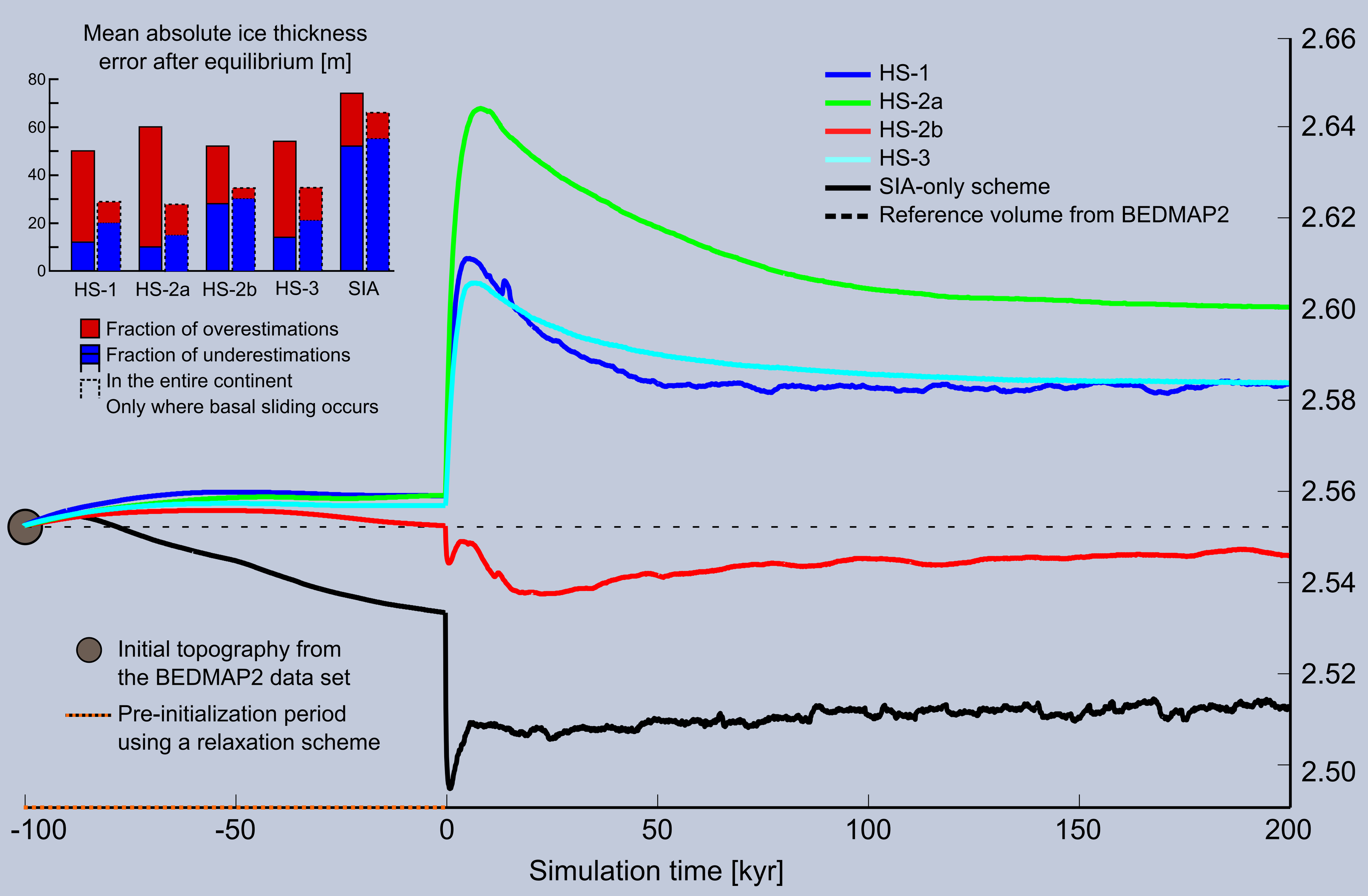


Fig. 2: Evolution of total grounded ice volume and mean absolute ice thickness error after equilibrium.

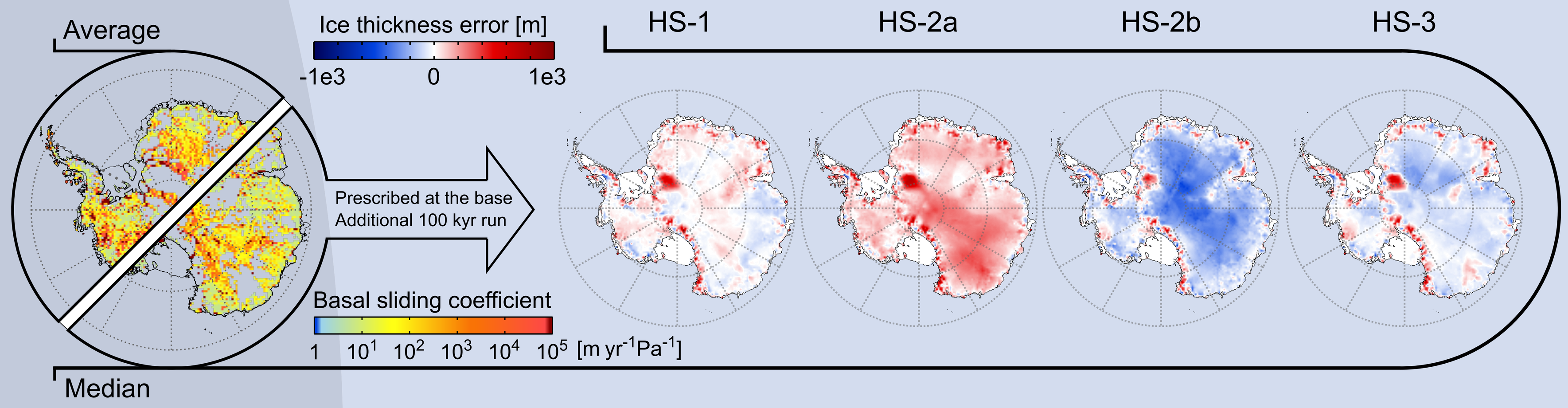


Fig. 3: Ice thickness error after additional 100 kyr run (starting from the resulting equilibrium states), using the median of the inferred basal sliding coefficients (hybrid schemes only).

Our results show that the automated calibration **compensates for differences** in the hybrid schemes, producing similar ice sheet configurations through different distributions of sliding coefficients. The uncertainty in the basal conditions limits an objective evaluation of the hybrid schemes.

Furthermore, the retrieved parameter distributions are **not exchangeable** between different hybrid schemes. This suggests that the results from the calibration of a specific ice sheet model cannot be transferred to a model that approximates the ice dynamics in a different way.

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