The role of fast processes for the stability of the Greenland ice sheet

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Introduction

Here, we investigate the problem of reproducing area partition (partition between ice-free and ice covered area) and mass balance partition (partition between surface melt and discharge into the ocean) of the Greenland ice sheet with steady state simulations using the ice sheet model SICOPOLIS. Fast processes play an important role to si-mulate both partitions at the same time. In dynamic ice-sheet modeling often solely the area partition criterion is used, because this is the most prominent feature and it can be seen by eye. While in mass balance studies the right amount of surface melt play the key role.

Model Setup

Greenland is represented schematically by a round island with a axisymmetric ice sheet. We study two setups: one with flat bedrock and low velocities (“classical model”) and another one with bedrock troughs in which high sliding velocities are prescribed in order to emulate fast processes.

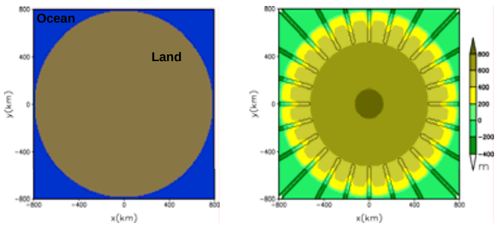

Fig. 1: Left: Model domain. Right: Uplifted bedrock with troughs.

Boundary conditions

Surface:

•Constant accumulation 0.3 m water equivalent (mwe) per year.

•Melting via monthly standard PDD with β_1=0.003 m mwe/(day °C) for snow, β_2=0.008 m mwe/(day °C) for ice, σ=5 °C, P_{max}=0.6.

•Axisymmetric surface temperature:

$$T_s = T_0 + T_A \sin(\omega t) - \gamma r + \Delta T$$

•TA=10 °C, γ=0.008 °C/m. T_0 is tuning parameter, T_0=-6 °C.

Bedrock:

•Over stream areas always fast sliding according $v_b = -C_s\, H$ *nabla h*, C_s = 200 a^{-1}.

•Slow hard-rock sliding if $T = T_{pmp}$, no-slip for $T < T_{pmp}$.

•Geothermal heat flux 50 mW m^{-2}.

Results

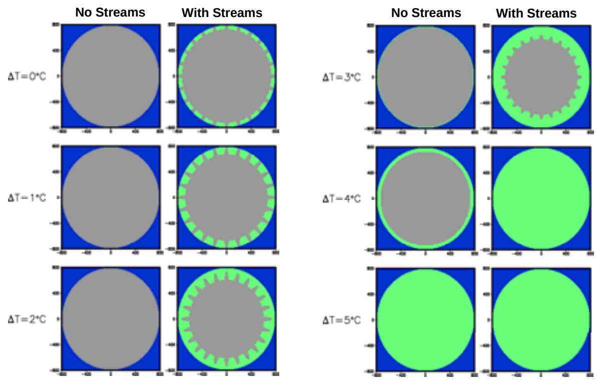

Fig 2: Simulated ice cover versus temperature difference.

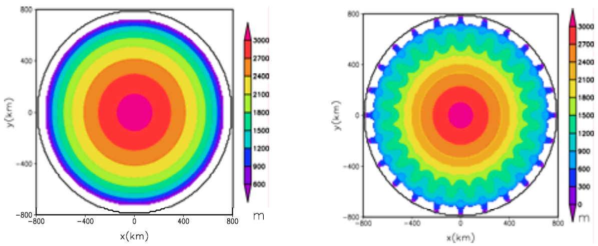

Fig 3: Ice surface elevation at ΔT=4 for the model without streams (left panel) and at ΔT=0 for the model with ice streams (right panel).

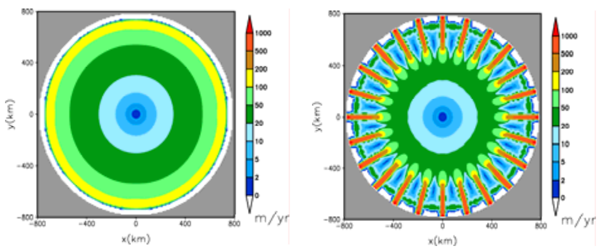

Fig. 4: Ice surface velocity at ΔT=4 for the model without streams (left panel) and at ΔT=0 for the model with ice streams (right panel).

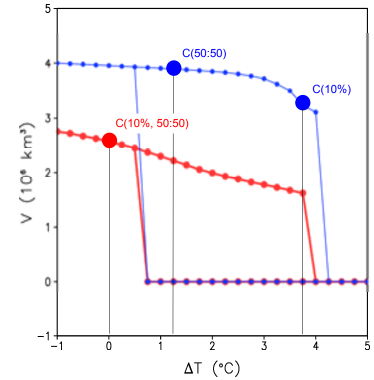

FIG. 4: Stability diagram. The dots indicate ice volume from steady state simulations. Blue for runs without ice streams and red from runs with ice streams.

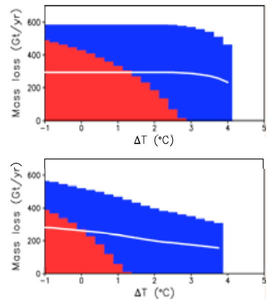

Fig. 5: Partition of total mass loss in the classical model (upper panel) and in the model with fast processes parameteri-zation (lower panel). Surface melt is depicted in red and discharge into the ocean in blue. The white lines indicate 50:50 partition.

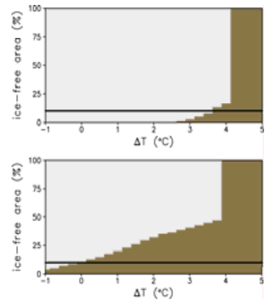

Fig. 6: Ice-free area in percentage (brown bars) in the model without (upper panel) and with (lower panel) fast processes. The black lines depict 10 percentage ice-free area.

Conclusions

•In our model setup without ice streams, it is not possible to yield 50:50 total mass loss partition and 10% ice cover with the same forcing.

•With inclusion of fast processes via an ad-hoc parameterization a 50:50 total mass loss partition with about 10% ice-free area can be simulated at the same time.

•Our simulations suggest that the mass balance partition criterion should receive more attention in dynamical ice sheet modedeling.