How will the Greenland Ice Sheet develop under Extreme Melt Events?

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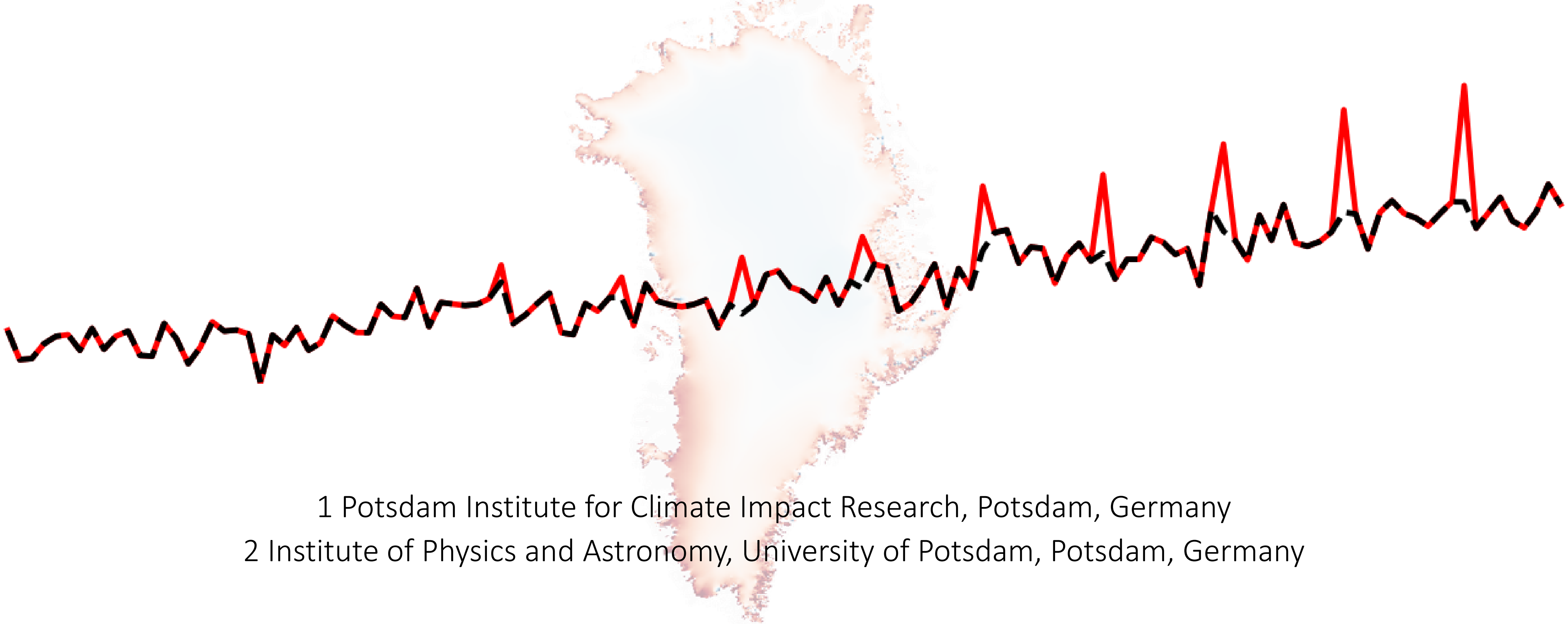

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How will the Greenland Ice Sheet develop under Extreme Melt Events?

1. Methods
2. Projected future Changes
3. Static vs Dynamical
4. Summary

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1 Methods

The Parallel Ice Sheet Model (PISM)

- 3D numerical ice-sheet/ice-shelf model PISM[1] solving a hybrid of the Shallow Ice Approximation (SIA) and Shallow Shelf Approximation (SSA)
- Ice-ocean-interactions not considered in this study
- PDD-scheme for deriving surface mass balance (SMB) from prescribed air temperature and precipitation

Experimental Design

- Spin-up with scalar temperature field changes over 125 ka to climatological mean 1971-1990 (temperature and precipitation) derived from MARv3.9 with ERA-Interim
- Projection with scalar temperature field derived with MARv3.9 from ERA-Interim (1971-2017)[2] and Miroc5(2018-2100) RCP8.5[3]
- Extreme temperatures added for the month of July every 20, 10 and 5 years

1 https://pism-docs.org/wiki/doku.php
2 ftp://ftp.climato.be/fettweis/MARv3.9/ISMIP6/GrIS/ERA_1958-2017/
3 ftp://ftp.climato.be/fettweis/MARv3.9/ISMIP6/GrIS/MIROC5-rcp85_2006_2100/

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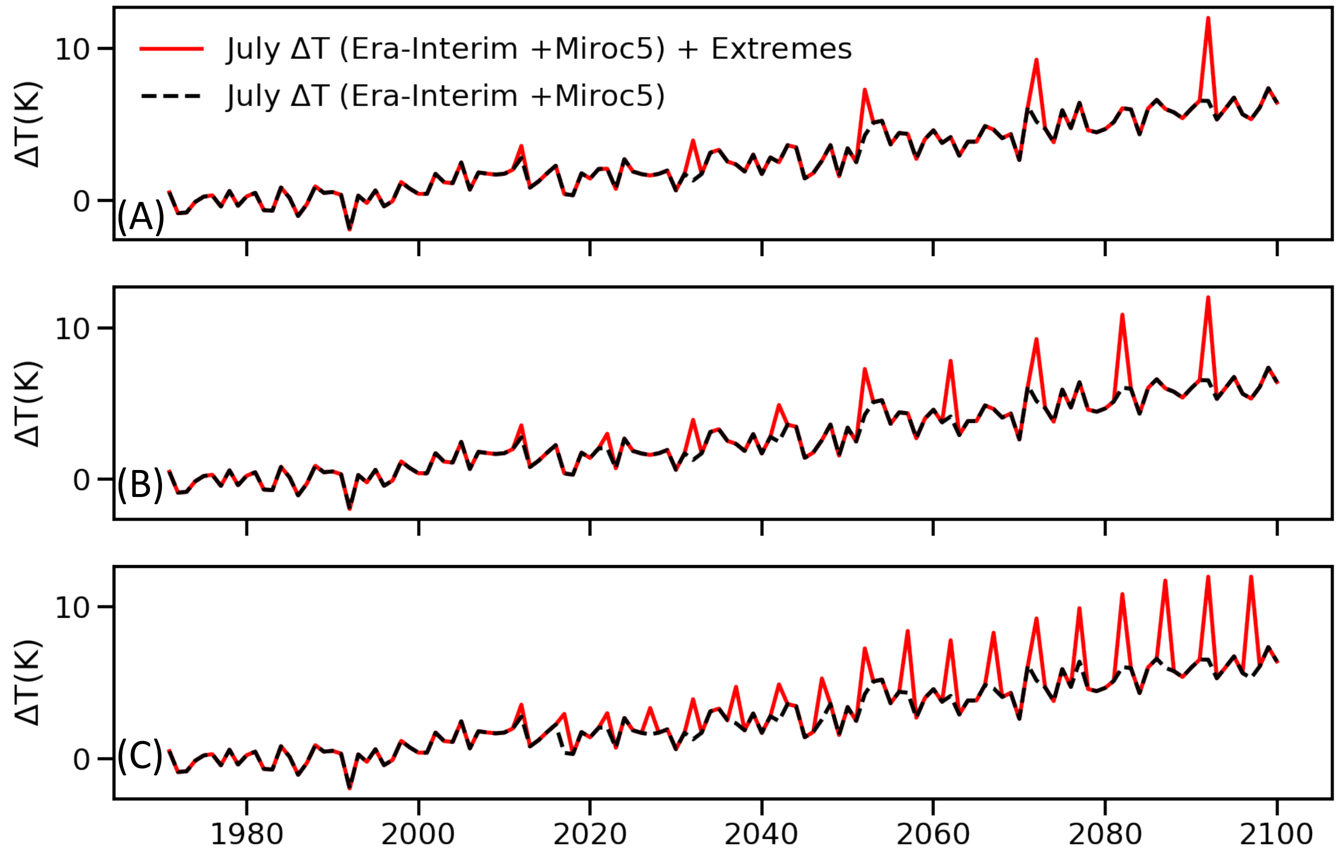
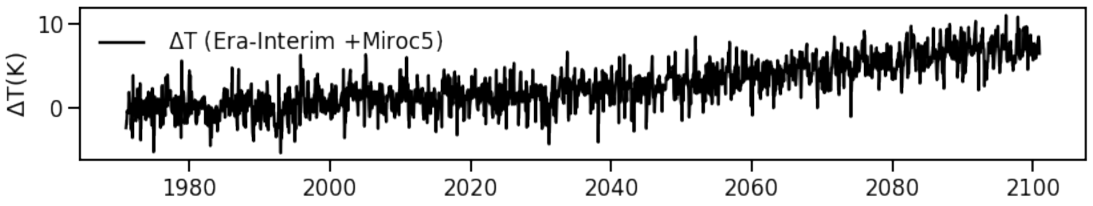
Projected future Changes

Forcing

July temperature changes with extremes every 20,10,5 years





- A warming signal from the average surface warming calculated by the regional Model MARv.3.9 from ERA-Interim (1970-2017) and CMIP5 Mirco5 RCP8.5 (hereafter Miroc5), and then applied uniformly to the entire ice sheet.

- An extreme temperature in July is added that shows a warming twice as high as the 10 year monthly average every 20 (A), 10 (B) and 5 years (C).

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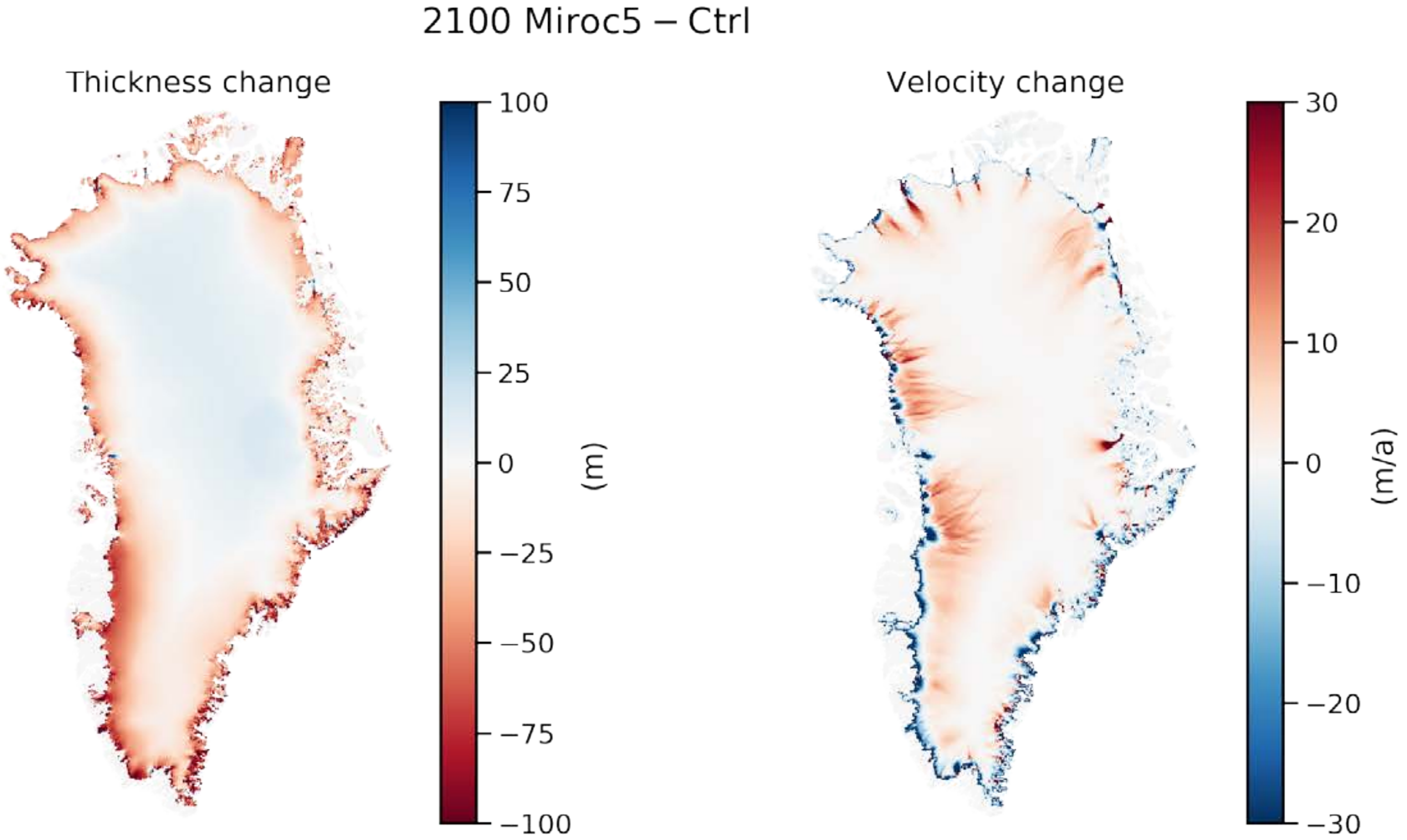
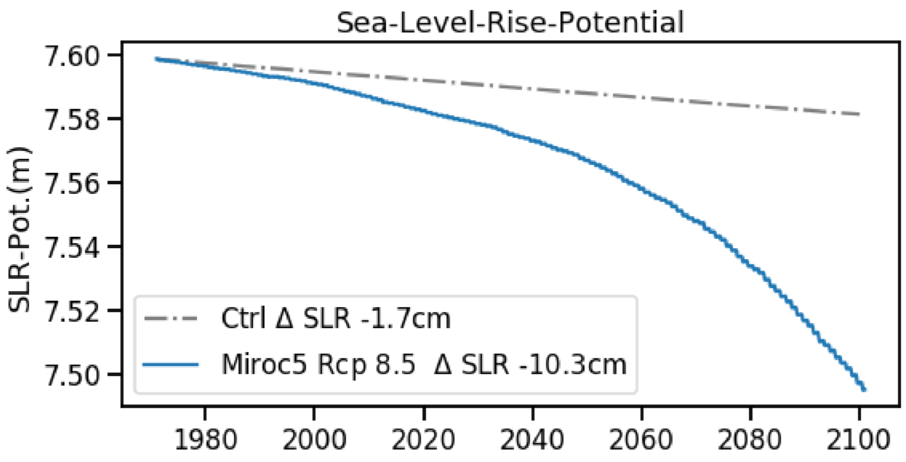
2 Projected future Changes — Results



- Temperature changes lead to thinning at the ice margins and a slight thickening in the ice interior

- Thinning and flattening @margins leads to a slowdown of the ice flow while the resulting steepening of the neighboring surface increases the ice velocity



- Sea-level-rise increases by 8,6cm (subtracted by control run)

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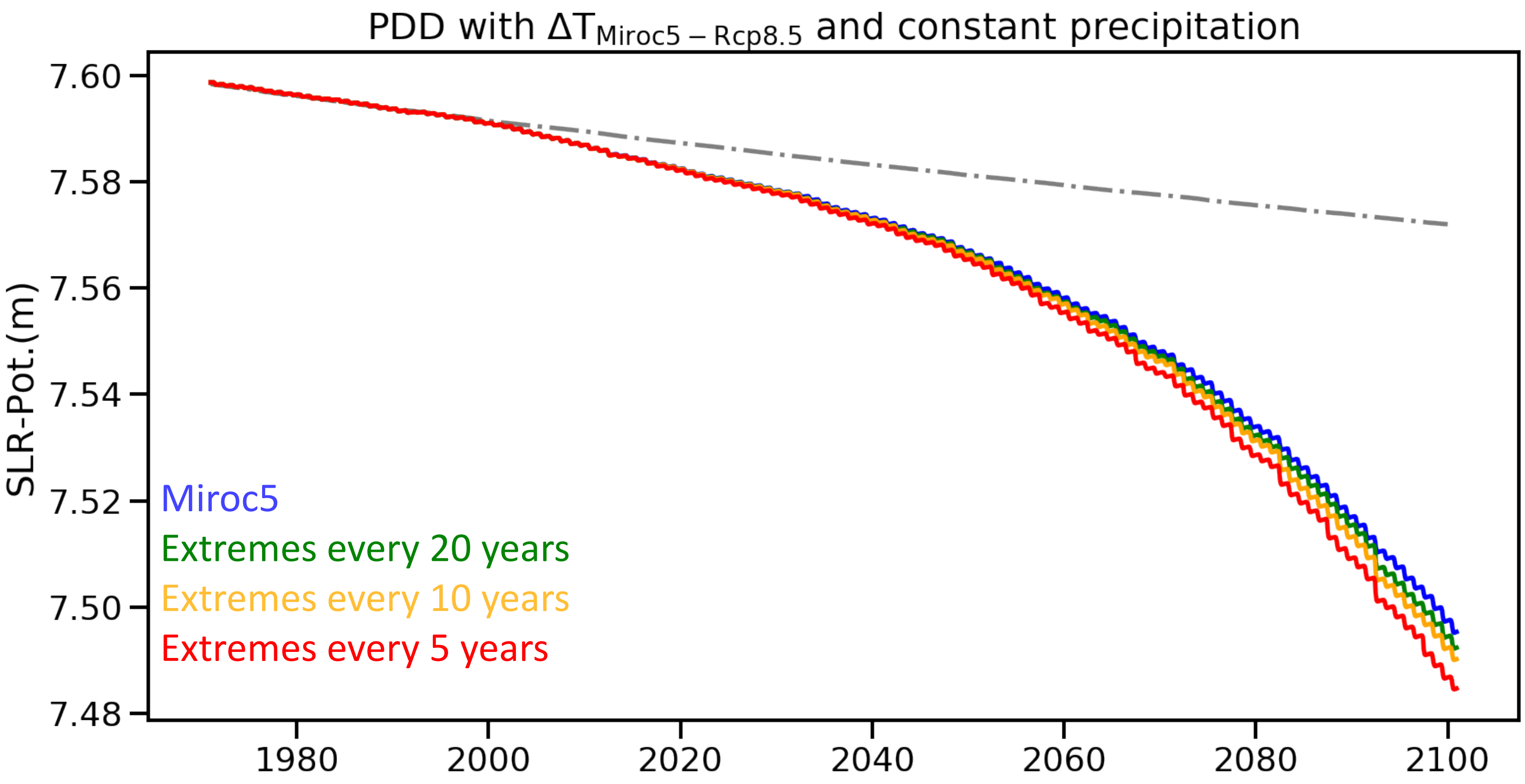
2 Projected future Changes — Results



- The more frequent the extremes the higher the sea-level response.

But how does the dynamical part change with the extremes?

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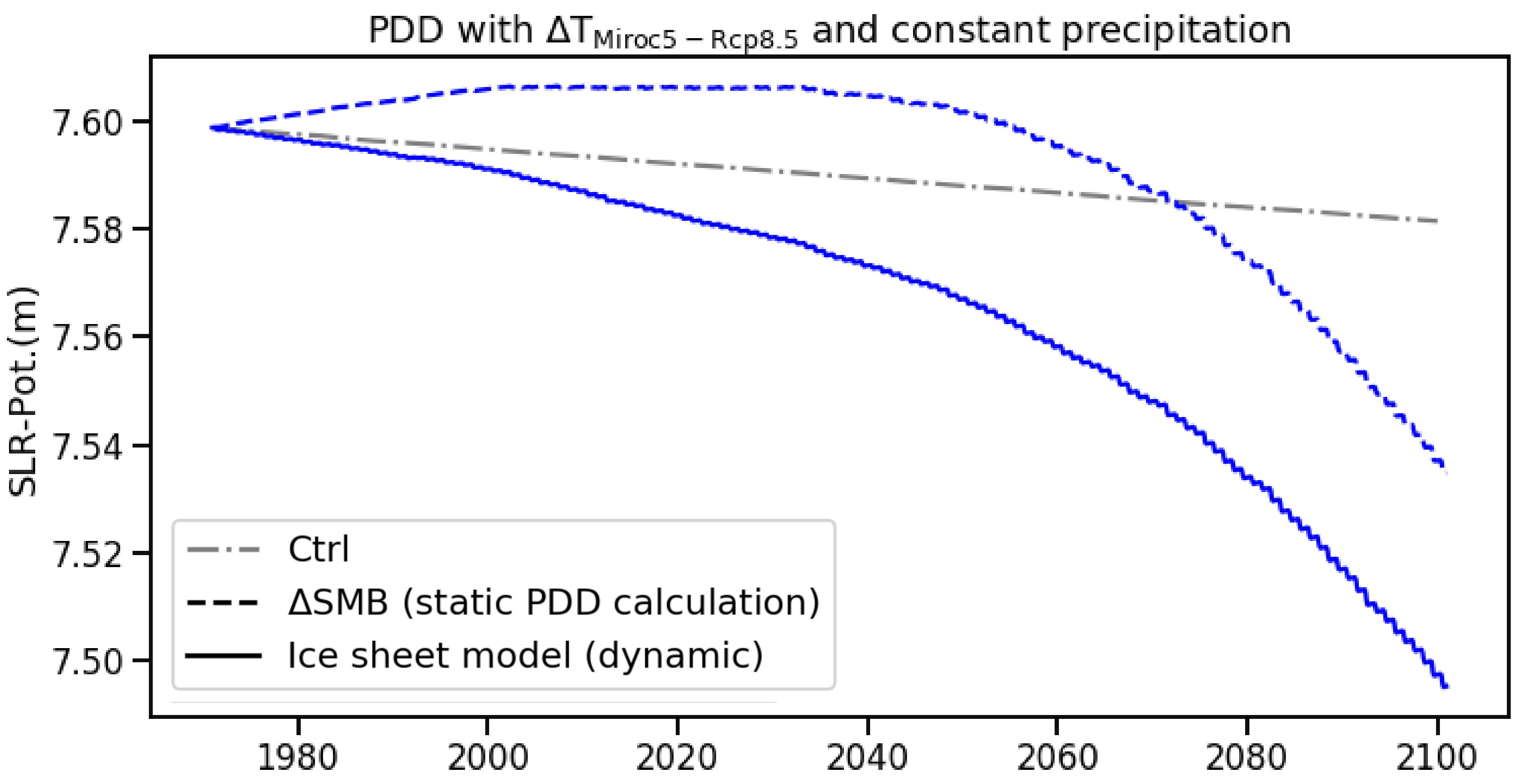
3 Static vs Dynamical



- The dynamical processes of the ice flow add 3.9 cm SLR for the Miroc5 scenario without extremes.

Why?

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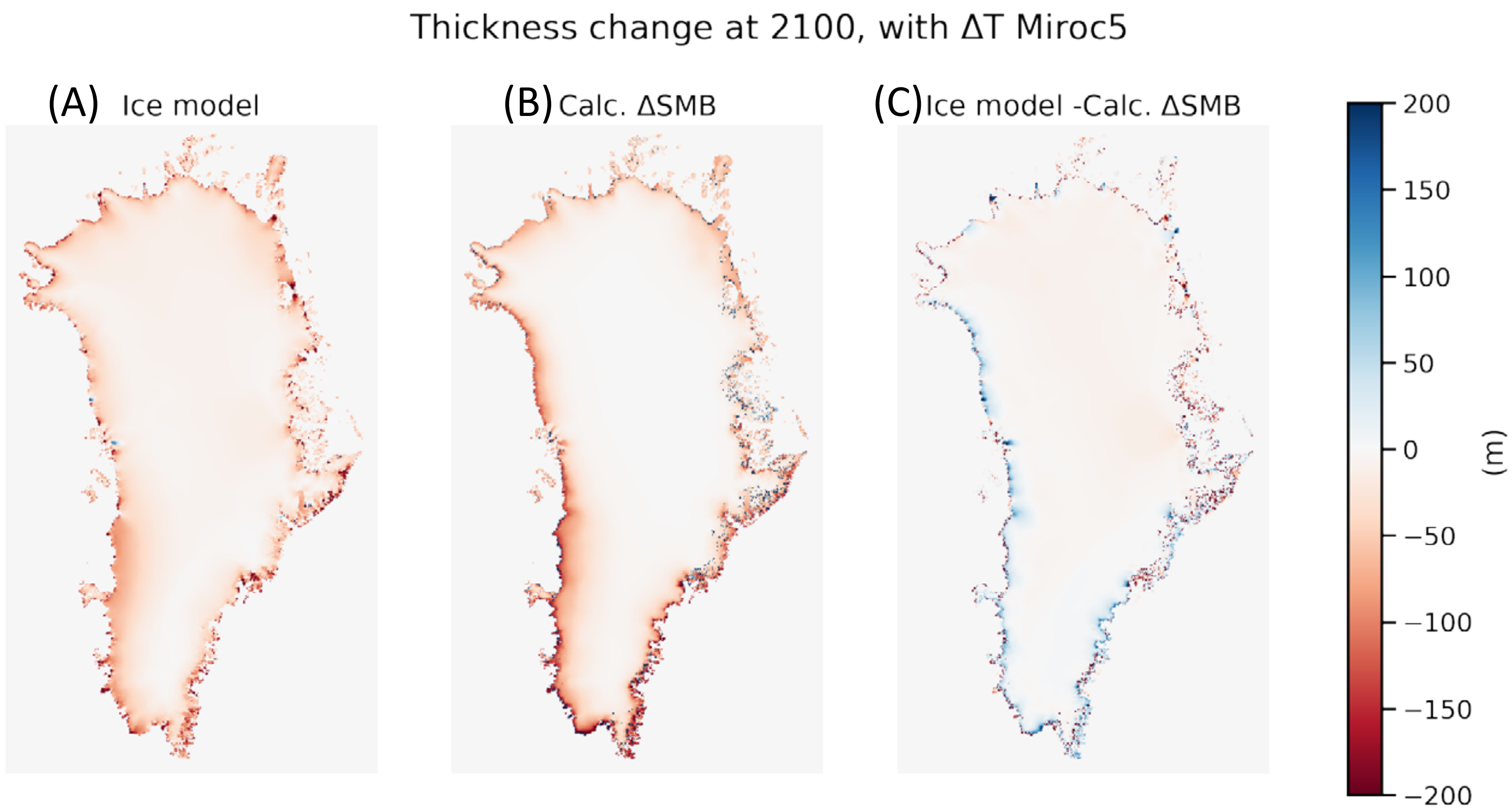
3 Static vs Dynamical



Overall, the ice transport from the interior to the margins leads to additional ice loss in most of Greenland with ice dynamics (A) compared to the SMB-only case (B). Directly at the ice-sheet margins, however, less ice is lost (C, blue shading) due to the delivery of new ice from the ice interior that is suppressed in the SMB-only case(B).

- Ice thickness anomaly in year 2100 projected (A) with the fully dynamic ice sheet model, and (B) with pure ΔSMB calculations, i.e. without ice dynamics. (C) Difference betwen (A) and (B).

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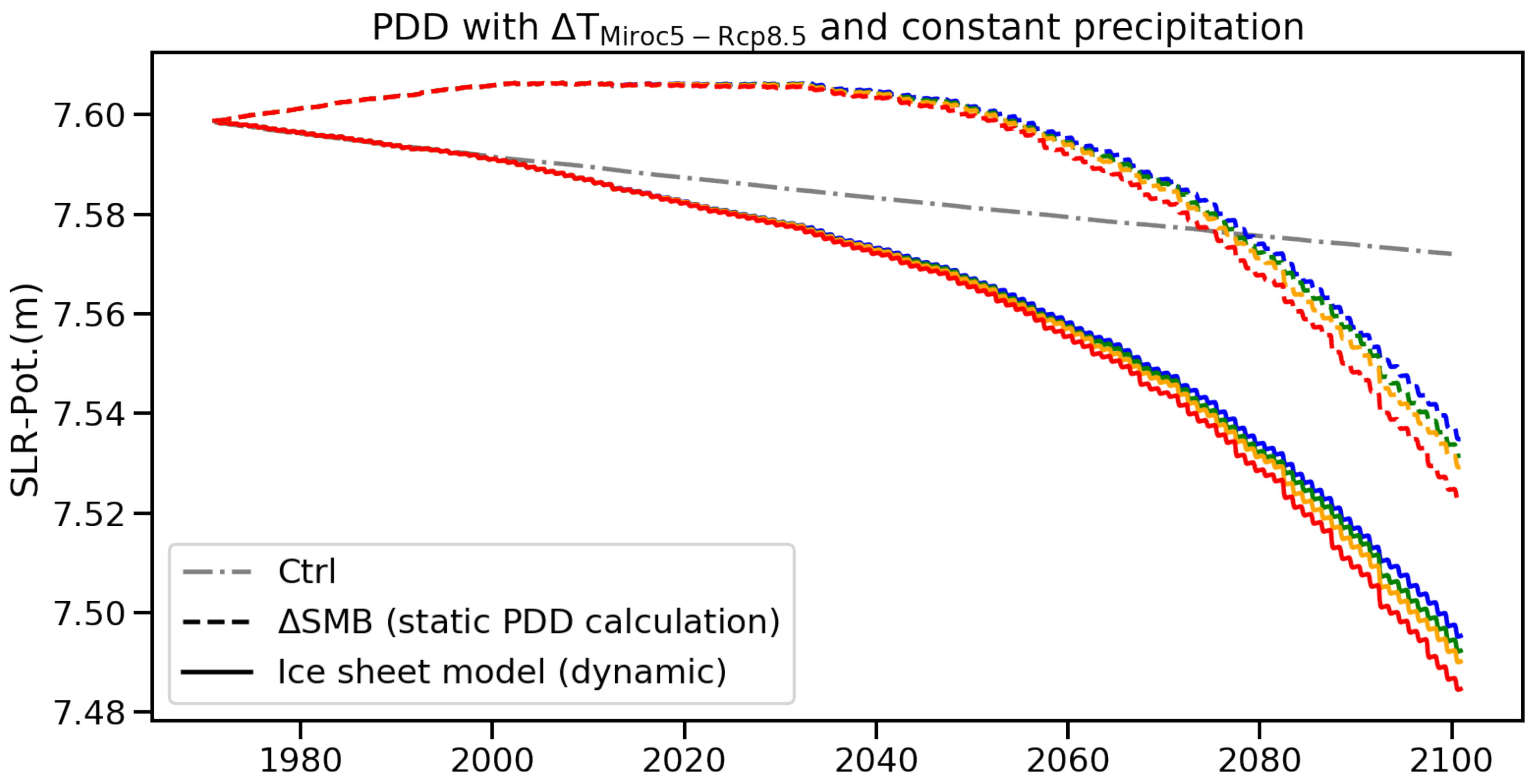
3 Static vs Dynamical



- The dynamical processes of the ice flow add 3.9 cm SLR for the Miroc5 scenario without extremes.
- Extremes every 20 years
- Extremes every 10 years
- Extremes every 5 years

But how does the dynamical part change with the extremes?

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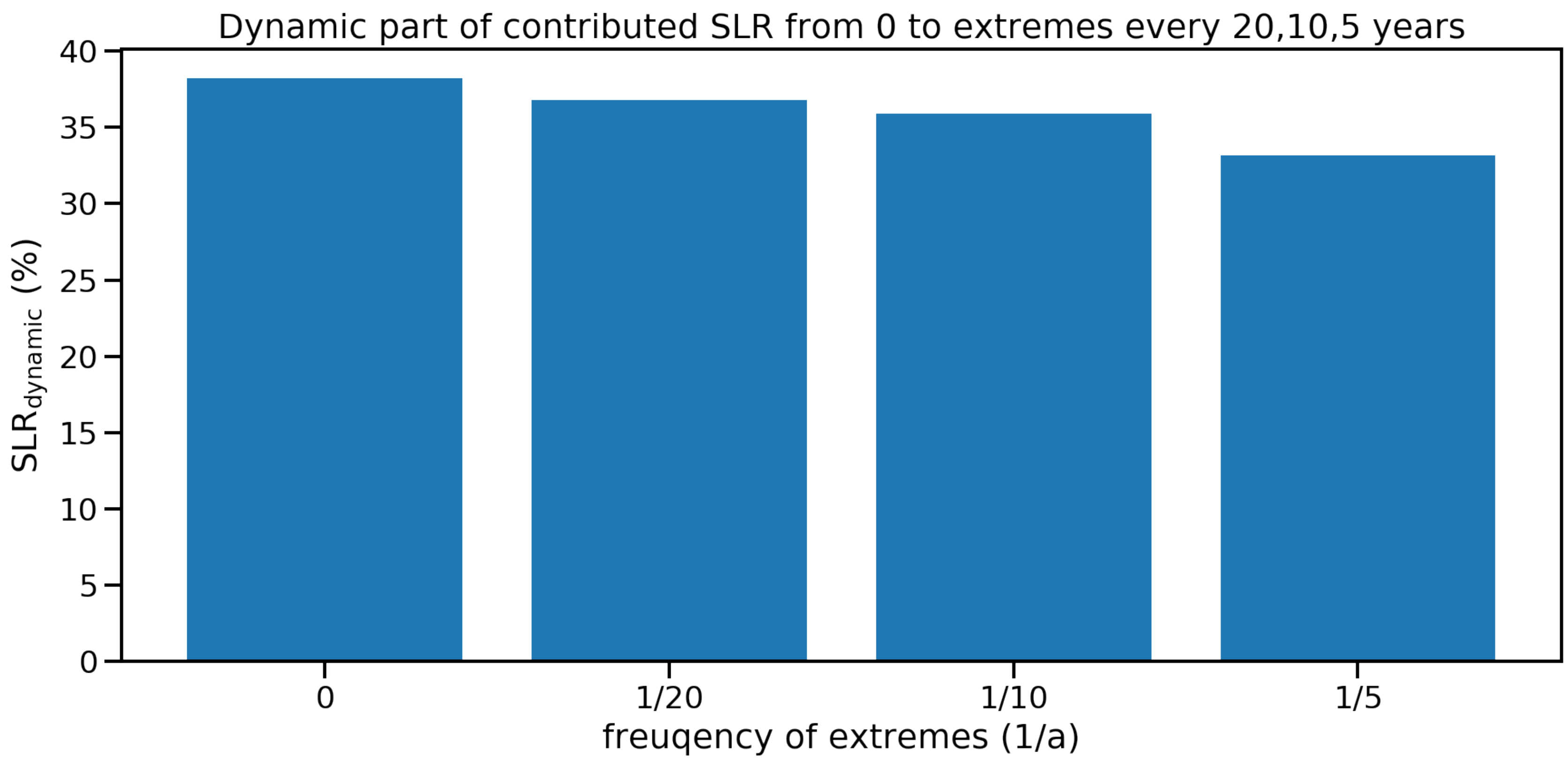
3 Static vs Dynamical



Relative share of dynamical ice loss (100 ·(ΔSMB_PISM – ΔSMB_static)/ ΔSMB_PISM)

The dynamical part decreases with increasing frequency of extremes. Generally, more mass loss/thinning decreases the ice flow.

But how does the dynamical part change with the extremes?

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4 Summary and Outlook

General dynamic response:

Due to dynamic transport of ice, we find a general speedup of the ice flow in the interior of the ice-sheet, and slowdown directly at the margins. The decreasing ice velocities at the margins locally also decrease the relative share of the dynamical ice loss.

Fully dynamic run vs. SMB-only:

Generally - due to the dynamic response - Greenland loses more ice than in the ΔSMB (surface-mass-balance)-only case. However, this dynamical share of the mass loss decreases with increasing frequency of extremes.
At the ice-sheet margins, melting mostly leads to thinning and flattening of the surface such that ice velocities decrease and thus ice transport is slowed down locally.

Outlook:

- Test extremes with regional patterns
- Add ice ocean interaction

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