Effects of extreme melt events on the Greenland Ice Sheet

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Effects of extreme melt events on ice flow and sea level rise of the Greenland Ice Sheet

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2 Motivation

- In recent decades Greenland has been subject to several extreme melt events (2010, 2012, 2019)
- They are attributed to strong negative North Atlantic Oscillation index (NAO) in these summers, that led to persistent anticyclonic pressure heights over Greenland (blocking events)
- Observation show an increasing trend in Geenland blocking events and with progressing climate change extremes are expected to become more sever and frequent
- So far, projections do not include extremes
- We asses their total contribution to the Greenland ice sheet until 2300

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2 Methods

The Parallel Ice Sheet Model (PISM)

- 3D high-resolution numerical ice-sheet/ice-shelf model which solves Shallow Ice Approximation (SIA) and Shallow Shelf Approximation (SSA) simplify Stokes equations
- No Ice-Ocean-Interaction
- PDD-scheme that calculates 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) and Miroc5 (2018-2100) RCP8.5
- Extreme temperatures where added for July every 20, 10 and 5 years

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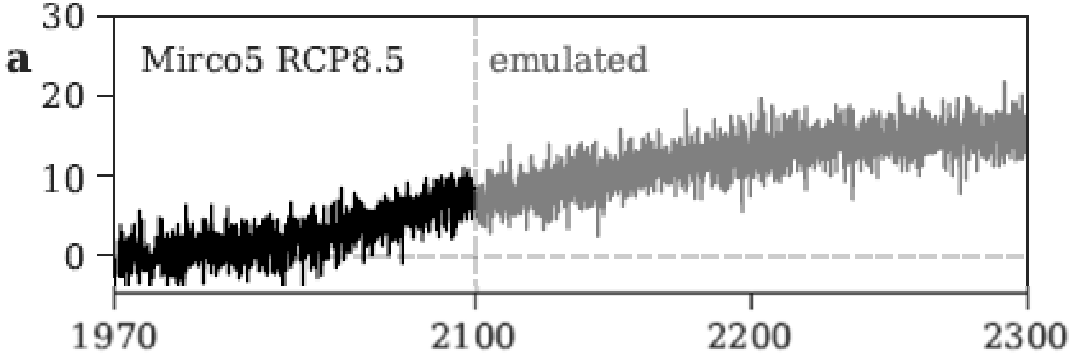
2 Methods

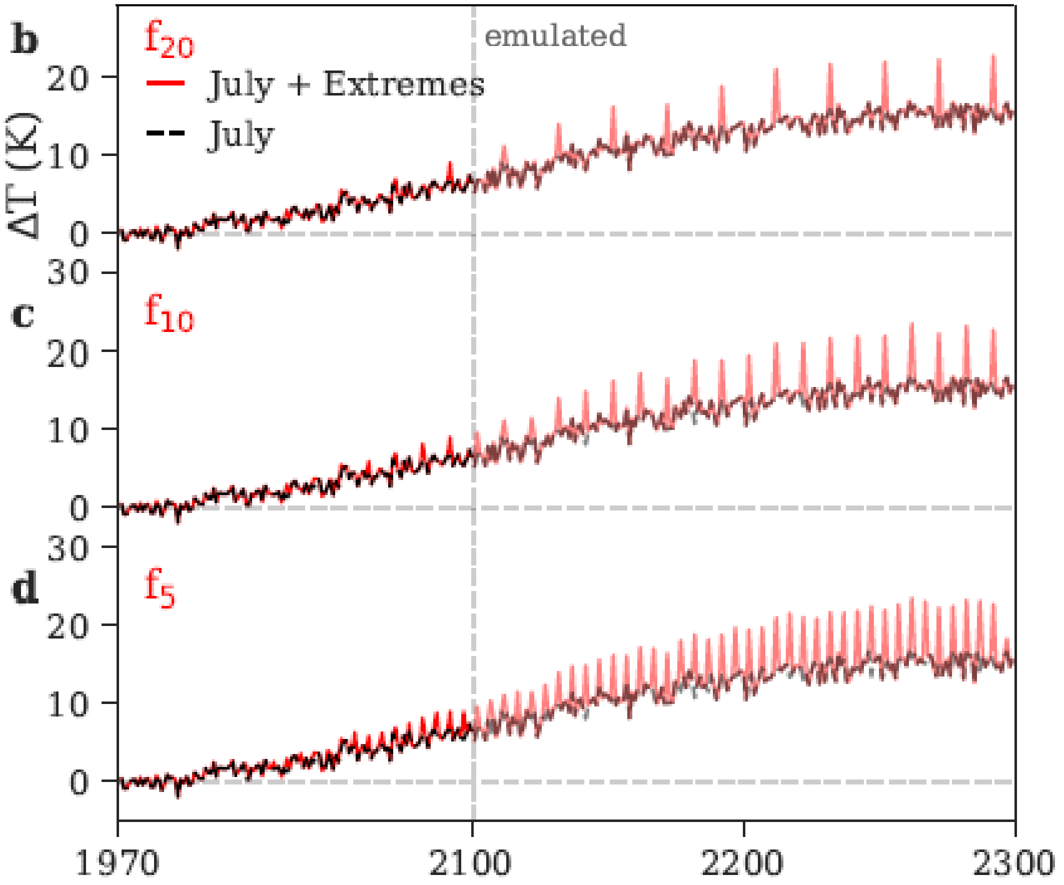
Forcing

Monthly Temperatures



- 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 is applied equally to the entire ice sheet. (Hereafter Miroc5)

July temperature with added extremes



- An extreme temperature in July is added that shows a warming 1.5($I_{1.5}$) times as high as the 10 year monthly average every 20 (**b**), 10 (**c**) and 5 years (**d**)
- Also extremes with 2 times – I_2 and 1.25 times -$I_{1.25}$

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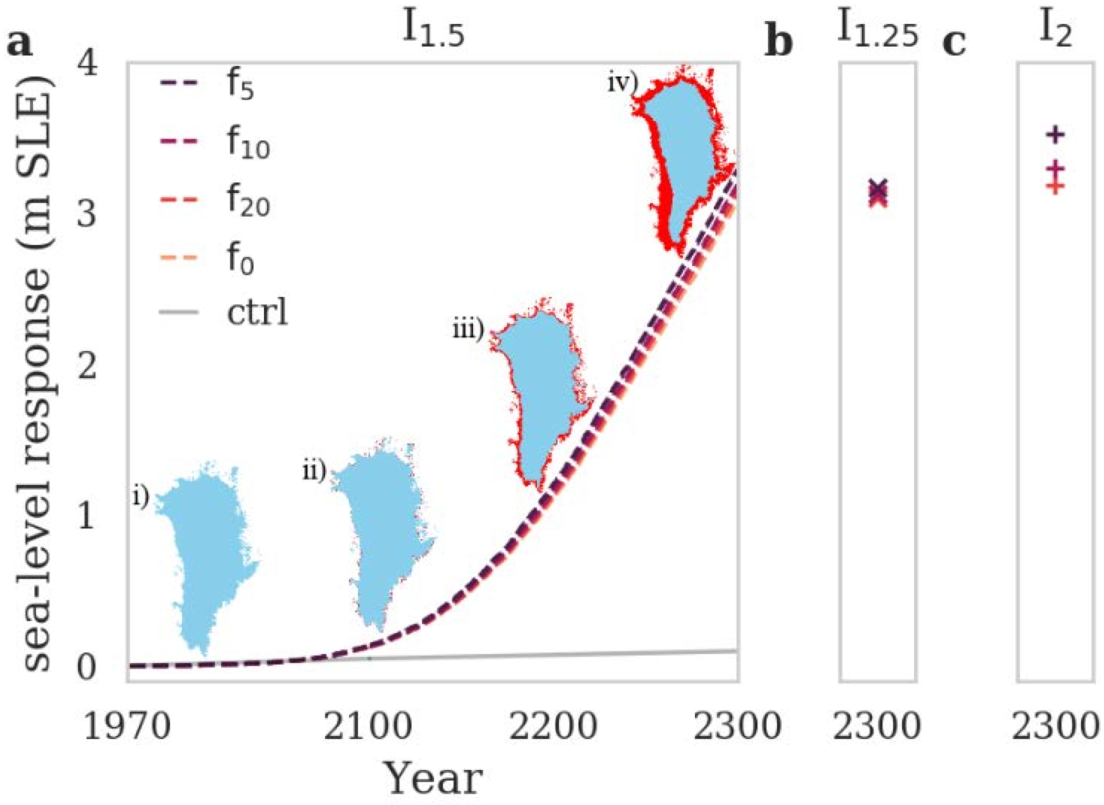
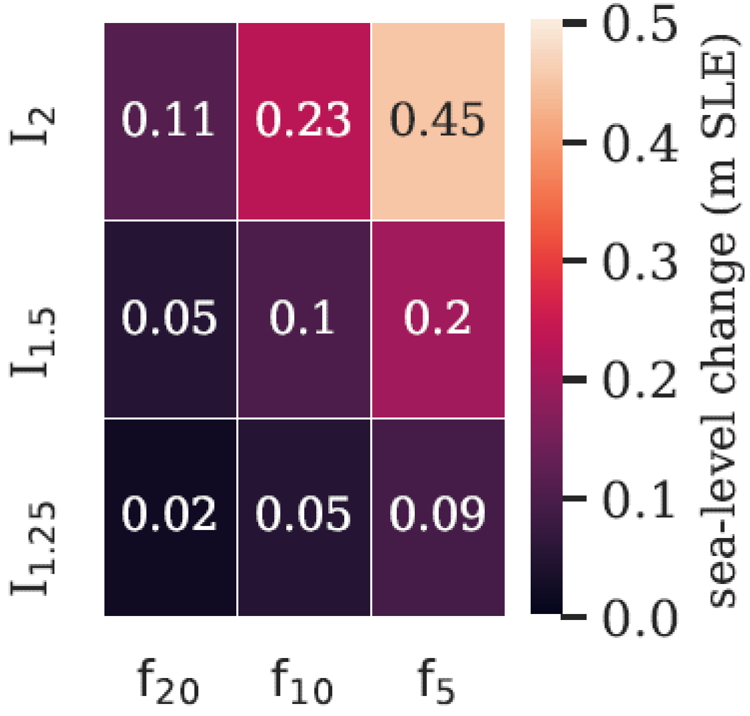
Sea level rise





- **Sea-level rise until 2300.** Most severe extreme scenario leads to 3.5 m SLR compared to the 3 m SLR without extremes in the year 2300.

- **Importance of intensity and frequency of extremes**. Doubling in intensity or frequency leads to doubling in additional SLR. Together their impact is nonlinear.

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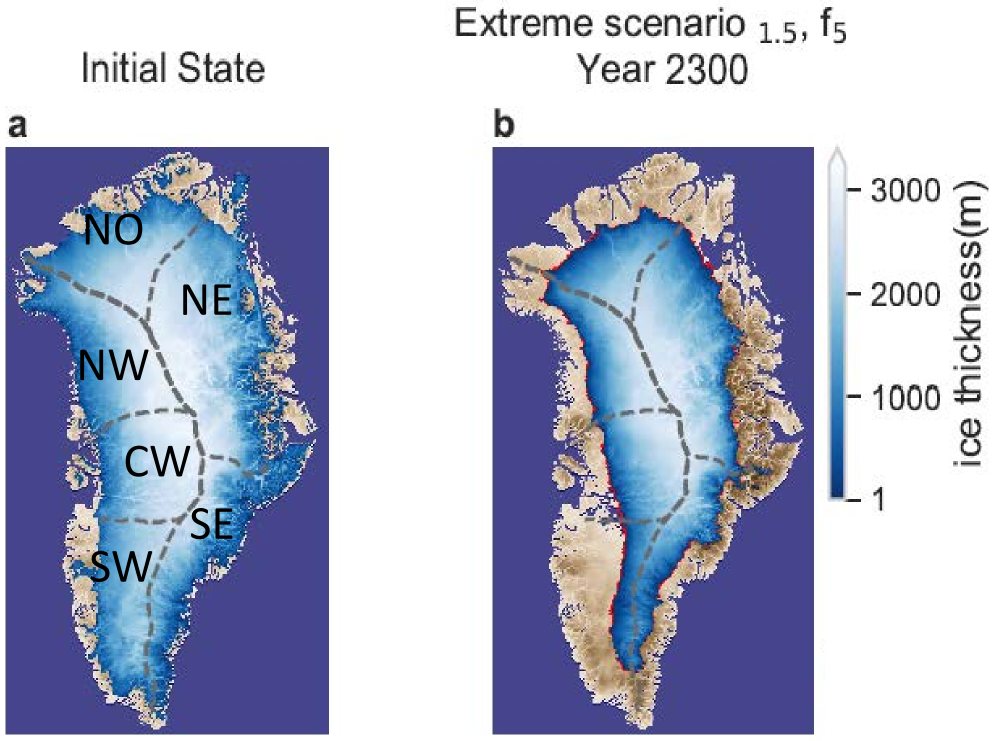
2 Result

Ice volume



- Ice loss primarily at margins (more melting due to higher temperature /lower surface)
- Western Greenland topography is lower than east, thus more exposed to higher temperatures
- Total 14% ($298 \cdot 10^3$ km²) of initial area is lost in 2300, most sever extreme scenario adds 18 10^3 km²

- Temperature changes leads to retreat. Red line indicates area loss due to extreme.

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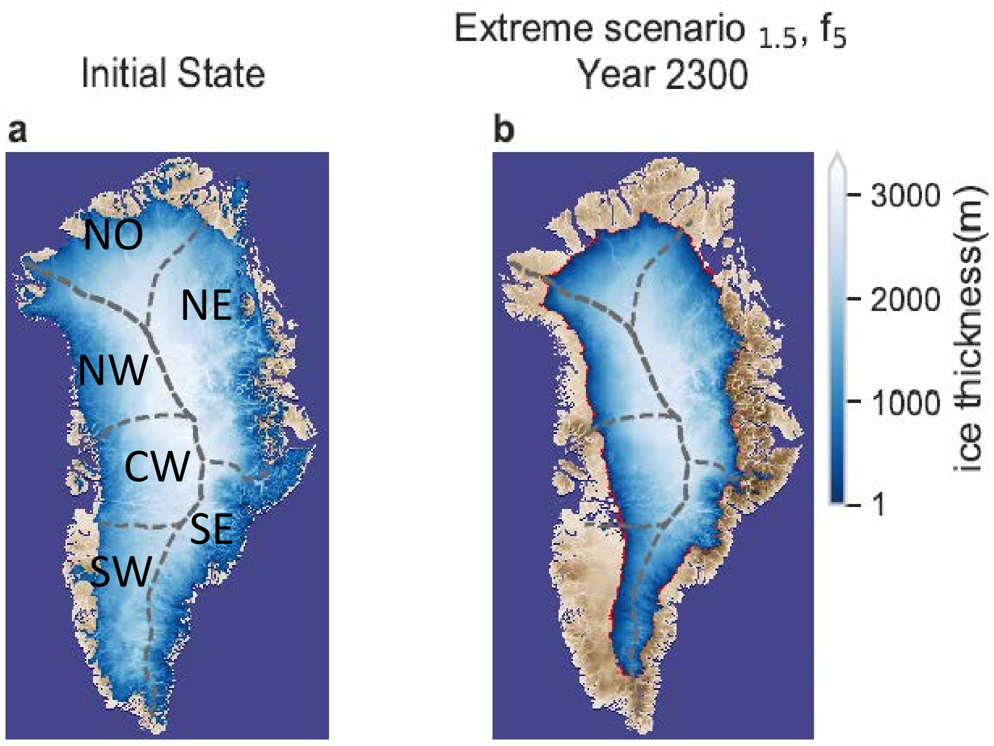
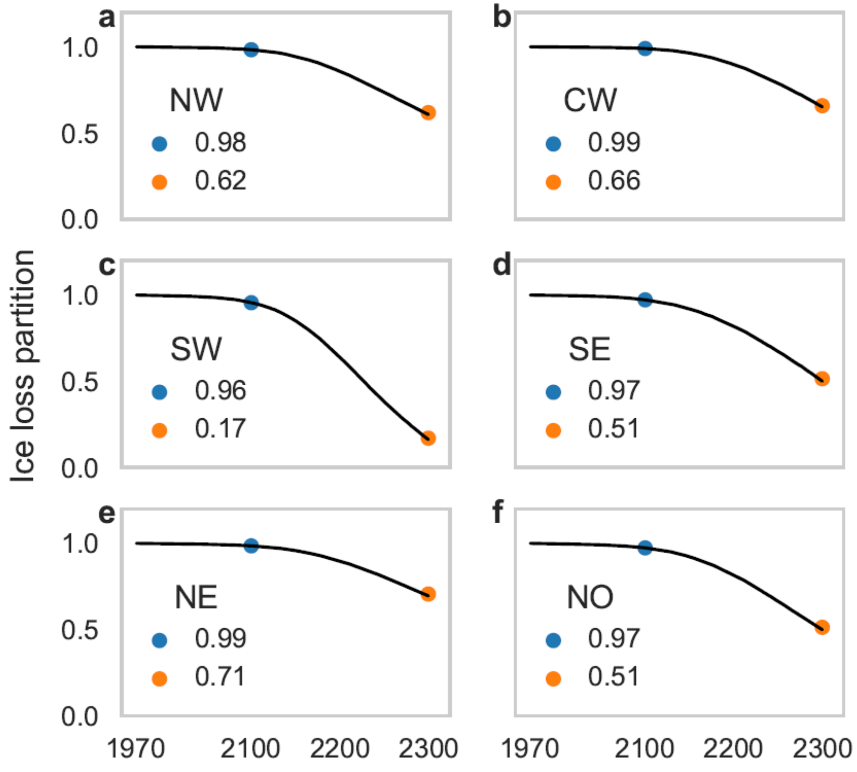
2 Result — Ice volume



Temperature changes leads to retreat. Red line indicates area loss due to extreme.

Ice loss of each sector



- Furthest retreat in SW (258 10^3Gt /83%)
- Same amount NE but only 29% of initial volume

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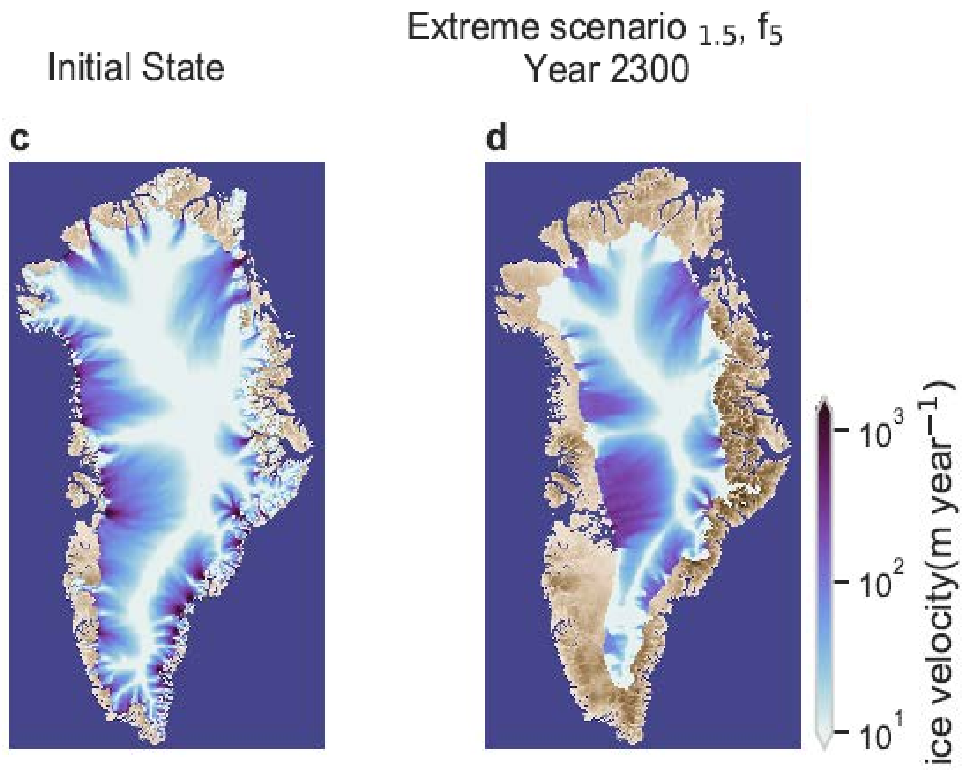
2 Projected future Changes — Dynamics



- **Surface velocities** for the initial state and the year 2300.

- Average speedup from 25 m/year to 52 m/years
- In 2300 glaciers with minimum velocity of 500 m/year are lost, due to glacier retreat

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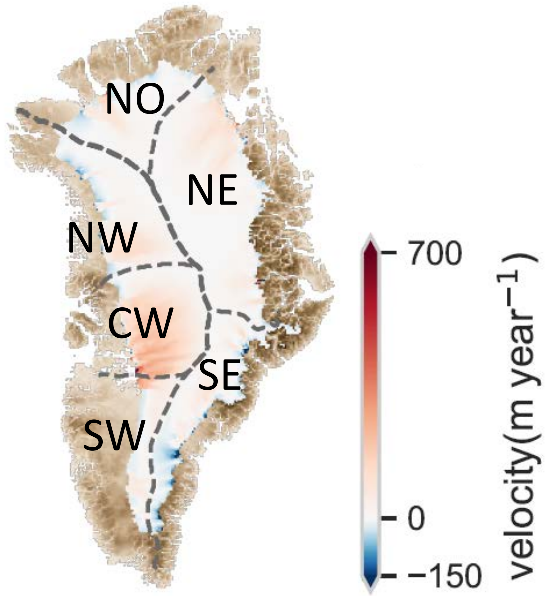
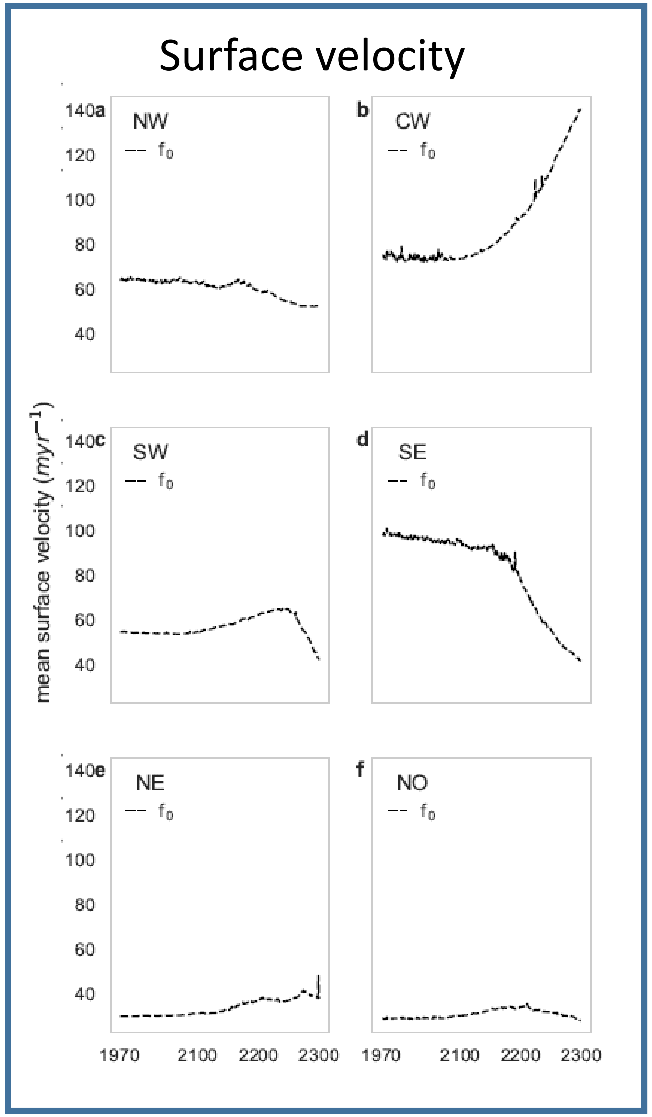
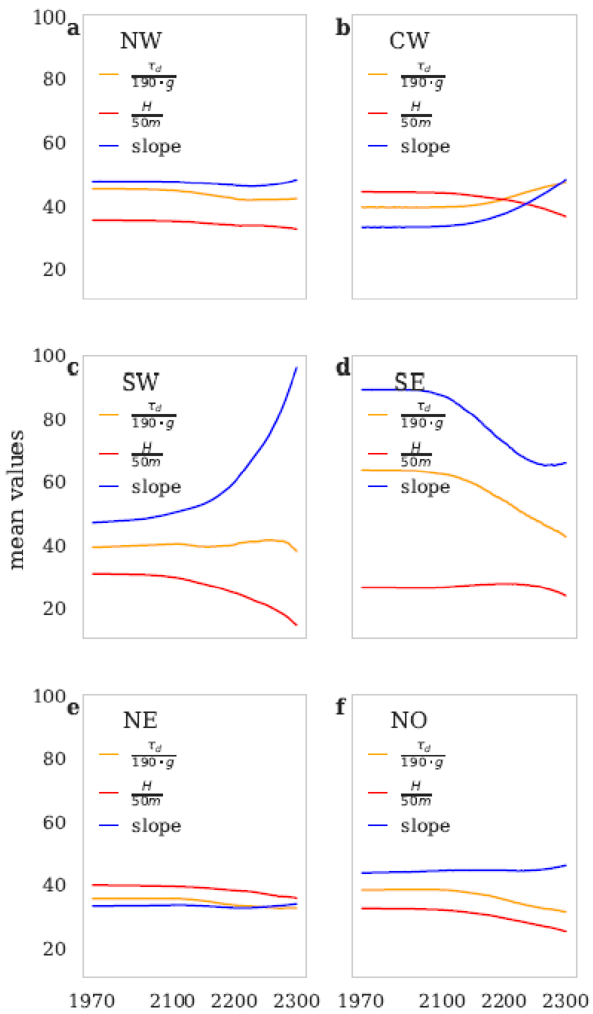
2 Projected future Changes — Dynamics



- **Velocity change**. Overall speedup at catchment areas and mostly slow down at margins.
- CW sector only sector with continued acceleration.





- Velocity is mainly driven by driving stress, a product of surface slope and ice thickness
- Although there is often steepening, thinning reduces the driving stress
- Increased extremes lead to decreased velocities due to thinning

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4 Summary

- Extremes decrease surface velocities, due to the reduced driving stress invoked by the additional SMB loss and thinning
- Extremes can lead to additional retreat of the ice-sheet margins and additional ice volume loss compared to the baseline climate change scenario
- Severe extremes could increase SLR by up to half a meter by the year in 2300
- Intensity and frequency of extremes play equally important role

THANKS!

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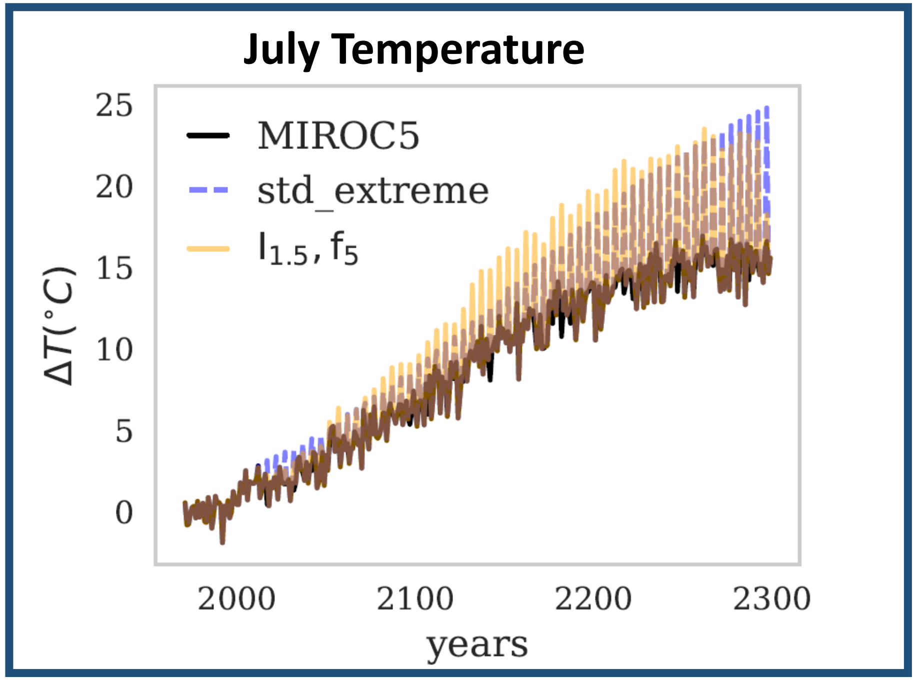
Forcing why?

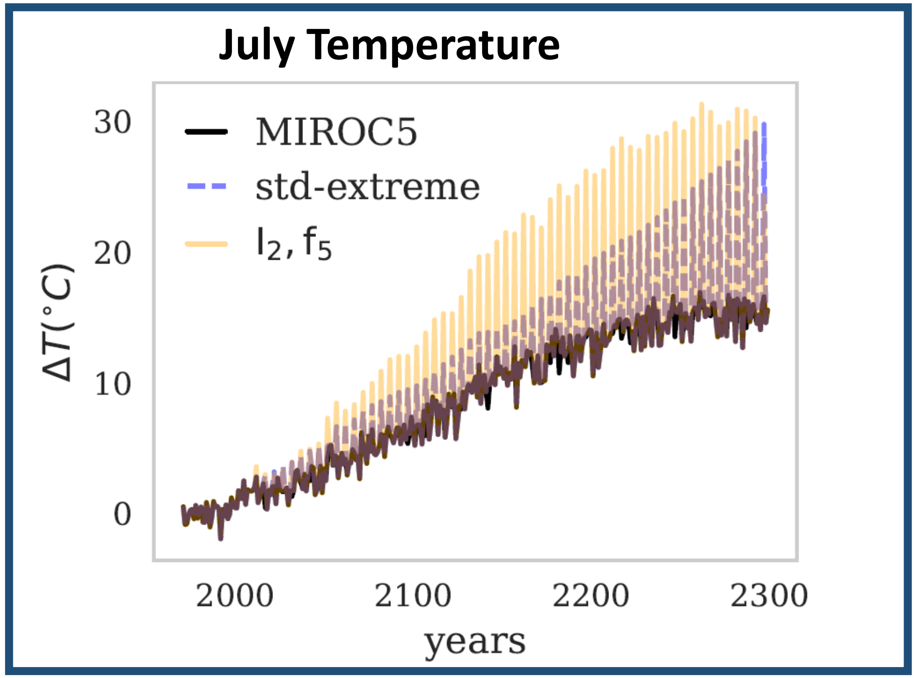
- frequency (every 20,10 and 5 years):

based on the observed heat wave probabilities of 5 to 20 % in the Arctic at present

- intensities (factor of 10-yr running mean): simplistic way of considering growing standard deviation



- Past temperature distribution (> 1979) i.e. 2.6 standard deviation resembles $I_{1.5}$ f_5



- Last 15-yr temperature distribution i.e. 2.2 standard deviation resembles I_2 f_5

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