Influence of Arctic sea ice loss on the Greenland Ice sheet surface mass balance

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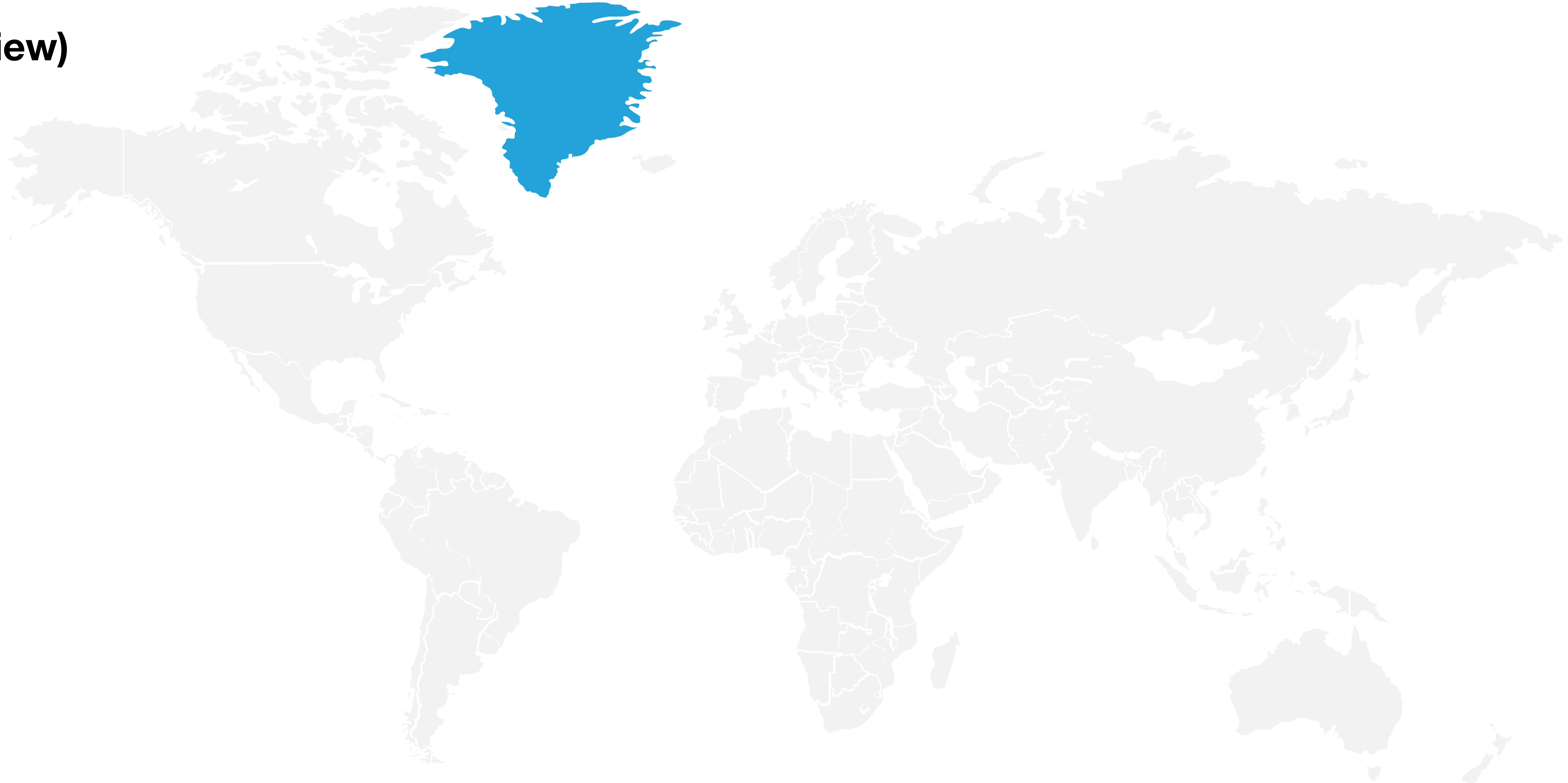
(Climate dynamics, in review)



European Research Council
Established by the European Commission

Motivation

- The Greenland ice sheet has been losing mass since the 1990s

- At the same time, Arctic sea ice loss is declining rapidly

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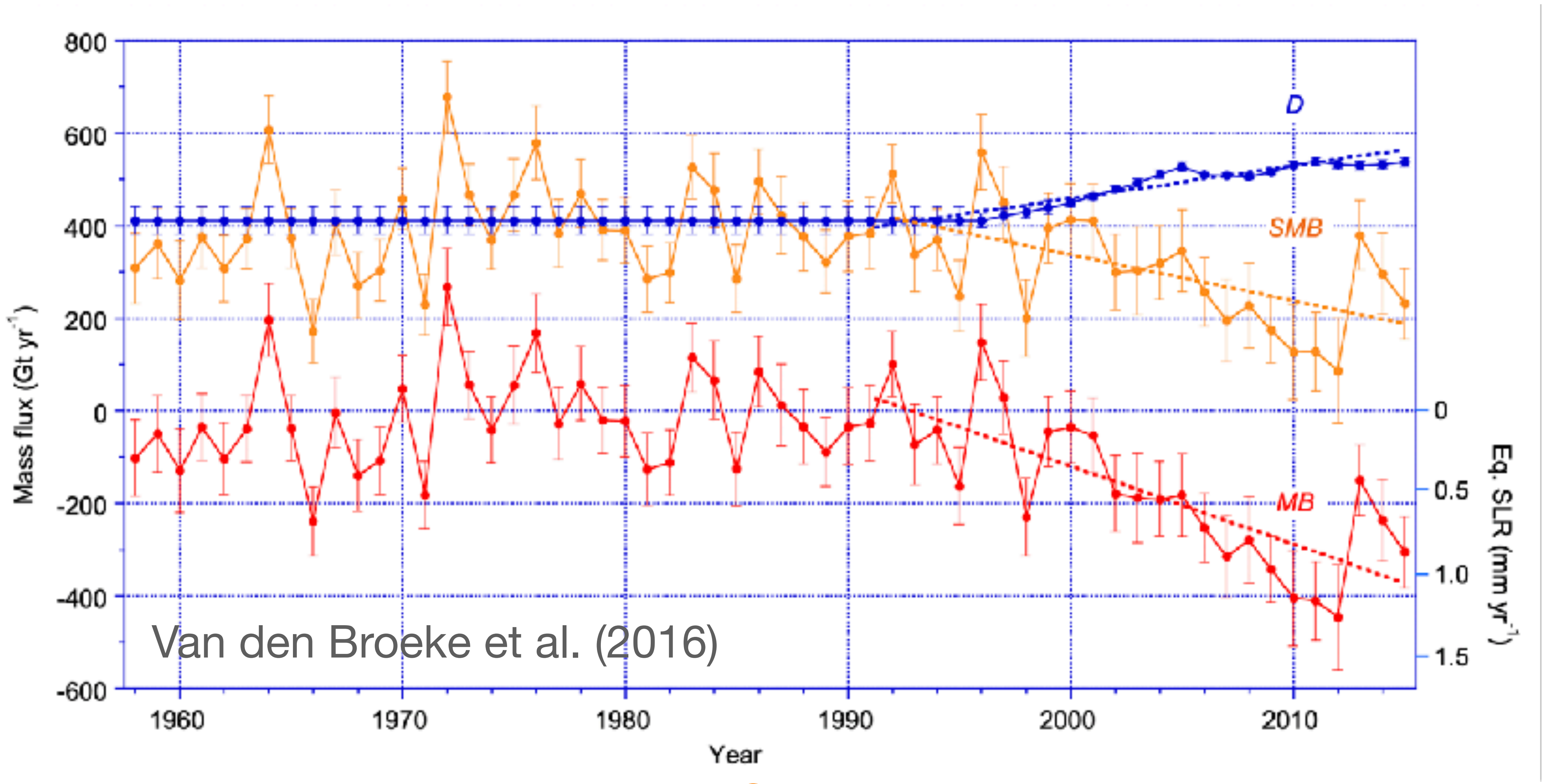
Nonlinear rise in Greenland runoff in response to post-industrial Arctic warming

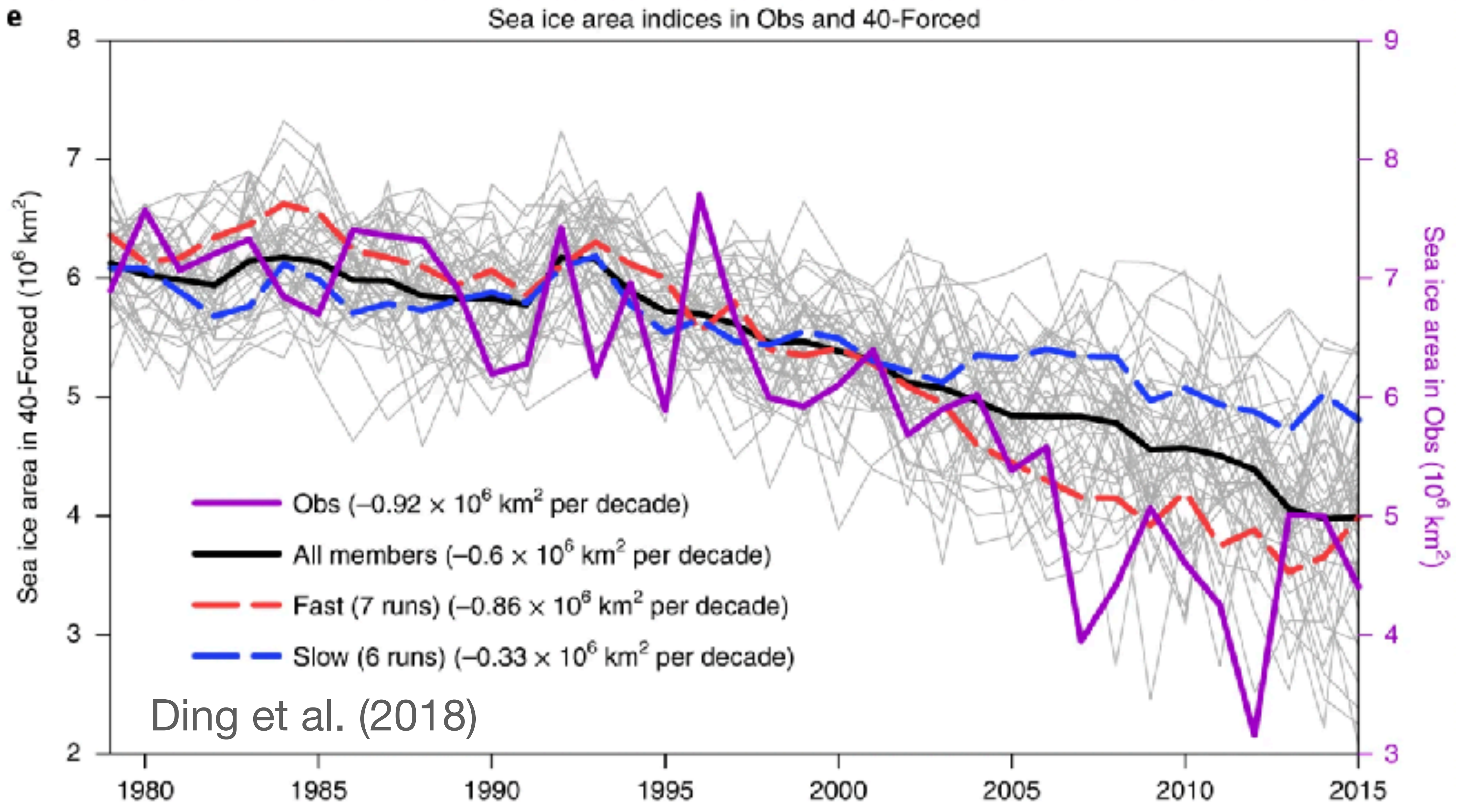
Luke D. Trusel, Sarah B. Das, Matthew B. Osman, Matthew J. Evans, Ben E. Smith, Xavier Fettweis, Joseph R. McConnell, Brice P. Y. Noël & Michiel R. van den Broeke

- What is the impact of Arctic sea ice loss on the Greenland ice sheet surface mass balance?



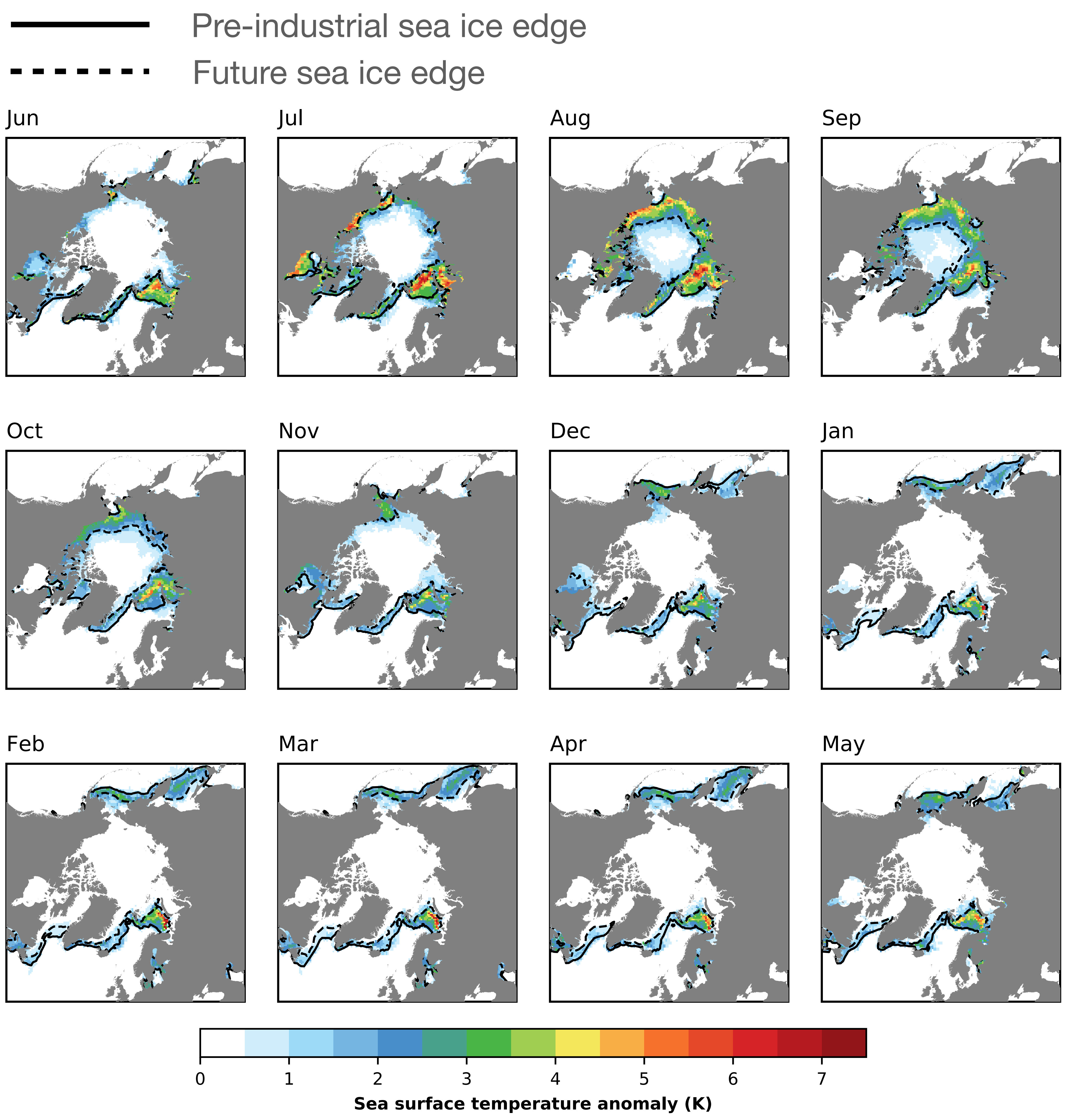
MB = SMB - D

SMB = accumulation - runoff



Method

- Community Earth System Model 2.1
- Includes an interactive simulation of the Greenland ice sheet surface mass balance through elevation classes downscaling
- 1° horizontal resolution
- Prognostic atmosphere and land, prescribed sea ice and sea surface temperature
- Run two experiments
  - Pre-industrial Arctic sea ice concentrations
  - Future (+2K) Arctic sea ice concentrations and SST's where sea ice is reduced by more than 10%
- Each experiment consist of a 100-years ensemble



What do we already know?

Observations

✅ Regional enhancement of 500 hPa Geopotential heights
✅ Higher Arctic temperatures increases downwelling long wave radiation to the GrIS surface, leading to more surface melt
✅ No contribution from turbulent heat flux, due to katabatic blocking wind effect
❌ Causality

Regional climate modeling

✅ Annual increase of precipitation over the GrIS
❌ Small number of simulations (5 years)
❌ Not capable of capturing general circulation changes

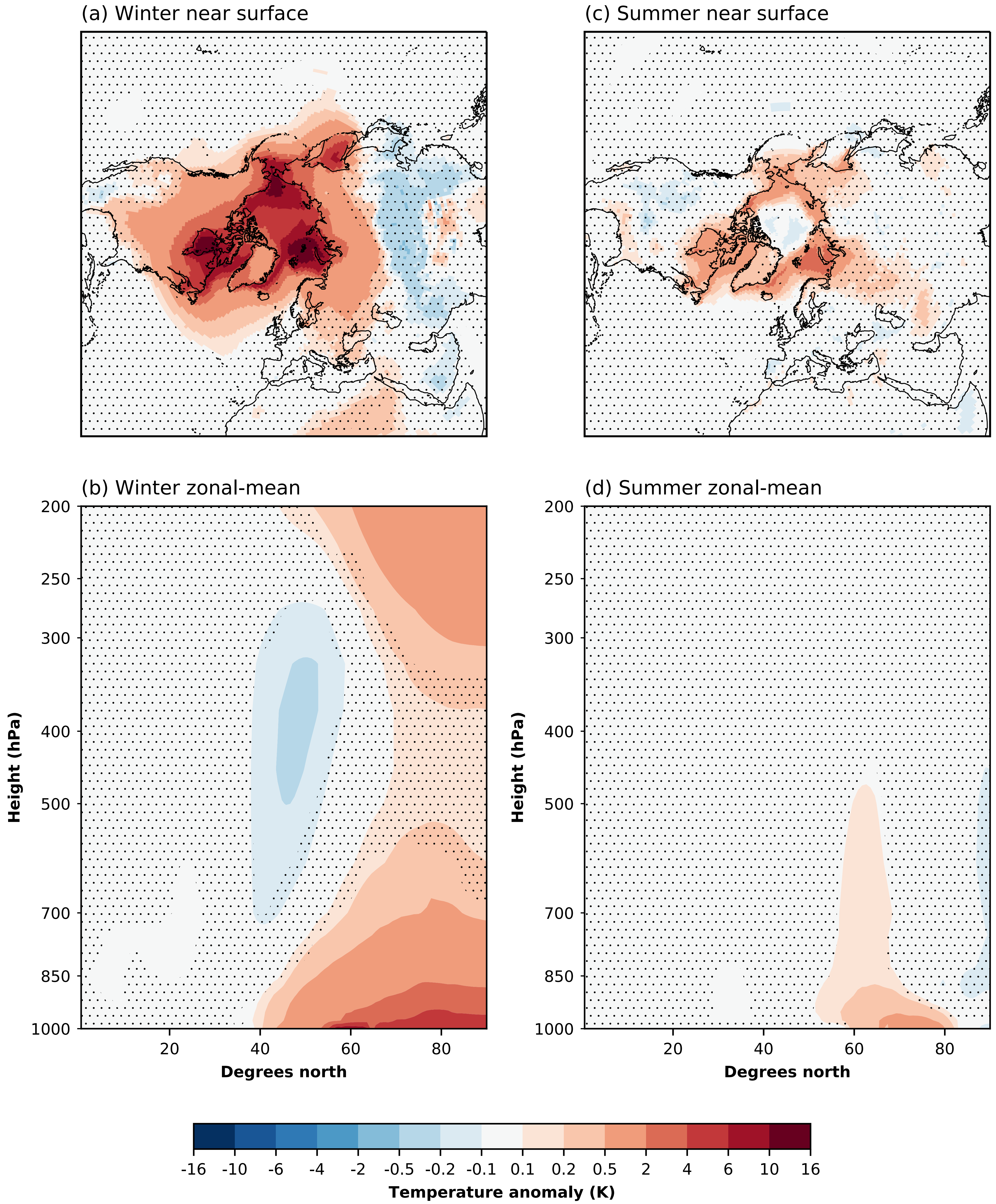
Global climate modeling

✅ More surface melt at the GrIS surface
✅ Increased blocking frequency
❌ No explicit calculation of the GrIS surface mass balance

Novelty here

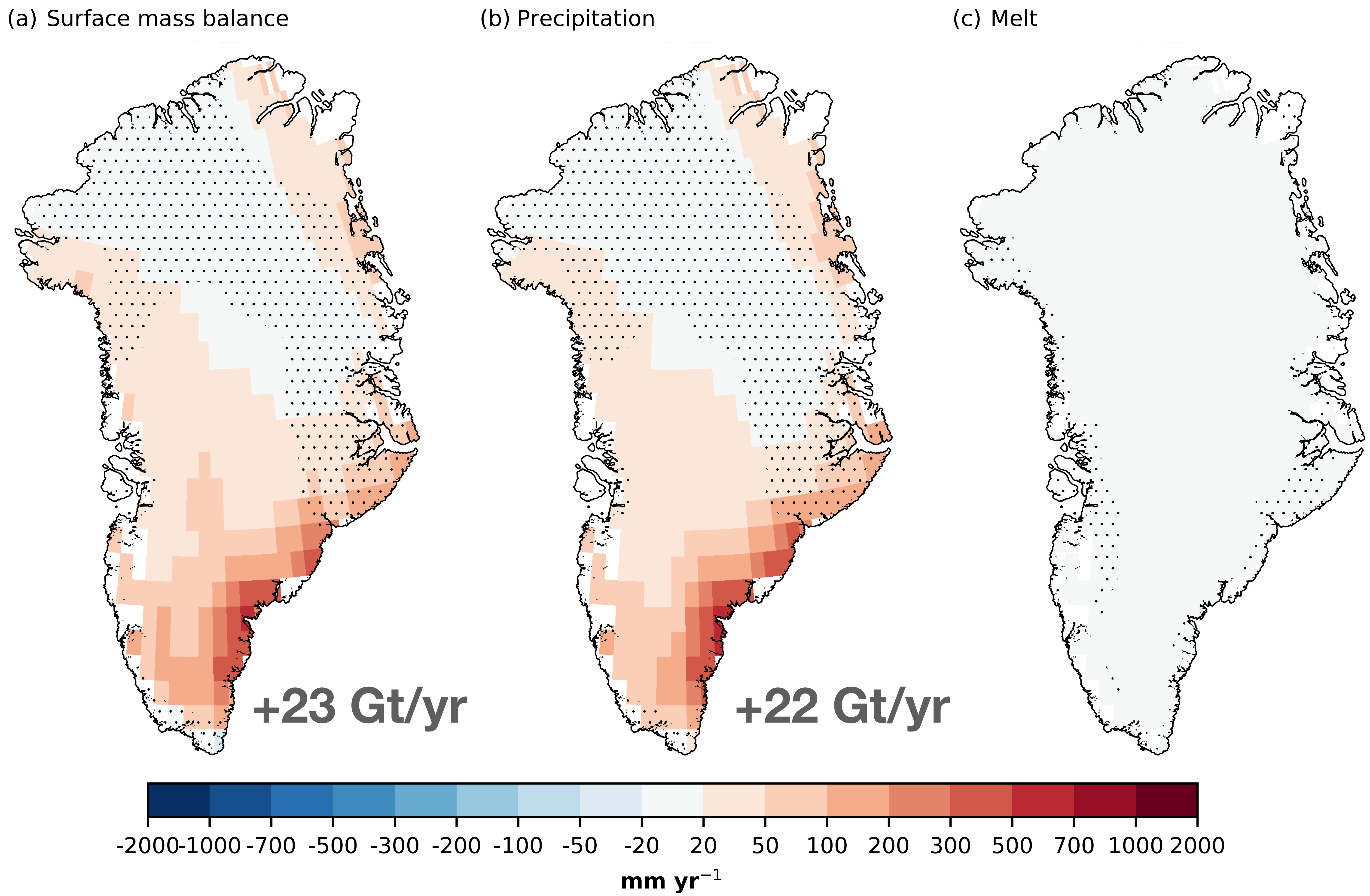
Explicit and advanced simulation of the GrIS surface mass balance
High number of simulations

Arctic warming



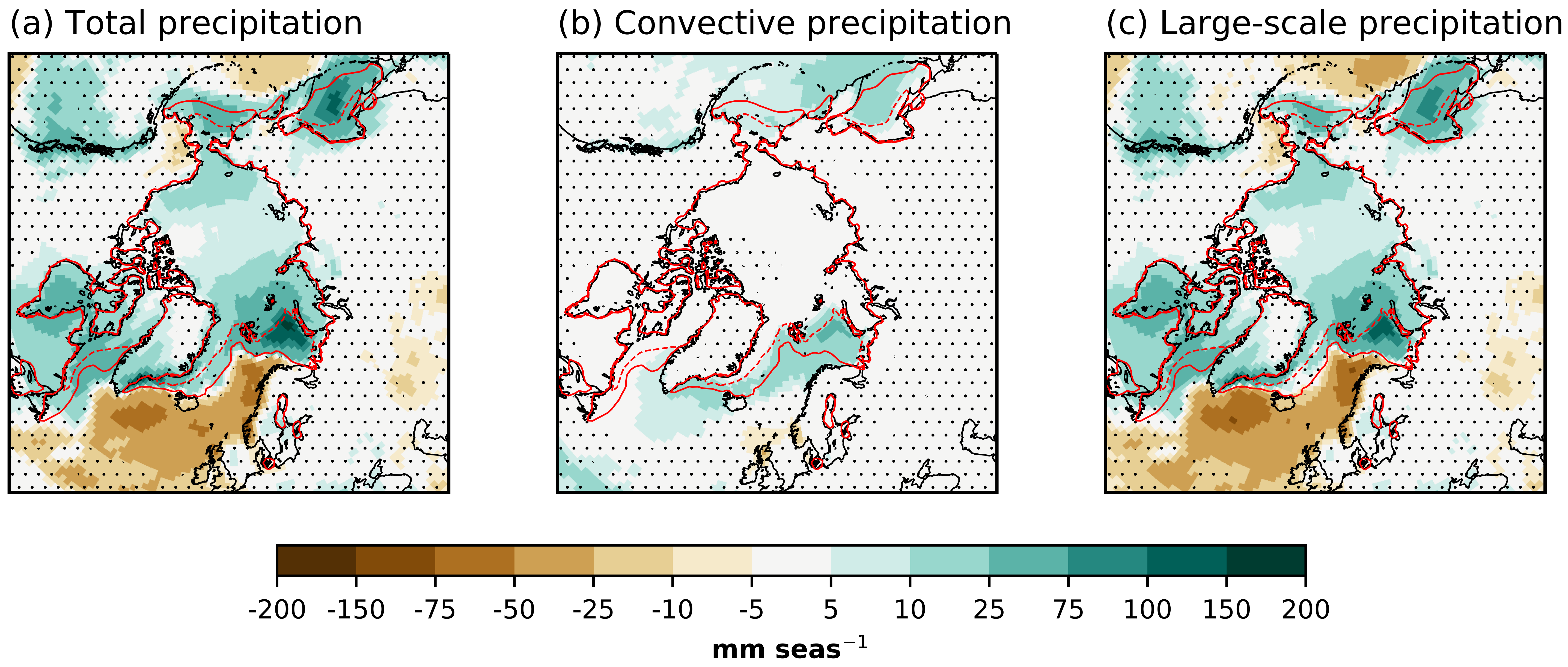
- Widespread pan-Arctic warming during winter
- Warming extending through the mid-troposphere
- Most warming confined to 60-80°N in summer

Winter surface mass balance response



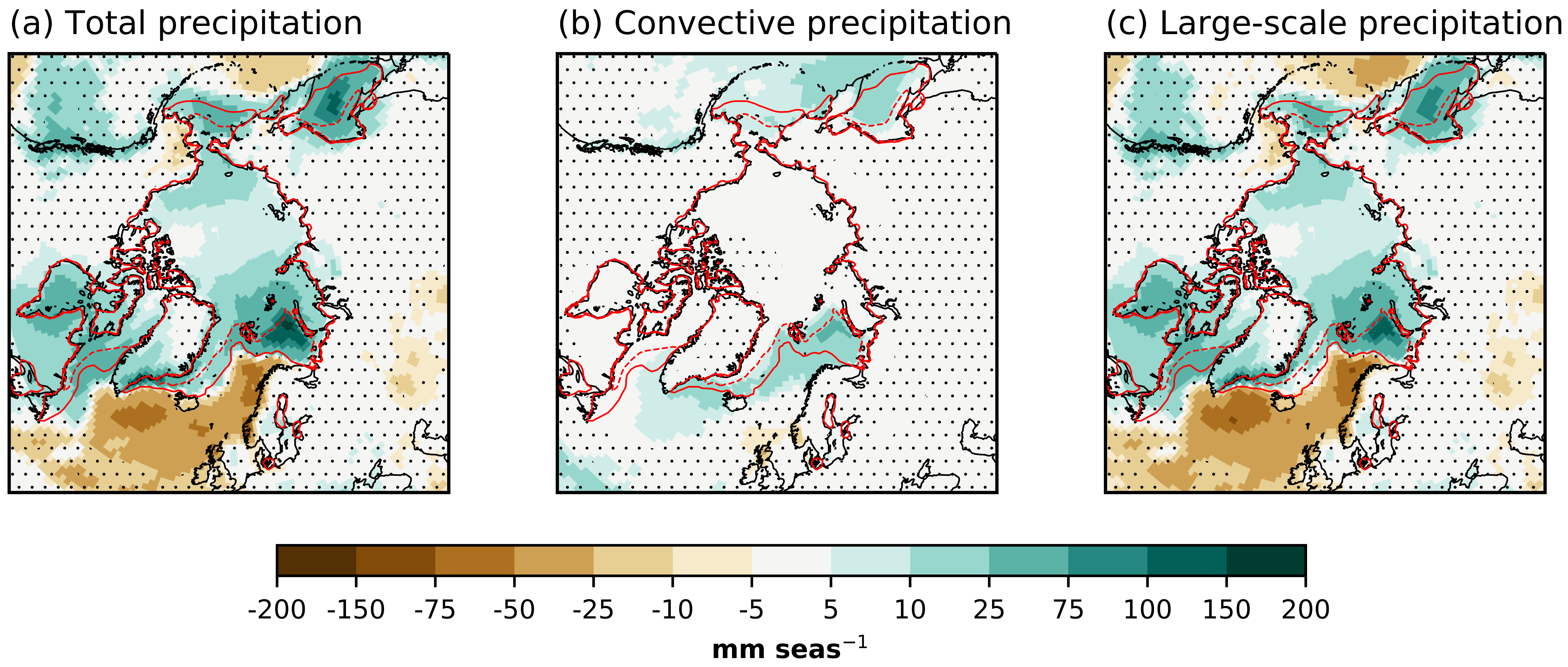
- Higher surface mass balance due to precipitation increase

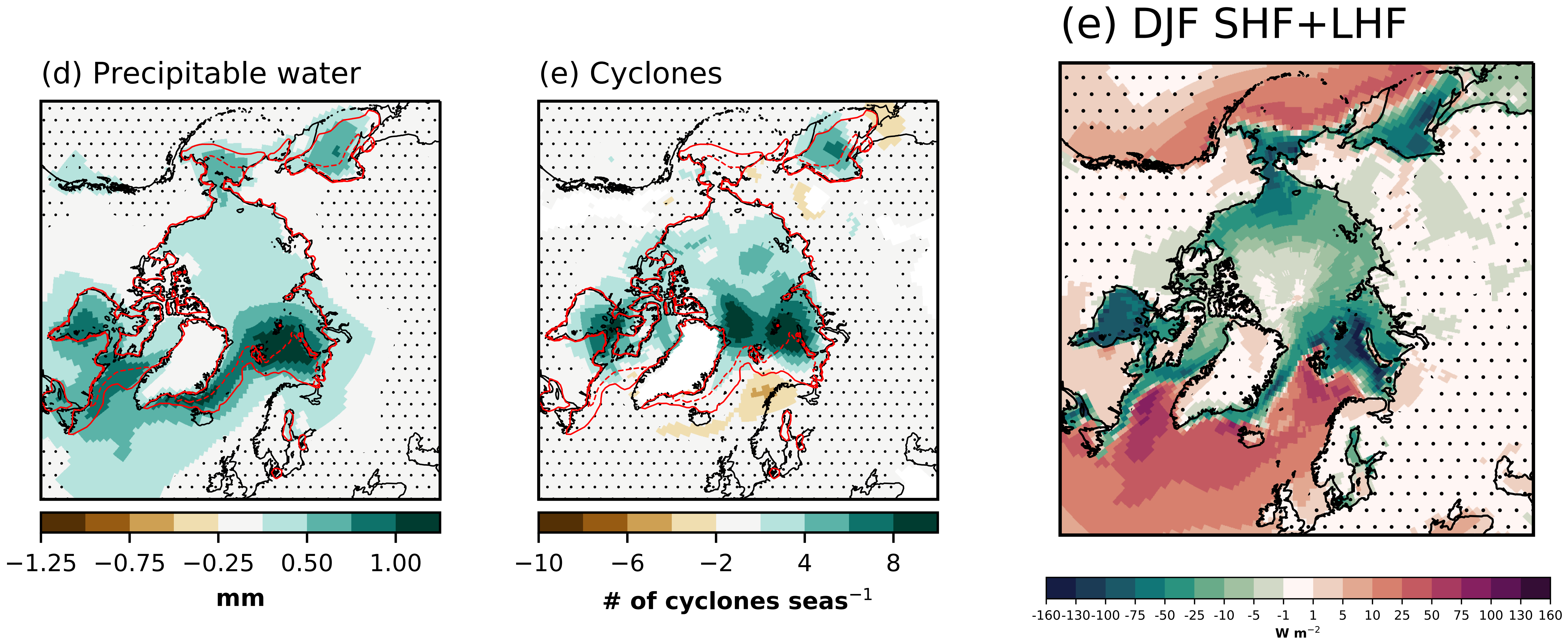
Winter precipitation



- GrIS precipitation increase is due to more large-scale precipitation

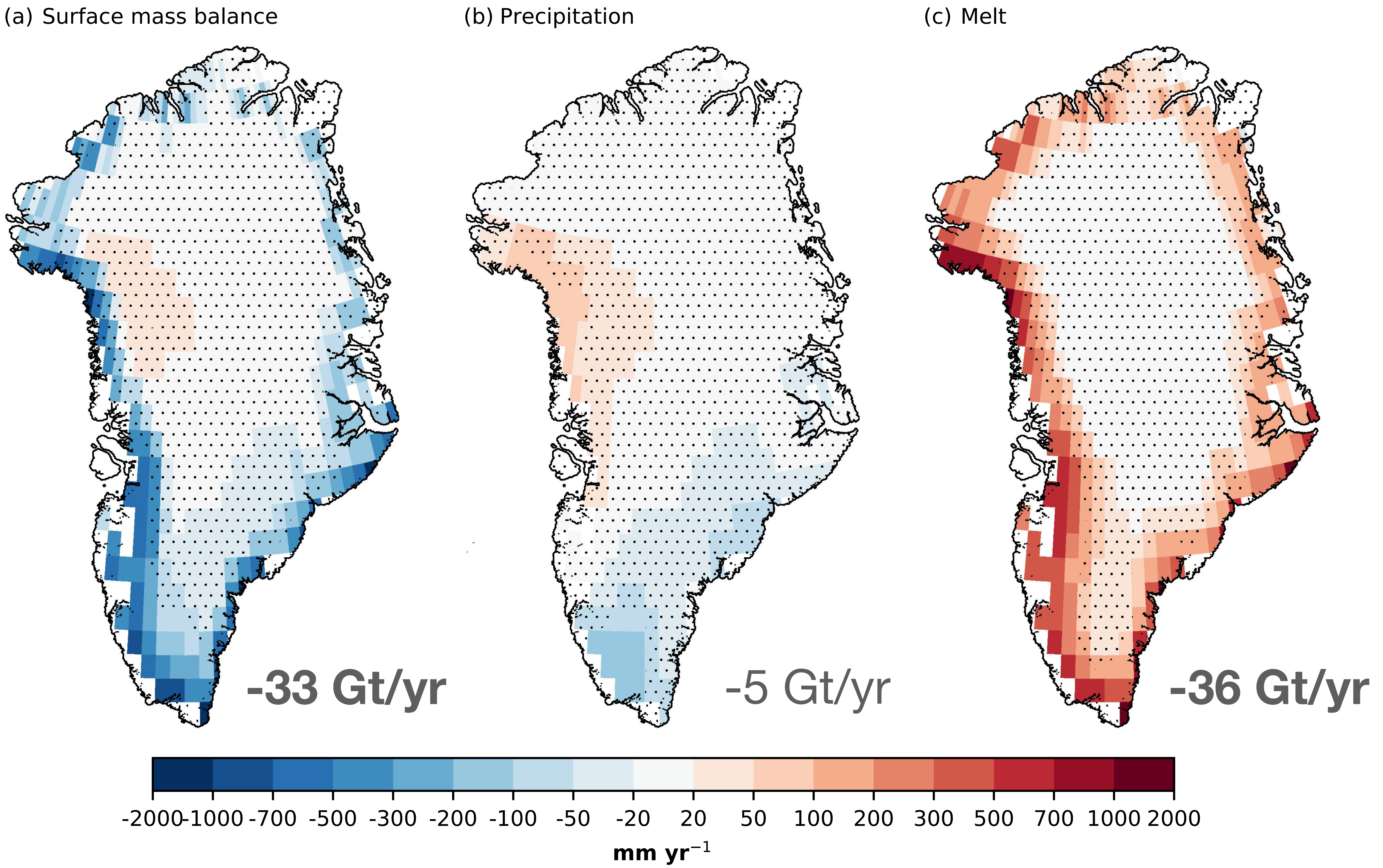
Winter precipitation





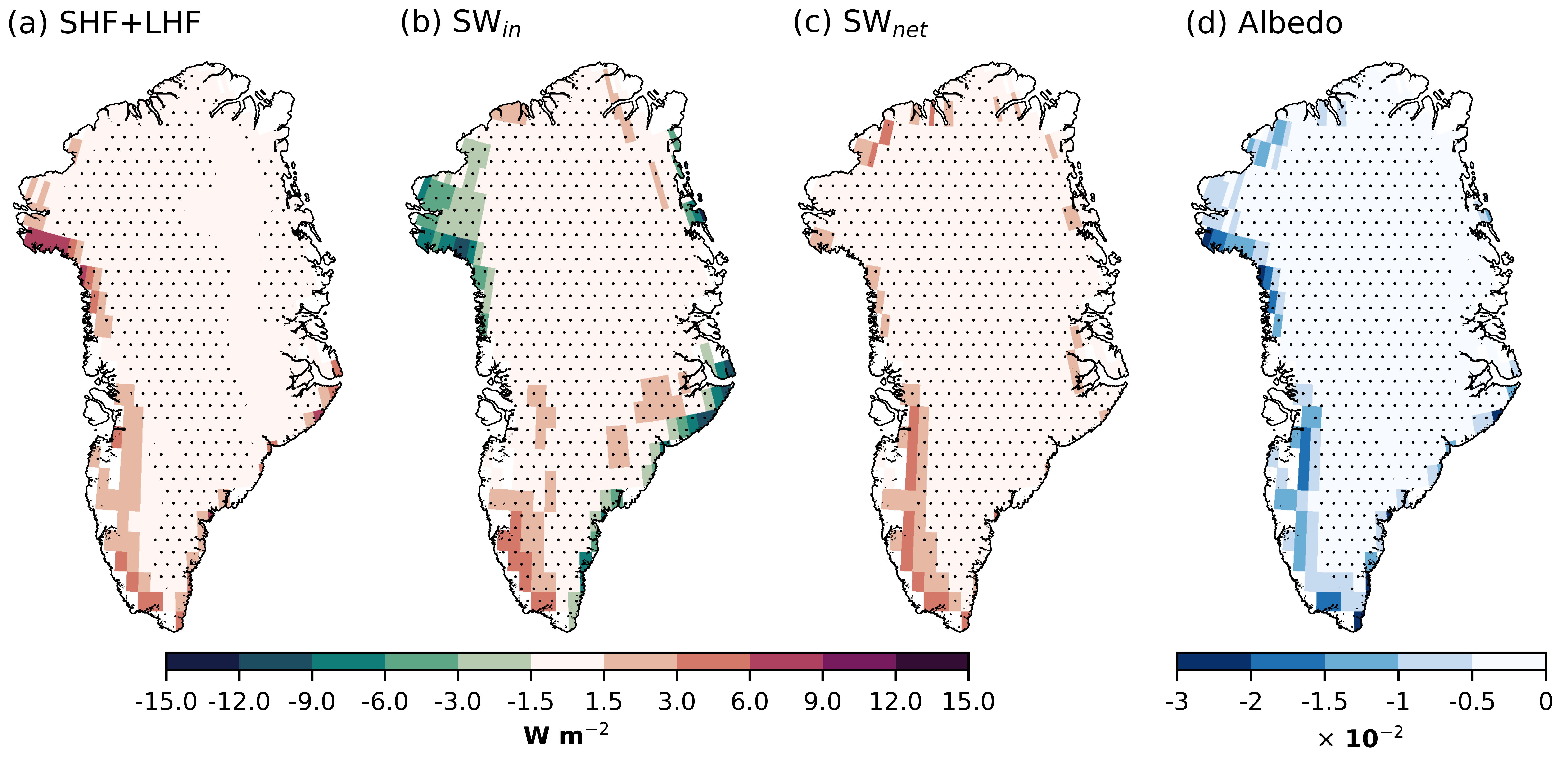
- GrIS precipitation increase is due to more large-scale precipitation
- More precipitable water, particularly in areas of sea ice loss
- Higher cyclone frequency in the Arctic, less in the North Atlantic
- In areas of sea ice loss, much increased SHF+LHF transfer from ocean to atmosphere
- In North Atlantic, less SHF+LHF from ocean to atmosphere

Summer surface mass balance response



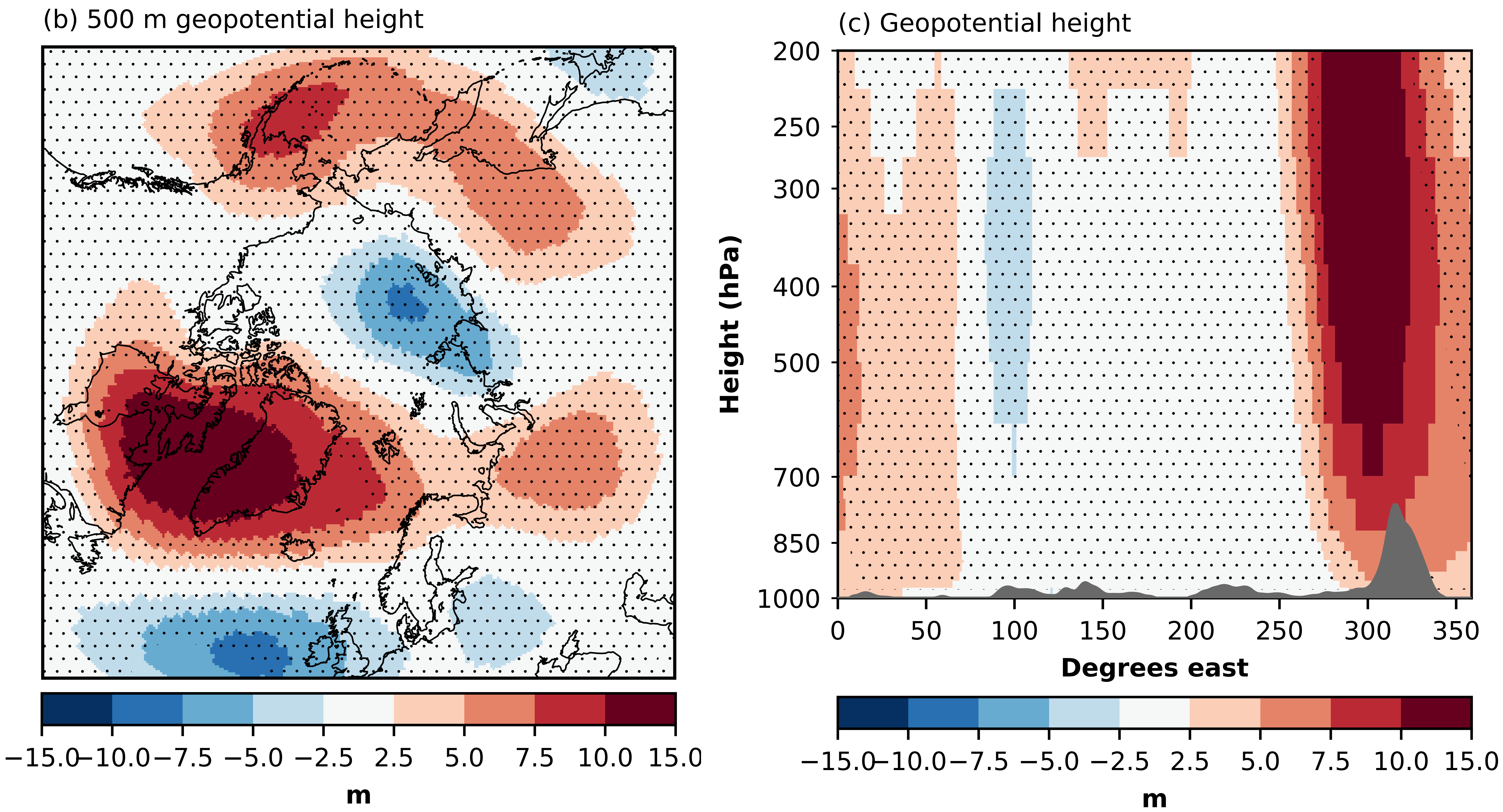
- SMB decrease around the margins due to melt increase
- Redistribution of mass through precipitation changes

Summer energy balance



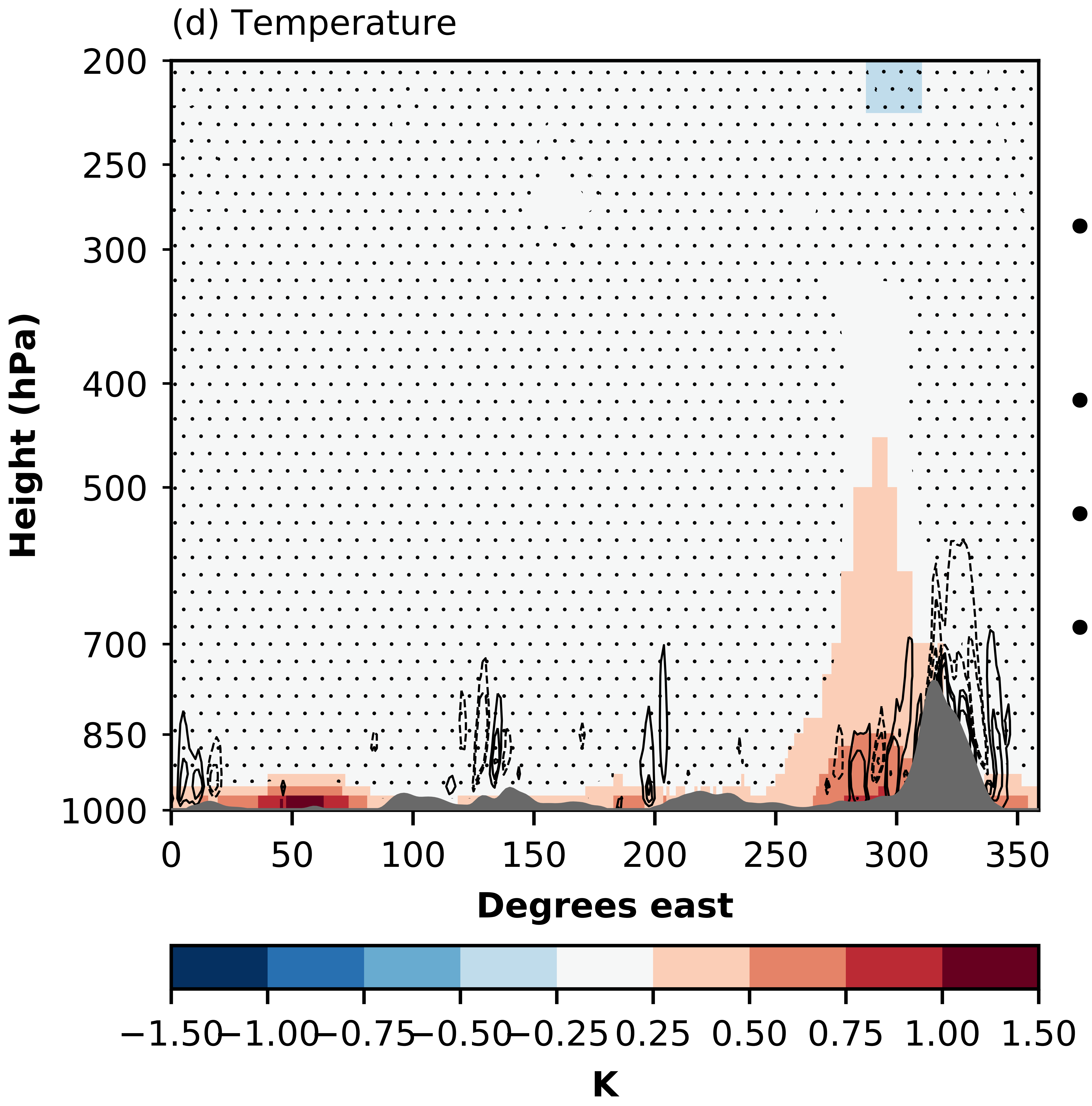
- Increased SHF+LHF at the margins
- Change in incoming shortwave not significant, but is consistent with precipitation pattern
- Net shortwave increases significantly due to lowering of surface albedo

Circulation changes



- Deep regional enhancement of the geopotential heights over Greenland
- Accounting for about 16% of the current observed regional enhancement
- Why this location?

Circulation changes



- Greenland act as an obstacle to the westerlies
- Complex and turbulent flow
- Causes vertical advection of heat
- Deep heating -> strong circulation response

Summary

- Sea ice loss, together with increased SST's warm the Arctic surface and atmosphere in summer and winter
- The Arctic warming enhances the hydrological cycle over the GrIS
  - More precipitation in winter
  - More meltwater production in summer
- Causes regional enhancement of 500 hPa Geopotential heights

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Questions?