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A regional atmospheric warming threshold for irreversible Greenland ice sheet mass loss

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The mass balance of the Greenland ice sheet (GrIS, units Gt per year) equals the surface mass balance (SMB) minus solid ice discharge across the grounding line. As the latter is definite positive, an important threshold for irreversible GrIS mass loss occurs when long-term average SMB becomes negative. For this to happen, runoff (mainly meltwater, some rain) must exceed mass accumulation (mainly snowfall minus sublimation). Even for a single year, this threshold has not been passed since at least 1958, the first year with reliable estimates of SMB components, although recent years with warm summers (e.g. 2012 and 2019) came close. Simply extrapolating the recent (1991-present) negative SMB trend into the future suggests that the SMB = 0 threshold could be reached before ~2040, but such predictions are extremely uncertain given the very large interannual SMB variability, the relative brevity of the time series and the uncertainty in future warming. In this study we use a cascade of models, extensively evaluated with in-situ and remotely sensed (GRACE) SMB observations, to better constrain the future regional warming threshold for the 5-year average GrIS SMB to become negative. To this end, a 1950-2100 climate change run with the global model CESM2 (app. 100 km resolution) was dynamically downscaled using the regional climate model RACMO2 (app. 11 km), which in turn was statistically downscaled to 1 km resolution. The result is a threshold regional Greenland warming of close to 4 degrees. We then use a range of CMIP5 and CMIP6 global climate models to translate the regional value into a global warming threshold for various warming scenarios, including its timing this century. We find substantial differences, ranging from stabilization before the threshold is reached in the RCP/SSP2.6 scenarios with a limited but still significant sea-level rise contribution (< 5 cm by 2100) to an imminent crossing of the warming threshold for the RCP/SSP8.5 scenarios with substantial and ever-growing contributions to sea level rise (> 10 cm by 2100). These results stress the need for strong mitigation to avoid irreversible GrIS mass loss. We finish by discussing the caveats and uncertainties of our approach.