GREENLAND ICE SHEET CONTRIBUTION TO 21ST CENTURY SEA LEVEL RISE AS SIMULATED BY THE COUPLED CESM2.1-CISM2.1

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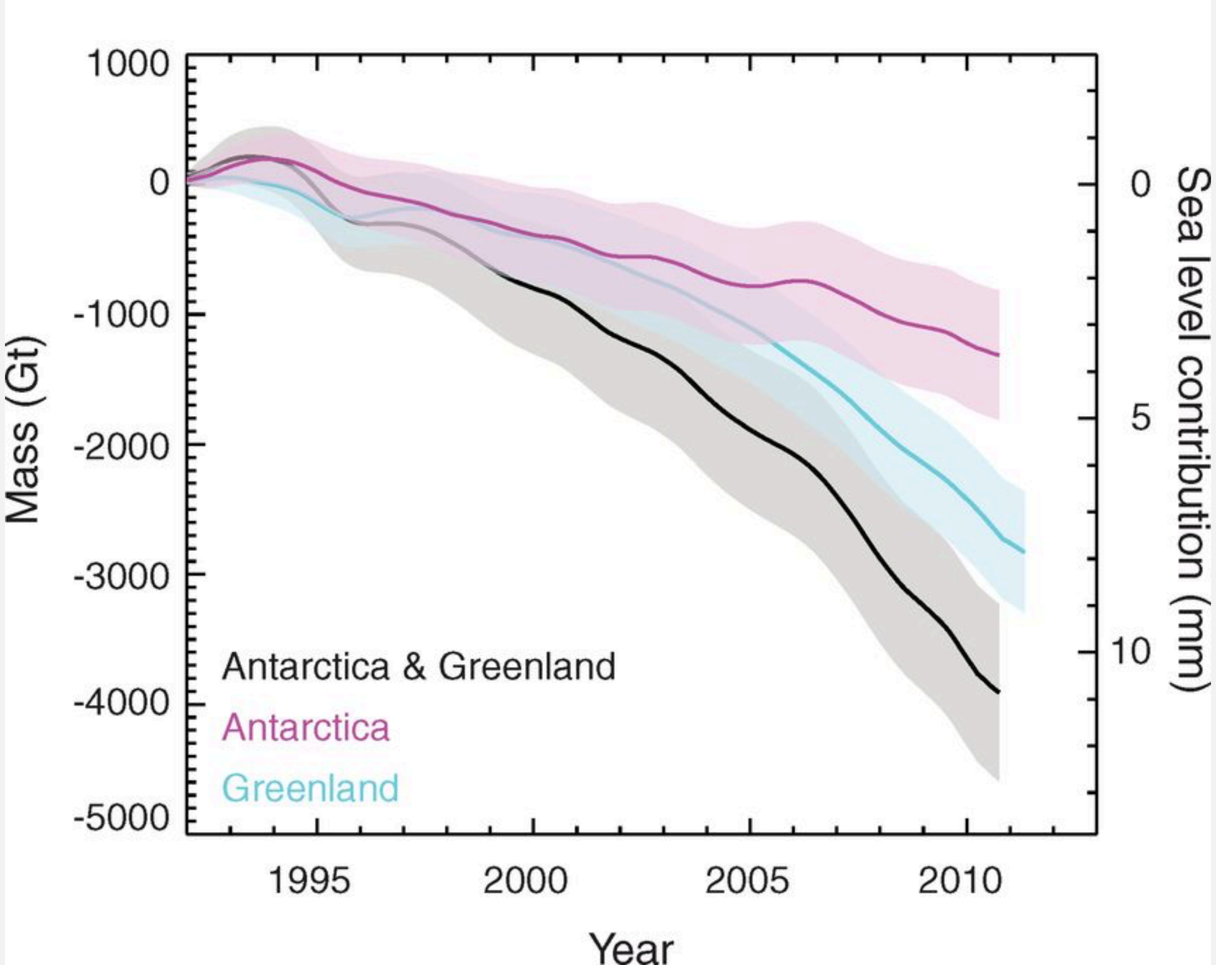
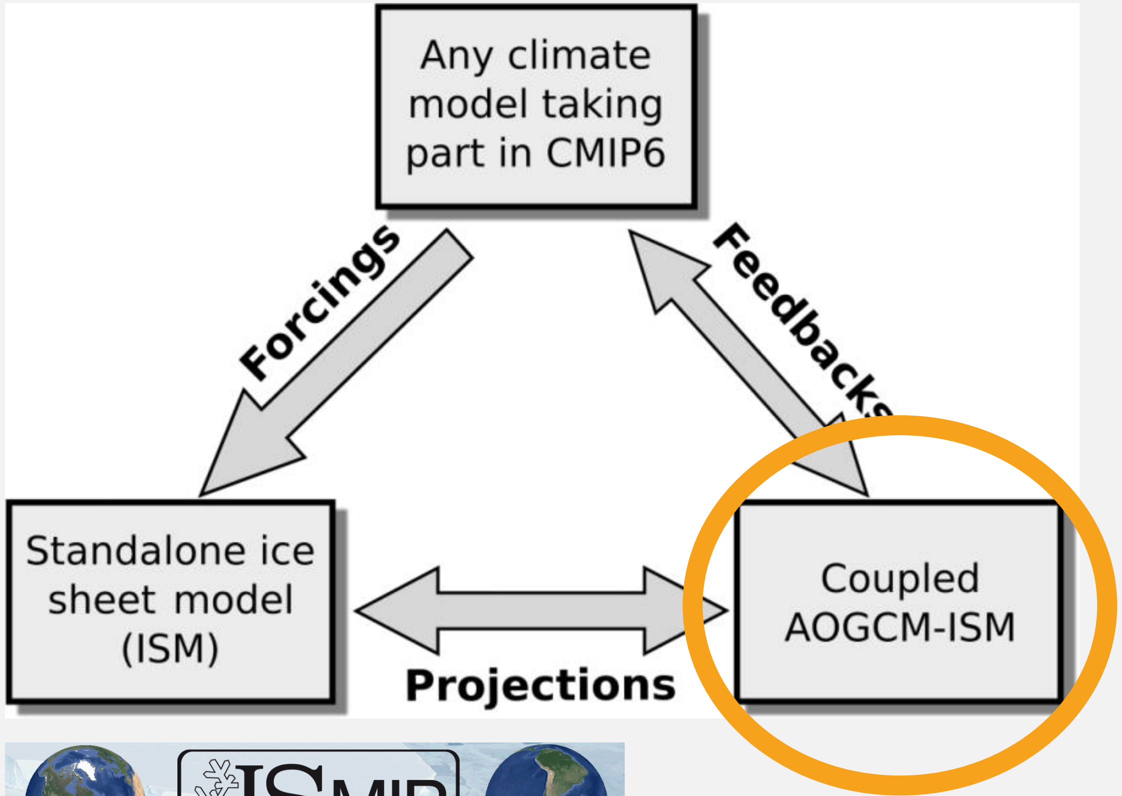
INTRODUCTION

GREENLAND IS LOSING MASS



Shepherd et al., 2012

ICE SHEET MODEL INTERCOMPARISON PROJECT (ISMIP6)



Nowicki et al., 2016

CESM2.1 contribution to ISMIP6
the following coupled AOGCM-ISM runs:

- piControl-withism [300 yrs]
- 1pctCO2to4x-withism [350 yrs]
- historical-withism [1850-2014]
- ssp585-withism [2015-2300]

METHOD – MODEL COUPLING

Community Earth System Model 2.1 and Community Ice Sheet Model 2.1

1) energy balance –based SMB calculation on multiple elevation classes
2) dynamic ice sheet margin in land model
3) GrIS fresh water fluxes to ocean model
   - no ocean thermal forcing
4) ice sheet topography update to atmosphere model

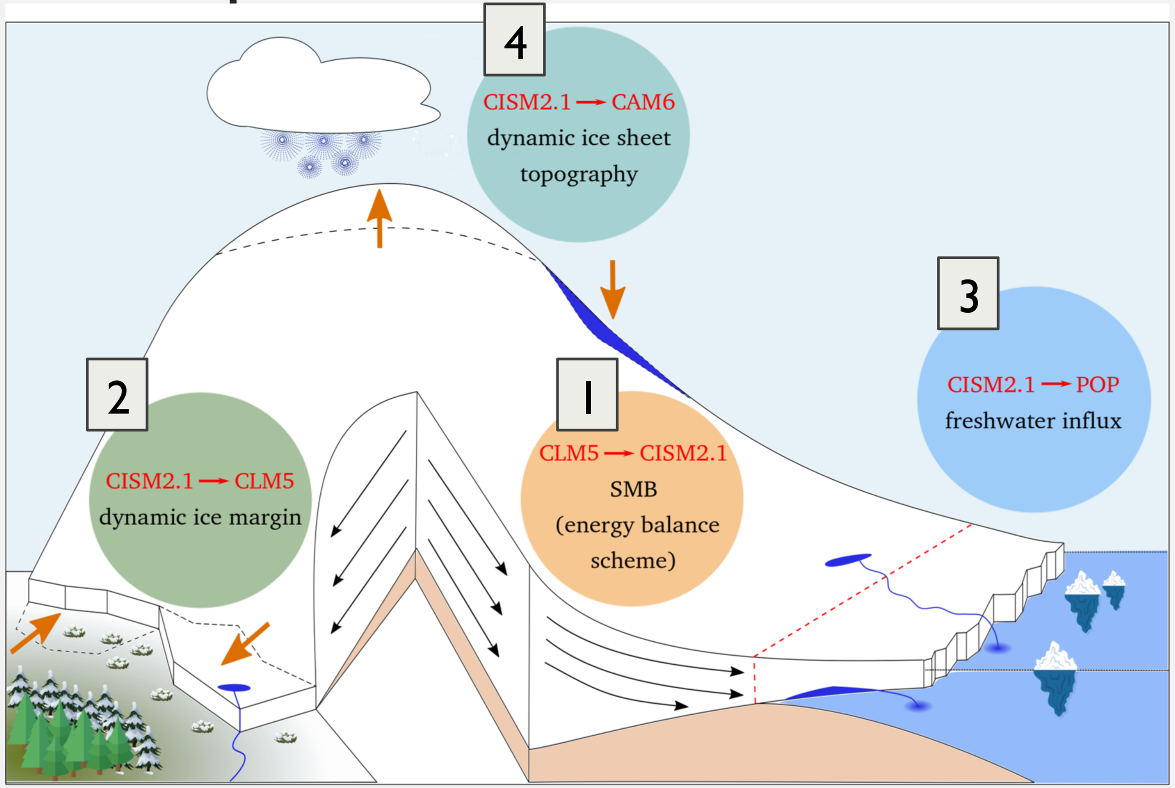


Figure with courtesy of M. Petrini

Muntjewerf et al. (in prep to JAMES). Description and demonstration of the coupled Community Earth System Model v2.1 - Community Ice Sheet Model v2.1 (CESM2.1-CISM2.1).

METHOD – EXPERIMENTAL SET-UP

Two simulations with forcing following ScenarioMIP (O'Neill et al., 2016)

Historical simulation:

1850 – 2014

forcing based on observations (GHG, aerosol, land-use change)

21st century projection:

2015 – 2100

scenario SSP5-8.5 forcing

METHOD – INITIALIZATION

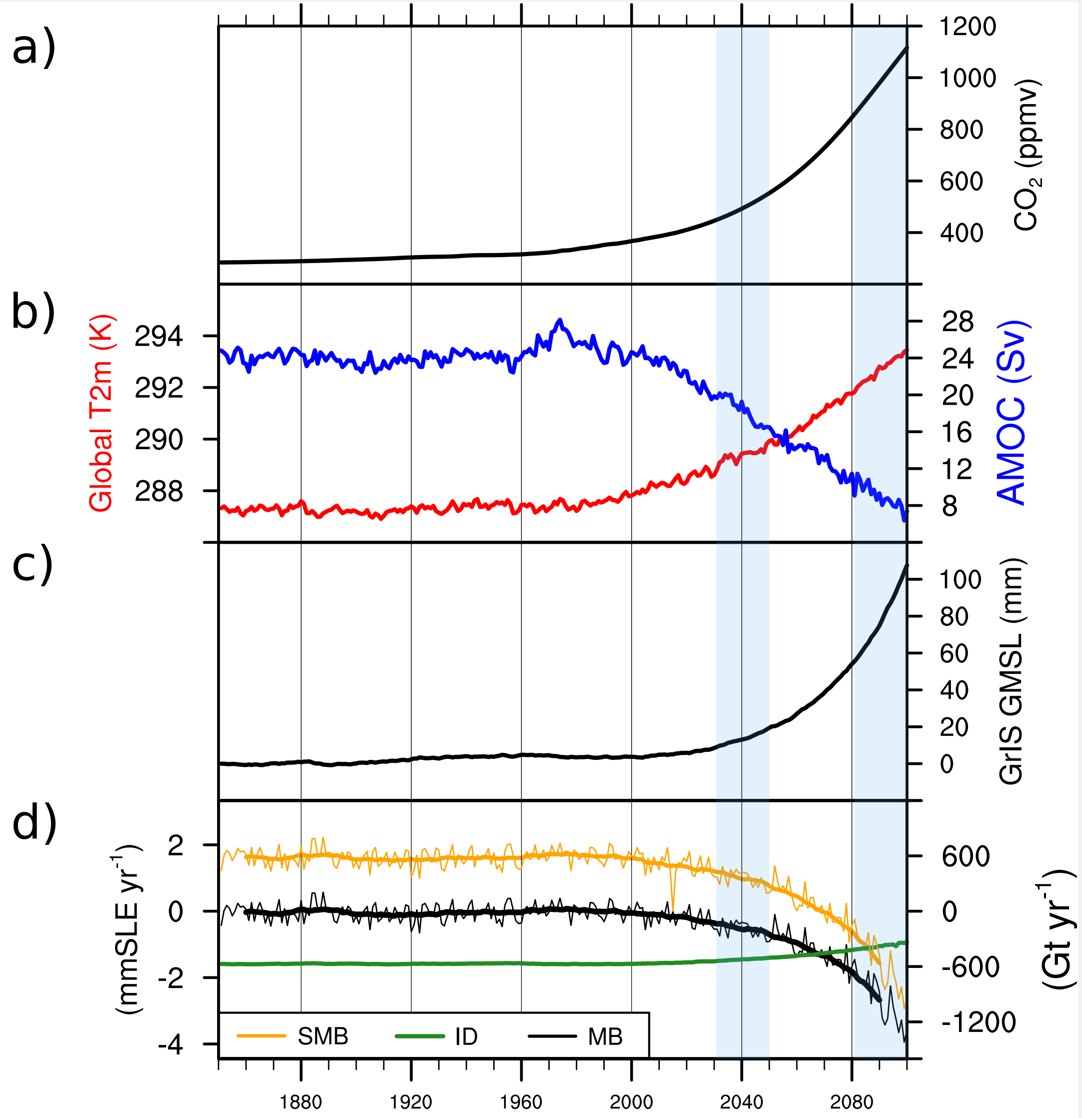
Motivation: Coupled ice-sheet/Earth system needs long time for equilibration (~10.000 years) but this is too expensive/slow to run synchronously

Procedure: 'Iterated' spin-up between fully-coupled and 'all-active-but-atmosphere' simulations, both with freely evolving GrIS, to 1850 conditions

GrIS near-equilibrium state: 0.03 mm SLE year^{1} residual drift, 12% volume overestimation (SW and E), 15% area overestimation (N-Tundra),

Lofverstrom et al. (under review). An efficient ice-sheet/Earth system model spin-up procedure for CESM2.1 and CISM2.1: description, evaluation, and broader applicability. *JAMES*.

GLOBAL CLIMATE EVOLUTION



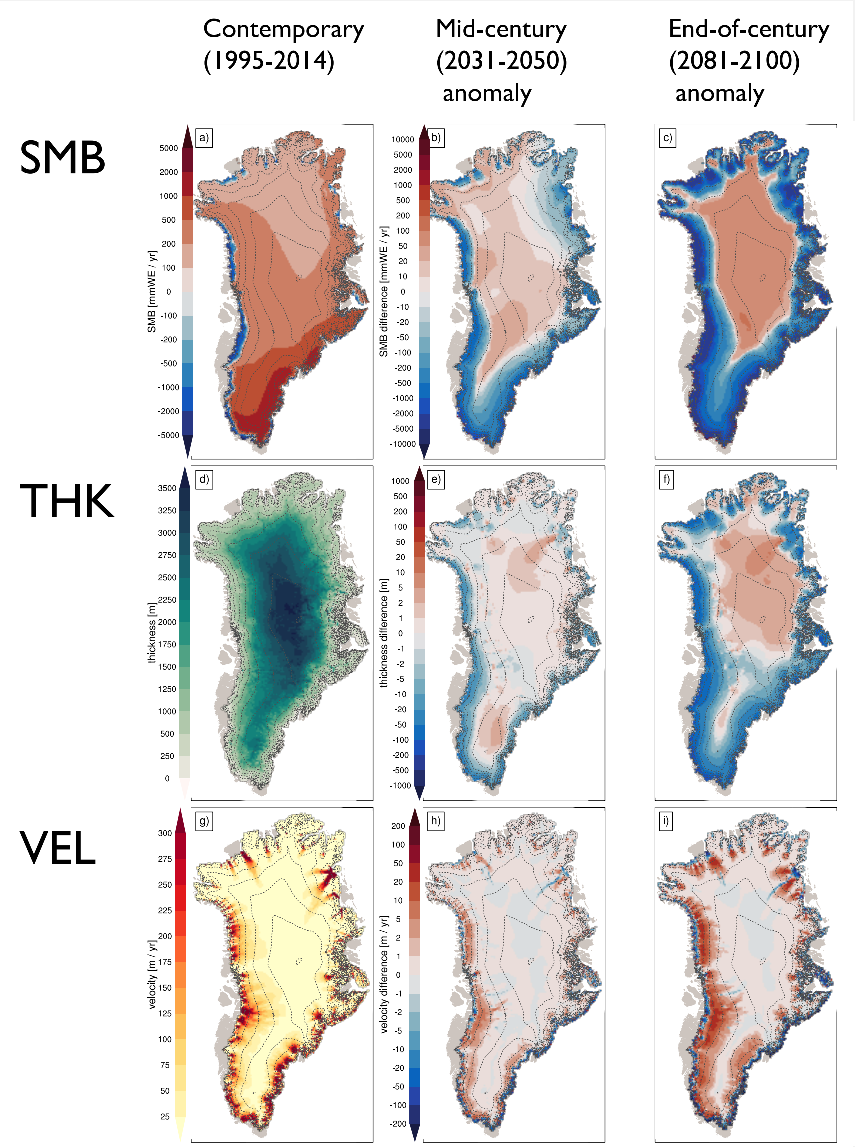
	Contemporary (1995-2014)	Mid-century (2031-2050)	End of century (2081-2100)
Atmospheric CO_2 (ppmv)			
- by start year of time segment	361	458	884
- by end year of time segment	397	566	1142
Global mean T2m change (K)	0.8	2.2	5.4
Cumulative Sea Level Rise (mm)			
- by end year of time segment	5	23	109
Sea Level Rise rate (mm yr^{-1})	0.08	0.55	2.68

- Global T2m increases 5.4 K w.r.t. pre-industrial
- AMOC collapse by end of century
- Underestimated rate of contemporary SLR
- Rate of SLR: 2.68 mm/yr avg last 2 decades
- 109 mm SLR in 2100

GRIS EVOLUTION

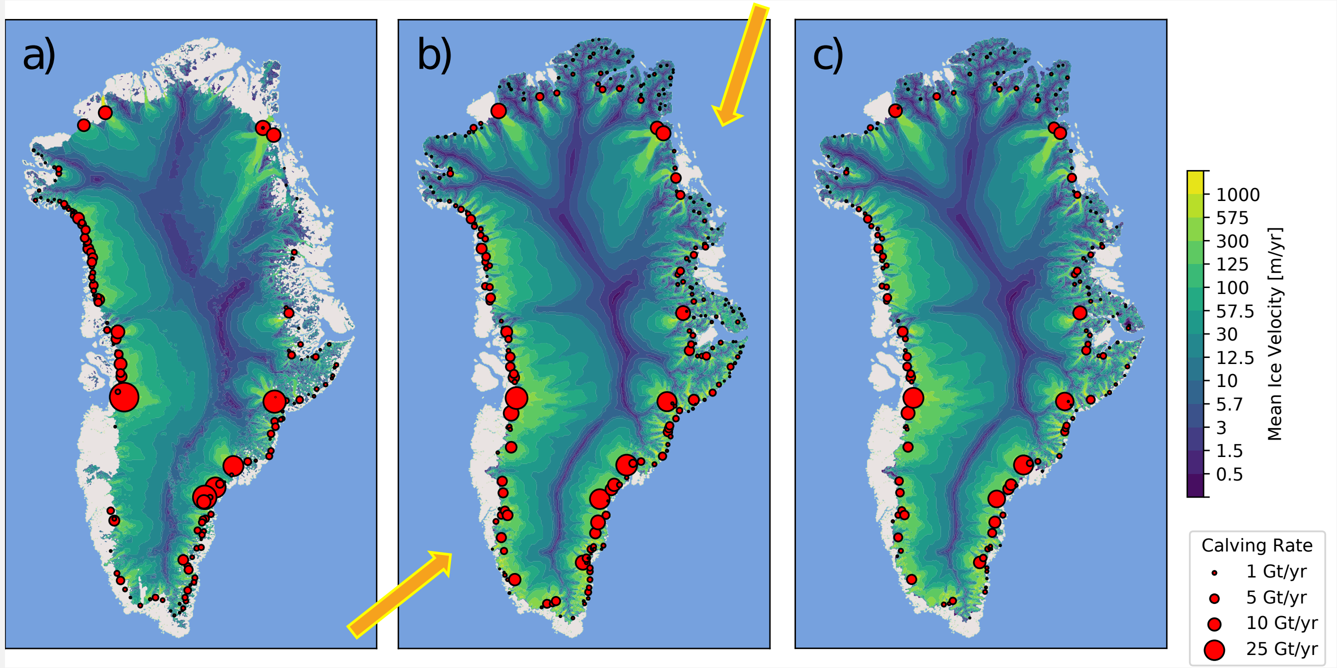
- Extension of northern ablation areas later than in the south
- Ice sheet thinning mainly below 2000m and in South
- Ice sheet thickens in the interior
- Surface velocities increase in intermediate area due to increase in elevation gradients
- GrIS in 2100 w.r.t. 1850: -3% area, -1.2% volume

	Contemporary (1995-2014)	Mid-century (2031-2050)	End of century (2081-2100)
Mass Balance (Gt yr^{-1})	27 [81]	-196 [71]	-964 [258]
SMB (Gt yr^{-1})	564 [82]	350 [75]	-565 [278]
Ice discharge (Gt yr^{-1})	568 [4]	523 [10]	379 [24]
Basal melt (Gt yr^{-1})	-24 [0]	-23 [0]	-20 [0]
GrIS area (10^6 km^2)			
- by end year of time segment	1.965	1.958	1.909



GRIS ICE DISCHARGE

Observed present-day Simulated present-day Simulated end of century

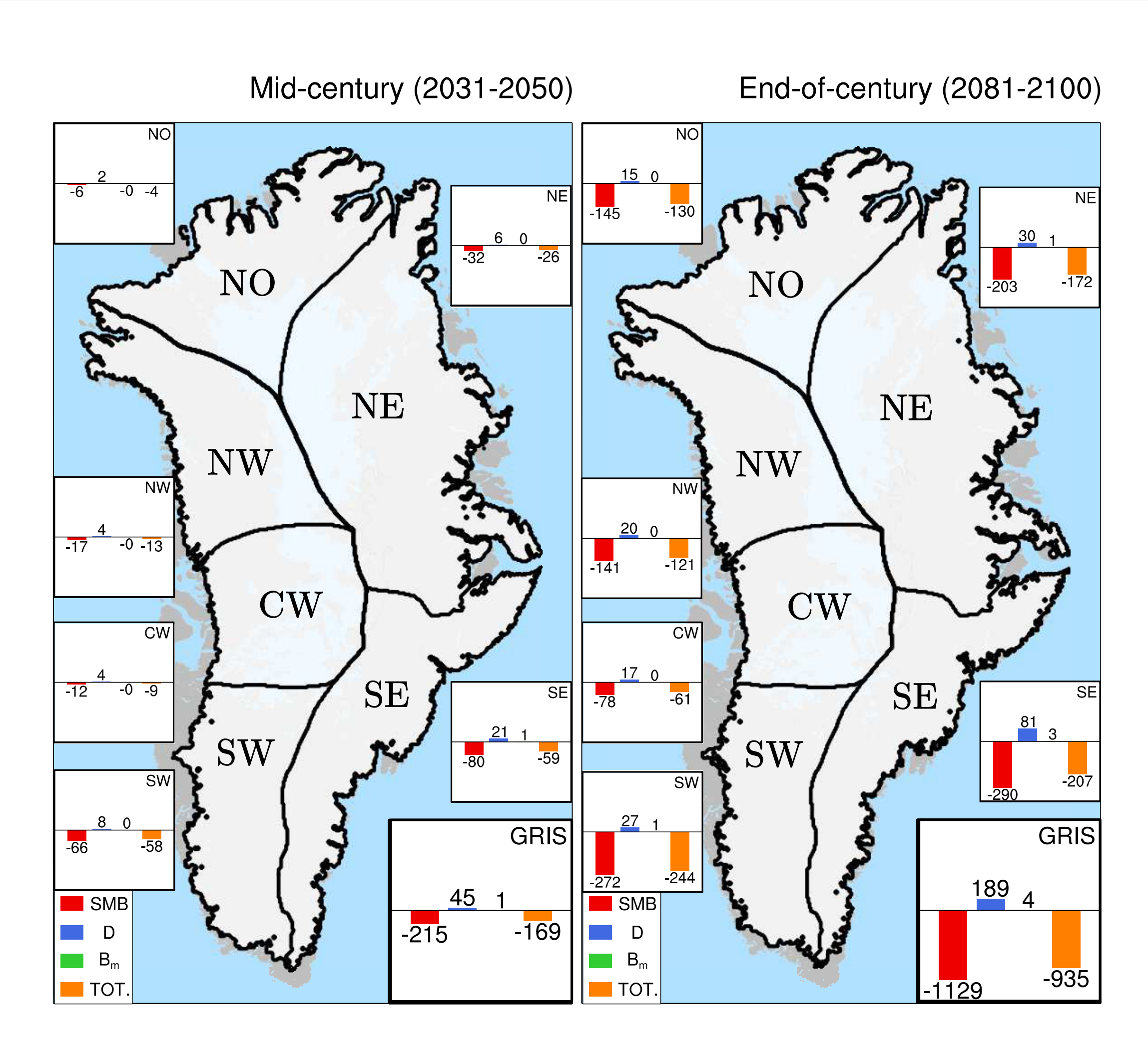


	Observed	Simulated
GrIS	510	569
NW	101	59
CW	101	77
SW	23	71
SE	224	220
NE	41	99
NO	20	43

- Modelled surface velocity in agreement with observations
- Modelled ice discharge overestimated in basins where the thickness is overestimated (SW, NE, NO)
- Decrease in ice discharge (523 Gt yr^{1} mid-century to 379 by end-of-century) but no ocean forcing

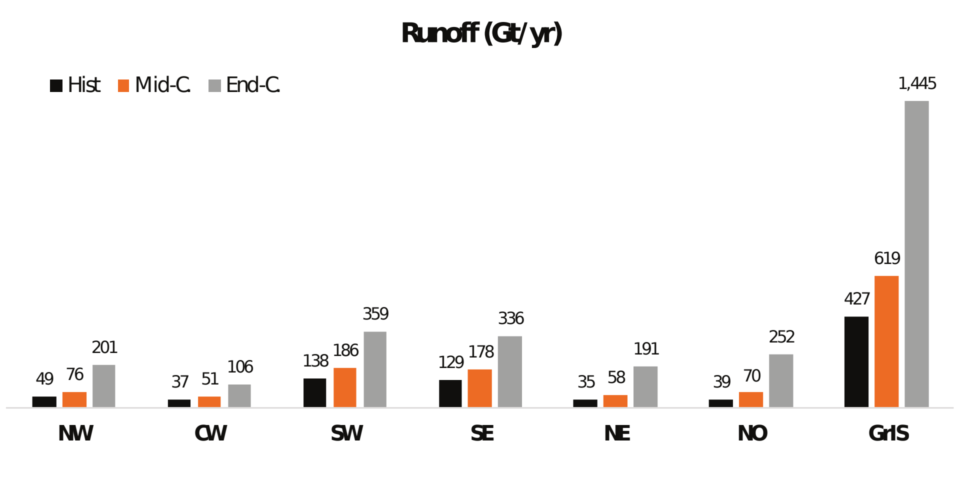
a) observed discharge and surface velocities
From Enderlin et al. (2014) and Joughin et al. (2015)

BASIN SCALE ANALYSIS

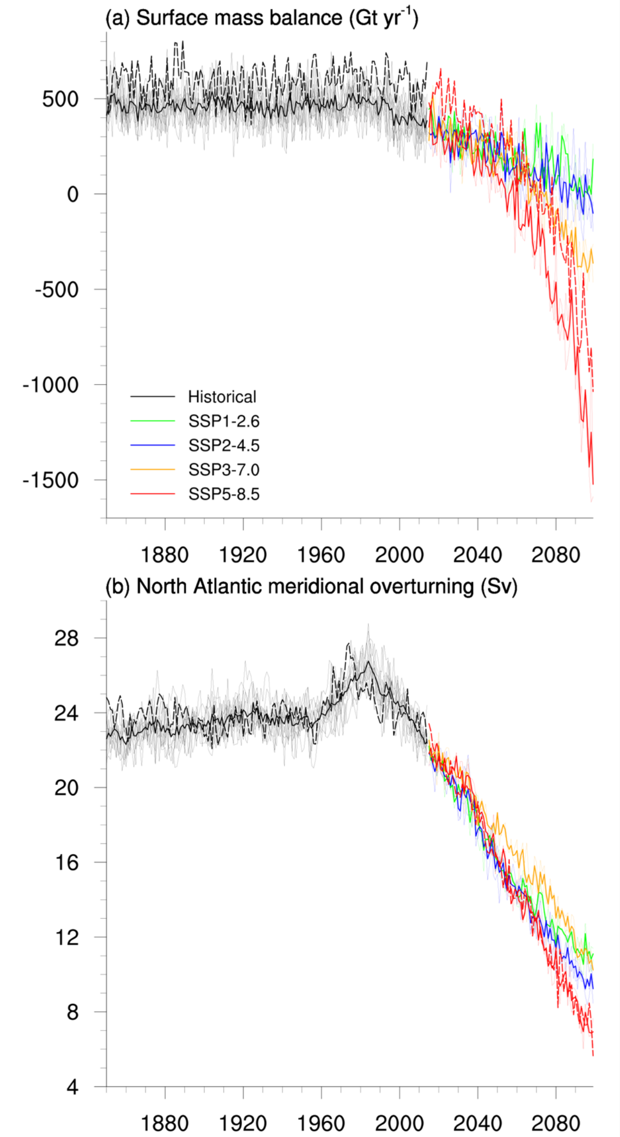


Drainage basins following Rignot and Mouginot (2012)

- By mid-century, most of SMB reduction originates in the South. Northern basins 26% of GrIS total
- By e-o-c, Northern basins contribute 43% of the GrIS total mass loss – due to increase in runoff
- SW is largest contributor to SLE (e-o-c)



WITH AND WITHOUT EVOLVING GRIS



Comparison of SMB and NAMOC response CESM2.1 without interactive GrIS

- CESM2.1 SMB (ensemble mean: 390 Gt/yr, 11 members) closer to observed historical SMB than CESM2.1-CISM2.1 (571 Gt/yr) – likely due to GrIS geometry
- Similar historical NAMOC (peak in 1960s-1970s) and high sensitivity in response to scenario forcing

CONCLUSIONS

- Relatively strong global warming and AMOC weakening by 2100
- GrIS contribution to SLR:
  - 23 mm SLE by 2050
  - 109 mm SLE by 2100
- Northern basins runoff strongly increases during the 2nd half of the century, as ablation area expansion occurs later, and further inland, than in the South.

QUESTIONS?

questions later:

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The presented results are available here:

Muntjewerf, L., Petrini, M., Vizcaino, M., Ernani da Silva, C., Sellevold, R., Scherrenberg, M. D.W., et al. (2020). Greenland Ice Sheet contribution to 21st century sea level rise as simulated by the coupled CESM2.1-CISM2.1. *Geophysical Research Letters*, 47, e2019GL086836. https://doi.org/10.1029/2019GL086836