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

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CESM Land Ice Working Group Meeting 2020
February 10th 2020
INTRODUCTION

GREENLAND IS LOSING MASS

Shepherd et al., 2012
INTRODUCTION

ICE SHEET MODEL INTERCOMPARISON PROJECT (ISMIP6)

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]
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

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).
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
**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 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)  |                          |                          |                             |
| SMB                     | 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 (10⁶ km²)     |                          |                          |                             |
| - by end year of time segment | 1.965                  | 1.958                   | 1.909                       |
GRIS ICE DISCHARGE

- 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)
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)
Comparison of SMB and NAMOC response

- 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
- 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 2\textsuperscript{nd} half of the century, as ablation area expansion occurs later, and further inland, than in the South.
The presented results are submitted to GRL: Muntjewerf et al. (pending revisions). Greenland Ice Sheet Contribution to 21st Century Sea Level Rise as Simulated by the Coupled CESM2.1-CISM2.1.