**INTRODUCTION**

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<th>Future (Greenland)</th>
<th>Last deglaciation (Northern Hemisphere)</th>
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<td>CESM</td>
<td>Raymond Sellevold (GrIS-Arctic connections)</td>
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<td>CESM-CISM</td>
<td>Laura Muntjewerf (ISIMIP6 projections)</td>
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<td>Carolina E. de Silva (ice-ocean interaction)</td>
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**Software engineering support**
Bill Sacks, Erik Kluzek (NCAR)

**Coupled Ice Clim**
June 2016-May 2021

**DELFT RESEARCH GROUP**

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Raymond Sellevold - PhD
Carolina E. de Silva - PhD
Sarah Bradley - Postdoc
Michele Petrini - Postdoc
Miren Vizcaino - PI

European Research Council
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NWO
Netherlands Organisation for Scientific Research
INTRODUCTION

ICE SHEET MODEL INTERCOMPARISON PROJECT (ISMIP6)

- ISMIP6 is a CMIP6-endorsed MIP
- experiments to explore uncertainty in sea level rise
- Sea-level projections for the IPCC-AR6 in sync with the CMIP scenarios

ISMIP6 follows the timeline of CMIP6
→ Submission papers Dec. 2019

Nowicki et al., 2016
INTRODUCTION

ICE SHEET MODEL INTERCOMPARISON PROJECT (ISMIP6)

CESM2.1 contribution to ISMIP6
As one of the first climate modeling centers; we provide the community with the following coupled AOGCM-ISM runs:

- piControl-withism [300 yrs]
- 1pctCO2to4x-withism & 1pctCO2to4x-ism_non-interactive [500 yrs]
- historical-withism [1850-2014]
- ssp585-withism [2015-2300]
Fully coupled CESM2.0 AOGCM-ISM: all components active [BG compset]

Presented here are results from 2 test runs:
• Pre-industrial -1850 steady forcing [40 years]
• 1% yr\(^{-1}\) increase CO\(_2\) up till the value of 4 times the pre-industrial concentration [130 years]

**NOTE** test simulations:
- Too large spun-up initial ice sheet (volume +30% i.e. ~10 m SLE)
- CLM/CICE/MOSART from JG_2, CAM branched from PI #297_yr0078,
- 1pct-run did not complete the full 140 years; ocean component crash at year 130
Results

• Global climate
• Arctic climate
• Greenland climate
• Greenland ice sheet evolution
- Polar amplification: larger change in surface temperatures near the poles.
- Cooling patch in the North Atlantic
• Southward movement of ITCZ
• Southward movement of ITCZ

• Reduced precipitation at the high precipitation region in the South East of Greenland – related to the colder ocean surface, less evaporation
**NAMOC COLLAPSE**

- NAMOC is weakening a lot
- Maximum is going south

**North Atlantic Meridional Overturning Circulation (Annual) [Sv]**

- BG_1850
- BG_1pct
- Albedo decreases at the poles
- Loss of sea ice:
  - Only seasonal NH sea ice on by the last decade of the 1pct run
• Greenland ice sheet mean snow melt heat flux [W/m²] increases
• Seasonal cycle of snow melt heat flux amplifies
• GrIS average snow height [m] decreases
ICE SHEET RESPONSE TO INCREASED CO$_2$

- Stronger ablation zones at all margins
- Increased accumulation in the interior
- Standard deviation of SMB increases (red) $\rightarrow$ increased interannual variability, except in the SE high precipitation region
ICE SHEET RESPONSE TO INCREASED CO$_2$

- Mass balance tipping around year 70 [$MB < 0$]
- After year 70: regime shift in the SMB $\rightarrow$ accelerated decrease
- Last decade 4 times SMB $< 0$

<table>
<thead>
<tr>
<th>Gt/year</th>
<th>year 00-20</th>
<th>year 110-130</th>
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<tbody>
<tr>
<td>Mass Balance</td>
<td>32 [142]</td>
<td>-294 [191]</td>
</tr>
<tr>
<td>SMB</td>
<td>617 [124]</td>
<td>168 [164]</td>
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</table>
ICE SHEET RESPONSE TO INCREASED CO$_2$

- Mass loss in the South and East part of the Ice Sheet
- Mass gains in the North-West section → may be related to increased precipitation → may be related to residual trend; volume growth in 1850_control
ICE SHEET RESPONSE TO INCREASED CO$_2$

- Ice sheet velocities don’t change much between the start and the end [130 years]
- CISM2.1 has the capability of simulating shelves:
  - shelves that ground
  - floating shelves
- Production ISMIP6 runs will be without shelves
ICE SHEET RESPONSE TO INCREASED CO\textsubscript{2}

- Drift ice volume in Control run BG.1850
- Not until doubling of CO\textsubscript{2} there is an acceleration of mass loss [\sim year 70] in BG.1pct
- Sea level contribution after 130 years: 4.0 cm with respect to year 1 of BG.1pct
CONCLUSIONS

The **test** simulation of 1% yr⁻¹ increase CO₂ up till the value of 4 times the pre-industrial concentration demonstrates the climate-ice sheet coupling in CESM2.1.

Key responses of the global and polar climate to increased levels of CO₂:

- Global increase in surface temperatures
- NAMOC decrease
- Changes in the Greenland surface mass balance (↓), and contribution to eustatic sea level rise (↑)
Current status ISMIP6 runs
- finish the spin-up [presentation later today in the joint session]

Next simulations - to start soon:
- pre-industrial (1850) control
- 1 percent CO$_2$ increase till 4x CO$_2$
- Historical 20$^{th}$ century simulation and SSP5-8.5
QUESTIONS?

questions later:
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