Using CESM and CISM to simulate the long-term evolution of climate and the Greenland Ice Sheet during the Last Interglacial (~129,000 to 116,000 yrs ago)

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Photo by Leo Kampenhout
Last Interglacial [129-116 ka] – Some Evidence from Data

Ice cores
- 6 deep ice-coring projects have reached ice layers back to LIG
  - NEEM: surface elevation estimated 130 ± 300 m below present
  - Annual temperatures
    NEEM: +7 to +11°C
    GISP2: +4 to +8°C
  - Dye 3: new analysis suggests basal ice predates LIG

Raynaud et al., 1997; Johnsen et al., 2001; NorthGRIP, 2004; NEEM, 2013; Yau et al., 2016

Marine cores
- ODP sites offshore contain sediment sourced from Greenland
  - ODP 626: silt provenance suggests SGrIS present, smaller than in Holocene
  - ODP 626: shrub tundra and dense fern vegetation over S. Greenland
  - ODP 918 & 987: stable ice sheet in E. Greenland for most of past million years

De Vernal et al, 2008; Colville et al., 2011; Hatfield et al., 2016; Bierman et al., 2016
### Past Modeling of Greenland Ice Sheet during the Last Interglacial

<table>
<thead>
<tr>
<th>Study</th>
<th>SMB method</th>
<th>GIS melting (m of sea level equivalent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huybrechts (2002)</td>
<td>Index</td>
<td>5.5</td>
</tr>
<tr>
<td>Tarasov and Peltier (2003)</td>
<td>Index</td>
<td>2.7–4.5</td>
</tr>
<tr>
<td>Lhomme et al. (2005)</td>
<td>Index</td>
<td>3.5–4.5</td>
</tr>
<tr>
<td>Born and Nisancioglu (2012)</td>
<td>GCM snapshots</td>
<td>4.2–5.9</td>
</tr>
<tr>
<td>Otto-Bliesner et al. (2006)</td>
<td>One-way GCM coupling</td>
<td>2.2–3.4</td>
</tr>
<tr>
<td>Stone et al. (2012)</td>
<td>One-way GCM coupling</td>
<td>0.6–3.5</td>
</tr>
<tr>
<td>Robinson et al. (2011)</td>
<td>Energy-moisture coupling</td>
<td>0.4–4.4</td>
</tr>
<tr>
<td>Quiquet et al. (2013)</td>
<td>Index method</td>
<td>0.7–1.5</td>
</tr>
<tr>
<td>Helsen et al. (2013)</td>
<td>Asynch, 2-way coupling reg model</td>
<td>1.2–3.5</td>
</tr>
<tr>
<td>Calov et al. (2015)</td>
<td>Asynch, 2-way coupling reg model</td>
<td>0.6–2.5</td>
</tr>
<tr>
<td>Yau et al. (2017)</td>
<td>Asynch, 2-way coupling reg model</td>
<td>4.1–6.2</td>
</tr>
<tr>
<td>Goezler et al. (2016)</td>
<td>Synch, 2-way coupling global model</td>
<td>1.4</td>
</tr>
</tbody>
</table>
CESM (FV1x1) – CISM (4 km) – two-way coupling

**CESM**

- Atmosphere
- Coupler
- Ocean
- Sea Ice

**CISM**

- Land surface (Ice sheet surface mass balance)
- Ice sheet (Dynamics)
CESM (FV1x1) – CISM (4 km) – two-way coupling

Land -> Ice Sheet
(10 elevation classes + bare land)
- Surface mass balance
- Surface elevation
- Surface temperature

Ice Sheet -> Land
- Ice extent
- Ice surface elevation
- SMB mask

Land surface
(Ice sheet surface mass balance)

Ice sheet (Dynamics)

Coupler

Atmosphere

Sea Ice

Ice sheet -> Ocean
- Solid and liquid fluxes

Ocean

Ice sheet -> Atmosphere (offline)
- Surface topography
Early Last Interglacial (128 – 124 ka)

- Large boreal summer insolation anomalies (128-124ka) resulting from orbital forcing assume 127ka insolation anomalies representative.
- Stable GHG concentrations similar to late Holocene
- Continental and oceanic configurations almost identical to modern

**CESM1.5 (FV1x1) coupled to CISM1 (4km)**

1) LIG 127ka orbital forcing [LIG]
   - 2000 CISM yrs, 155 CESM yrs

2) LIG 127ka orbital forcing + (idealized) boreal forests to Arctic Ocean in North America and Eurasia [LIGveg]
   - + 2000 CISM yrs, 80 CESM yrs

Capron et al., QSR, 2017
Two Exploratory Simulations Last Interglacial (128 – 124 ka)

1) LIG 127ka orbital forcing [LIG]
   • 2000 CISM yrs, 155 CESM yrs

2) LIG 127ka orbital forcing + (idealized) boreal forests to Arctic Ocean [LIGveg]
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Two Exploratory Simulations Last Interglacial (128 – 124 ka)

1) LIG 127ka orbital forcing
   - 2000 CISM yrs, 155 CESM yrs
   - Overall SMB > 0
   - Ice sheet area: ~96% modern
   - SLE: 0.6 meters
   - Equiv. SLR: 0.1 m/kyr

2) LIG 127ka orbital forcing + boreal forests to Arctic Ocean
   - + 2000 CISM yrs, 80 CESM yrs
   - Overall SMB < 0
   - Ice sheet area: ~85% modern
   - SLE: 1.8 meters
   - Equiv. SLR: 0.7 m/kyr

Annual Sfc Albedo

Surface albedo ↓
Solar radiation absorbed at surface ↑
Temperature (locally & remotely) ↑
Sea ice (summer) ↓
Water vapor in atmosphere – GHG ↑
CLIMATE: Greenland & Arctic sea ice

Seasonal cycle over Greenland

JAS Sea ice thickness
Preindustrial

LIG
LIGveg

Surface meltwater

Land: 60-90N, 60-20W
Evolution of Greenland annual surface temperatures

**LIG simulation**
(Seasonal insolation anomalies)

**LIGveg simulation**
(+Boreal forests extended northward)

**YR 2000**
- NEEM Ann ΔT: +4°C
- Summit Ann ΔT: ~0°C

**YR 4000**
- NEEM Ann ΔT: +12°C
- Summit Ann ΔT: ~2°C

Global Mean Ann ΔT: 0°C  
Global Mean Ann ΔT: 0.7°C!
Evolution of Greenland ice sheet thickness

1) LIG simulation
• Overall SMB > 0
• Ice sheet area: ~96% modern
• SLE: 0.6 meters

2) LIGveg simulation
• Overall SMB < 0
• Ice sheet area: ~85% modern
• SLE: 1.8 meters
Evolution of Greenland ice sheet

**Volume**

- [km$^3$]
- [mm]
- [m]
- [kg/s]
- [degC]
- [km$^2$]
- [kg/s]

**Area**

- Mean temp
- Mean thick

**Sea-level equivalent**

- LIG: SLR: 0.1 m/kyr
- LIGveg: SLR: 0.7 m/kyr

**Calving**

- [kg/s]

**SMB**

- [kg/s]
Summary

- ~ Thickness change at ice cores
  - CampCentury  -450m
  - NEEM  -400m
  - NGRIP  -200m
  - Summit  -40m
  - Renland  +20m
  - Dye 3  -200m
Next steps

• Rerun with final CESM2 configurations and spunup GrIS initial state
• Refine vegetation map
• New calving/marine basal melt and other new parameterizations ... [maybe]

🌟 Transient simulation🌟