The Role of GCM Resolution in Simulated Glacial Inception

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Glacial Inception Studies with Climate Models

- Rind et al. (1989) -- GISS GCM (8° x 10°)
- Oglesby (1990) -- CCM1 GCM (R15)
- Dong and Valdes (1995) -- UGAMP GCM (T42)
- Gallimore and Kutzbach (1996) -- CCM1 GCM (R15)
- Pollard and Thompson (1997) -- Off-line Ice Sheet Model
- Khodri et al. (2001) -- IPSL GCM (T31)
- Yoshimori et al. (2002) -- AGCM
- Vettoretti and Peltier (2003) -- CCCMA GCM (T32)
- Kageyama et al. (2004) -- CLIMBER EMIC
- Calov et al. (2005) -- CLIMBER EMIC
- Kubatzki et al. (2006) -- CLIMBER EMIC
- Mysak (2008) -- McGill EMIC
- Vavrus et al. (2008) -- CAM3-SOM GCM (T42)
- Otieno and Bromwich (2009) -- CLM3-ERA40

Usual target is orbitally forced 115 ka BP event with coarse model
Early Anthropogenic Hypothesis

Deforestation ---------> Increased atmospheric CO₂ (8,000 years ago)
Rice Cultivation -------> Increased atmospheric CH₄ (5,000 years ago)
280 ppm pre-industrial CO₂

240 ppm CO₂ naturally

700 ppb pre-industrial CH₄

450 ppb CH₄ naturally

Enough greenhouse cooling to promote glacial inception?
CAM3 Atmosphere/Slab-Ocean Model (SOM)

- **T42 Resolution**
  - $2.8^\circ \times 2.8^\circ$

- **T85 Resolution**
  - $1.4^\circ \times 1.4^\circ$

**CONTROL:**
- 355 ppm CO$_2$
- 1700 ppb CH$_4$

**NOANTHRO:**
- 240 ppm CO$_2$
- 450 ppb CH$_4$

(modern orbital configuration)
GCM Topography

T85

T42

(meters)

100 400 600 900 1100 1400 1600 1900 2100 2400 2600 2900
Surface Temperature Changes
(NOANTHRO minus CONTROL)

Global Average

-2.85 K

-2.65 K
# Boreal High Latitude Climate Changes

<table>
<thead>
<tr>
<th></th>
<th>T42</th>
<th>T85</th>
<th>T85 - T42</th>
</tr>
</thead>
<tbody>
<tr>
<td>45° - 90°N:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface Temperature (K)</td>
<td>-3.6</td>
<td>-3.7</td>
<td>-0.1</td>
</tr>
<tr>
<td>Precipitation (%)</td>
<td>-11.8</td>
<td>-12.3</td>
<td>-0.5</td>
</tr>
<tr>
<td>Snowfall (%)</td>
<td>18.9</td>
<td>20.8</td>
<td>1.9</td>
</tr>
<tr>
<td>Snow Cover Duration (%)</td>
<td>11.4</td>
<td>10.4</td>
<td>-1.0</td>
</tr>
<tr>
<td>Sea Ice Area (%)</td>
<td>15.9</td>
<td>16.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Permanent Snow Cover Area (%)</td>
<td>80</td>
<td>147</td>
<td>67</td>
</tr>
</tbody>
</table>
Permanent Snow Cover Area (incl. Greenland):

3.8E6 km²  
4.0E6 km²
300 hPa Geopotential Height Response
(global mean change removed)

Annual

Winter
Sea Level Pressure Response

Annual

T85

T42

Winter

T85

T42

(hPa)
Baffin Island: role of elevation

**Elevation vs. Snow Cover Duration T42**

- Months of Snow Cover
- Elevation T42 (m)
- $r = 0.11$

**Elevation vs. Snow Cover Duration T85**

- Months of Snow Cover
- Elevation T85 (m)
- $r = 0.81$
Conclusions

• Much more extensive glacial inception with higher model resolution (N. Amer.)

• Expanded permanent snow cover at T85 mostly a regional response

• Dependence of glacial inception on model resolution is a function of both:
  (a) local topography
  (b) large-scale dynamics ---> regional circulations

• No ocean dynamics or interactive vegetation used here

• Role of tropical Pacific bears investigation in a fully coupled simulation

? Would even higher model resolution lead to even more glacial inception?
N.H. Insolation Trends

Caloric Insolation Season

CH₄

CO₂