Multi-decadal variability of Arctic climate in CCSM3 mid-Cretaceous simulations

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Recent Arctic variability and the potential causes

The warming in the early 20th is likely due to natural variability, and linked to sea-ice variability.

Bengtsson et al., 2004

Induced by modifications in the meridional heat transport between the Arctic and North Atlantic via:

- Atmospheric variability (NAO/AO)
- Wind-driven Arctic Ocean Oscillatory (AOO)
- Variability of the meridional overturning circulation (MOC)

Goosse and Holland, 2005
Methodology

Model:
T31x3 CCSM3 with dynamic vegetation model

Experiments:
- Mid-Cretaceous paleogeography and bathymetry.
- 99% of modern solar constant
- Four experiments initialized from a previous Cretaceous simulation.

Source: Scotese PALEOMAP project
Simulated mean climate

<table>
<thead>
<tr>
<th>Exp.</th>
<th>Atm. CO$_2$</th>
<th>Vegetation</th>
<th>Global SAT</th>
<th>MOC</th>
<th>70-90 °N SAT</th>
<th>Sea ice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(ppmv)</td>
<td>(°C)</td>
<td>(Sv)</td>
<td></td>
<td>(°C)</td>
<td>(10$^6$km$^3$)</td>
</tr>
<tr>
<td>1xv</td>
<td>280</td>
<td>13.6</td>
<td>21.9</td>
<td></td>
<td>-17.6</td>
<td>15.7</td>
</tr>
<tr>
<td>10xn</td>
<td>2800</td>
<td>23.1</td>
<td>20.4</td>
<td></td>
<td>4.9</td>
<td>0.1</td>
</tr>
<tr>
<td>10xv</td>
<td>2800</td>
<td>24.0</td>
<td>18.2</td>
<td></td>
<td>7.0</td>
<td>0.06</td>
</tr>
<tr>
<td>16xv</td>
<td>4480</td>
<td>25.6</td>
<td>9.6</td>
<td></td>
<td>8.4</td>
<td>0.01</td>
</tr>
</tbody>
</table>

[Maps showing climate data for 1xv and 10xv conditions]
Time series of Arctic SAT
Variability of Arctic SAT
Simulated Arctic variability: spectrum of SAT
The role of meridional heat transport

- The driving role of oceanic heat transport is persistent.
- The leading role of atmospheric heat transport decreases with warmer climate.
Variability of MOC
The role of MOC

MOC variation is a response rather than a driver of the anomalous OHT except in the 16xv experiment.
Atmospheric variability: PSL EOF1

T41 modern CCSM3 simulation
Yeager et al., 2006
Atmospheric circulation triggers changes in sea-ice, which influences oceanic heat transport.
The role of BSF
Positive cloud feedbacks in the ice-free simulations.
The multi-decadal Arctic variability varies with mean climate in terms of regularity and magnitude.

Anomalous oceanic heat transport acts as a driver for the Arctic multi-decadal variability, which is due to atmosphere-sea ice interaction in the 1xv experiment, and due to changes in BSF in the ice-free 10xn and 10xv experiment. In contrast, MOC variation can be only considered a response to the Arctic change.

Anomalous atmospheric circulation leads to the Arctic multi-decadal variability when sea-ice feedback is significant.

Cloud feedbacks tend to damp the variability in the 1xv experiment, yet to reinforce the variability in the rest ice-free warm simulations.
Examples of warming events
Methods

- Remove least-squared quadratic trend
- Hanning-window with a bandwidth of 11 applied prior to spectrum
- 10-year running mean is applied prior to regression/correlation
Warming events
CRF