The tropical impacts of projected Arctic and Antarctic sea ice loss

Mark England, Columbia University
Lantao Sun, NOAA/ESRL
Clara Deser, NCAR
Lorenzo Polvani, Columbia University and LDEO
The Arctic is only half the story
Both Arctic and Antarctic sea ice loss will have important tropical impacts.
Motivation

Screen et al., 2018 [Nat. Geosci.]
Motivation

Screen et al., 2018 [Nat. Geosci.]
Projected Arctic sea ice loss shown to have important global effects
('mini global warming signal')
There is a clear tropical response to projected Arctic sea ice loss.
This tropical response emerges after a large instantaneous amount of Arctic sea ice loss after ~30 years.

Wang et al., 2018 [GRL]
When realistic, transient Arctic sea ice loss is imposed, the tropical response is still robust but takes longer to detect.
Aims

Address the following questions:

- Is there an important tropical response to Antarctic sea ice loss?
- If so, does it reinforce or weaken the tropical response to Arctic sea ice loss?
Previous work

- Atmosphere-only runs with WACCM to investigate the effect of projected end of the century Arctic and Antarctic sea ice loss.
- Without ocean coupling, response is limited to mid- and high-latitudes.

Previous work

England et al., 2018 [J. Climate]
Community Earth System Model (CESM)
Whole Atmosphere Community Climate Model (WACCM):

- High top model which participated in CMIP5
- Simulates climatological Arctic and Antarctic sea ice conditions well
- Ran in fully coupled mode
- 2° by 2.5° horizontal resolution
- 66 vertical levels with model lid extending up to lower thermosphere
Experimental setup

- Perform four time-slice experiments, each for 350 years, discarding first 100 years
- Target future sea ice conditions averaged from three members of WACCM run out to 2100 under RCP 8.5 conditions.
- Sea ice is perturbed using the ghost forcing method (see Deser et al., 2015 [J. Climate]; Tomas et al., 2016 [J. Climate]; Screen et al., 2018 [Nat. Geosci.])
- All other forcings (CO$_2$, ODSs etc.) are kept at 1955 values.
## Experiments

### Atmosphere-only runs

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Arctic</th>
<th>Antarctic</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1955-69</td>
<td>1955-69</td>
<td>150</td>
</tr>
<tr>
<td>Melt Arctic</td>
<td>2085-99</td>
<td>1955-69</td>
<td>150</td>
</tr>
<tr>
<td>Melt Antarctic</td>
<td>1955-69</td>
<td>2085-99</td>
<td>150</td>
</tr>
</tbody>
</table>

England et al., 2018 [J. Climate]
<table>
<thead>
<tr>
<th>Experiment</th>
<th>Arctic</th>
<th>Antarctic</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1955-69</td>
<td>1955-69</td>
<td>150</td>
</tr>
<tr>
<td>Melt Arctic</td>
<td>2085-99</td>
<td>1955-69</td>
<td>150</td>
</tr>
<tr>
<td>Melt Antarctic</td>
<td>1955-69</td>
<td>2085-99</td>
<td>150</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Arctic</th>
<th>Antarctic</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1955-69</td>
<td>1955-69</td>
<td>250</td>
</tr>
<tr>
<td>Melt Arctic</td>
<td>2085-99</td>
<td>1955-69</td>
<td>250</td>
</tr>
<tr>
<td>Melt Antarctic</td>
<td>1955-69</td>
<td>2085-99</td>
<td>250</td>
</tr>
<tr>
<td>Melt both</td>
<td>2085-99</td>
<td>2085-99</td>
<td>250</td>
</tr>
</tbody>
</table>

England et al., 2018 [J. Climate]  
England et al., [in prep]
Sea ice loss

Arctic sea ice

Antarctic sea ice

Sea ice extent [x10^6 km^2]

Sea ice loss
Annual mean temperature response

England et al., [in prep]
Temp. response

b) Arctic sea ice loss (A)

c) Antarctic sea ice loss (AA)

d) Combined Arctic and Antarctic sea ice loss (A & AA)

England et al., [in prep]
Temp. response

England et al., [in prep]
Precip. Response in DJF

- Precip. [mm/day]

England et al., [in prep]
Northward Heat Transport

Total NHT

Atmosphere NHT (atm. only)

England et al., [in prep]
The tropical response to Antarctic sea ice loss is as large as the tropical response to Arctic sea ice loss.

- Together, Arctic and Antarctic sea ice loss is ~ 25% of projected tropical surface temperature change and ~30% of precipitation change from RCP8.5.
- The response to Antarctic sea ice loss is remarkably similar to the response to Arctic sea ice loss.
- The signal from the poles is mostly carried to the tropics by the ocean. Interestingly Antarctic sea ice loss, but not Arctic sea ice loss, causes some cross-equatorial atmospheric energy transport.
Sea ice climatology

Climatology 1979-2000

Arctic

Antarctic

Sea ice extent [x10^6 km²]

- WACCM4
  - Observations
Temp. response