Zonal-mean atmospheric response to future Arctic sea ice loss: The role of ocean-atmosphere coupling

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### 3 pairs of simulations, nominally 1° horizontal resolution all components

<table>
<thead>
<tr>
<th>Description</th>
<th>Model Configuration</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 member RCP8.5 ensemble 2080-99 (late 21\textsuperscript{st} century)</td>
<td>Fully coupled (all component models active), forced with projected GHG’s and “observed” radiative forcings</td>
<td>( \Delta \text{ (RCP8.5) climate response to increased GHG’s} )</td>
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<tr>
<td>6 member historical ensemble 1980-99 (late 20\textsuperscript{th} century)</td>
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<tr>
<td>Late 21\textsuperscript{st} century Arctic sea ice</td>
<td>Active atmosphere and land only, sea ice and SST prescribed as boundary conditions, GHG @ 2000</td>
<td>( \Delta \text{ (ICE}_{\text{atm}} ) atmosphere response to projected Arctic sea ice changes, uncoupled framework )</td>
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<td>Late 21\textsuperscript{st} century Arctic sea ice</td>
<td>Fully coupled but with ice model forced to mimic late 21\textsuperscript{st} and 20\textsuperscript{th} century Arctic sea ice GHG @ 2000</td>
<td>( \Delta \text{ (ICE}_{\text{coupled}} ) atmosphere/ocean response to projected Arctic sea ice changes, fully coupled framework )</td>
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</table>
Arctic Sea Ice Concentration

RCP8.5 GHG

1980-99, 20th

2080-99, 21st

September

Sea Ice Extent ($\times 10^6$ km$^2$)

20th C

21st C
CESM (1°) Arctic Sea Ice Concentration

RCP8.5 GHG

1980-1999

2080-2099

Discard first 100 years as the system adjusts (AMOC)

ICE_coupled (360 years)

ICE_atm (260 years)

Sea Ice Extent (x10^6 km²)

September
Artificially controlling Arctic sea ice in CESM (GHG fixed at year 2000)

20th Century (1990)

- Warms as it comes into equilibrium, so need to remove energy in the ice model

21st Century (2090)

- Need to add energy in the ice model to melt ice

- 0.10 Wm⁻²

- 0.43 Wm⁻² (global equivalent) \(Q_{\text{LW}}\) in ice model only
Annual $T(z)$ and $U(z)$ Responses to Arctic Sea Ice Loss

Ice Coupled

Ice Atmosphere

Difference

Active ocean results in global scale warming
Annual $T(z)$ and $U(z)$ Responses to Arctic Sea Ice Loss

Both ice simulations have an equatorward shift in the jet.

Active ocean results in a global responses.
Arctic Sea Ice Loss Contribution to RCP8.5 Response

Greater hemispheric symmetry in the absence of Arctic sea ice loss
Absence of poleward shift of NH winter westerlies in RCP8.5 due to offsetting influences of GHG increase and Arctic sea ice loss
Conclusions

We were able to simulate the atmosphere/ocean response to projected 21\textsuperscript{st} century Arctic sea ice loss in fully coupled simulations.

When ice and associated SST’s are prescribed as lower B.C.’s, the response is confined to the vicinity of the ice loss. In contrast, the response is global with an active ocean model.

The zonal wind response to Arctic sea ice loss in both ice simulations is an equatorward shift in the mean zonal jet.

This equatorward shift accounts for the absence of a winter poleward jet shift in the NH RCP8.5 simulations.
Tropical Coupled Response to Arctic Sea Ice Loss

a) Precipitation Ice_coupled Climatology (mm day$^{-1}$)

b) Precipitation Ice_coupled (mm day$^{-1}$)

c) SST Ice_coupled (°C)

d) Precipitation RCP8.5 (mm day$^{-1}$)
RCP8.5
Our coupled runs
Lowered albedo run

Sea Ice Loss ($10^6$ km$^2$)

Arctic Ocean Heat Flux Response (Wm$^{-2}$ upward)

- Maximizes in winter
- Underestimated in lowered albedo run

Inverted axis