The interactions between the Arctic and the midlatitudes from atmospheric relaxation experiments

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The idea of Arctic influence on mid-low latitudes

- Relatively new
- In direct competition with the tropical influence (e.g., ENSO)
- Controversial and still hard to prove
- But has a promising future
The relaxation experiments and relaxation equation

\[ \frac{dx}{dt} = F(x) - \alpha(x - x_{\text{ana}}) \]

X: state vector of the model
\( \alpha \): relaxation coefficient (0.1)
\( X_{\text{ana}} \): state vector of ERA-Interim data
Buffer zones: about 5° in latitude and 100 hPa in pressure

*ECMWF atmospheric model (T_L255L60); Relaxation towards ERA-Interim data; 35 winters and summers with 9 members each;*

*Relaxed variables: Temperature, horizontal wind and surface pressure.*

These relaxation experiments can be used to study ‘teleconnected’ influences, but they cannot be used to study the impacts of boundary forcing like sea ice loss.
### Summary of the relaxation experiments

<table>
<thead>
<tr>
<th>Name of experiment</th>
<th>Boundary conditions</th>
<th>With relaxation</th>
<th>Horizontal area with relaxation</th>
<th>Vertical extent with relaxation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SST-Sealce-Obs</td>
<td>Observed SST/Sea ice</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>SST-Sealce-Clim</td>
<td>Climatological SST/Sea ice</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Arctic</td>
<td>Climatological SST/Sea ice</td>
<td>Yes</td>
<td>70°N-90°N</td>
<td>Surface to 300 hPa</td>
</tr>
<tr>
<td>Tropical</td>
<td>Climatological SST/Sea ice</td>
<td>Yes</td>
<td>20°S-20°N</td>
<td>Full atmosphere</td>
</tr>
<tr>
<td>TropMidlat</td>
<td>Climatological SST/Sea ice</td>
<td>Yes</td>
<td>57.5°S-57.5°N</td>
<td>Full atmosphere</td>
</tr>
</tbody>
</table>
Impacts on the midlatitudes: The Arctic versus Tropics (detrended) Ye et al. 2018 JGR Atmos

The Arctic has a potential to influence the midlatitudes during boreal winter;

Such influence over Northern Eurasia might be even more significant than by the tropics.
The atmospheric pathway for the Arctic influence
Relaxation of the Arctic troposphere

✓ Has some strong impacts on the surface temperature at midlatitude continent particularly Northern Eurasia

✓ Leads to some significant changes to the zonal winds (also geopotential height) at mid-high latitudes

✓ Has some strong impacts on the intensity of the Siberian High (important component of the East Asian winter monsoon)
Impacts of the tropics versus midlatitudes on the Arctic

Tropics: important pathway over North America

Midlatitudes: important pathways over North Atlantic, west Eurasia, North Pacific

Impacts on temperature: weaker constraints than circulation; Midlatitudes more important
In addition to the lack of interannual variability of sea ice/SST, the local radiative/cloud processes may be a key to explaining the poor temperature constraints.
Principle findings

✓ The Arctic has strong influences on the climate variability over the midlatitude continent particularly Northern Eurasia

✓ The primary pathways include modulation of zonal winds/jet stream and the Siberian High

❖ In terms of forcing of the Arctic climate/circulation, the tropics and the midlatitudes have different pathways

❖ The local radiative/cloud processes are seemingly important
Recent climate changes in the Arctic and midlatitudes

Decline in Arctic Sea Ice Extent

Sea ice extent (million km²)

Decade

Essentialy Ice Free

Ice-free?

Stroeve et al. 2012

Stroeve et al. 2012
Recent climate changes in the Arctic and midlatitudes

Arctic Amplification (AA)

Midlatitude cooling (also global warming hiatus)

More extreme events
Modulation of the Siberian High may extend the Arctic influences further south
Future work

How might the **air-sea coupling** have contributed to the Arctic-midlatitude linkages (comparing the uncoupled and coupled experiments)?
Overview

1 Recent climate changes in the Arctic and midlatitudes

2 Impacts of the Arctic versus tropics on the midlatitudes

3 Impacts of the tropics versus midlatitudes on the Arctic

4 Summary and future work
The recent Eurasian cooling and the intensification of the Siberian High

Reproduced Cooling trend

Intensification of the Siberian High
Increase in extremes of Siberian High index and Siberian surface temperature

(a) Extreme SH index days 2013-2002 vs. 1990-2001

(b) Extreme surface temperature days 2013-2002 vs. 1990-2001

Tripolar Z500 circulation pattern

DJF UV300/Z500/Blocking trends 1990-2013

(a) Z500 ERA-Interim

(b) Z500 Arctic relaxation

(c) Blocking frequency trend
Recent Arctic climate changes and possible relation to the recent Eurasian cooling and the intensification of the Siberian High

Ten(10)-year overlapping trend trend

- A large part of the Siberian cooling trend is accounted for by the Z500 tripole circulation trend
- The enhanced activity of the tripole circulation is likely driven by the extra-tropical SSTs
- The recent intensification of the Siberian High and part of the Siberian cooling are driven by the decadal variations in the coupled atmosphere-ocean system
- Direct impacts of Arctic troposphere: possibly secondary
The roles of atmosphere-ocean coupling in the Arctic-midlatitudes linkage

Not Available
The APPLICATE Project

APPLICATE (Advanced Prediction in Polar regions and beyond: modelling, observing system design and LInkages associated with a Changing Arctic climaTE)

A focus on the Arctic is important for improved predictions of weather and climate in the mid-latitudes because the changes taking place in the Arctic due to climate change—the retreat of sea ice, warming seas and a warming atmosphere—have the potential to influence weather and climate in the mid-latitudes.

Work Package 3 has two primary objectives:

To coordinate a suite of novel multi-model experiments designed to identify the oceanic and atmospheric linkages between the Arctic region and the northern mid-latitudes

To advance our understanding of the mechanisms by which mid-latitude weather and climate could respond to the substantial Arctic climate change that is expected in the coming decades