Evaluating impacts of recent sea-ice and SST changes on the Northern Hemisphere winter climate change through coordinated experiments

Fumiaki Ogawa\textsuperscript{1,2}, Noel Keenlyside\textsuperscript{1,2,3}, Nour-Eddine Omrani\textsuperscript{1,2}, Yongqi Gao\textsuperscript{2,3}, Torben Koenigk\textsuperscript{4}, Vladimir Semenov\textsuperscript{5,9}, Lingling Suo\textsuperscript{2,3}, Shuting Yang\textsuperscript{6}, Tao Wang\textsuperscript{7}, Guillaume Gastineau\textsuperscript{8}, Hoffman Cheung\textsuperscript{1,2}, Tetsu Nakamura\textsuperscript{10} and Jinro Ukita\textsuperscript{11}

1 University of Bergen, Norway.
2 Bjerknes Centre for Climate Research, Norway.
3 Nansen Environmental and Remote Sensing research Center, Norway.
4 Swedish Meteorological and Hydrological Institute, Sweden.
5 Helmholtz Centre for Ocean Research Kiel, Germany.
6 Danish Meteorological Institute, Denmark.
7 Institute of Atmospheric Physics, Chinese Academy of Sciences, China.
8 Sorbonne Universités/UPMC/CNRS/IRD, France.
9 Shirshov Institute of Oceanology, Russia
10 Hokkaido University
11 Niigata University

Ogawa et al, (2018, GRL)
Observed recent winter climate changes

Winter-time Surface temperature trends 1990-2013
December-January-February

“Arctic amplification” of the warming

Cooling

Con contributed by Sea Ice loss?

-However, atmospheric unforced variability could be also important. (McCusker et al. 2016, NGEO).

-This study: Multi-model coordinated experiments to consider the relative contributions of sea-ice, SST changes and internal atmospheric variability.
Coordinated AGCM experiments for 1982-2014

- Prescribed lower boundary condition: NOAA OI-SST daily data

<table>
<thead>
<tr>
<th>Model</th>
<th>Resolution</th>
<th>Top level (hPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAM4</td>
<td>1° x1°</td>
<td>3</td>
</tr>
<tr>
<td>IAP</td>
<td>T85</td>
<td>10</td>
</tr>
<tr>
<td>WACCM</td>
<td>1° x1°</td>
<td>0.000006</td>
</tr>
<tr>
<td>IFS</td>
<td>T255</td>
<td>0.01</td>
</tr>
<tr>
<td>LMDZOR</td>
<td>2.5°x1.25°</td>
<td>0.04</td>
</tr>
<tr>
<td>AFES (30 member)</td>
<td>T79</td>
<td>0.09</td>
</tr>
</tbody>
</table>

- Polar Sea Ice Extent (65-90°N) in September 1982-2014
  - Sea Ice reduces

- Initial condition was modified to make 20 ensemble members.

- Output data is online (Ogawa et al., 2018).

- Here we focus on the multi-model ensemble mean of the simulated trend in winter (DJF mean, 1982-2014).

- RCP8.5
Polar surface warming is mostly associated with sea-ice reduction.
2-m temperature trend (Arctic) [K/10 yrs], Shading: 95% confidence

- Warming over the north Canada and Greenland regions appear without SST change.
  → Remote impact by tropical SST change (Ding et al. 2014) is not critical.
Both of the experiments do not show robust cooling, but rather warming.

→ The siberian cooling is unlikely the forced response to sea-ice reduction.
• Simulated SLP trend shows opposite sign over north Eurasia.
• Consistent with the absence of the Siberian cooling.
Trend of zonal-mean Temperature [K/10yrs], zonal mean U [m/s/10yrs]

- ERA Interim: Sea ice impact is only near the surf. (Screen et al. 2012)
- Observed Arctic amplification extends upward.
- CTRL (SST varying): The upward extension was reproduced.
- SSTC (SST climatology): Sea ice impact is only near the surf.
- Absence of Negative AO-like pattern

Temperature

Zonal wind

Pressure (hPa)
The atmospheric internal variability can reproduce the observed cooling, though it is more like an extreme case. (McCusker et al 2016).
These observed trends seem dynamically-linked realization unforced by sea-ice.
Trend of Z 250hPa & wave activity flux

- Arctic and Siberian region is dynamically connected (Honda et al. 2009)
- Similar evidence is found for the 5-member composites.
- Not reproduced in MME: forcing by SIC or SST is less likely the driver.
Do high-top model reproduce better? (Sun et al., 2015; Nakamura et al., 2016)

- Model top above 0.1hPa (4 models): WACCM, IFS, LMDZOR, AFES
- Model top below 1hPa (2 models): CAM4, IAP4

High-top model does not necessarily better reproduce the observed trend.
Summary

• A coordinated AGCM study on the observed recent decadal climate changes

Key Results

• The Arctic amplification of Northern Hemisphere winter
  - Sea-ice reduction warms near the surface, but not above. (supporting Screen et al. 2012 GRL).
  - The teleconnection from the tropics seems not critical for the warming over Canada/Greenland

• Eurasian surface cooling and negative NAO trends in winter
  - Observed trend seems an extreme one due mainly to internal atmospheric variability. (supporting McCusker et al. 2016, NGEO).
  - (Mori et al. 2019, NCC) The amplitude of WACE could be too small in AGCMs.

• High-top model is not necessarily better to reproduce the AA.

Reference: