The Regional Influence of Large-Scale Atmospheric Variability on the Wintertime Arctic Surface Radiation Budget and Sea Ice Growth

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The two-way relationship between sea ice and atmospheric variability in the Arctic is facilitated by surface turbulent and radiative fluxes.

- Complex, seasonally dependent coupling
# Effects on Radiative Fluxes

<table>
<thead>
<tr>
<th>Sea Ice Cover Reduction</th>
<th>Sea Ice Thickness Reduction</th>
</tr>
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<tbody>
<tr>
<td>• Increased shortwave absorption warms surface, increasing upwelling LW flux</td>
<td>• Warmer ice surface -&gt; increased upwelling longwave fluxes</td>
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### Turbulent Fluxes

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<td>• Large increase in turbulent fluxes, especially in winter if $T_{\text{surface, ice}}$ and $T_{2m} &lt; T_{\text{ocean}}$</td>
<td>• Warmer ice surface, more upward sensible heat flux</td>
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Sea Ice Thickness and Extent Variability

Arctic Atmospheric Variability

Credits: NASA Goddard Space Flight Center/ Kathryn Mersmann, producer
Cyclones impact sea ice concentration and surface temperature, and thus sea ice growth.
These moisture/warm air intrusions are part of the bimodal nature of net LW fluxes over the Arctic in winter.

What organizes these moisture intrusions over the entire fall and winter season in the Arctic?
Low-Frequency Modes (Monthly Timescales)

Arctic Dipole (AD)
- 2\textsuperscript{nd} EOF in winter
- Poleward flow across the Atlantic sector of the Arctic associated with a negative AD pattern

Arctic Oscillation (AO)
- Leading EOF of 1000mb geopotential height in winter
- Winter: number and depth of cyclones across the Arctic are positively correlated with AO.

Plotted: Regression of 2000-2015 DJF 925 mb geopotential height with the DJF a)AD and b)AO indices.
Data and Methods of New Results

• Methods
  • Regress AO and AD indices with CERES-EBAF and MERRA 2 data
  • Statistical significance test: Wilks 2016 FDR approach

• Data
  • CERES-EBAF surface flux data (*Kato et al.* 2013)
  • MERRA2 reanalysis data for atmospheric variables
  • Sea Ice Thickness: PIOMAS data

Goal: Quantify the surface radiative flux anomalies associated with AO and AD and their effects on sea ice growth
Areas of negative and positive temperature anomalies associated with AD (Atlantic sector) and AO (Greenland, Alaska/E Siberia)

Plotted: Regression Values of 850 mb winds (arrows), temperature (contours), and geopotential height (shading)

Highlighting and shown vectors: Statistically significant at the 90% level
Positive downwelling clear-sky surface longwave flux anomaly associated with AD across Atlantic sector across Greenland and E Siberia/Alaska.

Plotted: Regression of NDJF(DJF) AD index with a) downwelling clear-sky longwave surface flux.
Warming and moistening of atmospheric column: Increased downwelling clear-sky longwave surface flux. Opposite for AO.

Plotted: Regression of NDJF(ON) AD(AO) index with MERRA2 temperature and specific humidity

Dots indicate statistically significant regression values
Cloud radiative effect changes support positive clear-sky surface flux anomalies in AD case.

Plotted: Regression of NDJF(DJF) AD index with LW CRE
Result for AD: Reduction of sea ice growth from November-December (blue/purple shading) across the same regions where there is an increase in downwelling LW surface flux (contours)

AO: No significant change in sea ice growth associated with surface LW flux anomalies

Plotted: Regression of AO and AD index with LW all-sky surface flux (contours) and sea ice thickness growth (shading)
Consequence:

In years where the mean AD index is negative:

- increased downwelling surface LW flux
- increased cloud cover

which supports a decrease in growth of sea ice in the region.

**Correlations**

- Blue bars: AD index
- Orange line: all-sky downwelling LW radiation from CERES-SFC-EBAF
- Yellow line: Sea ice volume growth anomaly (PIOMAS data) for November 1- March 1

SI_Vol vs. LW_down_all: $r=-0.53$ significant at the 90% confidence level

SI_Vol vs. AD index: $r=0.37$ significant at the 80% confidence level
Summary

- This mechanism is most prominent over the Atlantic sector of the Arctic (Barents and Kara Seas) in November-February.
- Different mechanism links AO pattern to associated downwelling LW flux anomalies. Link to sea ice growth less clear.
- Clear-sky pathway is much larger-magnitude branch of the mechanism pathway relative to cloud radiative effect pathway.