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

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CERES Science Team Meeting

NASA Postdoctoral Program
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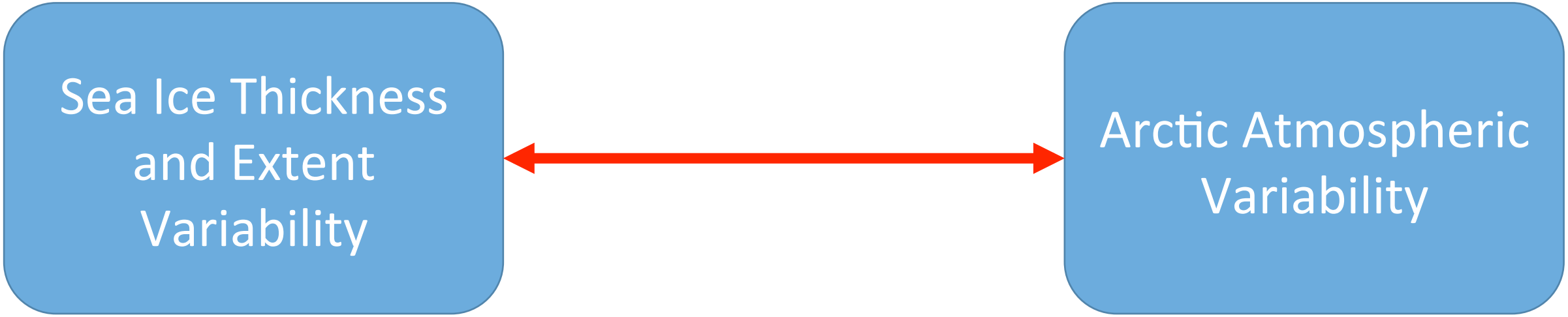
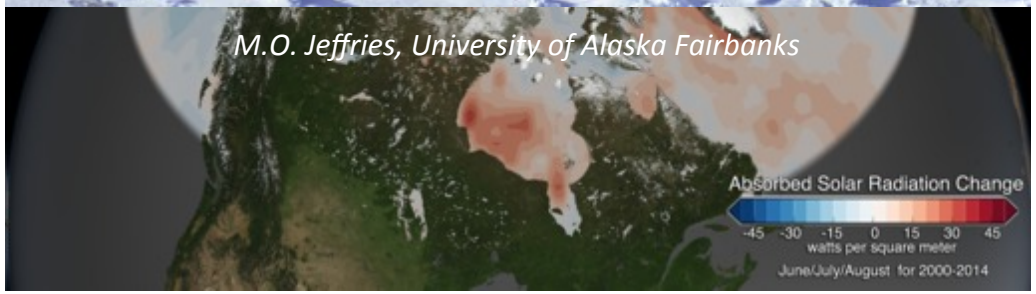


- The two-way relationship between sea ice and atmospheric variability in the Arctic is facilitated by **surface turbulent and radiative fluxes**
  - **Complex, seasonally dependent coupling**



NASA Scientific Visualization Studio

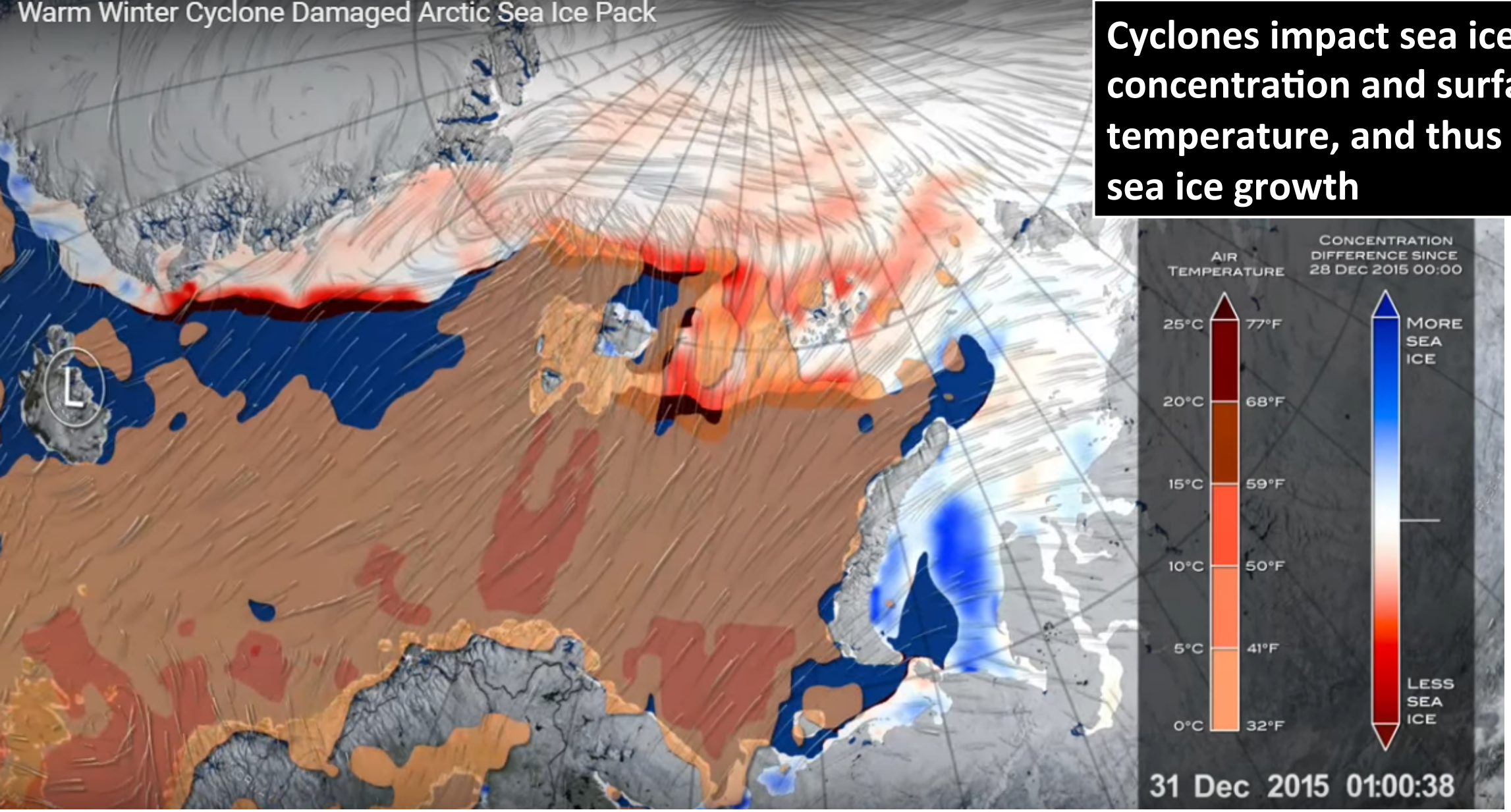
Sea Ice Thickness and Extent Variability → Changes in net surface turbulent & radiative fluxes → Arctic Atmospheric Variability

	Effects on Radiative Fluxes	Turbulent Fluxes
Sea Ice Cover Reduction	• Increased shortwave absorption warms surface, increasing upwelling LW flux	• Large increase in turbulent fluxes, especially in winter if $T_{surface,ice}$ and $T_{2m} << T_{ocean}$
Sea Ice Thickness Reduction	• Warmer ice surface -> increased upwelling longwave fluxes	• Warmer ice surface, more upward sensible heat flux

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

Credits: NASA Goddard Space Flight Center/Kathryn Mersmann, producer

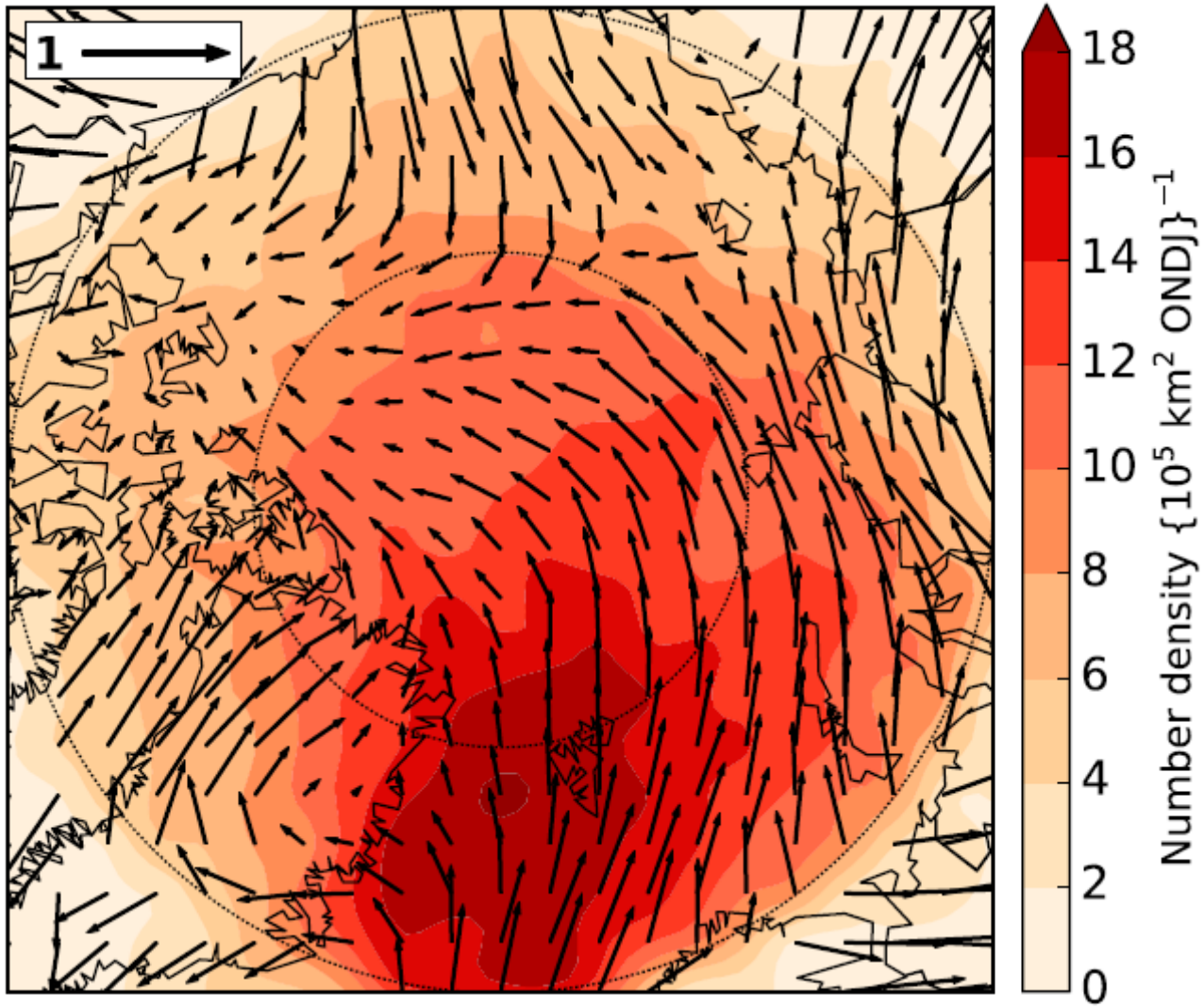
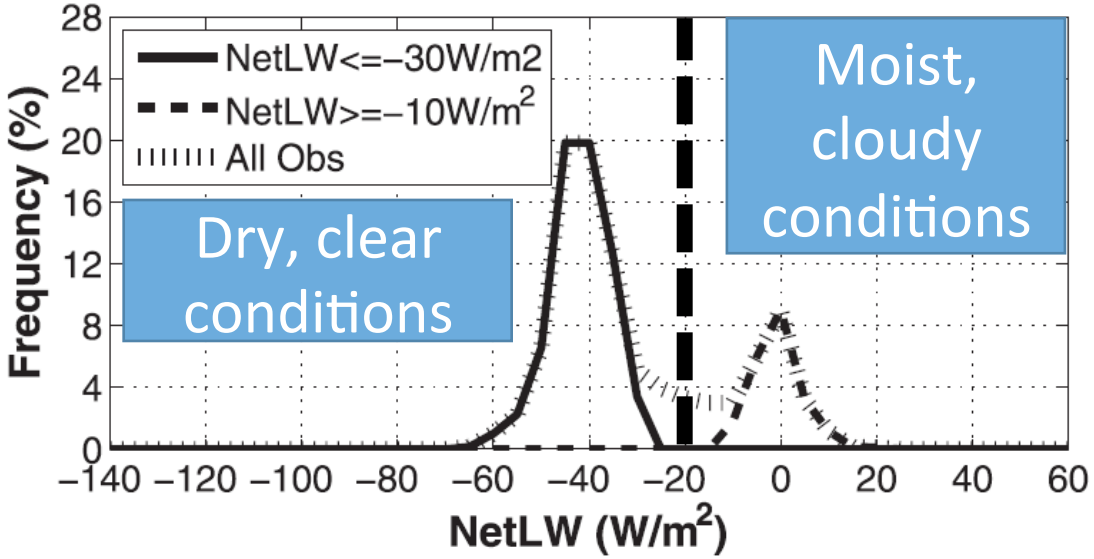


Figure 3, Woods and Caballero 2016

Figure 2, Stramler et al. 2011



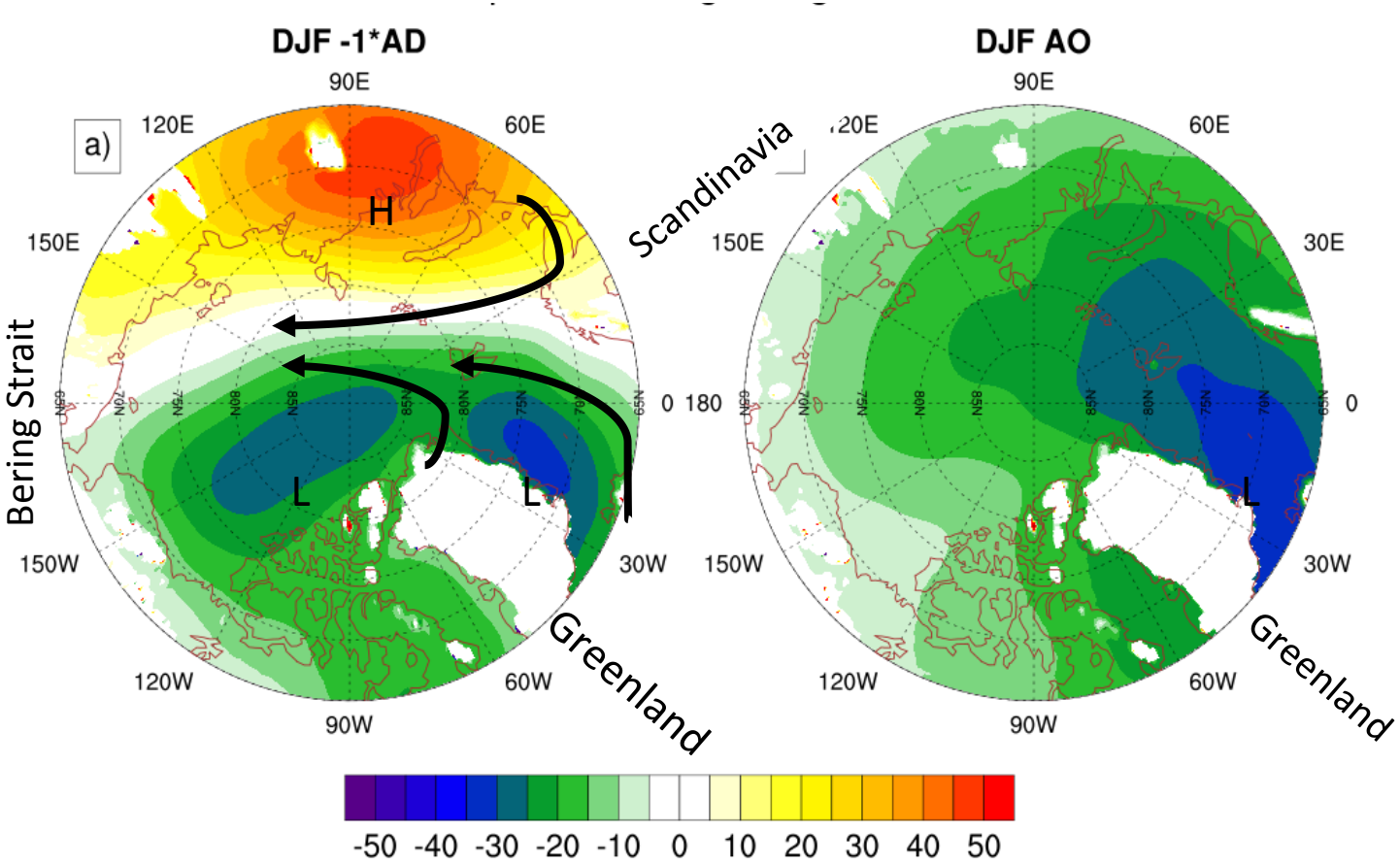
These moisture/warm air intrusions are part of the bimodal nature of net LW fluxes over the Arctic in winter.

What organizes these moisture intrusions over the entire fall and winter season in the Arctic?

Low-Frequency Modes (Monthly Timescales)

Arctic Dipole (AD)

- 2nd EOF in winter
- **Poleward flow across the Atlantic sector of the Arctic associated with a negative AD pattern**



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

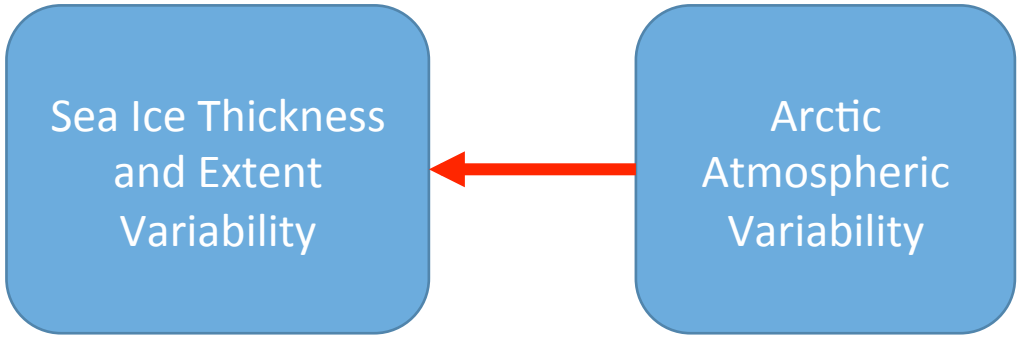
Arctic Oscillation (AO)

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

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



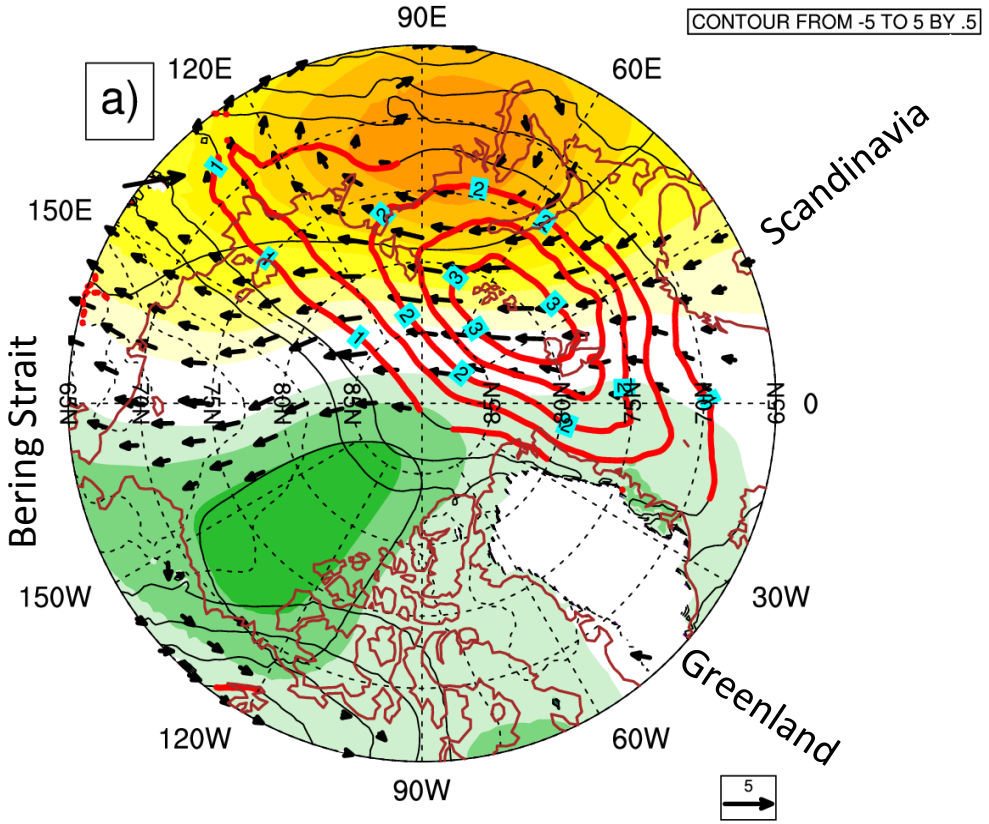
850 mb temperature, wind and geopotential height anomalies associated with AO and AD

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

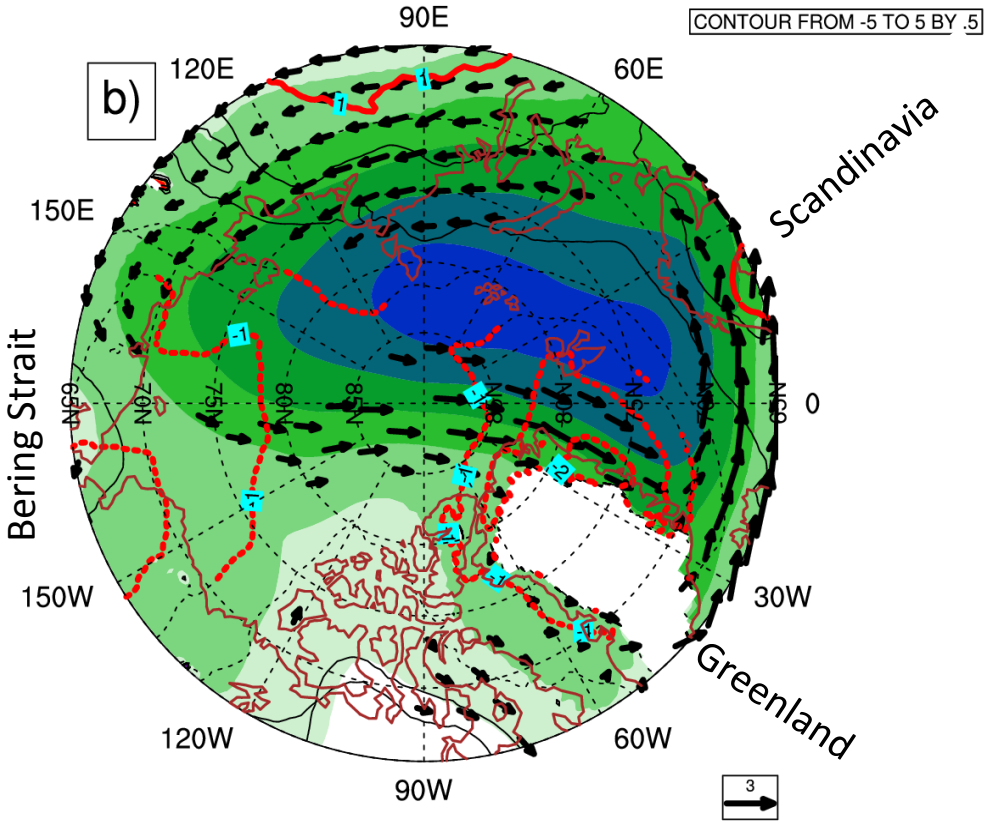
Highlighting and shown vectors: Statistically significant at the 90% level

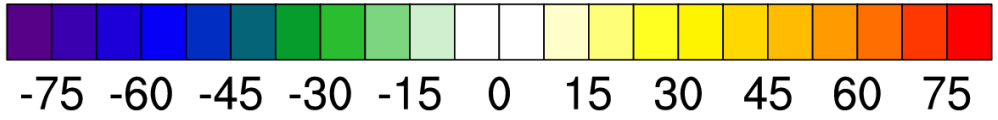
Areas of negative and positive temperature anomalies associated with AD (Atlantic sector) and AO (Greenland, Alaska/E Siberia)

NDJF AD



ON AO



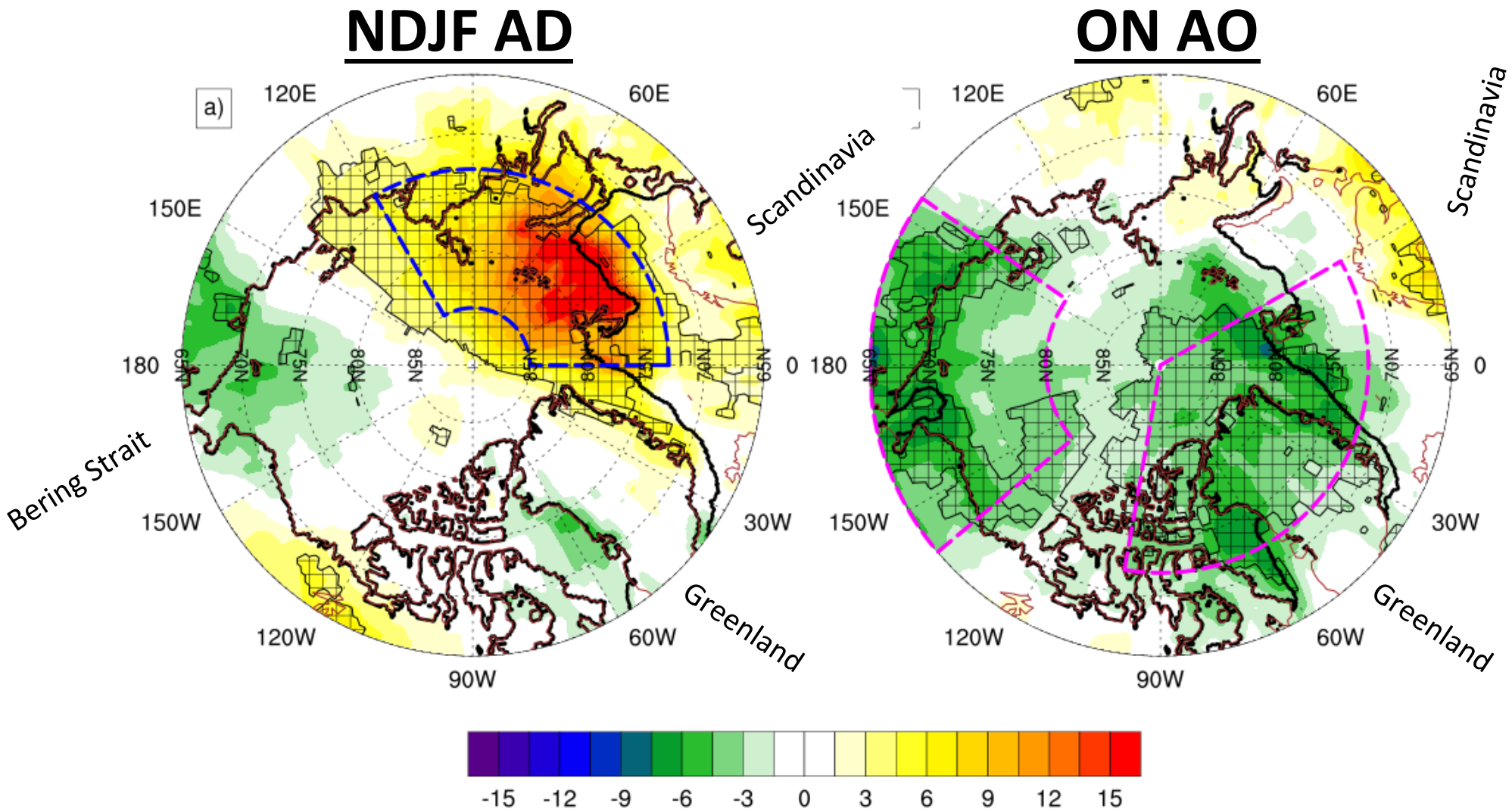


Clear Sky Effects

Positive downwelling clear-sky surface longwave flux anomaly associated with AD across Atlantic sector across Greenland and E Siberia/Alaska.

Downwelling clear-sky LW flux regression (units: W/m^2)

Plotted: Regression of NDJF(DJF) AD index with a) downwelling clear-sky longwave surface flux

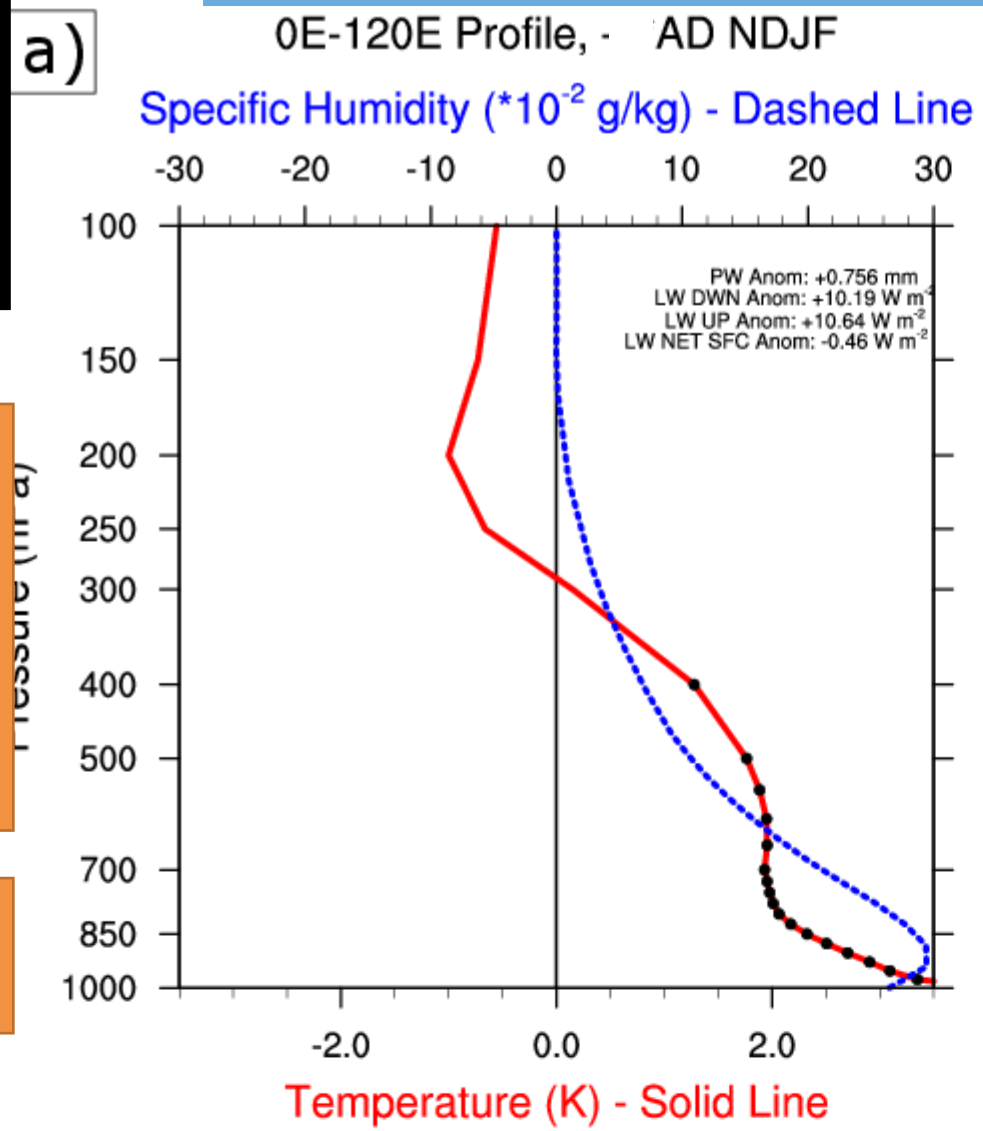


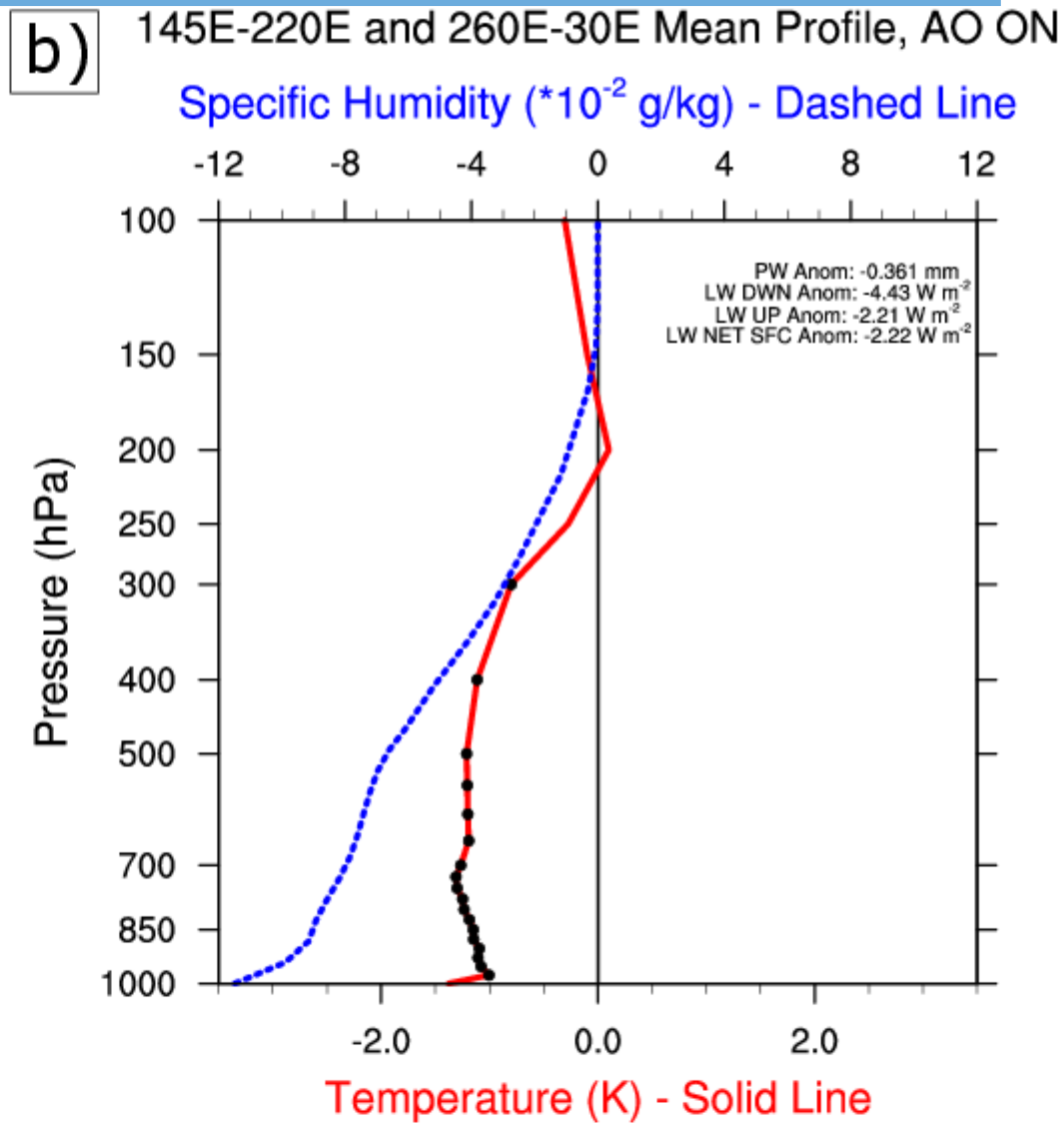
Vertical profile temperature and humidity changes

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





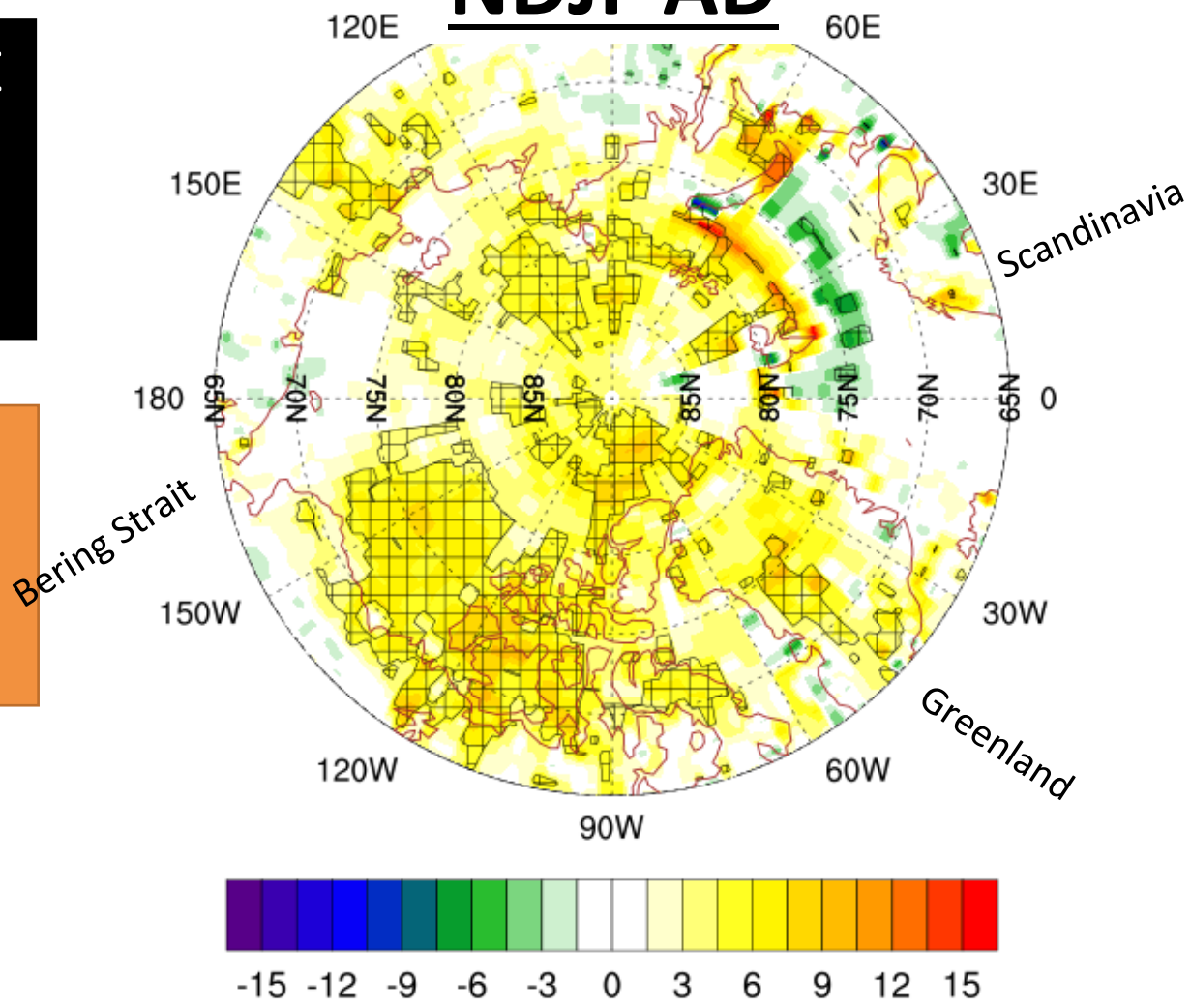
Cloud Effects

Cloud radiative effect changes support positive clear-sky surface flux anomalies in AD case.

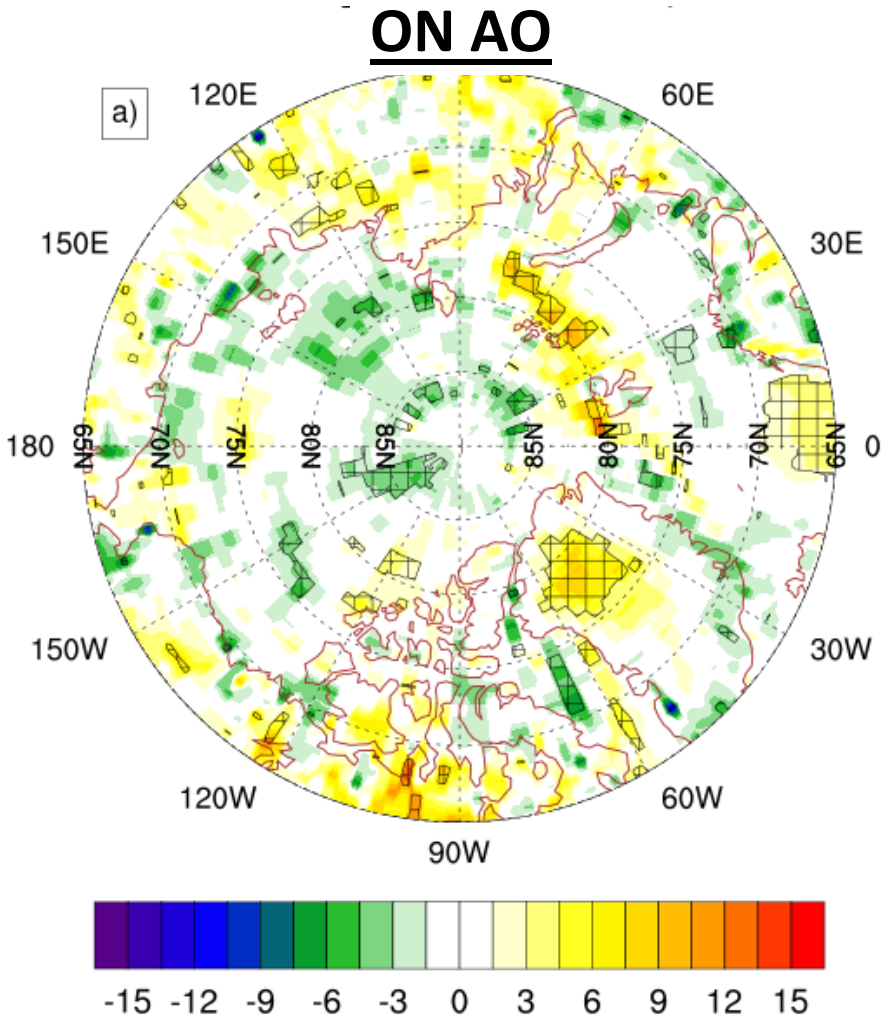
Surface CRE regression (units: W/ m^2)

Plotted: Regression of NDJF(DJF) AD index with LW CRE

NDJF AD



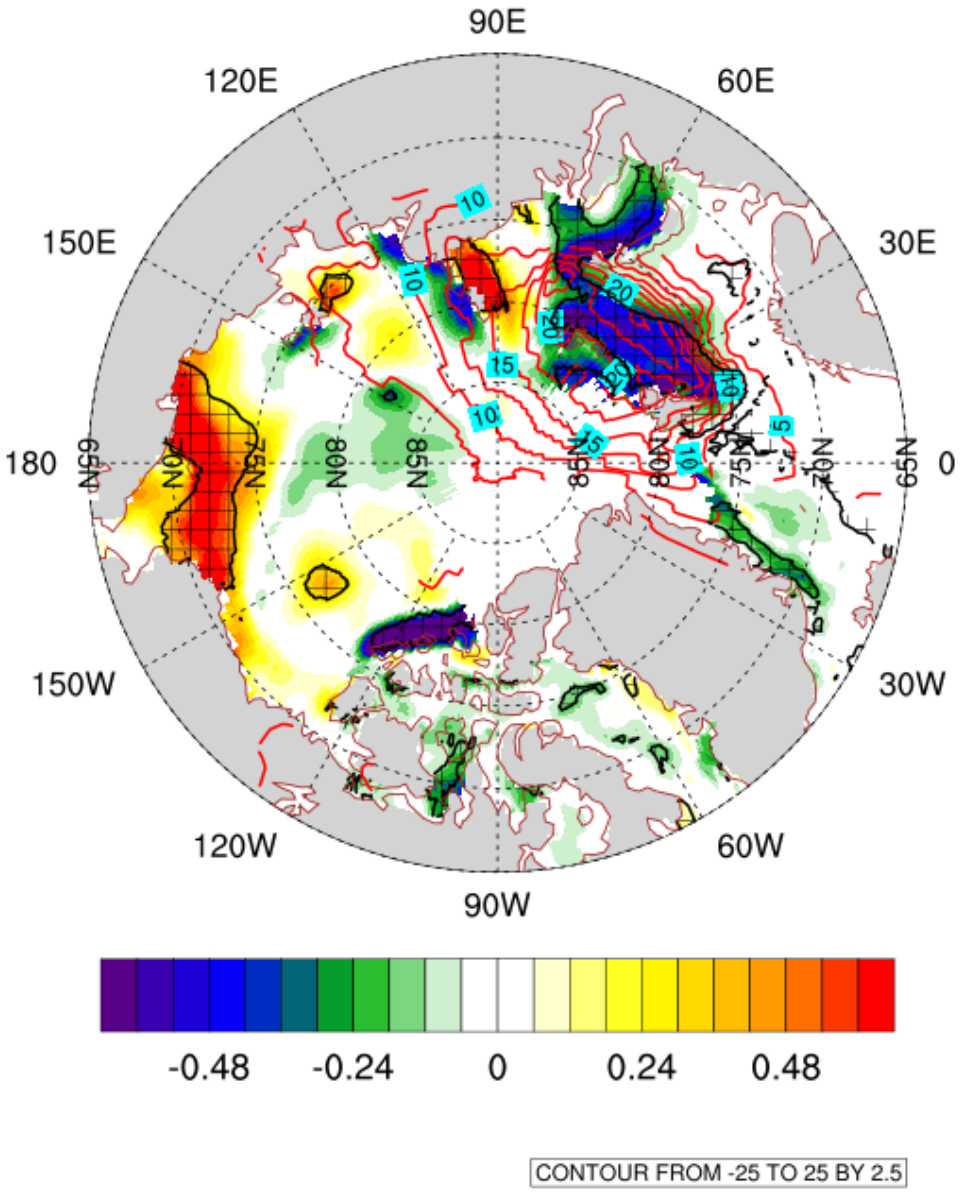
ON AO



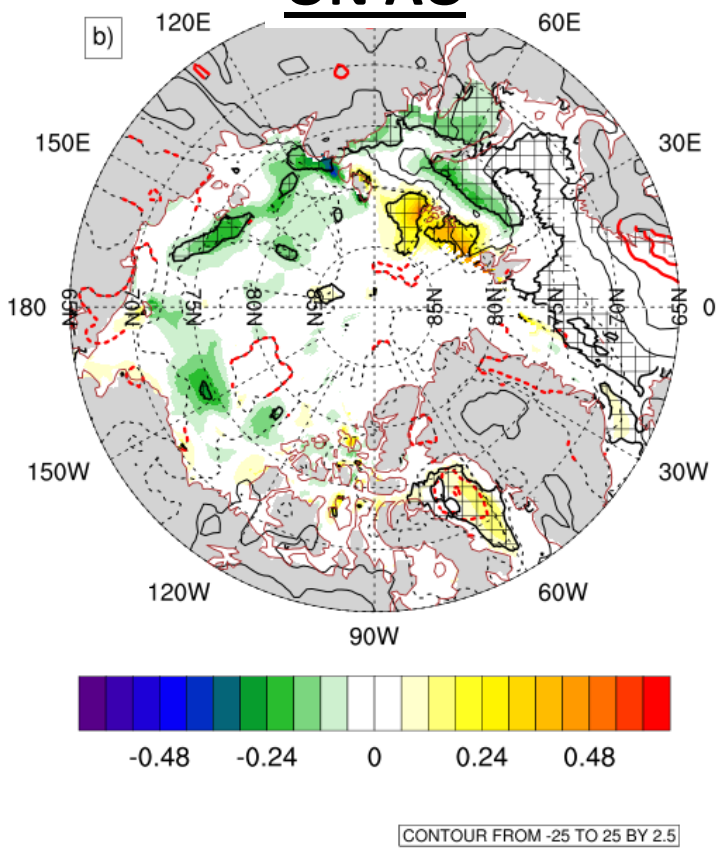
Result for AD: Reduction of sea ice growth from November-December (blue/purple shading) across the same regions where there is an increase in downwelling LW surface flux (contours)

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

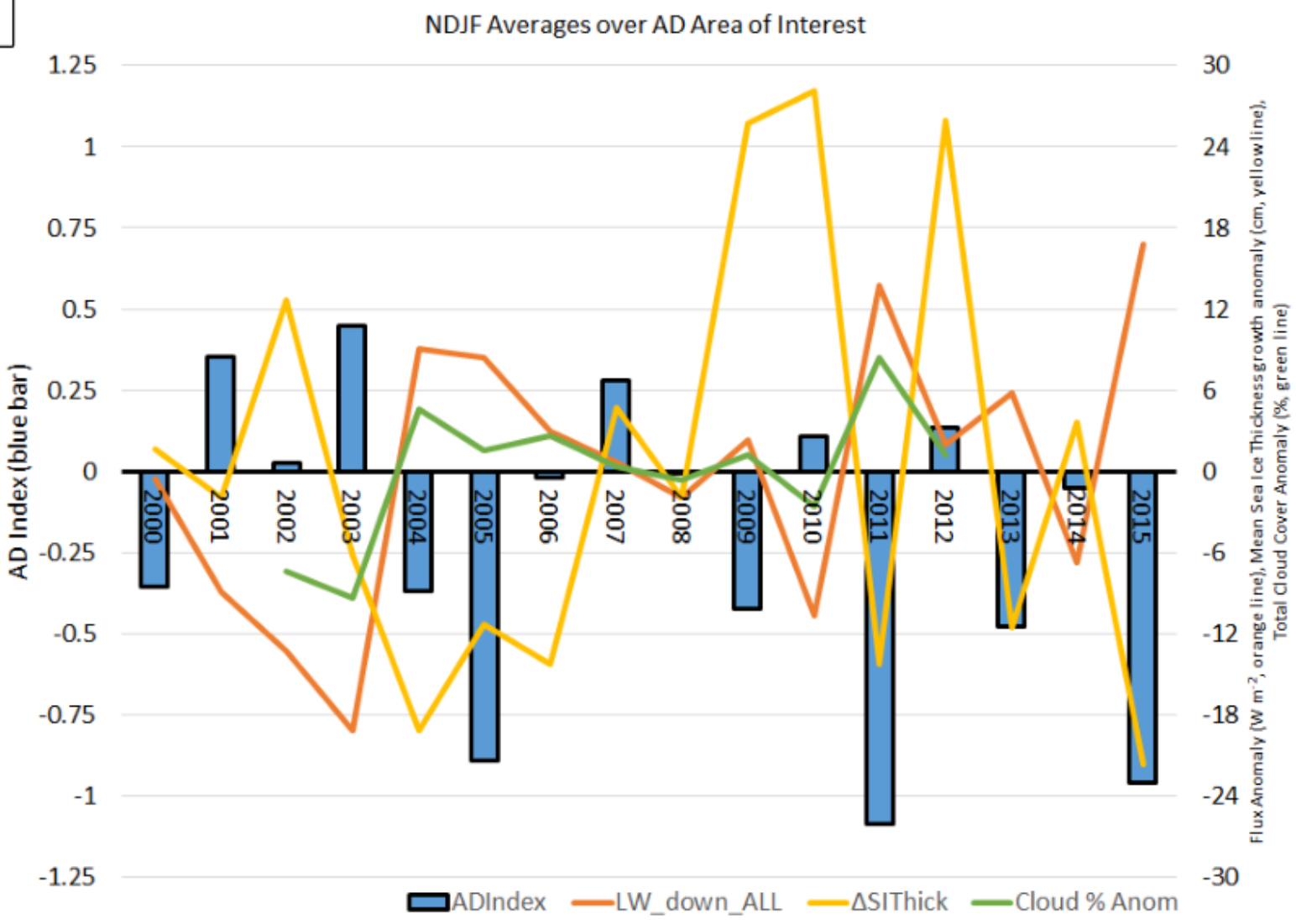
NDJF AD



ON AO



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.**

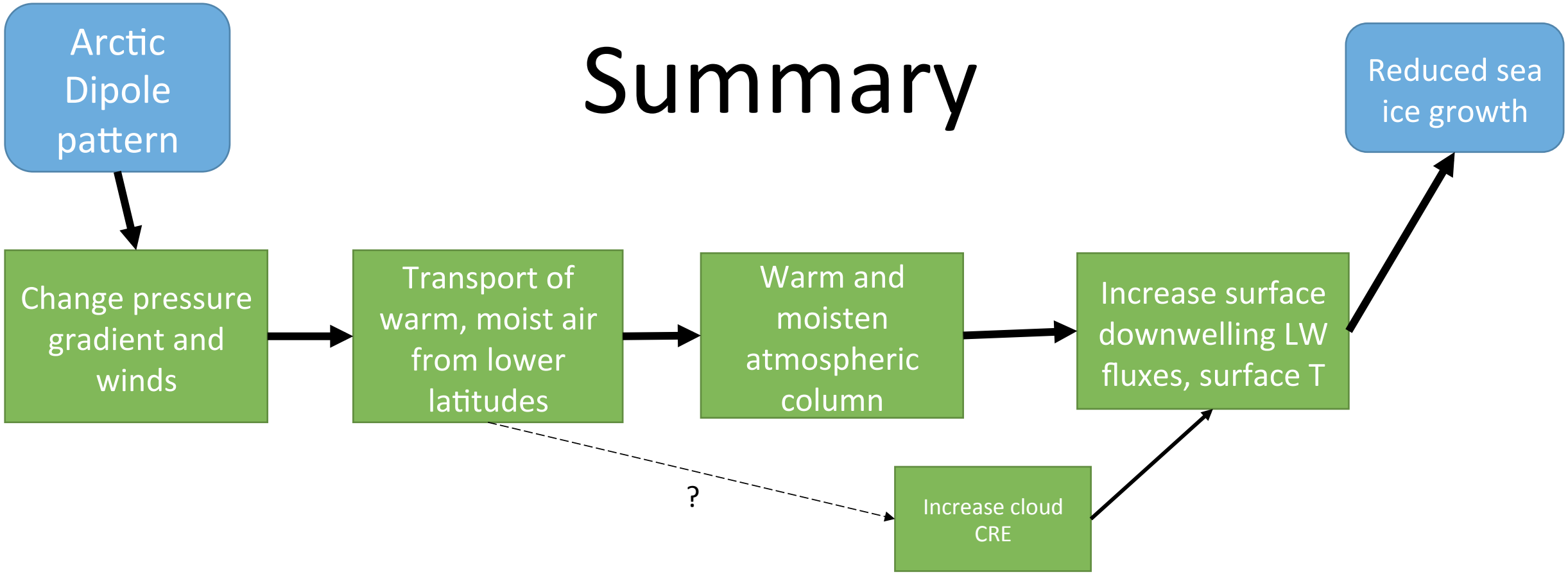
-**Blue bars:** AD index
-**Orange line:** all-sky downwelling LW radiation from CERES-SFC-EBAF
-**Yellow line:** Sea ice volume growth anomaly (PIOMAS data) for November 1- March 1

Correlations

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.