An observational estimate of the influence of Arctic sea ice loss on the atmospheric circulation in the cold season

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Work in Progress

BLUE ACTION

Difficulties with observational estimates of sea ice loss impact

- **Connection** between the observed sea ice loss and the slow atmospheric changes can easily be established, for instance by regression or trend analysis

- **Attribution** is difficult since other variables are also slowly decreasing or increasing (SST, GHG and aerosol concentration, snow cover extent, …)

- **AGCMs** can be used to single out the impact of sea ice loss but may be affected by model biases

- Hence, **attribution** should still be attempted using observations

Our basic assumptions

- The *direct* atmospheric response to the slow Arctic sea ice loss is the same as that to *interannual pan-Arctic* sea ice fluctuations *with identical spatial patterns*

  This disentangles the SIC impact from slow anthropogenic and forced climate variations

  The response to pan-Arctic sea ice patterns differs from cumulative regional effects

- The atmospheric response time is of the order of 1 or 2 months

  Consistent with Deser et al. 2007 and Frankignoul et al. 2014

- The response is sufficiently linear to be estimated by lag regression analysis

- Attribution is derived from multiple regression if there are significant concomitant interannual SST or snow cover changes

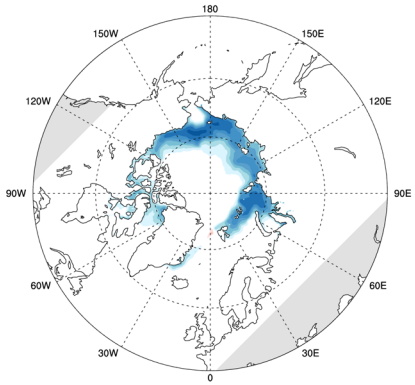
  Often disregarded in previous studies

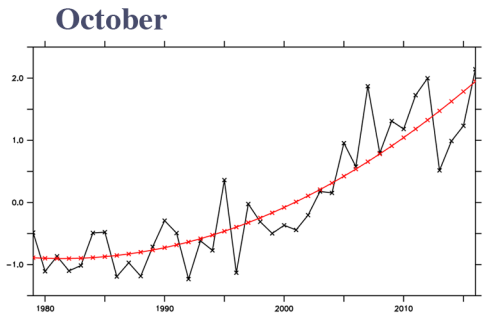
Observational data

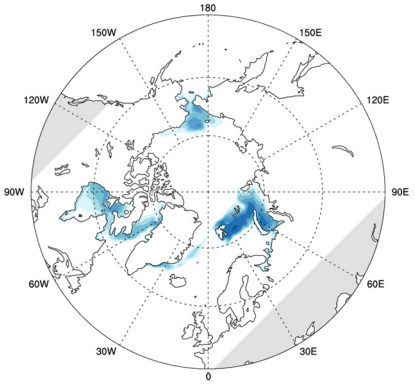
- Monthly sea ice concentration (SIC) from passive microwave measurements 1979-February 2017
- ERA-Interim, HadISST, snow cover from the NOAA/Rutgers University Global Snow Laboratory

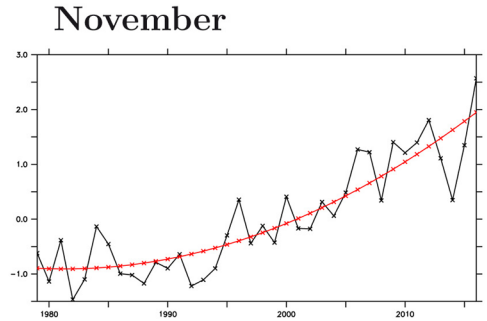
Method

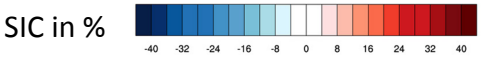
- Determine the main pattern of monthly sea ice loss from EOF analysis
- Represent sea ice loss by quadratic fit; interannual fluctuations are the residual
- Estimate the atmospheric response to the interannual SIC fluctuations
- Estimate statistical significance by controlling the False Discovery Rate
- Determine synchronous interannual SST and snow cover fluctuations. If FDR significant, use multiple regression for attribution

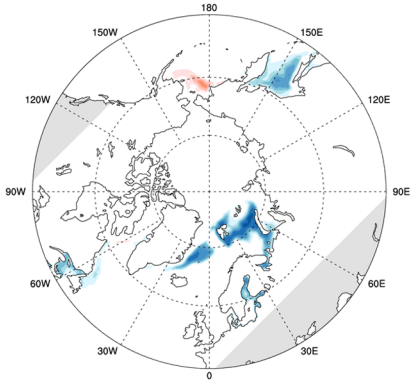


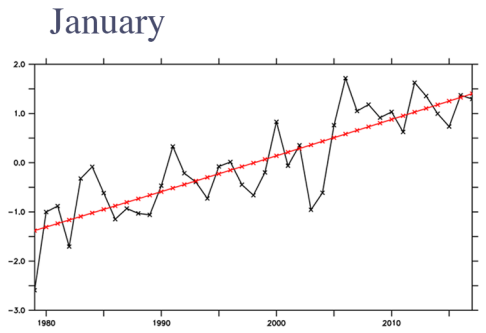








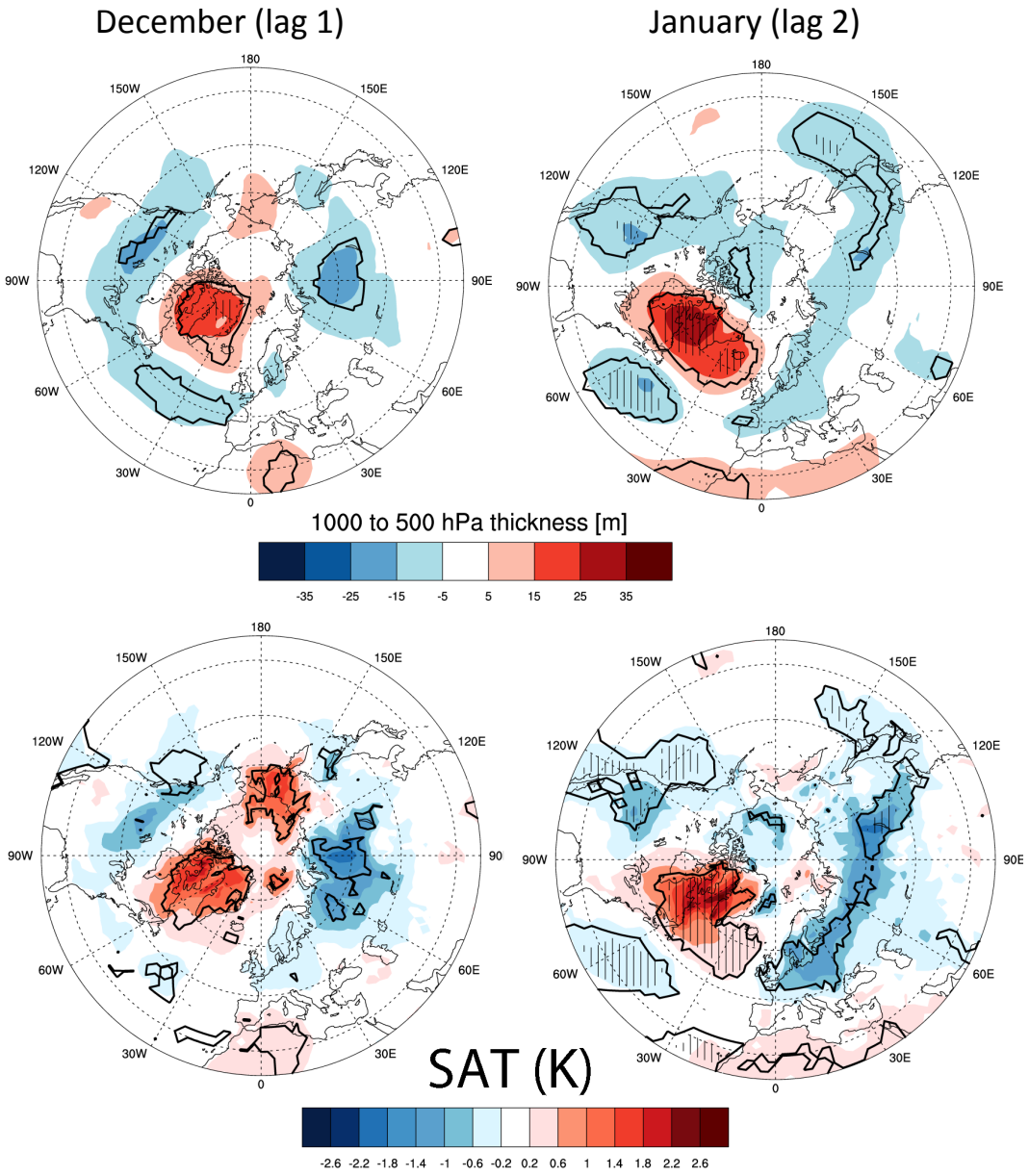




Sea ice loss well represented by first EOF and a quadratic fit to PC1

Removing the quadratic fit leads to interannual to fluctuations of *identical* spatial pattern

Lag regression on interannual SIC fluctuations in November



Warm SAT above SIC at short lag

Some hint of Warm Arctic-cold continent pattern, stronger in January

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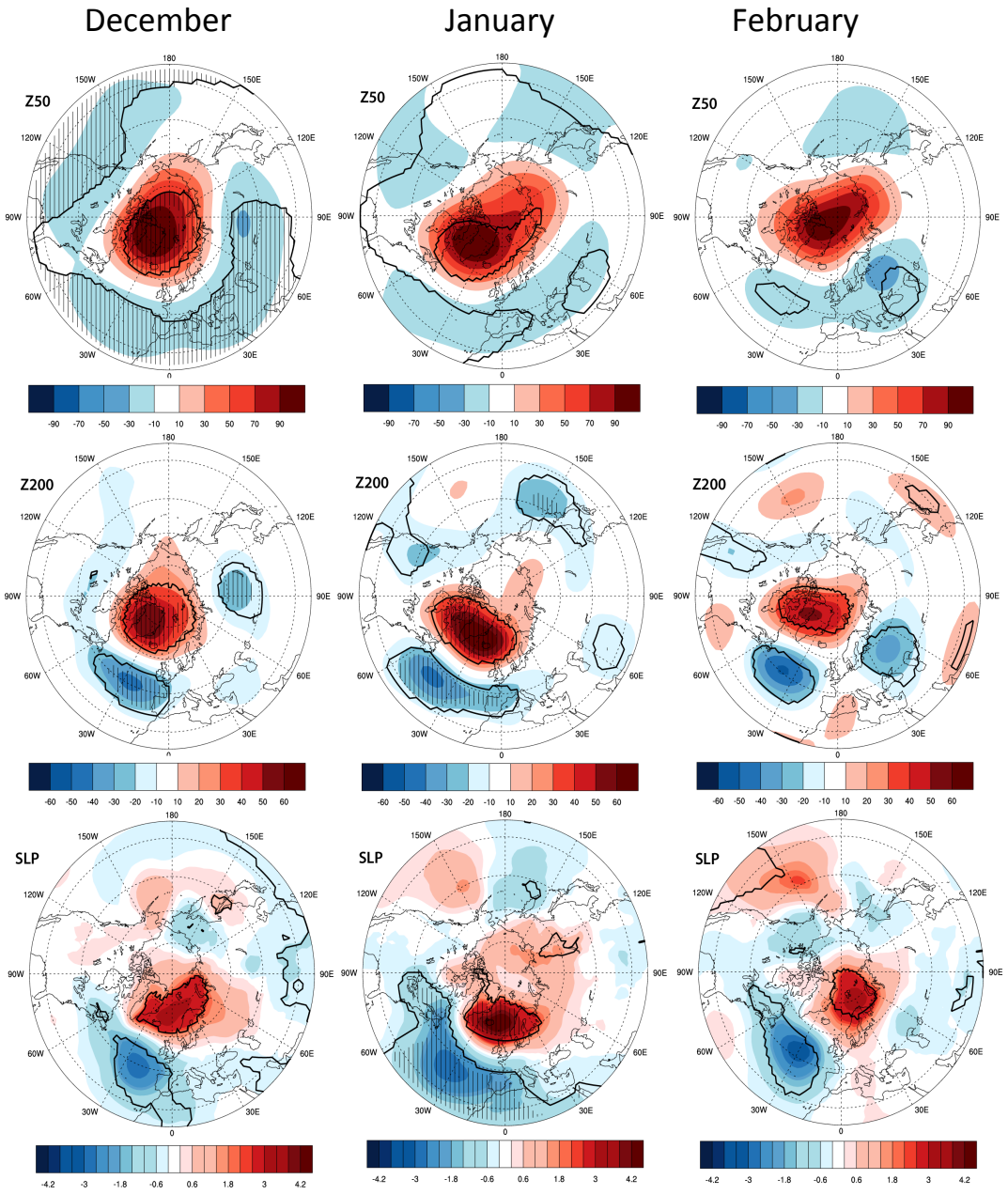


Black line

10% significance

Hatching

FDR of 10%

Negative AO-NAO signal

Field significant in stratosphere/upper troposphere in December

Reaches lower troposphere and maximum amplitude in January (2-month lag)

Weaker amplitude in February

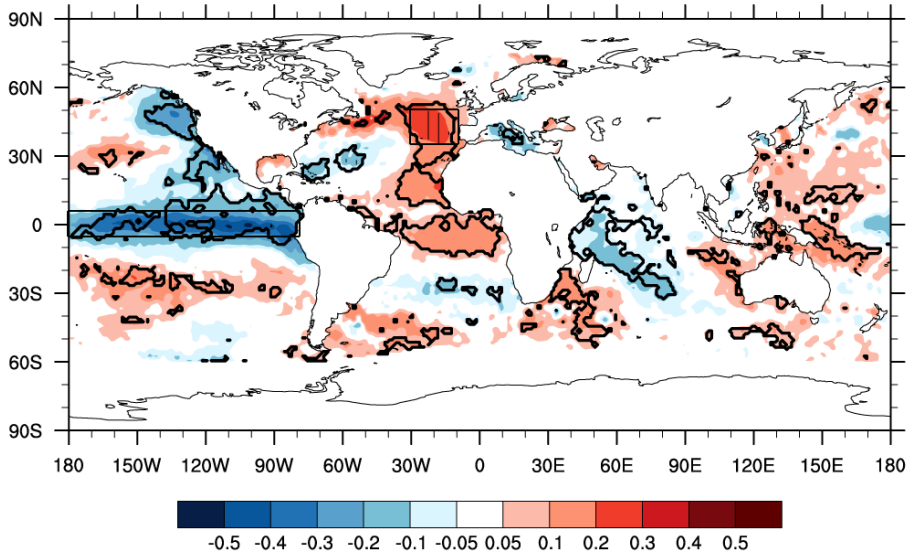
but

signal is stronger and field significant when regressed on December SIC (2-month lag)

Are there concomitant SST and snow cover anomalies in November?

Regression on quadratically detrended

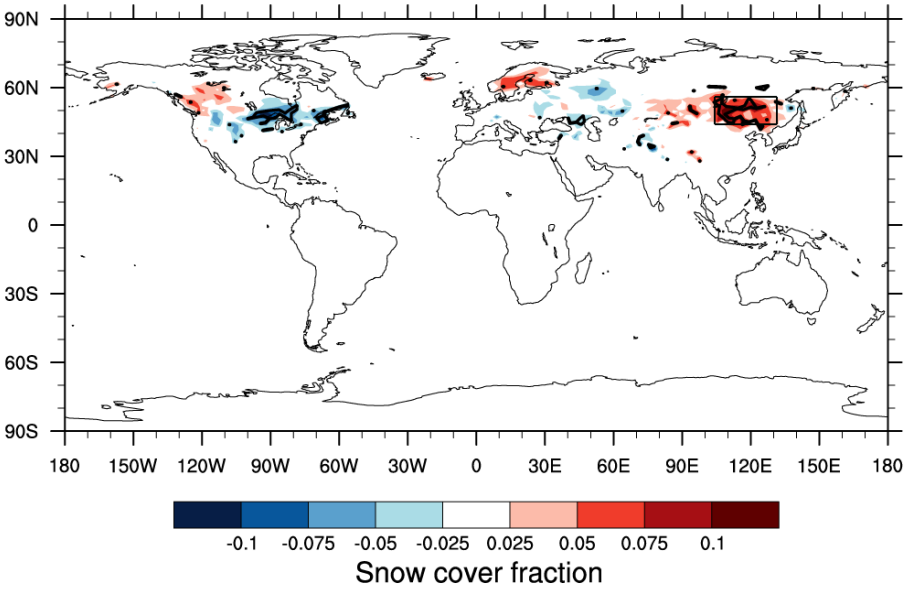
SST



Weak La Nina conditions
with very weak Indian cooling

Warm northeast Atlantic

Snow cover

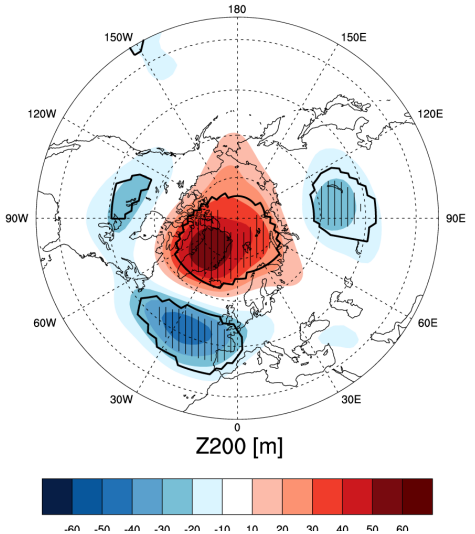


More snow in Siberia
with less in North America

10% significance level

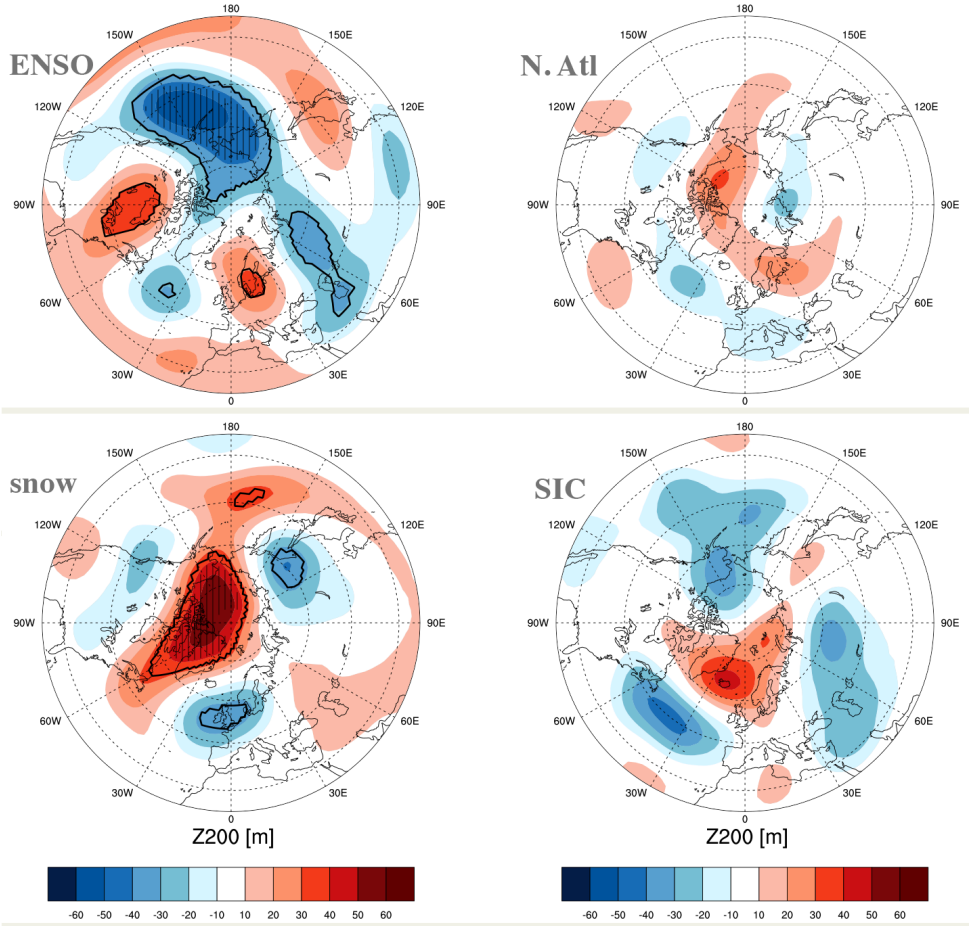
Lag multiple regression of Z200 in December on November time series

Simple regression on SIC



Lag multiple regression of Z200 in December on November time series

Significance estimated by block bootstrap method, 500 permutations



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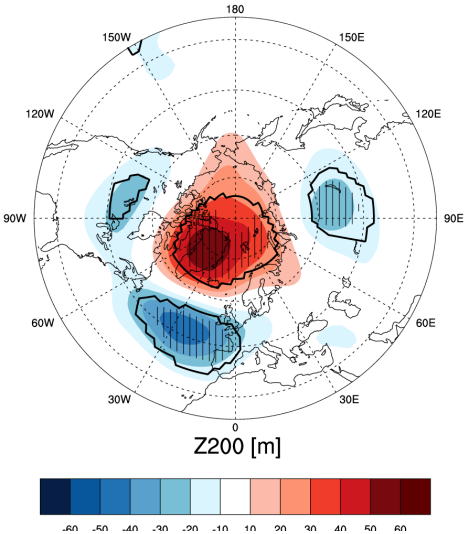


Mostly due to Siberian snow

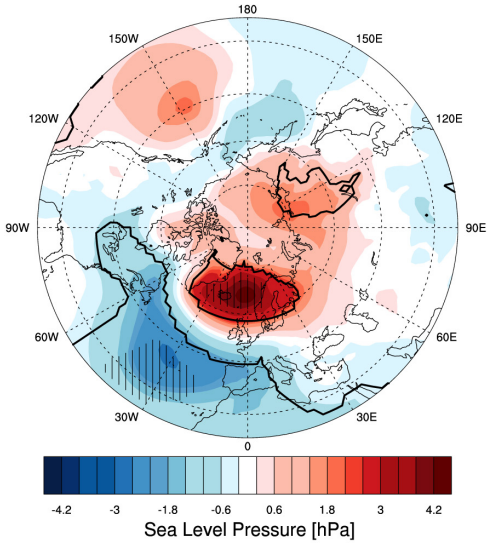
Significant ENSO and Siberian snow cover influence

No significant influence of Arctic sea ice loss pattern

Stratospheric signal due to snow

Lag multiple regression of SLP in January on November time series

Simple regression on SIC



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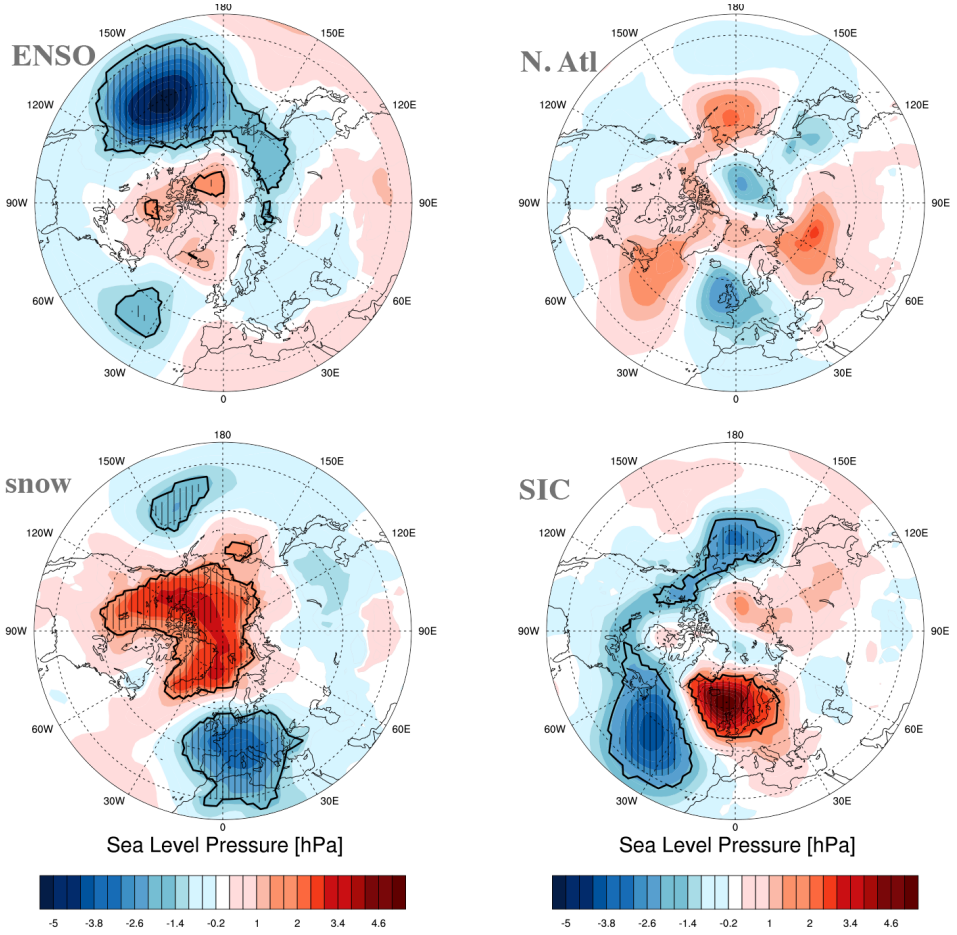

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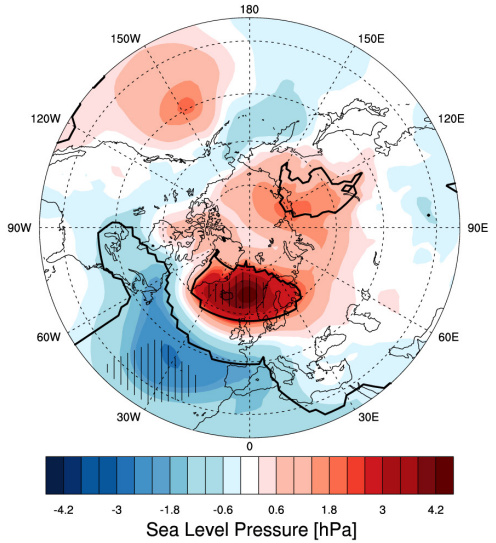

Negative NAO-like signal
is indeed largely due to SIC

Very similar results in February, much weaker signal in March

Conclusions

- Interannual SIC fluctuations with the same pattern as the sea ice loss in November and December are followed by a significant negative NAO-like signals from December to February (weaker in March)

- The December signal is due to Siberian snow cover, but the J, F, M signals are primarily due to SIC

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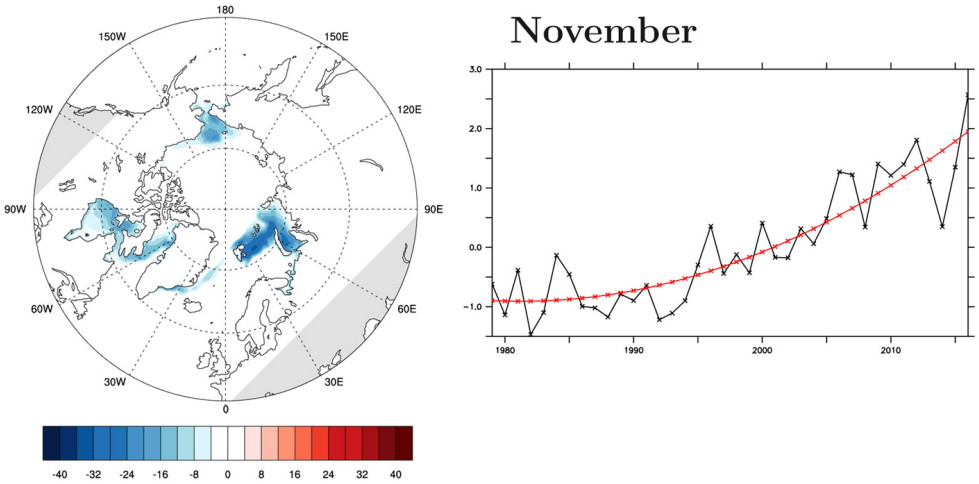
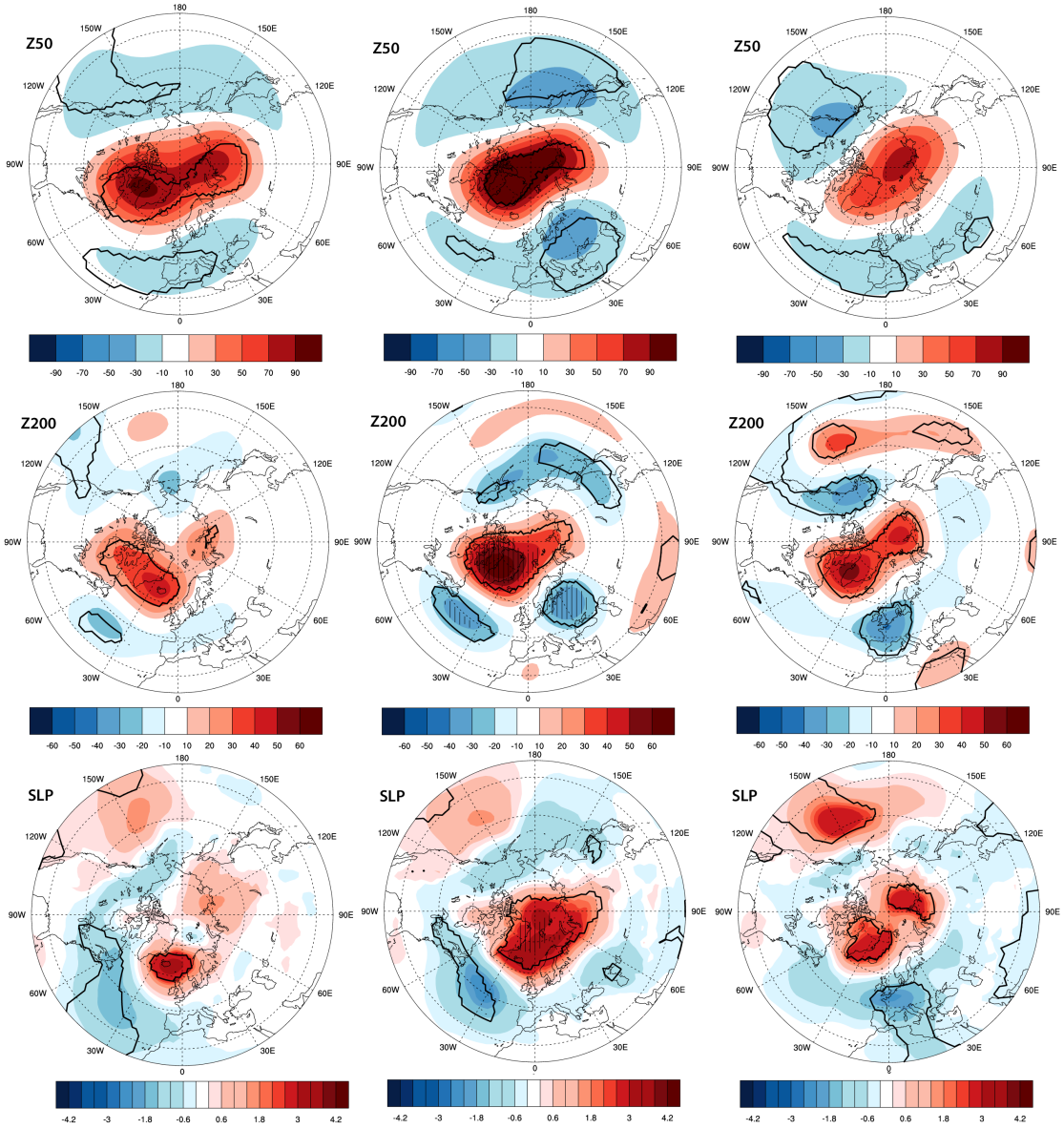


- **Scaling suggests that the sea ice loss from 1979 to 2017 drove a negative NAO signal that increased SLP by about 4 hPa and Z200 by 80 m above Greenland, and decreased SLP and Z200 by a little less above the subtropical North Atlantic**

Lag regression on interannual SIC fluctuations in December

January (lag 1) February (lag 2) March (lag 3)



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