An observational estimate of the direct atmospheric response to the Arctic sea ice loss in the cold season

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Work in Progress

Observational estimates of sea ice loss impacts

- **Connection** between the observed sea ice loss and slow atmospheric changes can easily be established, but **attribution** is difficult since SST, GHG and aerosol, snow cover, …also slowly decrease or increase
- **AGCMs** can be used to single out the direct 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 response is sufficiently linear to be estimated by lag regression analysis

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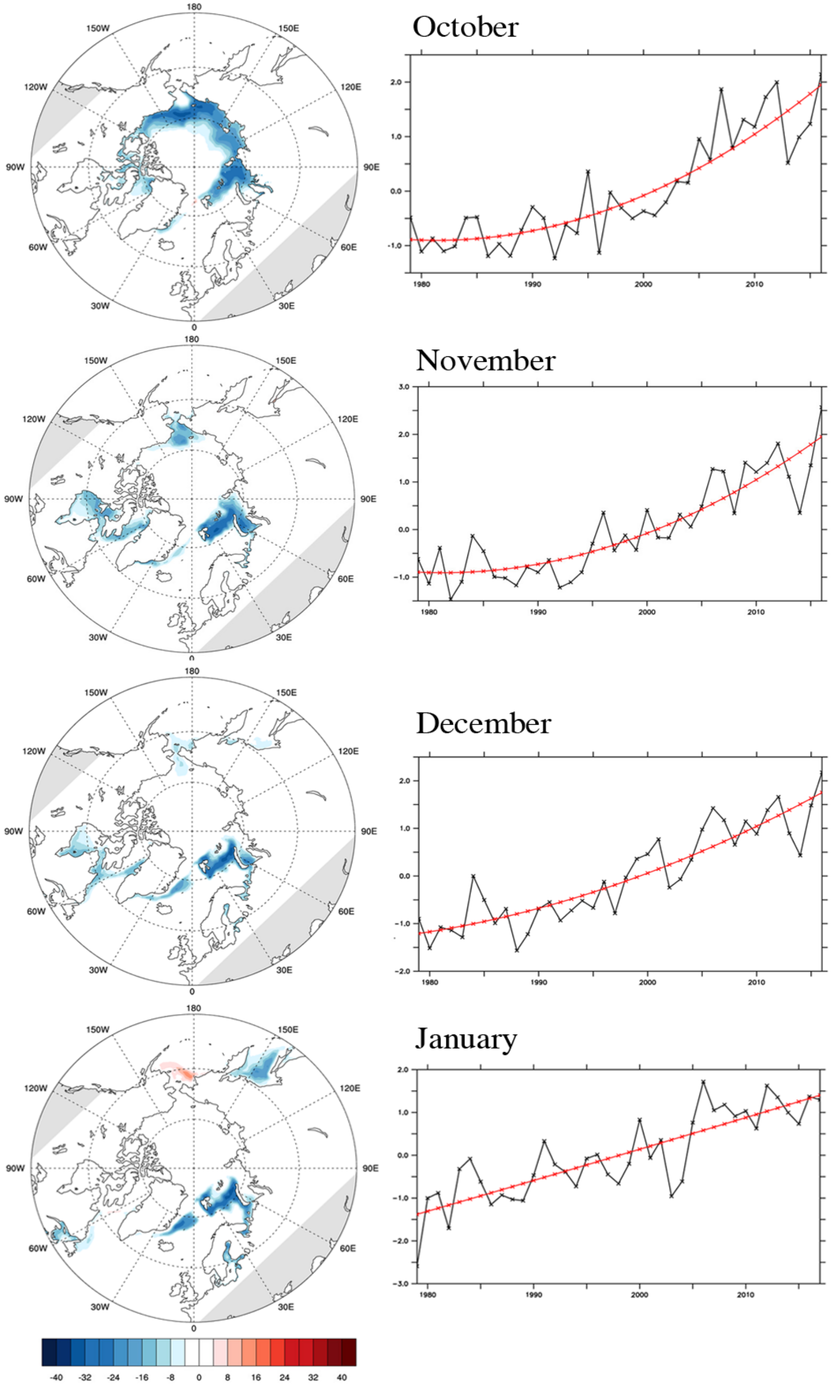
Observational data

- Monthly sea ice concentration from passive microwave measurements **1979-February 2017**

- ERA-Interim, HadISST, snow cover from Rutgers University



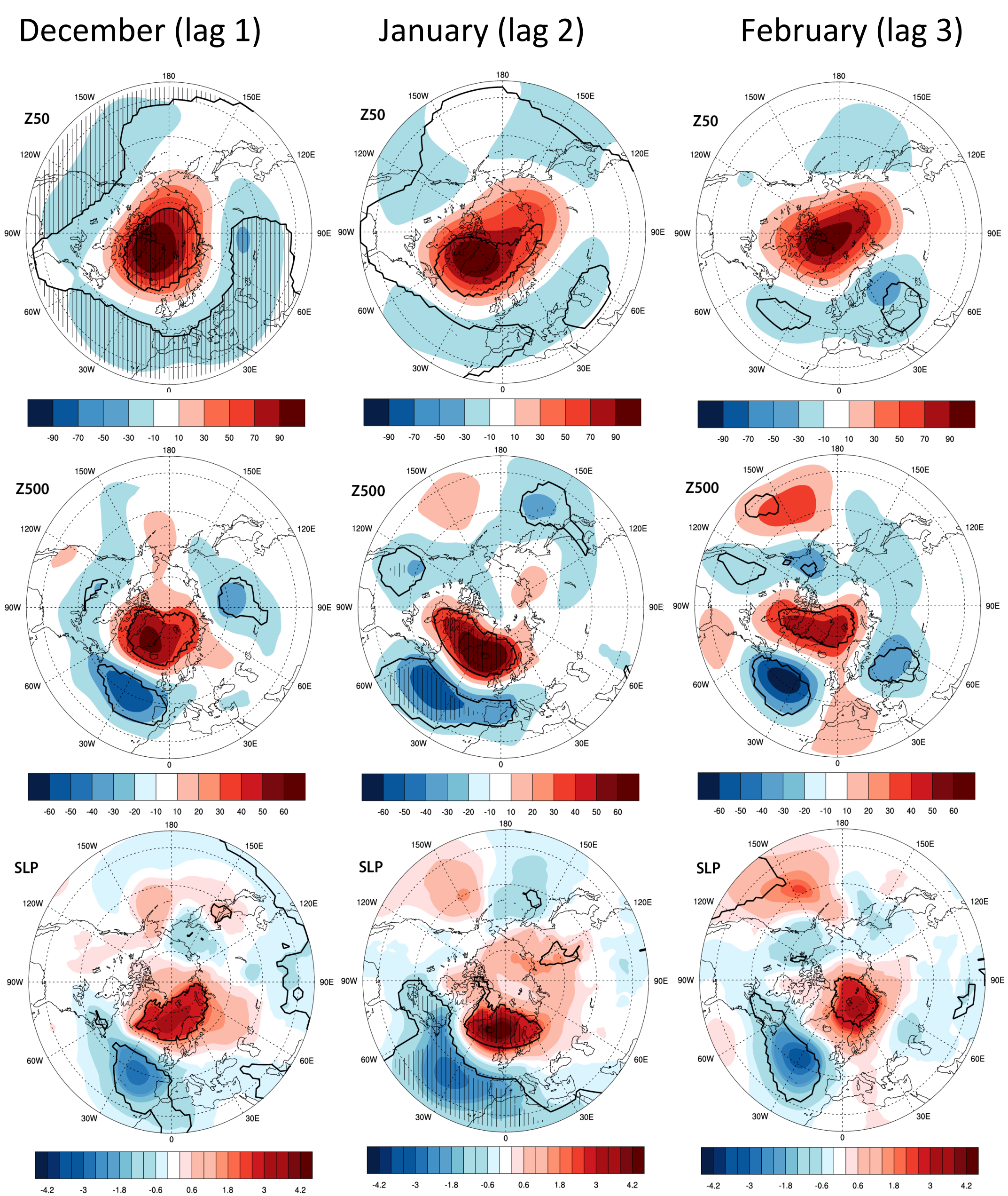
Main patterns of sea ice loss

Sea ice loss is 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 is performed on Interannual fluctuations

Lag regression on standardized interannual SIC fluctuations in November



Black line

10% significance

Hatching

FDR of 10%

Negative AO in the stratosphere
Field significant in December

Negative NAO in the troposphere
Largest and field significant
in January (2-month lag)

Weaker amplitude in February

but

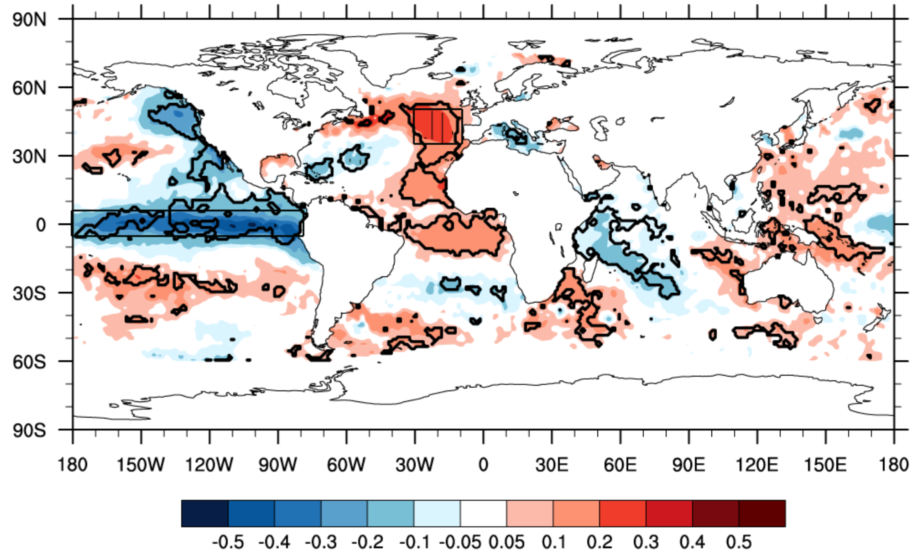
Amplitudes must be divided by 2
for typical SIC changes

February signal is similar and field significant when regressed on December SIC; weaker in March

Are there concomitant SST and snow cover anomalies in November?

Regression of quadratically detrended

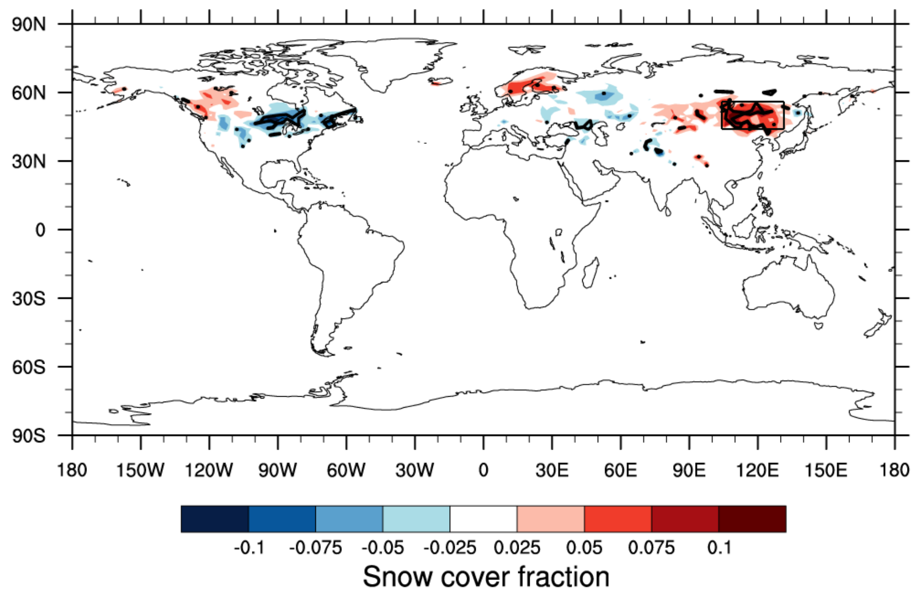
SST



Weak La Nina conditions with very weak Indian cooling

Warm northeast Atlantic (no significant impact)

Snow cover

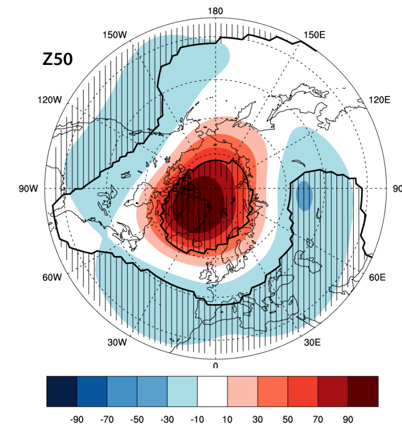


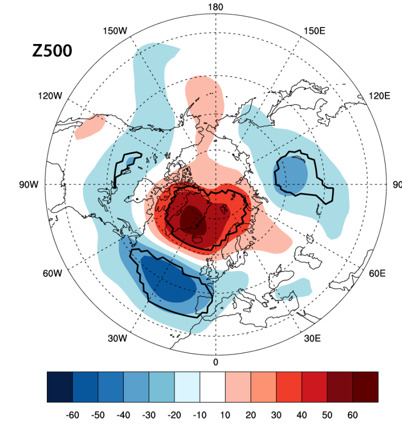
More snow in Siberia with less in North America

Multiple regression on 3 indices (SIC, equ. Pac. SST, Siberian snow)

Multiple regression in December on 3 standardized indices in November (lag 1)

Simple regression





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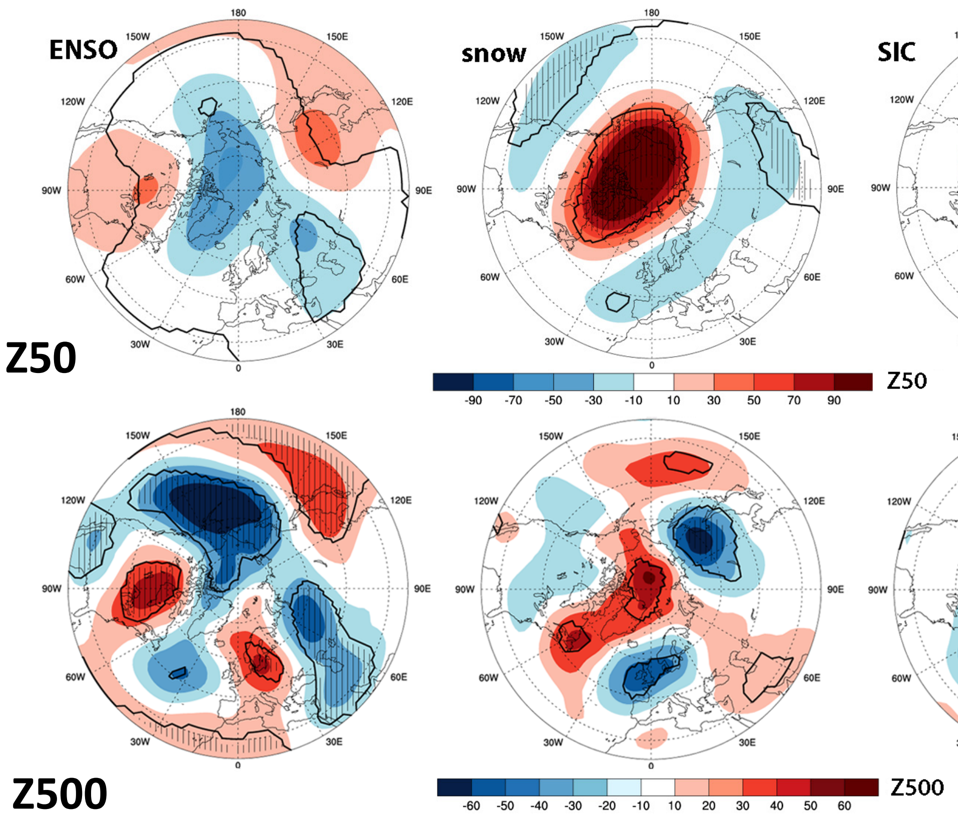
Statistical significance estimated by block bootstrap method 500 permutations



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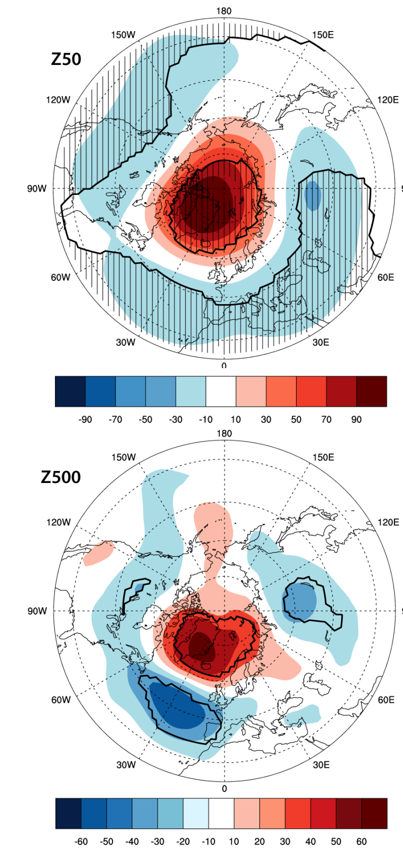

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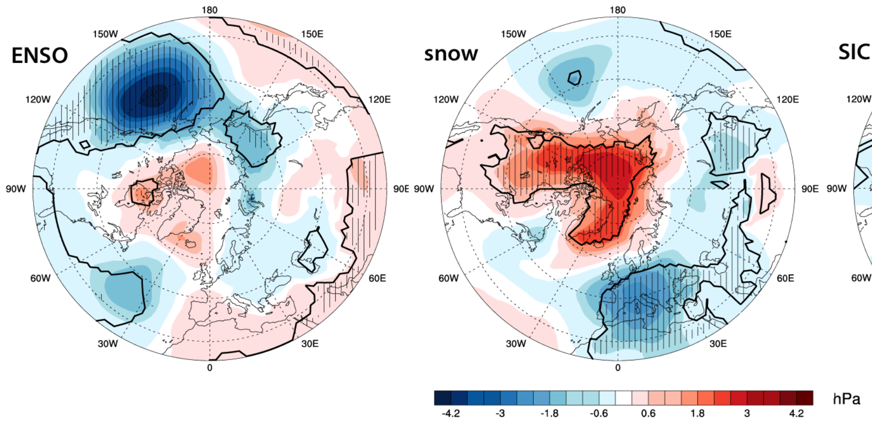
Stratospheric AO- signal is due to synchronous Siberian snow cover increase

Tropospheric NAO- signal is mostly due to SIC

Multiple regression in January on 3 standardized indices in November (lag 2)

SLP



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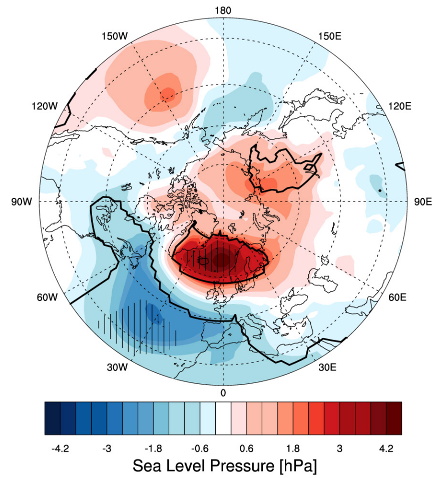

Negative NAO signal in January is largely due to SIC variability

Multiple regression in January on 3 standardized indices in November (lag 2)

Simple regression

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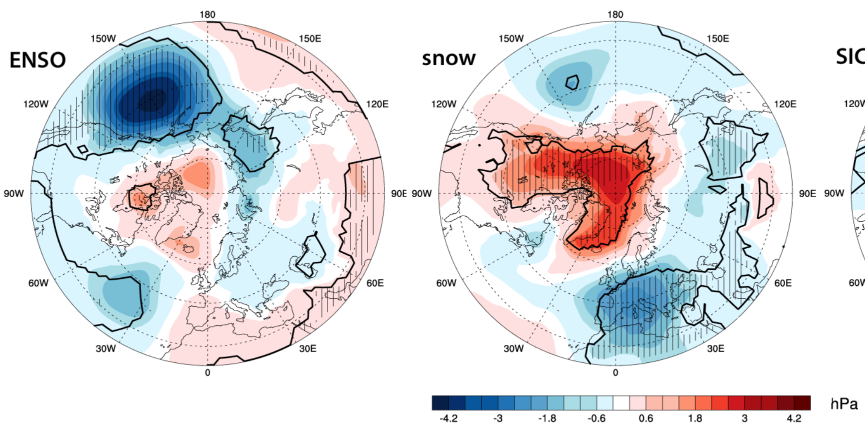

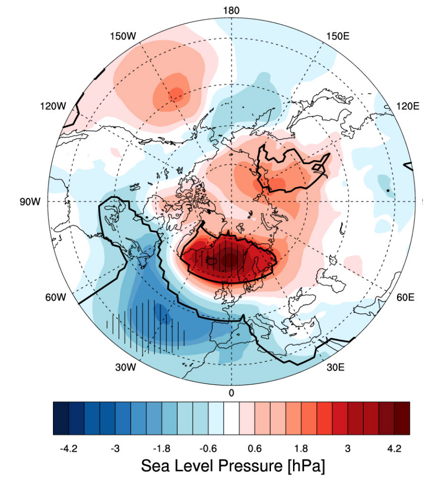

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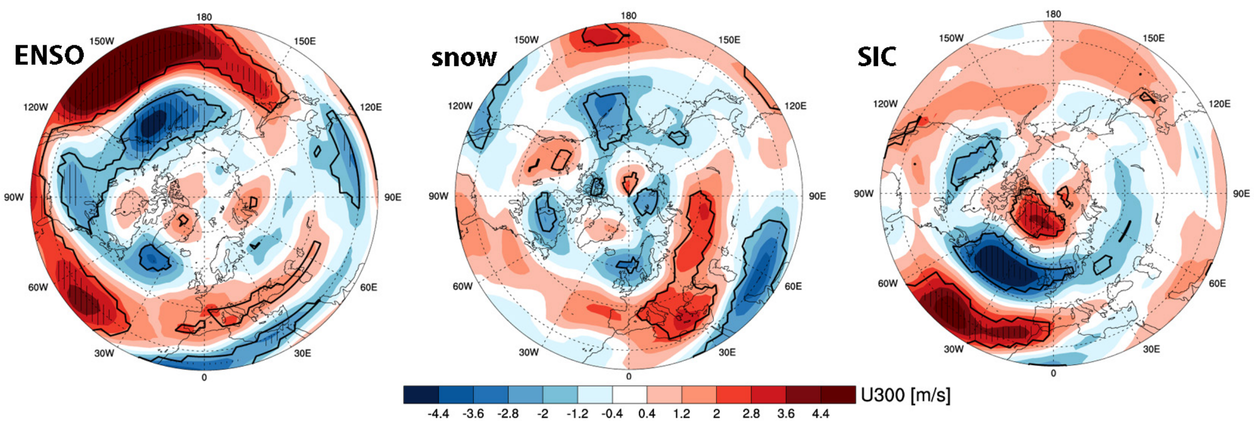
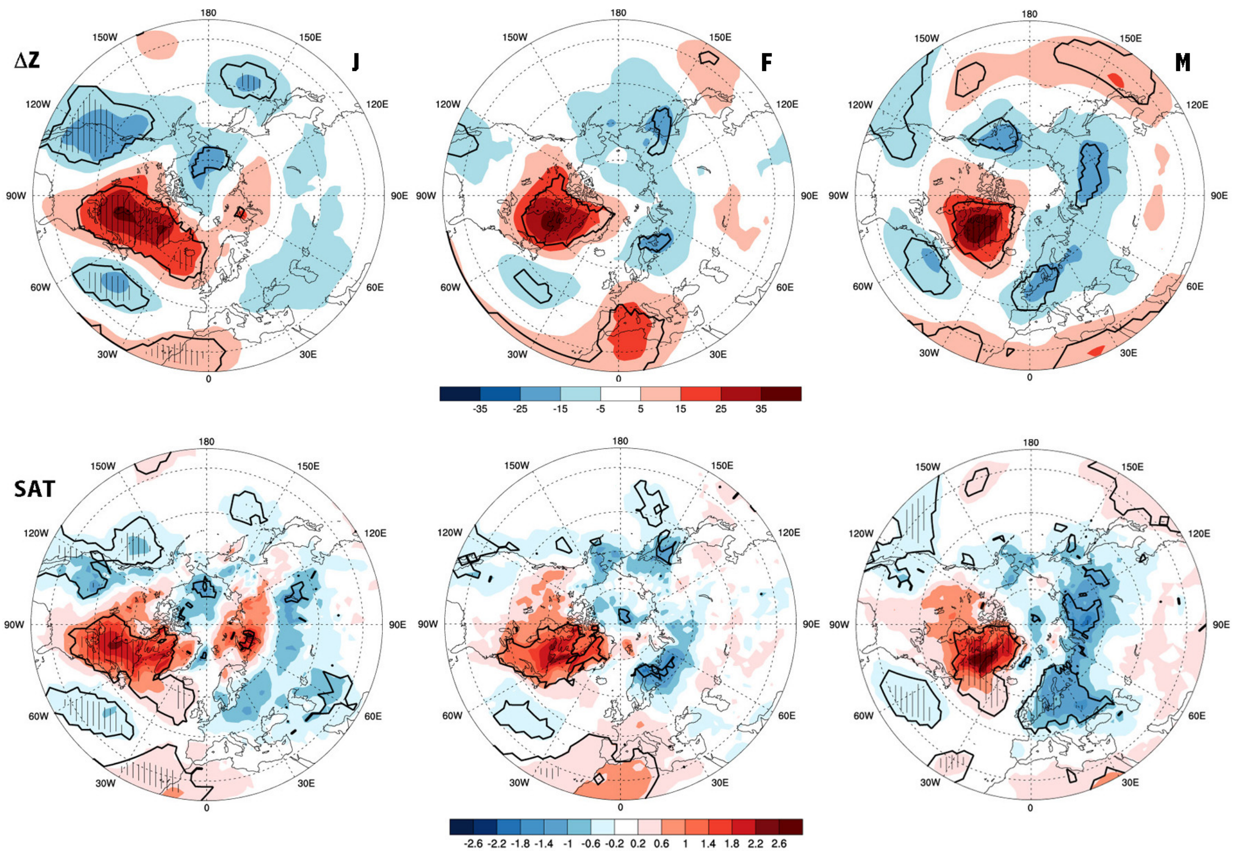


Negative NAO signal in January is largely due to SIC variability

Southward shift on the tropospheric jet in the North Atlantic sector

SAT and 1000-500 hPa thickness response to standardized SIC fluctuations

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



In addition, warm SAT above SIC retreat at lag 0 and, less, at lag 1

No evidence of warm Arctic cold Eurasia (WACE), except perhaps in March

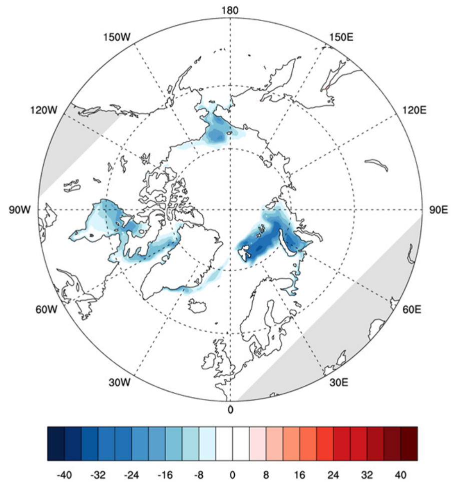
(stronger influence of Siberian snow)

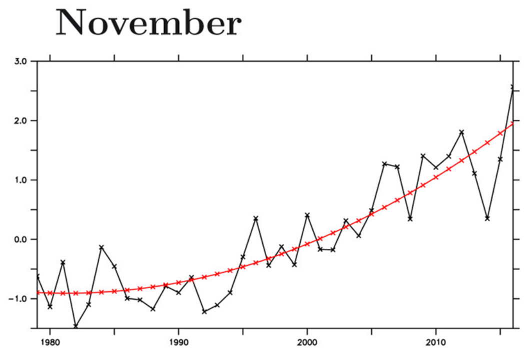
Response estimated by multiple regression (similar to regular regression)

Significant warming in northeast America, weak cooling in March in northern Europe

Estimation of the direct atmospheric impact of the sea ice loss

Assuming that the direct response to the sea ice loss is given by that to the interannual fluctuations, scaling leads to a strong estimated impact between 1979 and 2016





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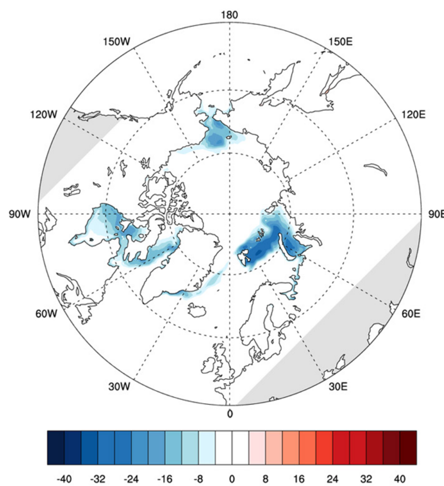

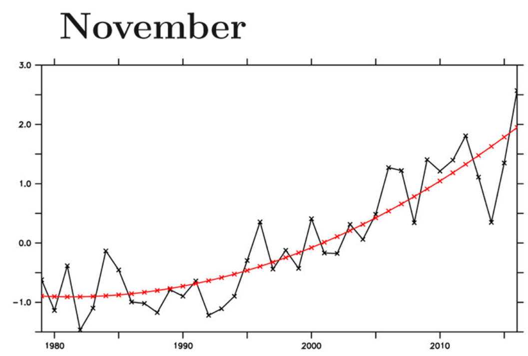

- **The NAO has become more negative**
- Z500 has increased in January and February by up 65 m over the subpolar gyre and decreased by 40 m in the subtropical North Atlantic
- **SAT has increased by up to 2.5 K in northeastern North America**
- SAT has decreased in March by up to 2 K over northern Europe
- No impact on WACE, except perhaps in March

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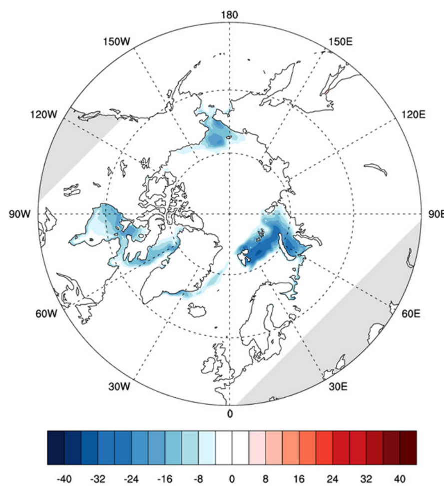

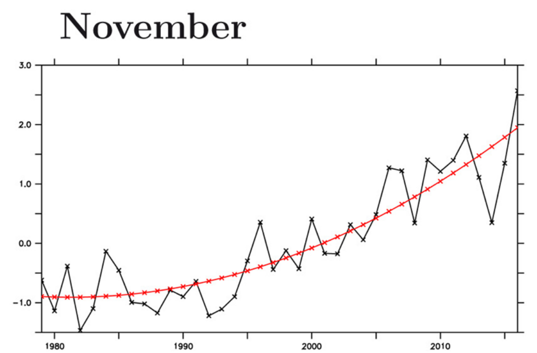

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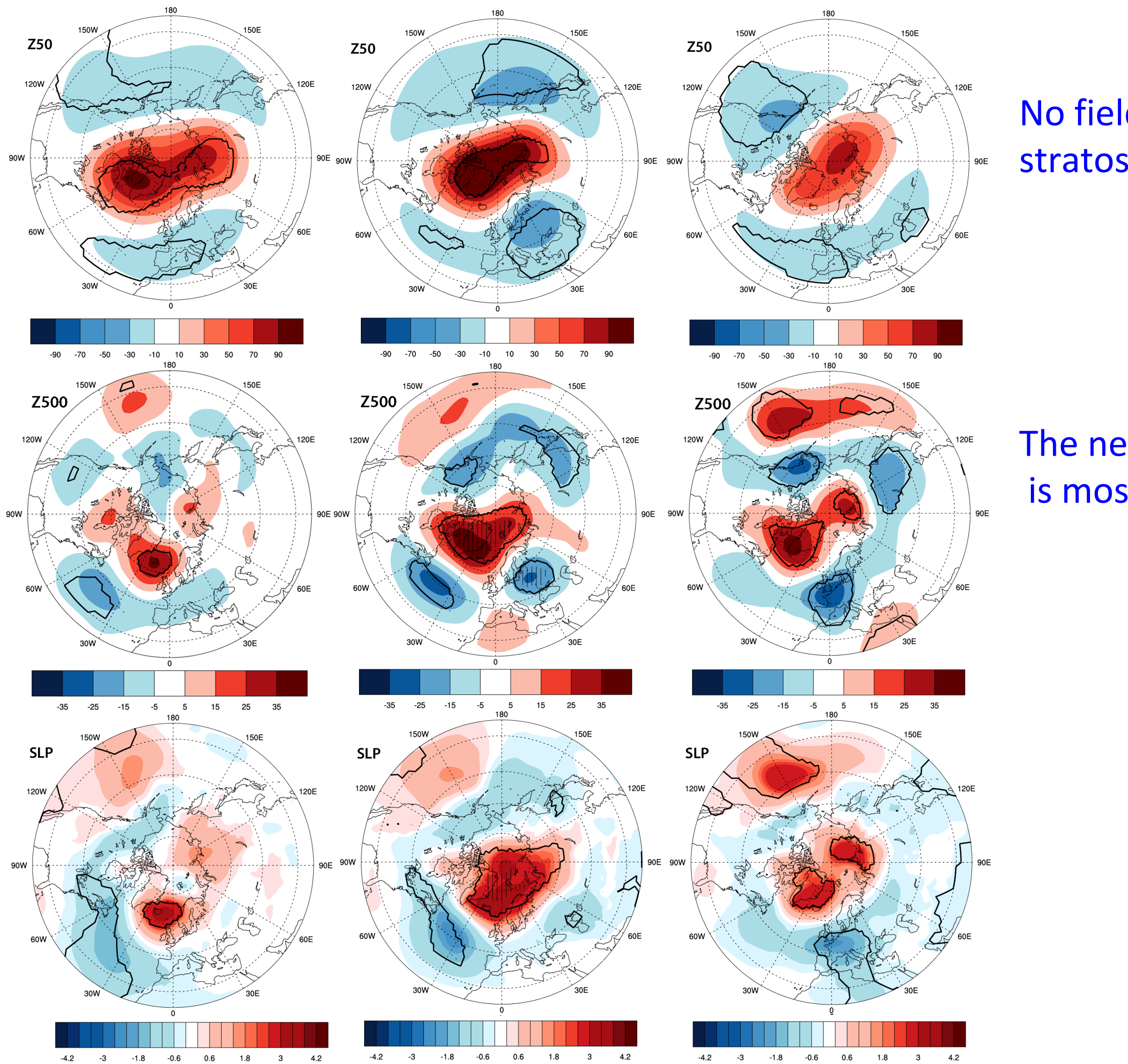
Such large changes are masked by the response to increasing GHG concentration, SST, decreasing snow cover and indirect sea ice influence

Lag regression on standardized interannual SIC fluctuations in December

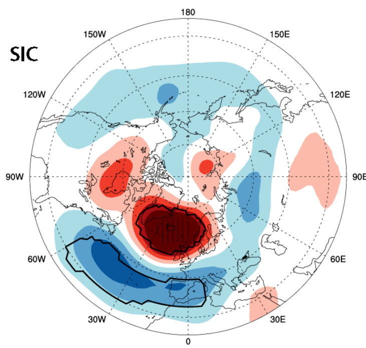
January (lag 1) | February (lag 2) | March (lag 3)



No field significant stratospheric signal

The negative NAO is mostly due to SIC

Multiple regression in January on SIC



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Summary

- Interannual SIC fluctuations with the sea ice loss pattern are followed by a NAO- from December to March (stronger in January and February)

- The stratospheric AO- signal is primarily due to Siberian snow cover

  (the sea ice loss influences the wintertime atmospheric circulation primarily via tropospheric processes; the maximum response is found at 2-month lag)

- There is a fast warming above sea ice retreat ns a warming of northesastern North America, but the WACE pattern is not due to the sea ice loss, except perhaps in Martch

Summary

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

- The stratospheric AO- signal is primarily due to Siberian snow cover

  (the sea ice loss influences the wintertime atmospheric circulation primarily via tropospheric processes; the maximum response is found at 2-month lag)

- There is a fast warming above sea ice retreat, but no clear evidence that the WACE pattern is due to the variability of the sea ice loss pattern

  (WACE seems to be in part driven by a sea ice seesaw between the Barents-Kara Seas and the Greenland Sea, see Mori et al. 2019, not by the *overall* SIC decrease)

- No significant large-scale impact was found in October and November

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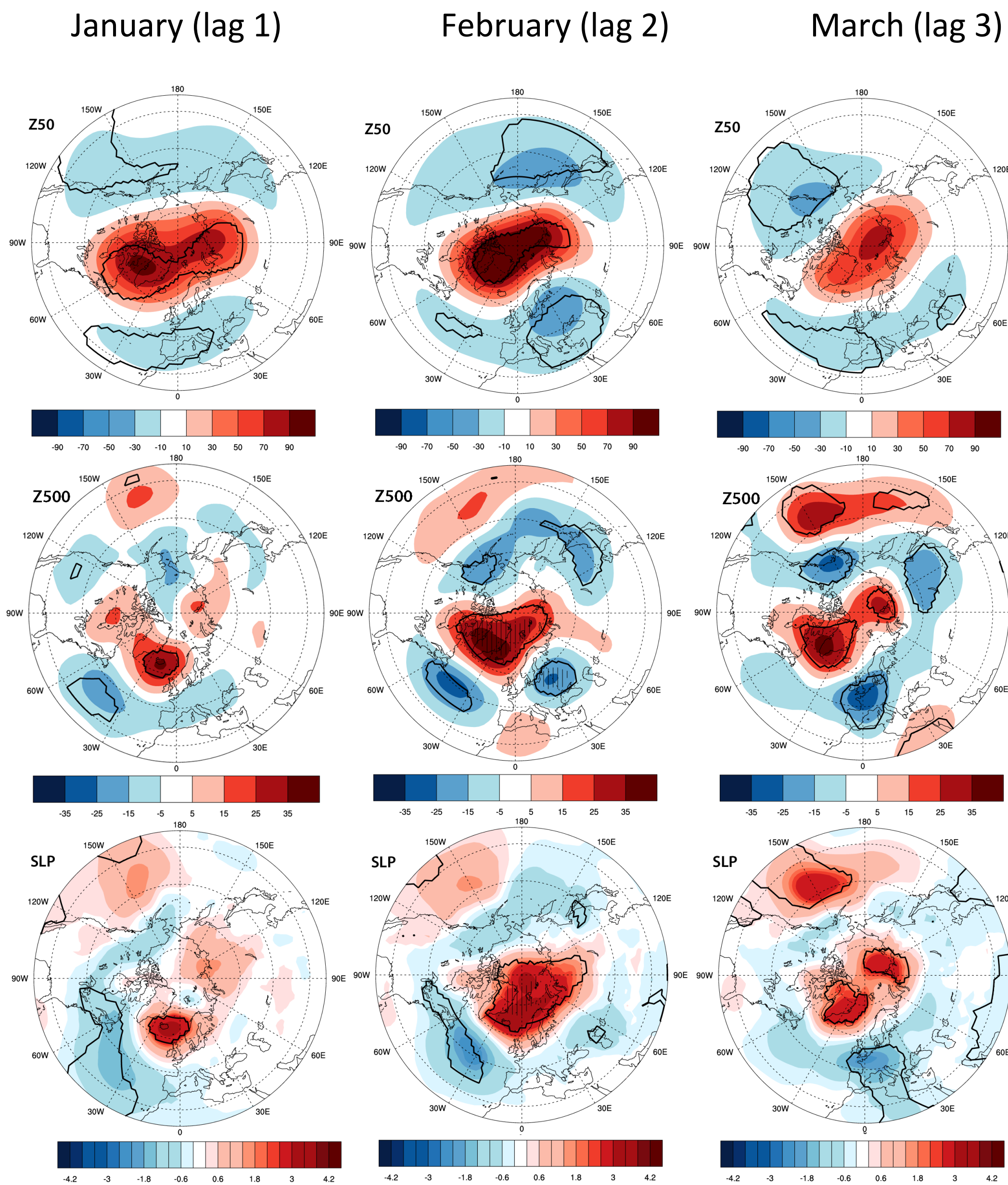

No field significant stratospheric signal

Clear NAO-tropospheric signal (strongest at lag 2)

Black line

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Hatching

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