The influence of Arctic sea ice loss on mid-latitude climate in the cold season

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Context

Since 1979, satellite observations have shown a rapid decline of the Arctic sea ice extent (SIE) and these trends might continue in response to increased greenhouse gas concentrations. The Arctic sea ice decline has strong local impacts, but its influence on the lower latitudes remains actively debated. This work aims at linking the anthropogenic sea ice loss to mid-latitudes winter climate by 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
- The response is sufficiently linear to be estimated by lag regression analysis
- Atmospheric response to SIC fluctuations is seen 1 to 3 months later.

Data & Methods

Observational data

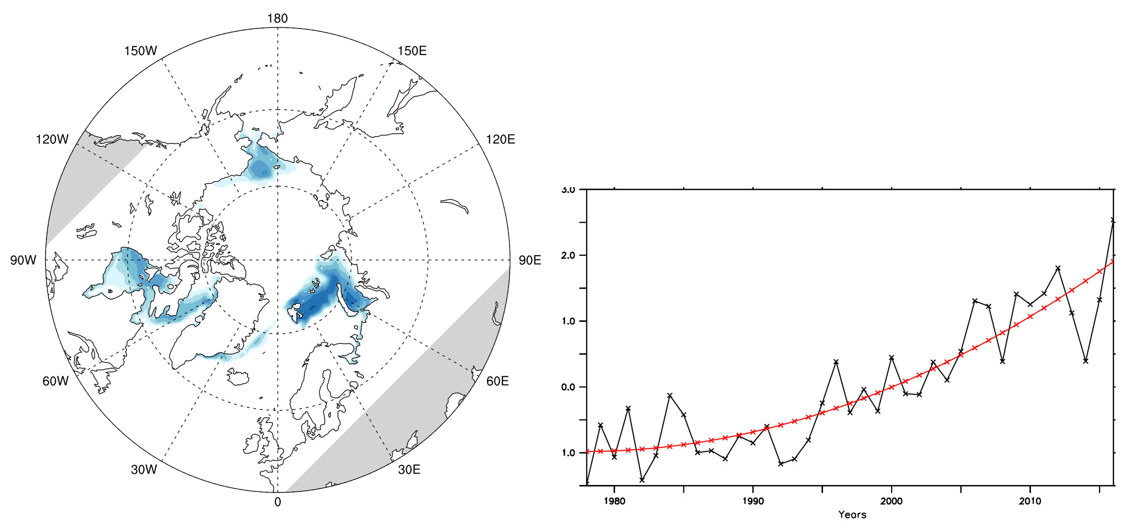
- Monthly sea ice concentration (SIC) from passive microwave measurements January 1979-February 2017 (*NASA-NSIDC*)
- ERA-Interim, HadISST, snow cover (*NOAA/Rutgers University*)

Method

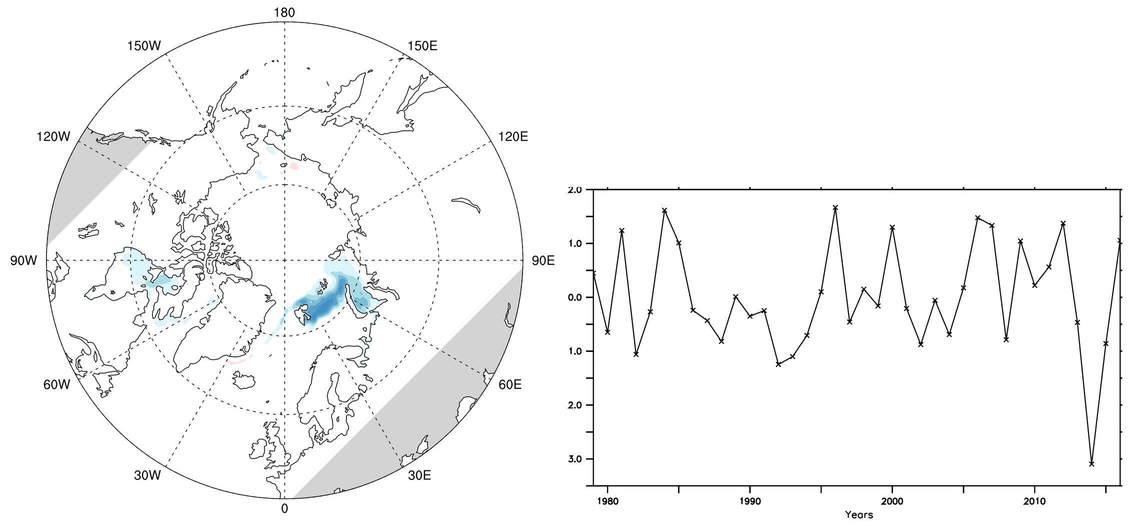
- Determine the main pattern of monthly sea ice loss between 1979 and 2016 from EOF analysis
- Represent sea ice loss by quadratic fit; interannual fluctuations are the residual
- Estimate the atmospheric response to the interannual SIC fluctuations
- Estimate statistical significance by controlling the False Discovery Rate (FDR)
- Determine synchronous inter-annual seas surface temperature (SST) and snow cover fluctuations. If FDR significant, use multiple regression for attribution
- Extrapolate these results to the quadratic decrease of the Arctic SIC.

November sea ice concentration (SIC) pattern

Raw SIC (with trend) - EOF1 *(left)* and PC1 *(right)*

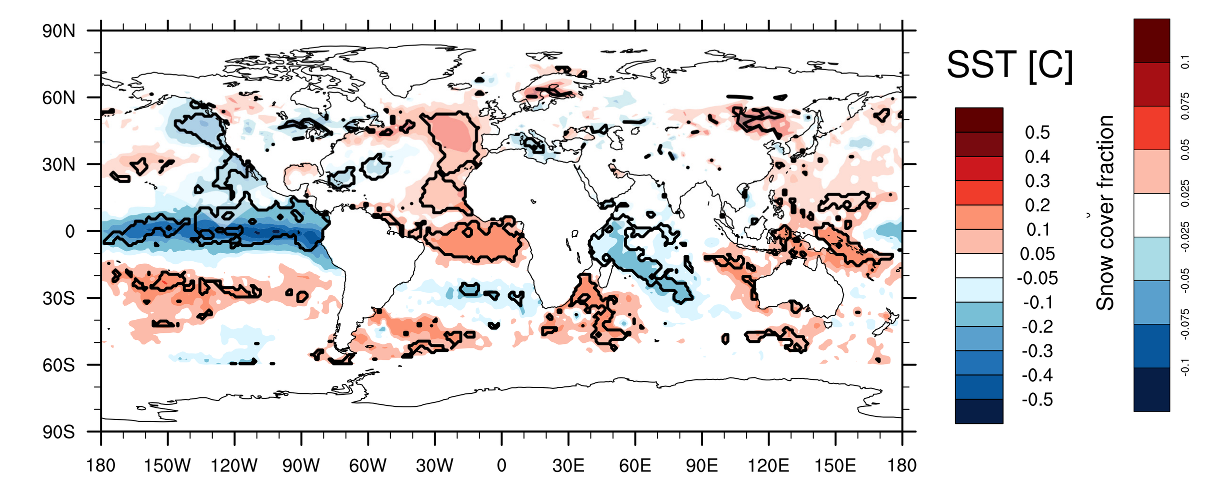


Interannual SIC (detrended) - EOF1 *(left)* and PC1 *(right)*



- Anthropogenic and inter-annual SIC fluctuations has identical spatial pattern with different amplitude

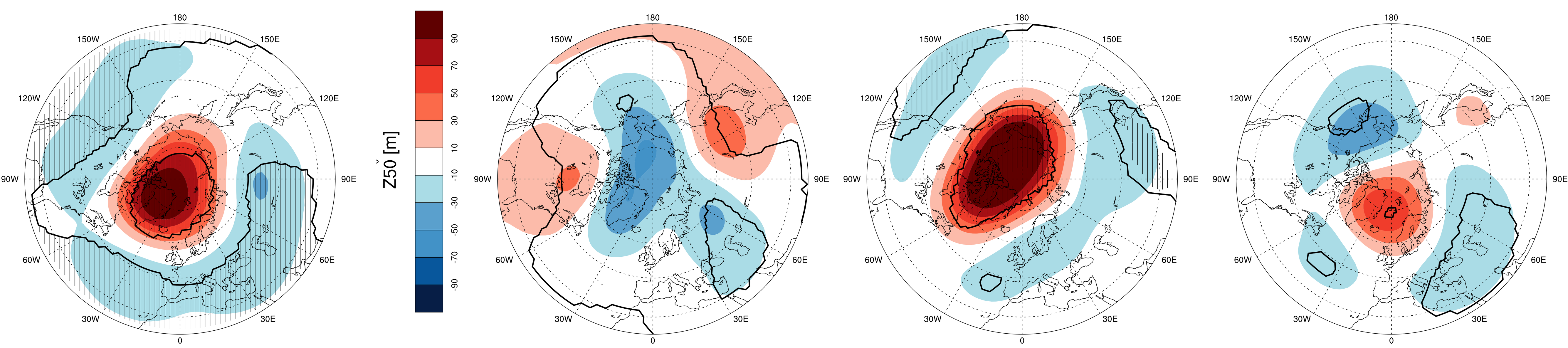
Concomitant SST & snow



ENSO (resp. Siberia snow) times series regression on quadratically detrended SST (resp. snow)

Weak la Nina and increased Siberian snow cover

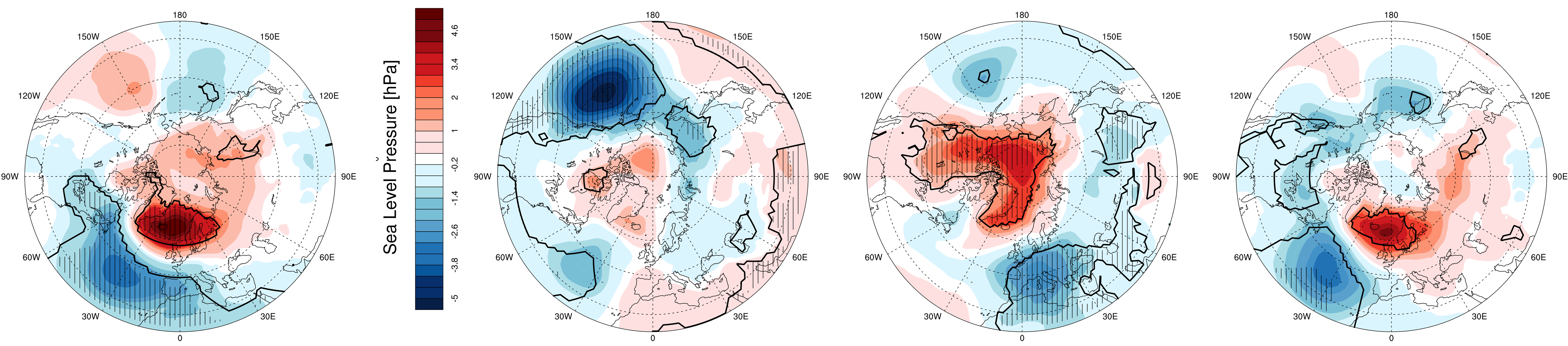
Lag multiple regression of geopotential height at 50 hPa (Z50) in December on November



Simple regression on SIC **Multiple regression on ENSO,** **SNOW** **and SIC**

- The simple regression suggests a downward negative NAO-like signal propagation from December to February (not shown)
- No significant influence of Arctic sea ice loss in stratosphere.
- December simple regression on SIC is mostly due to concomitant Siberian snow cover.

Lag multiple regression of sea level pressure (SLP) in January on November



Simple regression on SIC **Multiple regression on ENSO,** **SNOW** **and SIC**

- The contours indicate 10% significance and hatching is based on 10 % FDR significance.
- In January, negative NAO-like signal is largely due to SIC
- Very similar results in February and much weaker signal in March

Conclusions

- A negative NAO/AO-like relation with previous SIC fluctuations is found from December to March.
- Multiple regressions with SST and snow cover anomalies (concomitant with the SIC fluctuations) indicate that the December negative NAO-like signal is largely due to Siberian snow cover via a stratospheric pathway whereas the January, February, and March signal is attributed to the SIC via a tropospheric pathway.
- Scaling suggests that quadratic decrease in the Arctic SIC from 1979-2016 has increased SLP by 4 hPa and Z500 by 80 m above Greenland and increased surface air temperature over northeastern America by 2.5 K.

Acknowledgment

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