

Modulation of Arctic sea ice loss by atmospheric teleconnections from Atlantic Multi-Decadal Variability (AMV)

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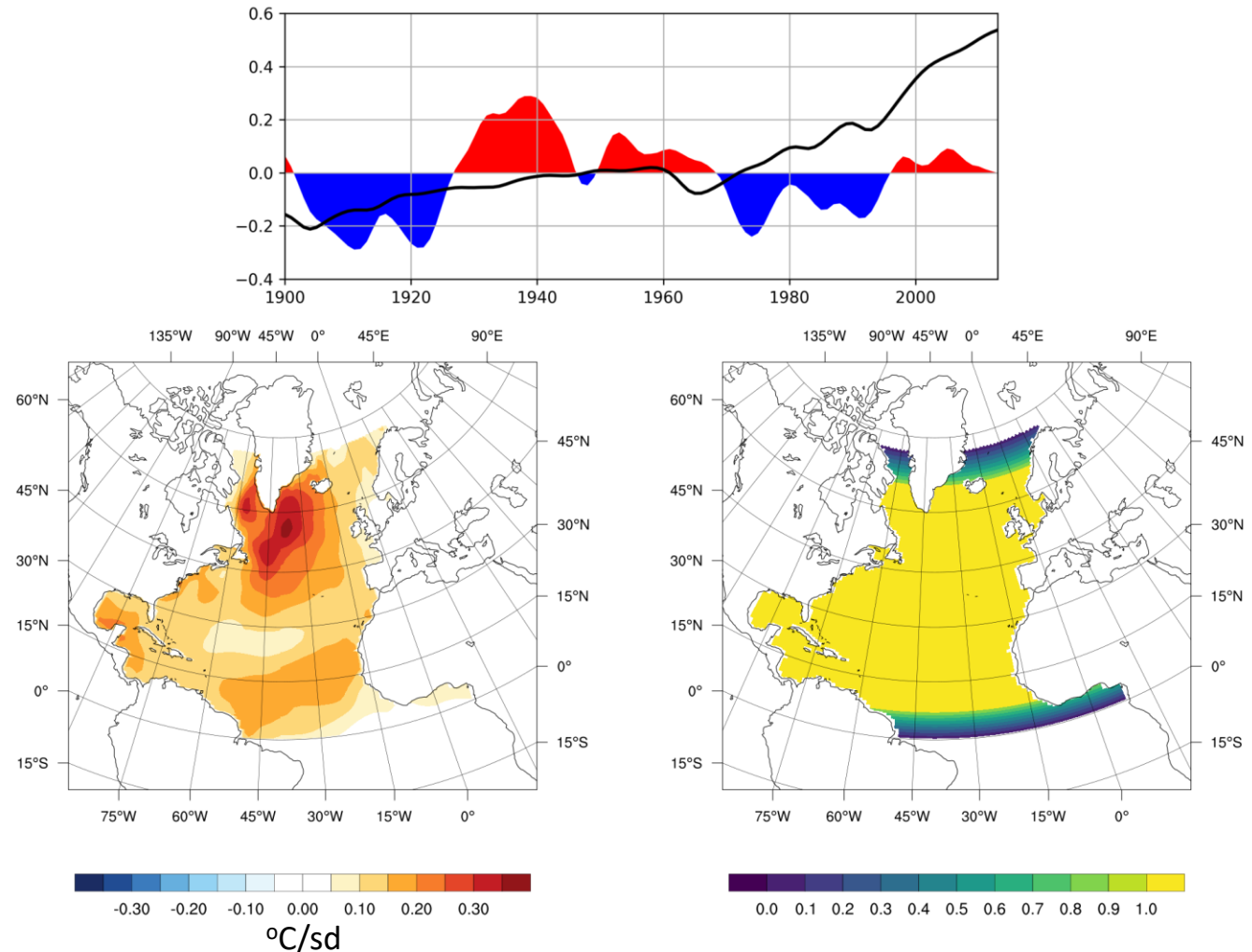


Background and Motivation

- The present study represents a component of our overarching goal of documenting climate impacts of sea surface temperature (SST) variability associated with AMV
- We follow an experimental protocol designed to isolate impacts from atmospheric teleconnections that result from imposed SST anomalies, i.e., the dynamical adjustments of the ocean are minimized
 - Global impacts (Ruprich-Robert et al. 2017, *J. Climate*)
 - Impacts on North American summer climate and heat waves (Ruprich-Robert et al. 2018, *J. Climate*)
 - Impacts on Arctic sea ice (Castruccio et al. 2019, *J. Climate*)

Experimental Setup

- Internal and external AMV components estimated using signal-to-noise EOF analysis following Ting et al. 2009
- Time-independent SST anomalies corresponding to 1 SD of the AMV index are added to (subtracted from) the model daily climatological SSTs for the AMV+ (AMV-) experiments
- Strong restoring time scale (typically 5 days over 10 m)
- 10-year simulations under pre-industrial conditions: long enough for atmospheric teleconnections to arise, yet short enough to limit oceanic drift issues in the North Atlantic



Models

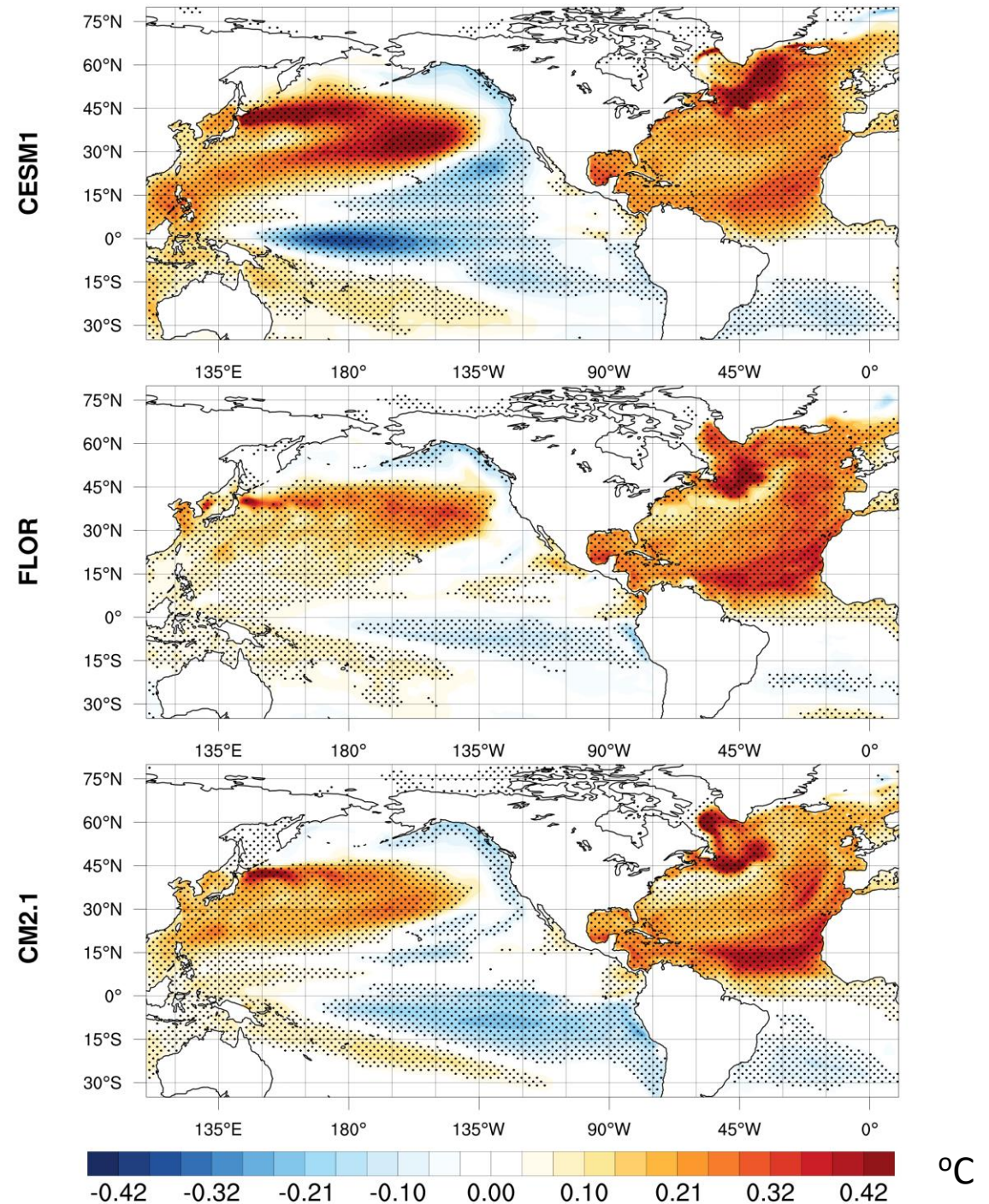
- Community Earth System Model version 1 (CESM1): 30 members
- GFDL Forecast-oriented Low Ocean Resolution (FLOR): 50 members
- GFDL Climate Model version 2.1 (CM2.1): 100 members

All three models use nominal 1° horizontal resolution in their ocean components, but employ different atmospheric resolutions: 2° CM2.1; 1° in CESM1; and 0.5° in FLOR

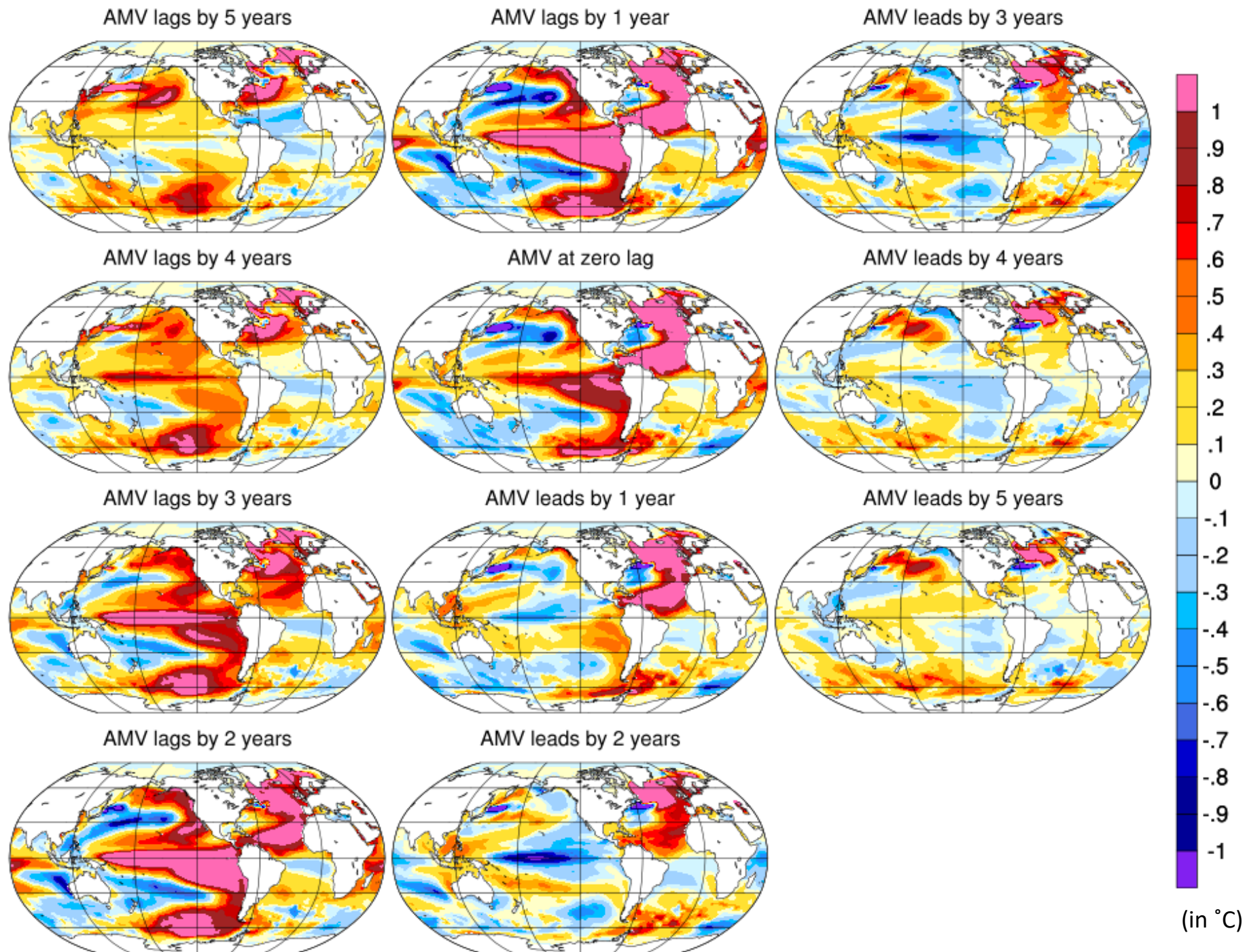
10-year average, AMV+ minus AMV- ensemble-mean differences are shown

A global impact example: Differences in DJFM sea surface temperature

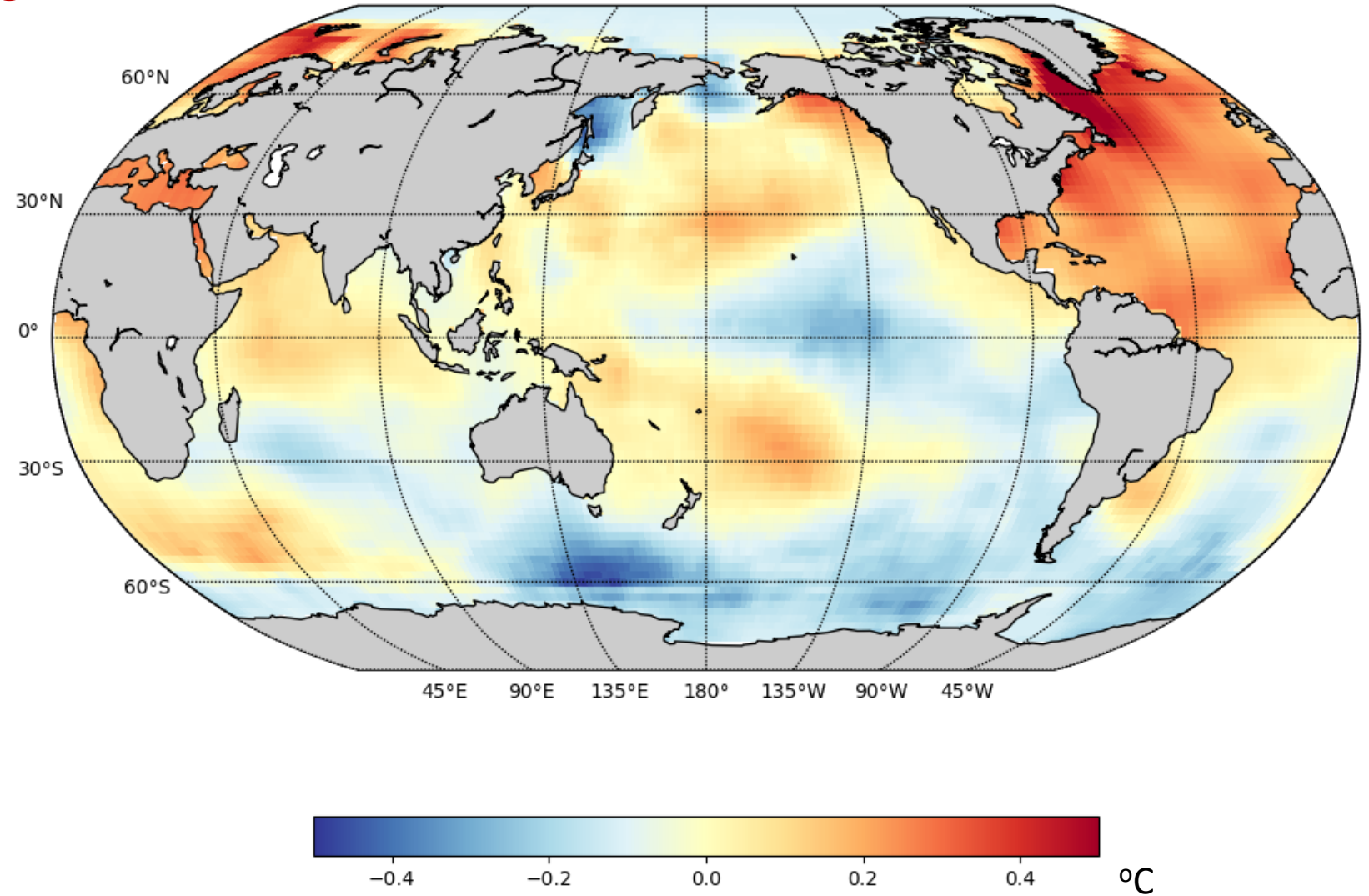
- A negative IPV response in the Pacific is associated with positive AMV



LENS PI control:
lagged SST
regression on
AMV index



Observation (ERSSTv4): AMV SST composite



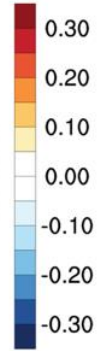
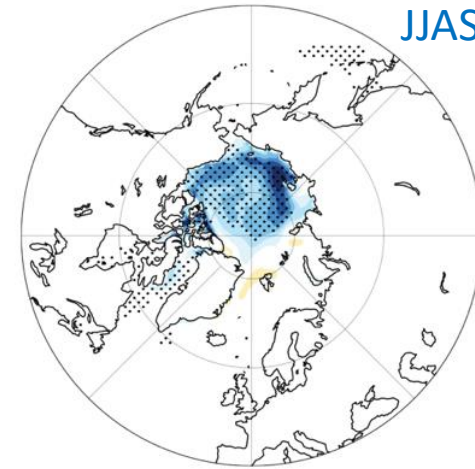
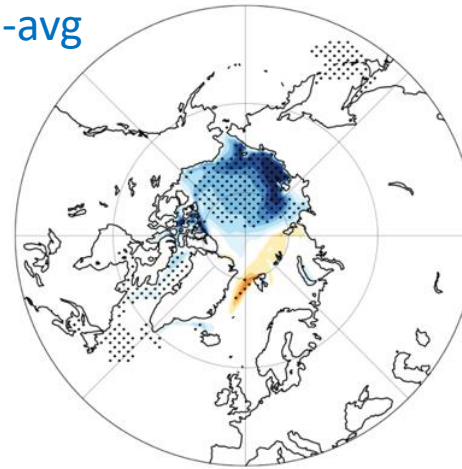
Differences in sea ice thickness

- Thinner sea ice in both winter and summer

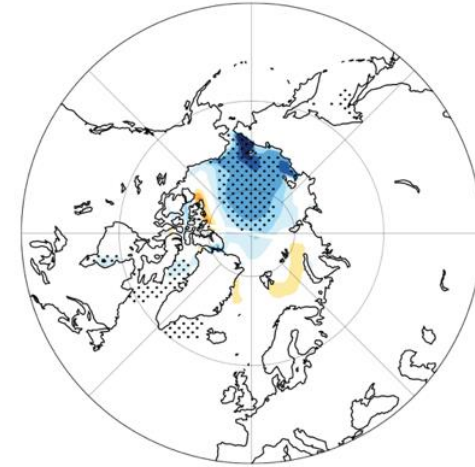
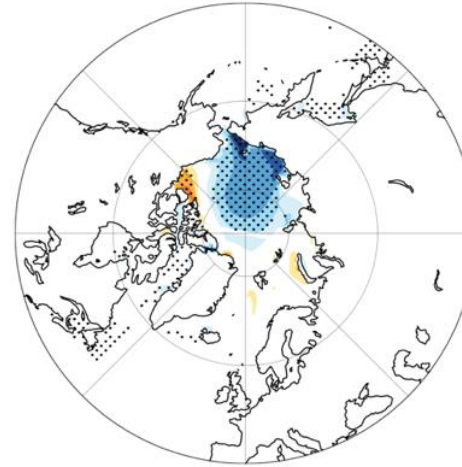
DJFM-avg

JJAS-avg

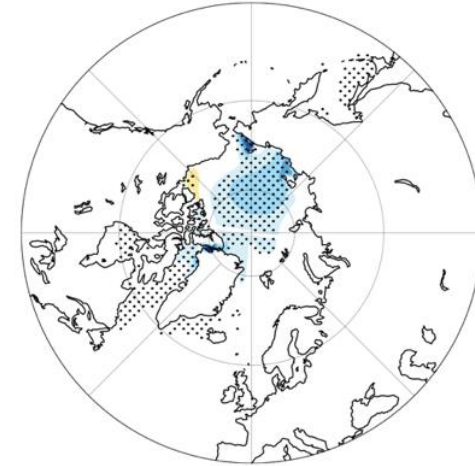
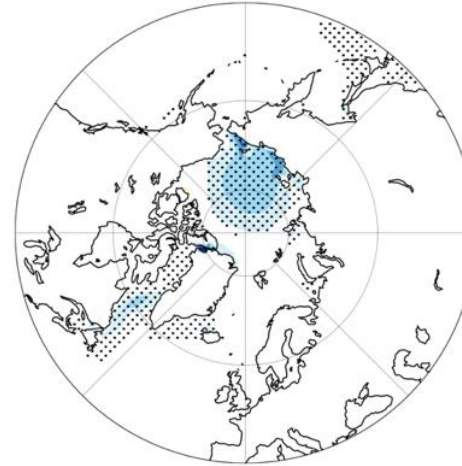
CESM1



FLOR

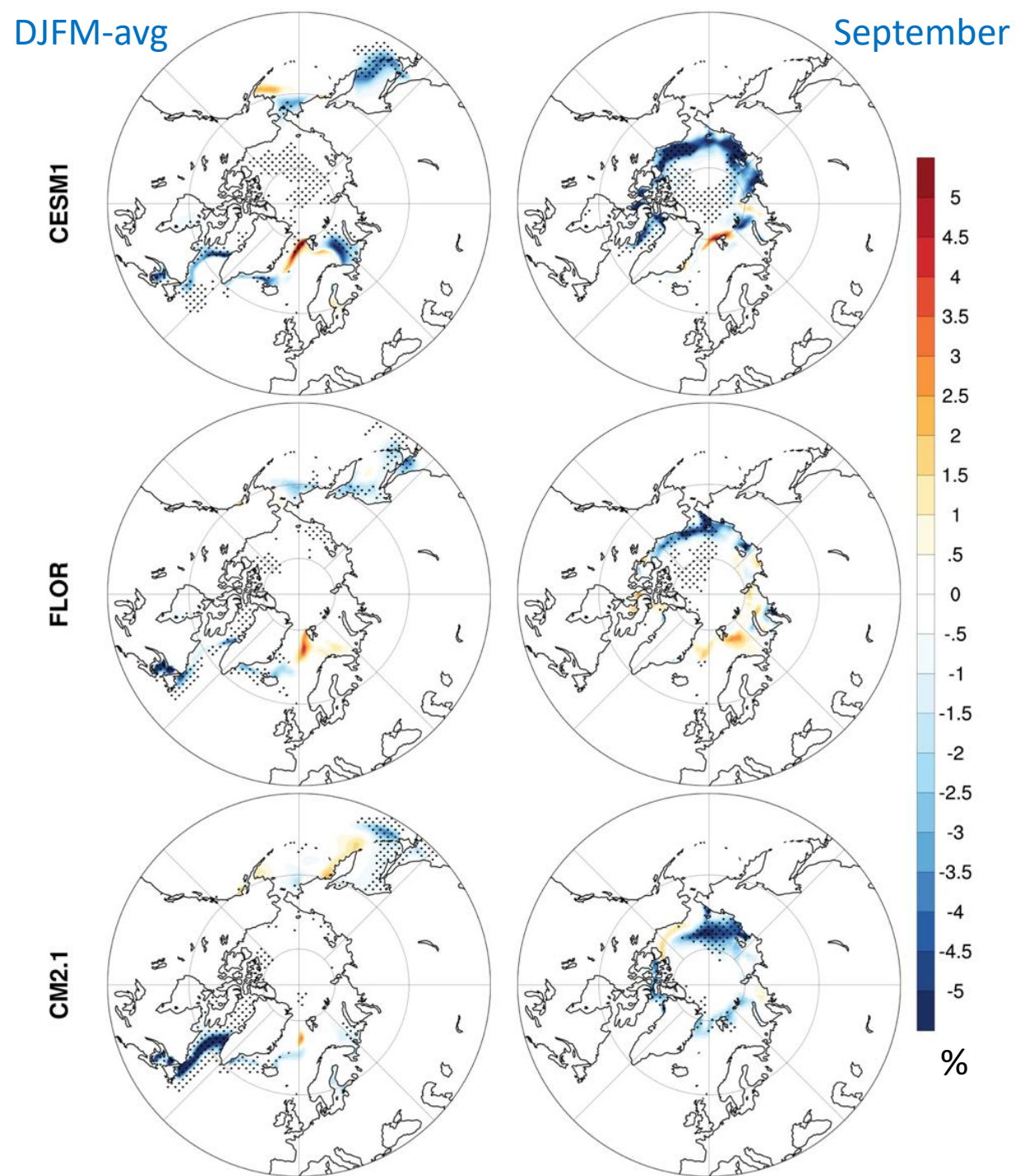


CM2.1



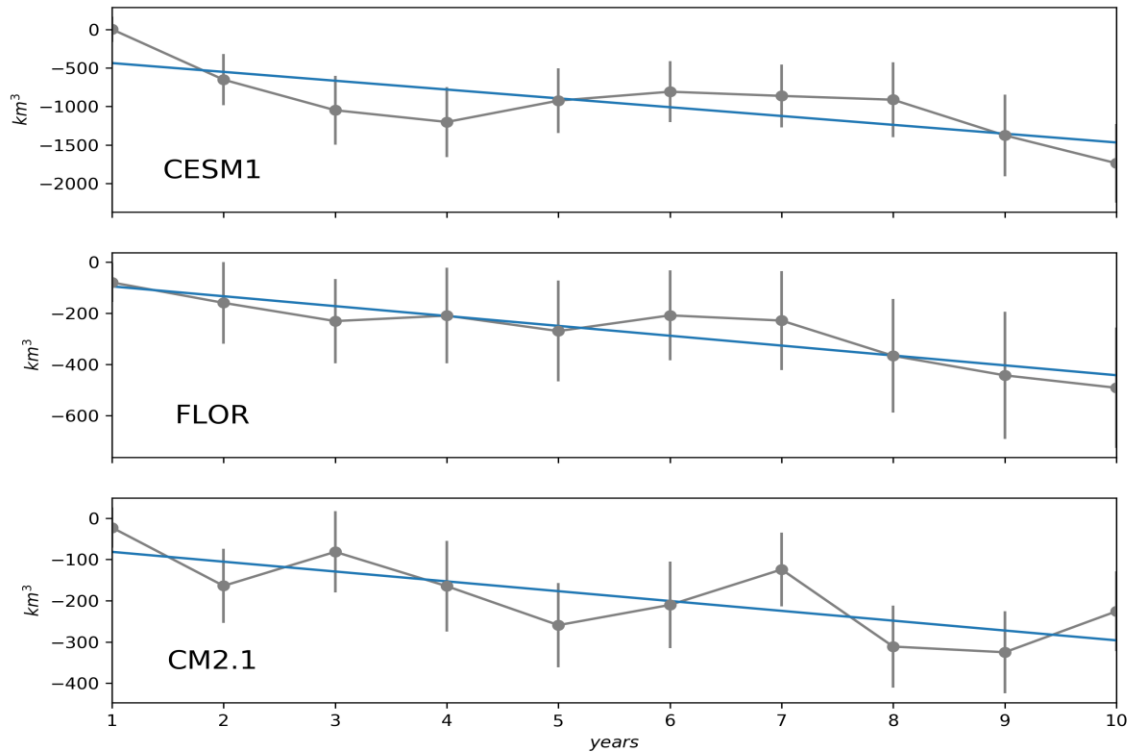
Differences in sea ice concentration

- Winter retreat of the ice edge in Labrador, Irminger, Barents, and Okhotsk seas
- Reduction in summer ice concentration exceeding 5% at the end of the melting season

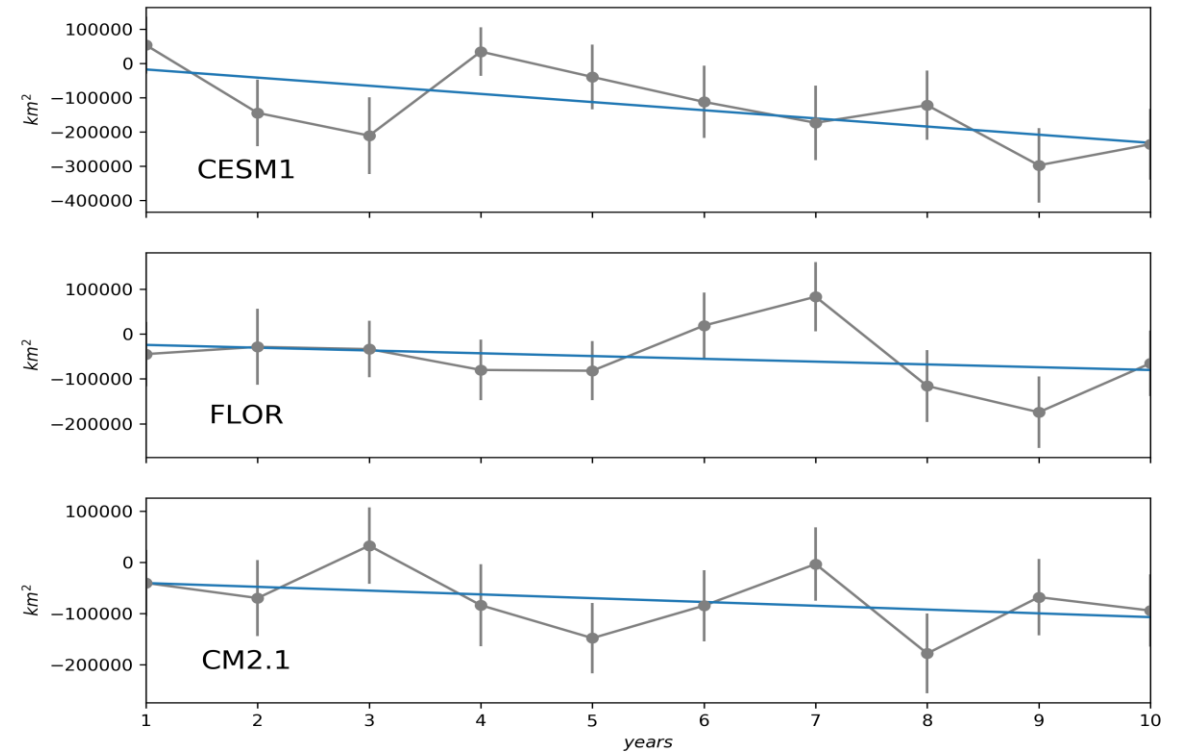


Temporal evolution in DJFM Arctic Ocean ice volume and area

Arctic Ocean sea ice volume



Arctic Ocean sea ice area



- The differences in thickness and area between AMV+ and AMV- tend to grow with time

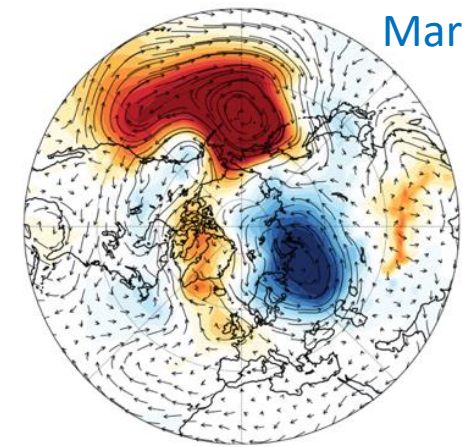
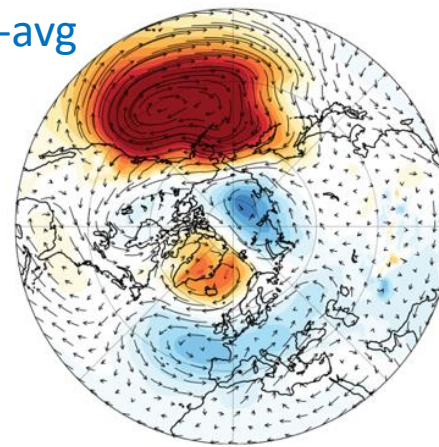
Differences in sea level pressure and winds

- Weakening of the Beaufort Sea high (BSH)
⇒ Anomalous cyclonic winds
- Dipole-like pattern in SLP in late spring
⇒ Enhanced transpolar winds

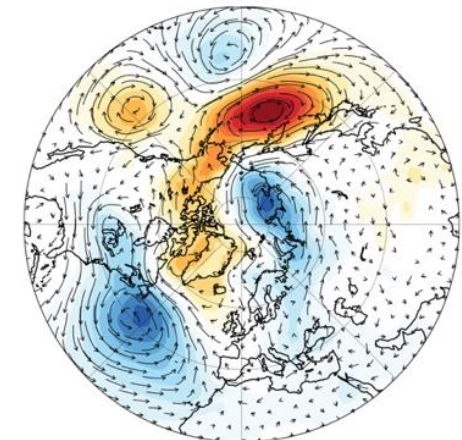
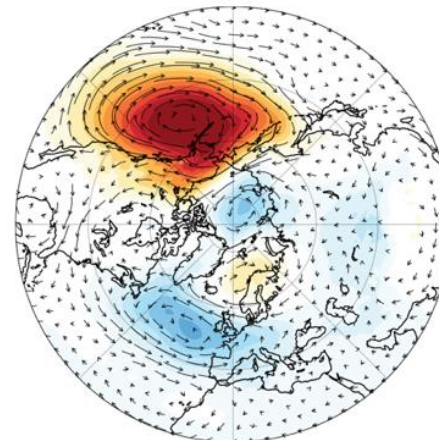
DJFM-avg

March/April

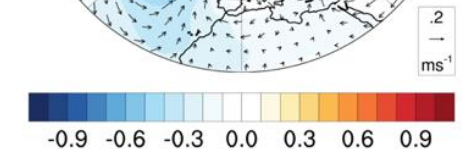
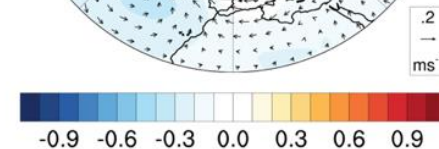
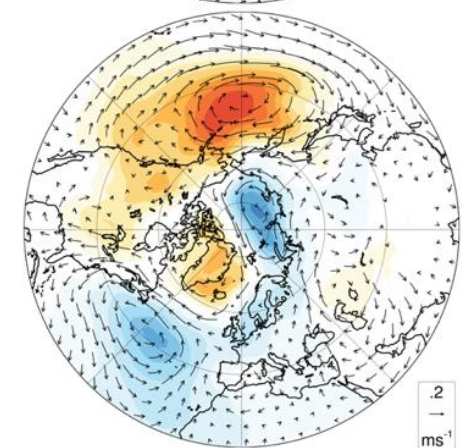
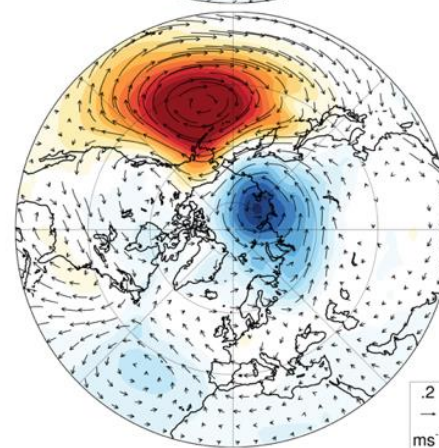
CESM1



FLOR



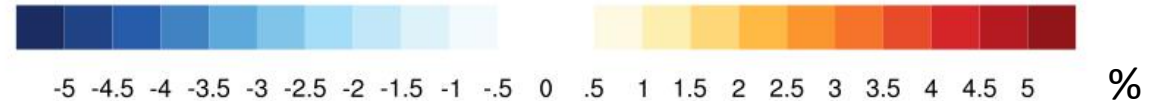
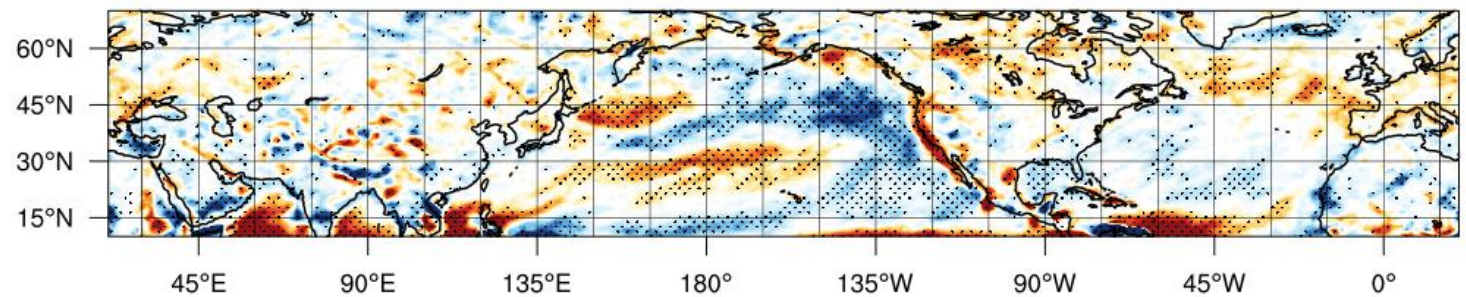
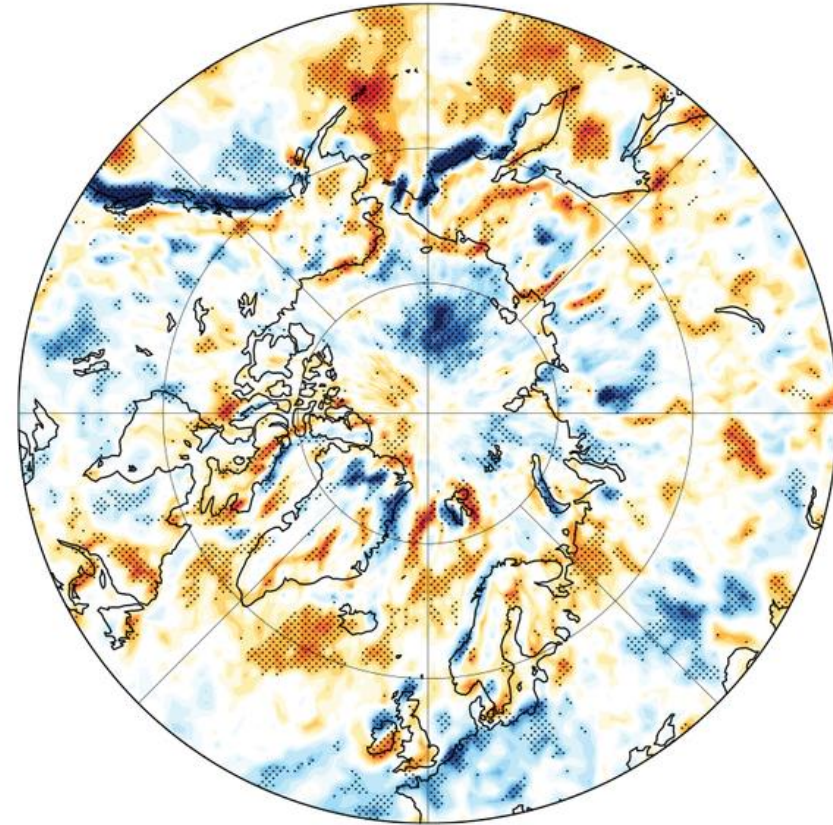
CM2.1



mbar

Differences in DJFM Arctic anticyclonic winds and mid-latitude cyclonic winds at 850 hPa

- Decrease in winter polar anticyclones
- Reduced frequency of extratropical cyclones



Consistent with Serreze and Barrett (2011)
and Wernli and Papritz (2018)

Dynamic effect

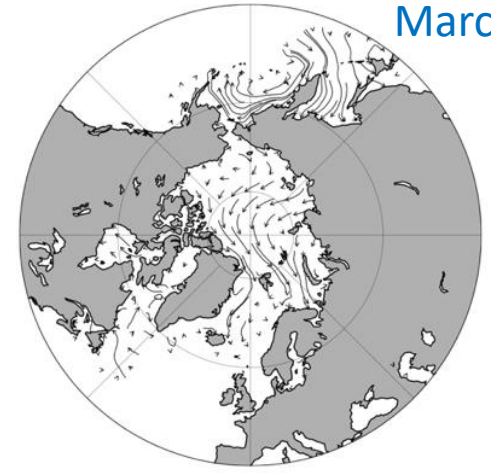
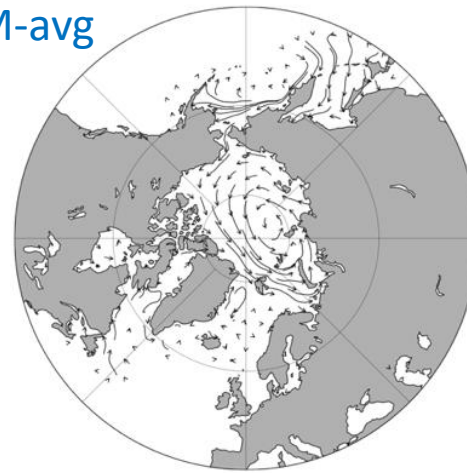
The anomalous winds:

- Anomalous cyclonic circulation and enhanced Transpolar Drift Stream
- Enhanced winter sea ice export through Fram strait
- Ice export increase peaks in March/April

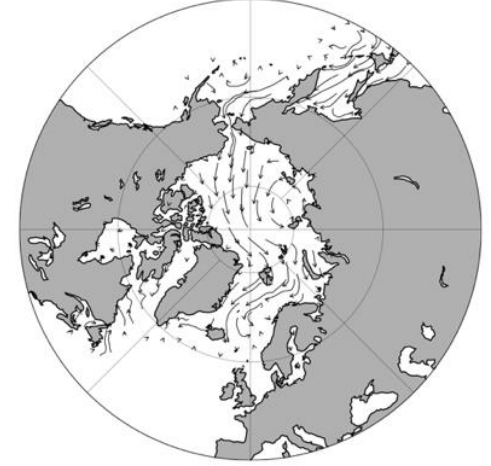
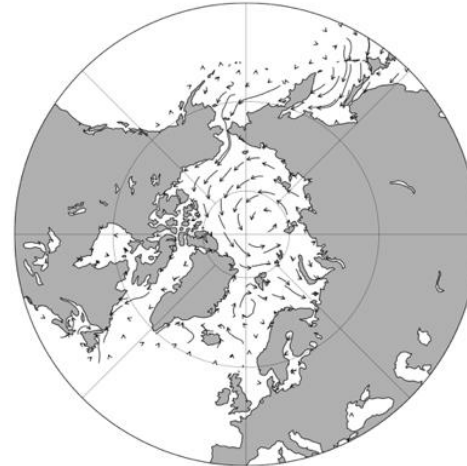
DJFM-avg

March/April

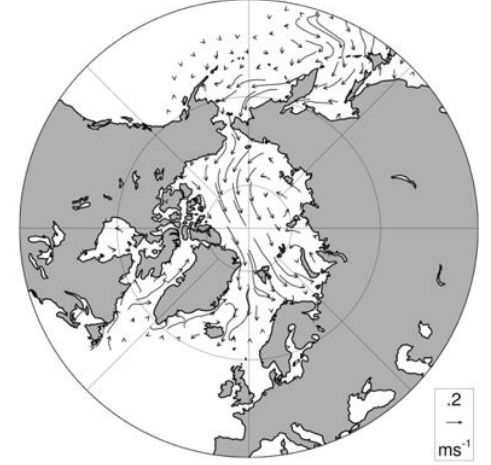
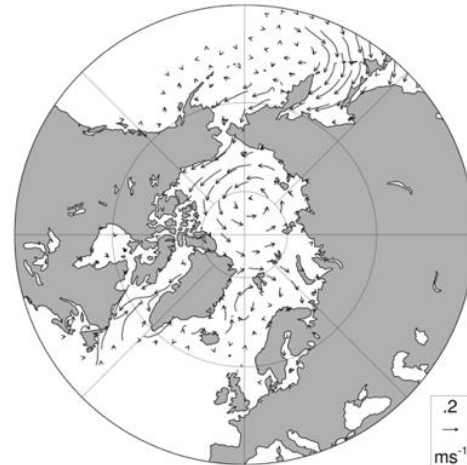
CESM1



FLOR



CM2.1

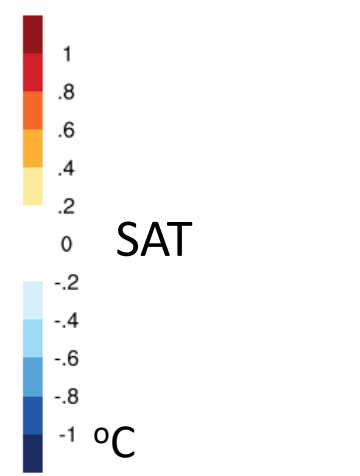
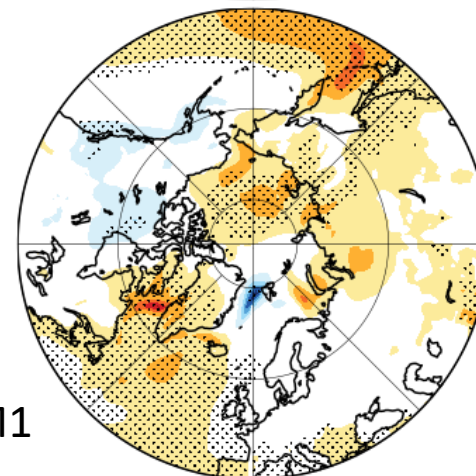
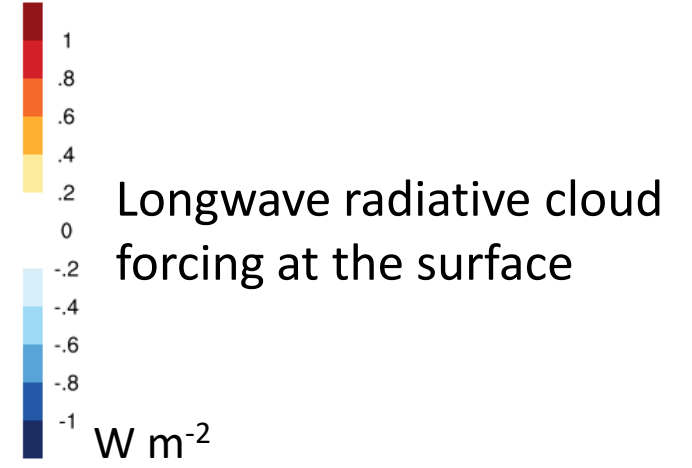
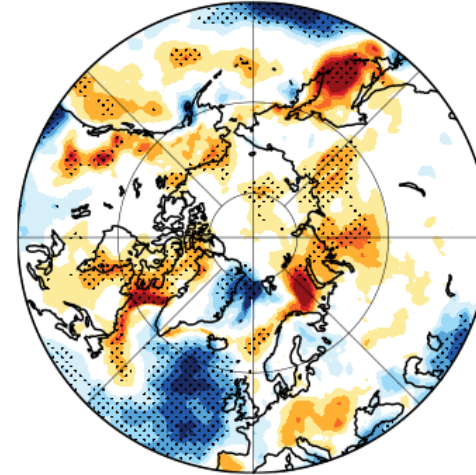
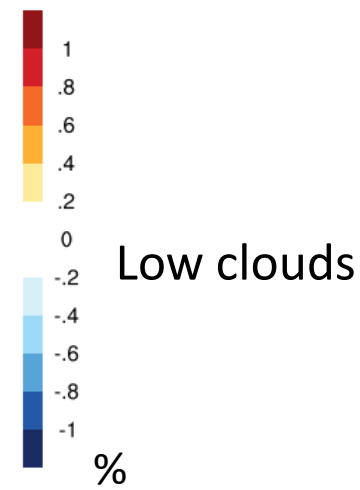
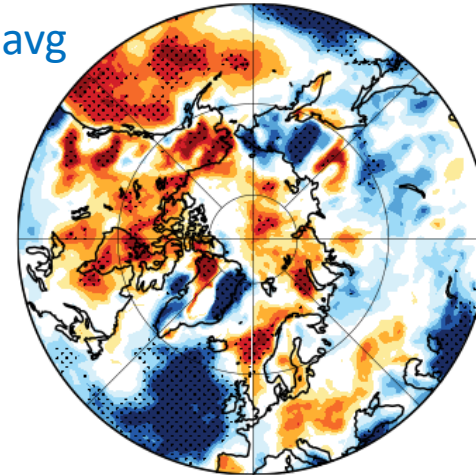


Thermodynamic effect

The decrease in winter polar anticyclones frequency:

- Enhancement of winter low cloud cover
- Increased downwelling longwave radiation at the surface as a response to the increased cloudiness
- Surface warming

DJFM-avg



From CESM1

Summary and Conclusions

AMV drives:

- similar Arctic sea ice changes (thinning) in three global coupled climate models
- Arctic sea ice fluctuations without AMV–related changes in ocean heat transport

Positive AMV anomalies lead to:

- decrease in the frequency of winter polar anticyclones
 - ⇒ weakening of the BSH
 - ⇒ warm anomalies in response to increased low-cloud cover
- Arctic Dipole–like sea level pressure pattern in late winter / early spring

AMV induced shifts in Arctic atmospheric circulation drive:

- anomalous wind driven ice motions (dynamic effect) and reduced winter sea ice formation due to warm surface temperature anomalies (thermodynamic effect)
 - ⇒ thinner, younger, and more prone to melt in summer Arctic sea ice pack
- decadal trend in ice volume loss of the order of 8-16% of the reconstructed trend
- decadal trend in September sea ice decline of up to 21% of the observed trend