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PRIMAVERA

This project is co-funded by the European Union

Barcelona Supercomputing Center
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Seasonal anomalies in Arctic sea ice and their association with Northern Hemisphere climate variability, on interannual timescales in EC-Earth model simulations

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Questions and goals

What is the unforced decadal and centennial variability of sea ice on interannual to multi-centennial timescales?

Can natural variability at different timescales tell us about the influence of Arctic sea ice on climate (if any at all)?

- Low Arctic SIC in recent may have been associated with anomalous seasonalities in polar and midlatitude regions, perhaps favoring wet summers (Screen, 2013) or colder winters over Eurasia (Peings and Magnusdottir, 2014; Kim et al., 2014; Mori et al., 2014, etc.)

- Yet clear picture of the climate response to sea ice loss in observations or climate models has failed to emerge (Screen et al., 2013), as it is easily overpowered by natural variability in the midlatitudes (Screen et al., 2014; Swart, 2017) and may depend on the background state of the atmosphere (Screen, 2017; Screen et al., 2018).

Goals:

(1) To assess interannual to decadal variability in Arctic sea ice cover in a large set of “freely evolving” and ”constrained” climate model simulations

(2) To assess what might be the influence of sea ice on climate at interannual or multi-decadal timescales.

Methodology and structure

Method:

PRIMAVERA: We analyze sea ice and climate interaction in freely evolving “control” simulations (perpetual 1950 radiative forcings) run at (a) standard resolution [300 years] and (b) high resolution [150 years].

PAMIP: We analyze climate response to sea ice change from 2 ensembles of simulations forced by present-day SST and 2000 radiative forcing with (a) present-day Arctic SIC and (b) future Arctic SIC.

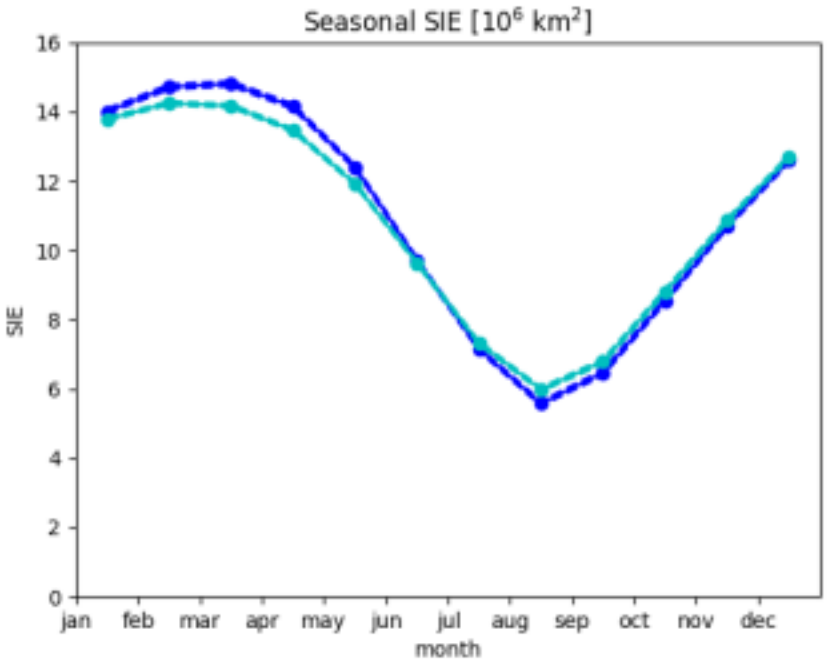
Structure:

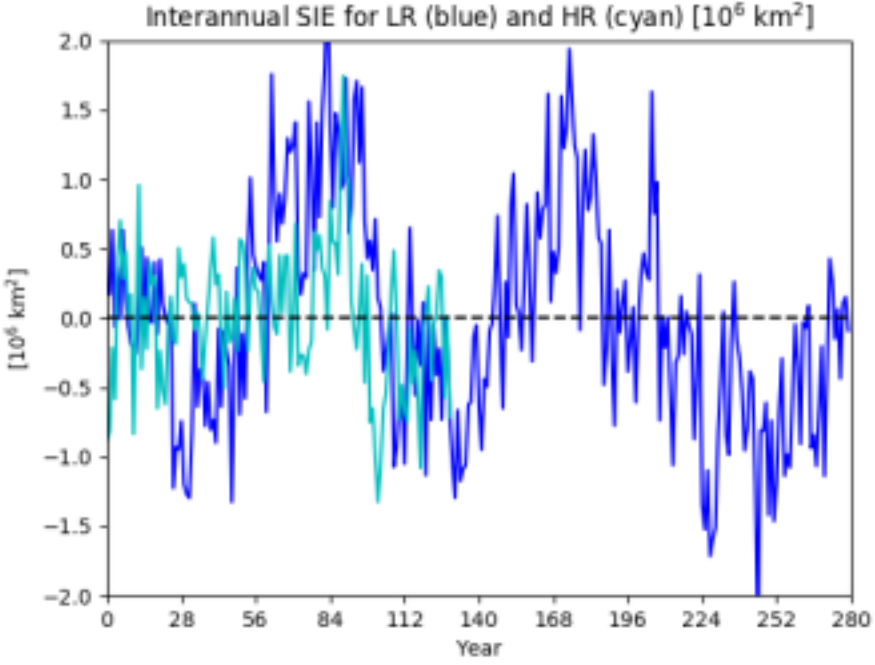
1. Decadal climate variabilities in freely evolving climate simulations are described (PRIMAVERA runs).

2. Climate variations associated with Arctic sea ice natural variability are decomposed into high and low-frequency components.

3. Climate signature associated with low/high SIE (from PRIMAVERA runs) are compared with the forced response of climate to a large decrease in sea ice extent (from PAMIP runs).

Fully-coupled EC-Earth: Seasonal and interannual SIE variability
(PRIMAVERA 1950-ocontrol runs)

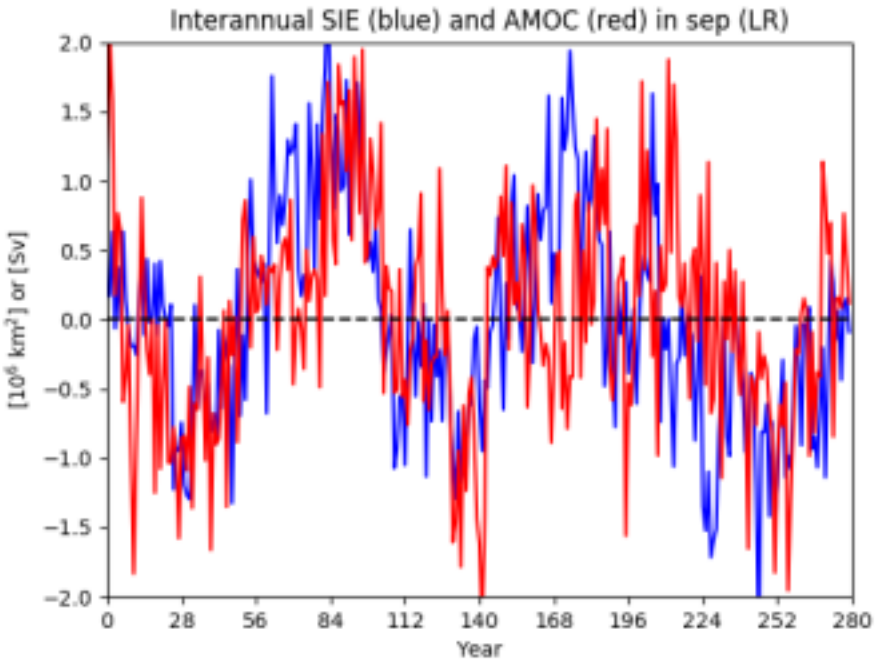


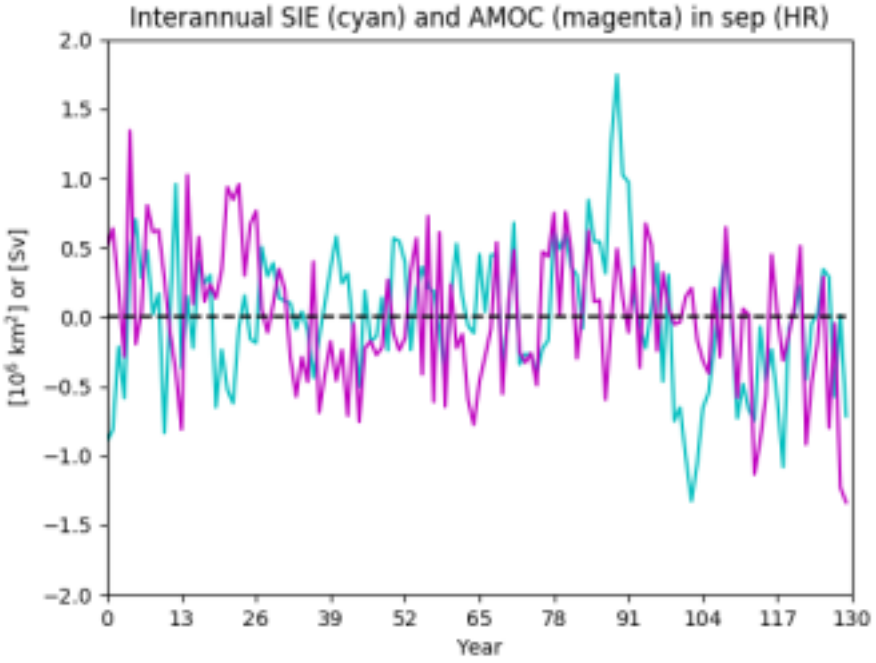


Multi-year SIE climatology is similar between standard (LR) and high-resolution (HR) simulation…..

…. But SIE has more low-frequency variability in LR than HR run.

SIE and AMOC in LR and HR

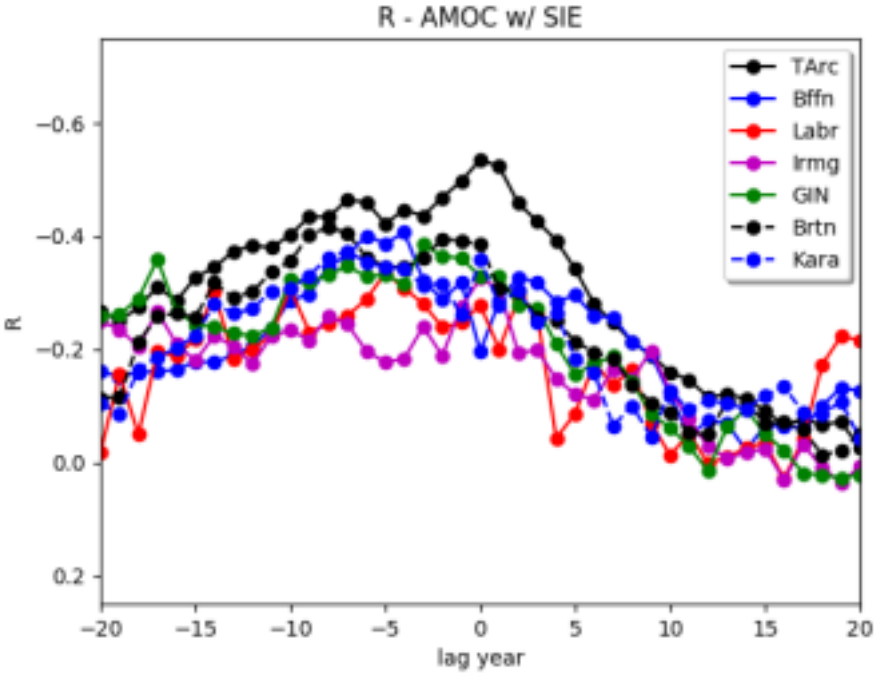


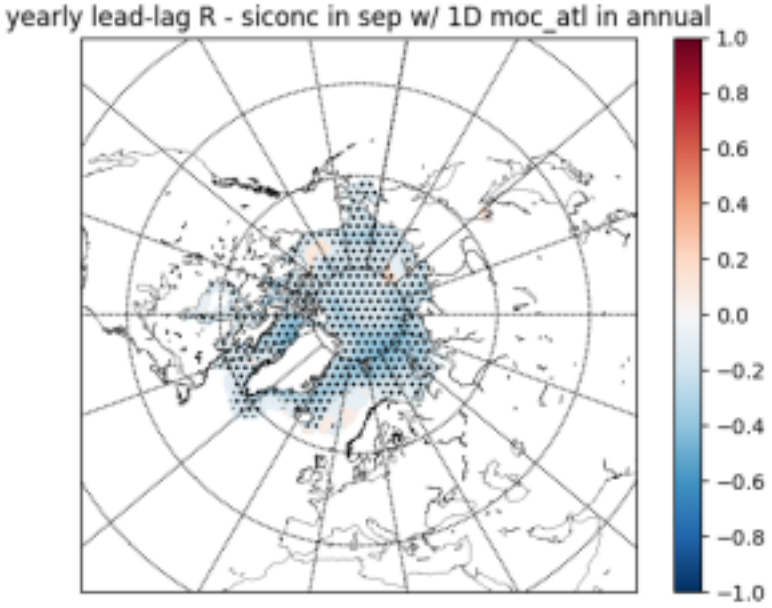


Atlantic meridional overturning circulation (AMOC) has much greater amplitude in the LR than HR run…

LR: The multi-decadal changes in the AMOC are coupled with those in SIE
HR: There is no statistical relation between AMOC and SIE

Timing of SIE and AMOC

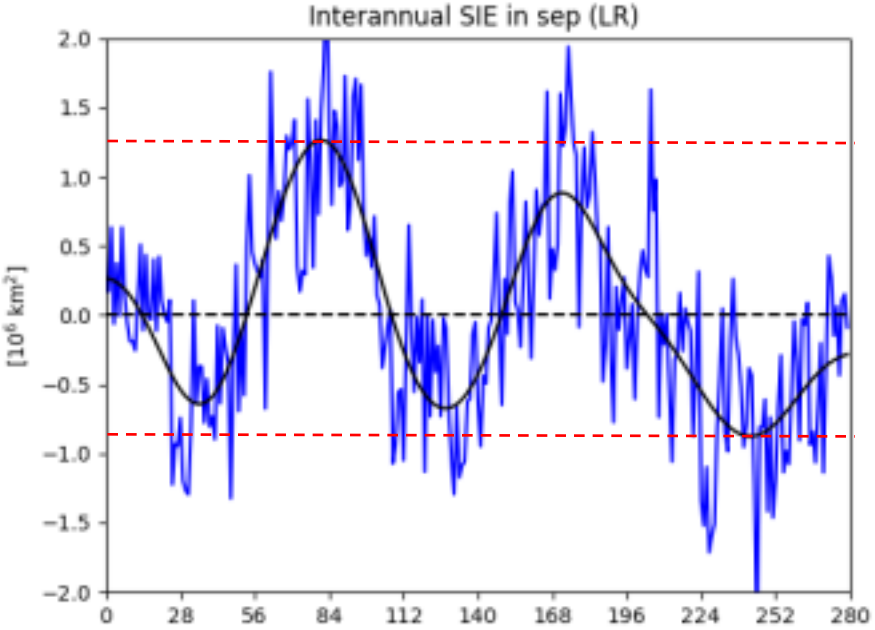


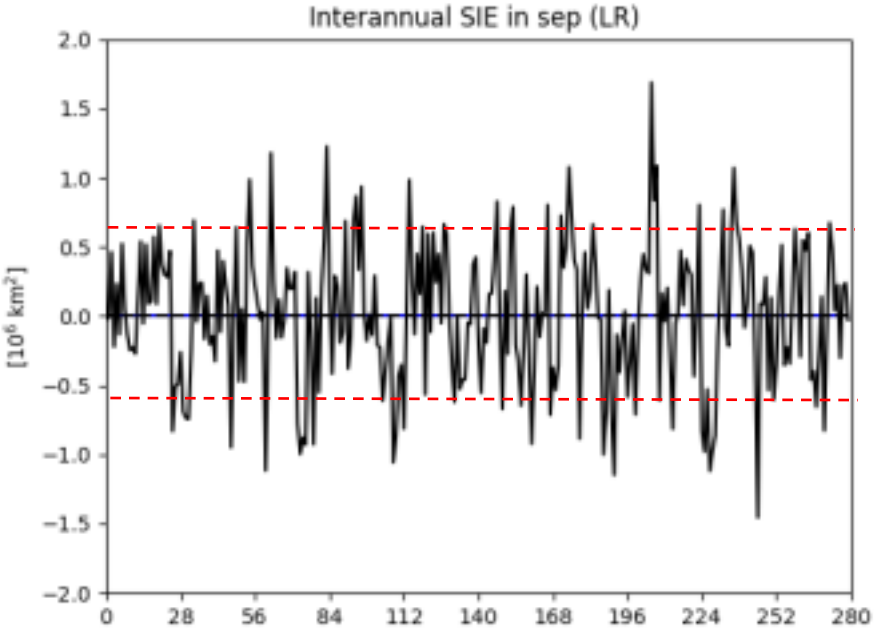


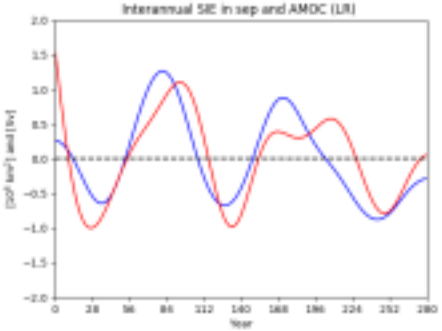
LR: changes in SIE appear to lead changes in AMOC by about 5 years.

What are the surface climate anomalies associated with SIE variability on interannual vs. multidecadal timescale?

SIE in LR (Low/High Frequency component)

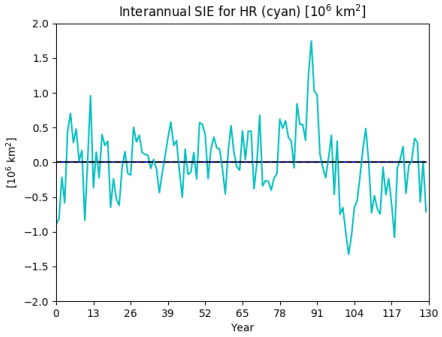




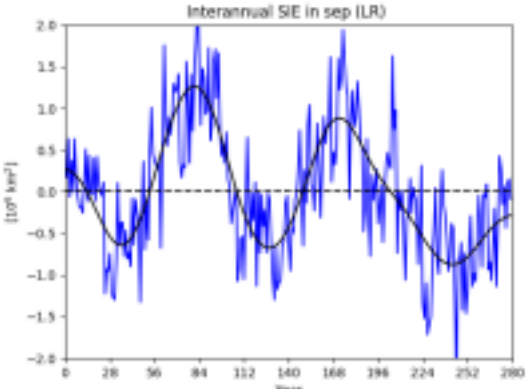


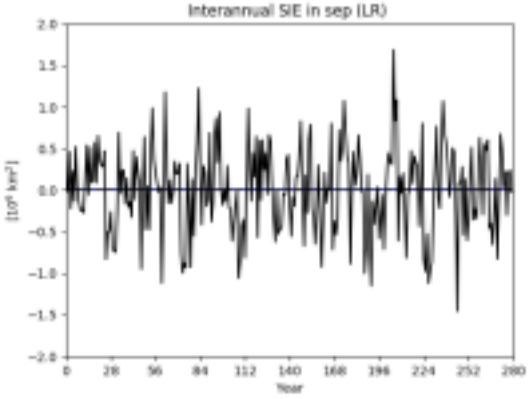
We decompose SIE in the LR simulation into a low- and high-frequency component

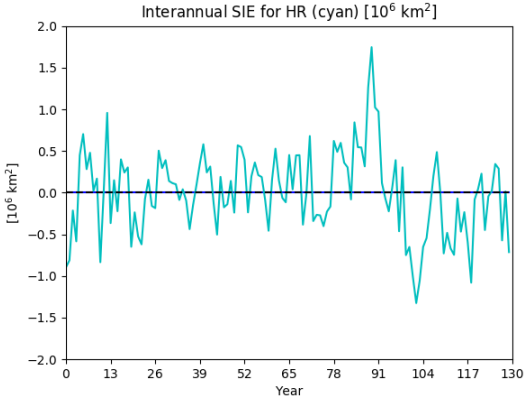
We create composites using years of low vs. high SIE

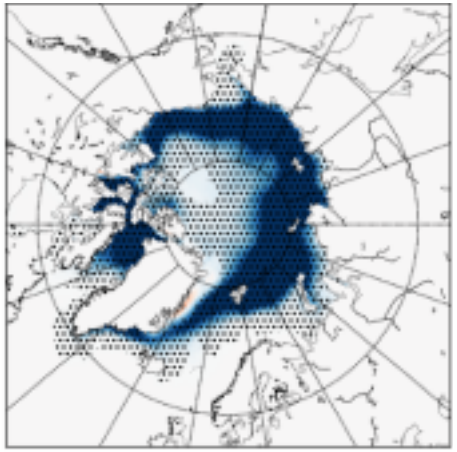


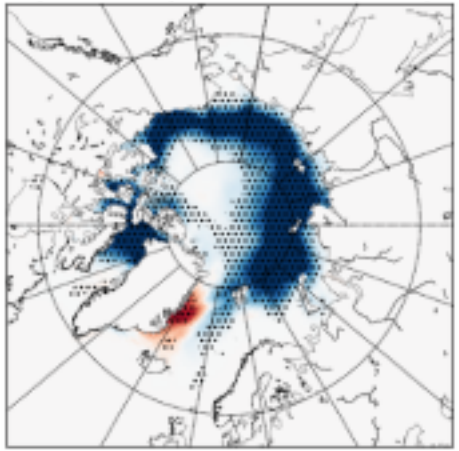
Comparing SIC patterns

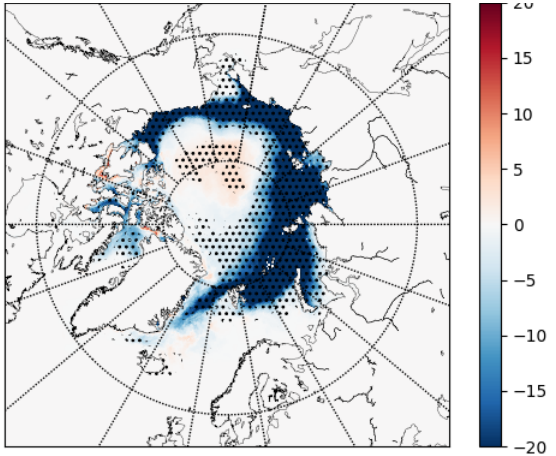






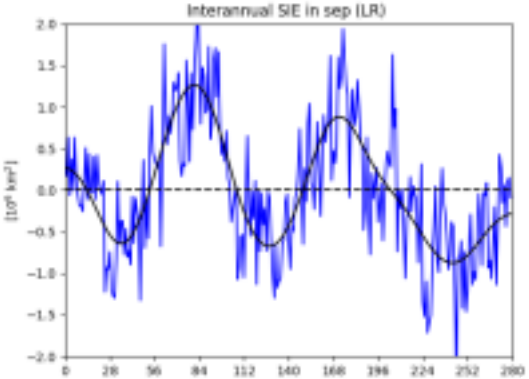


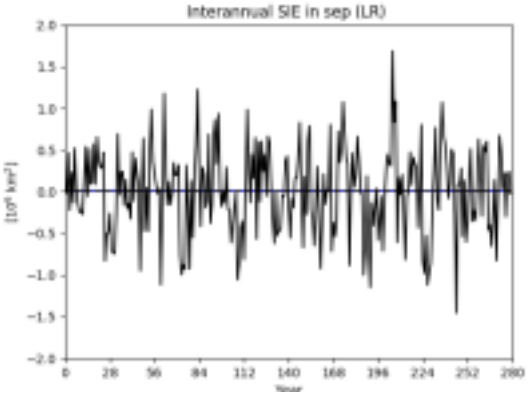


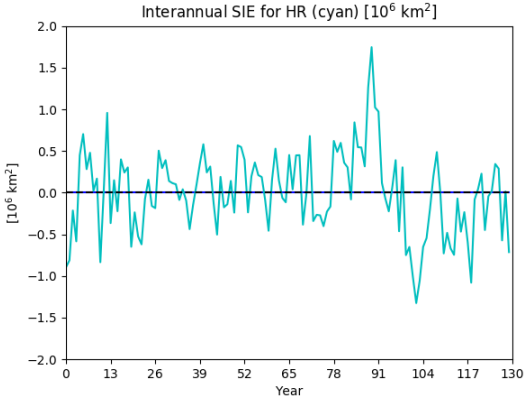


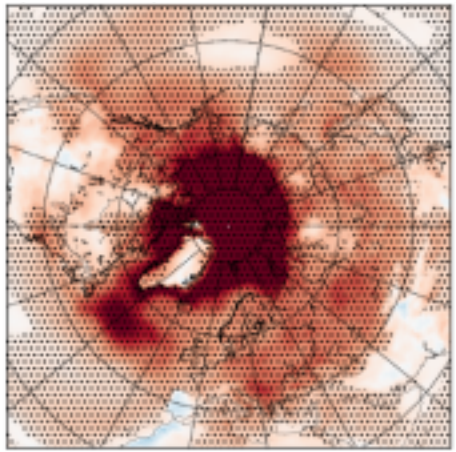
SIC variability patterns are similar across timescales and spatial resolution.

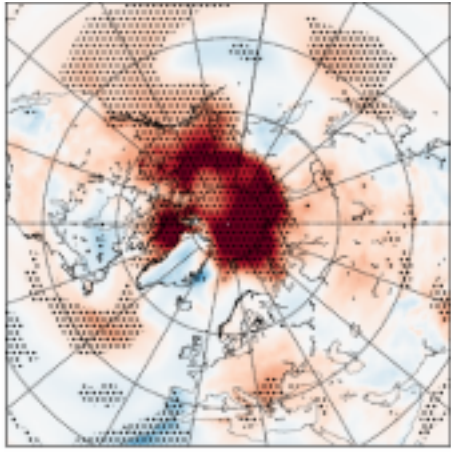
Comparing 2-m temperature patterns

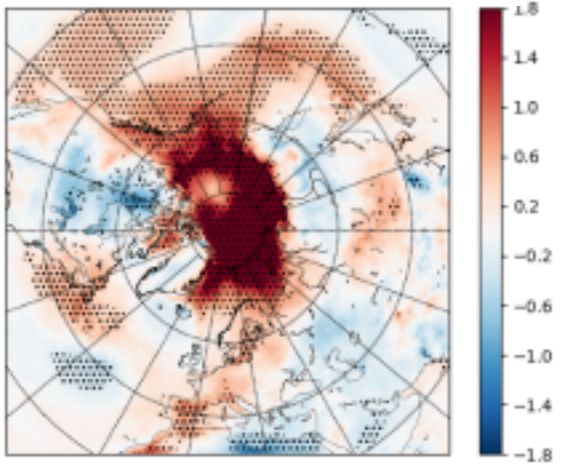




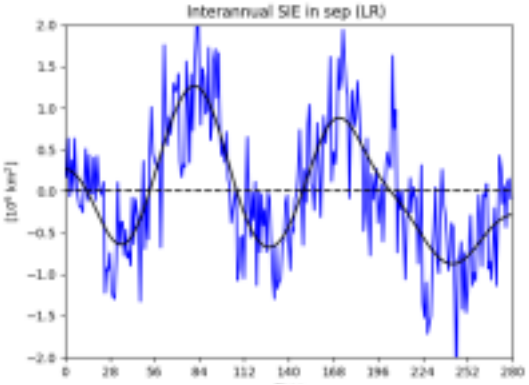


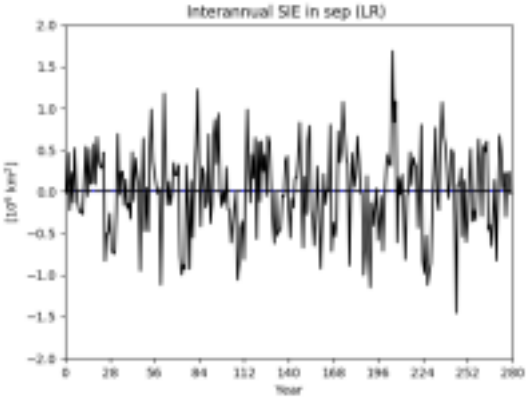


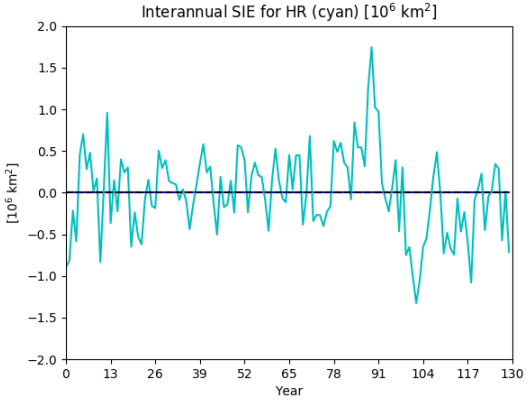


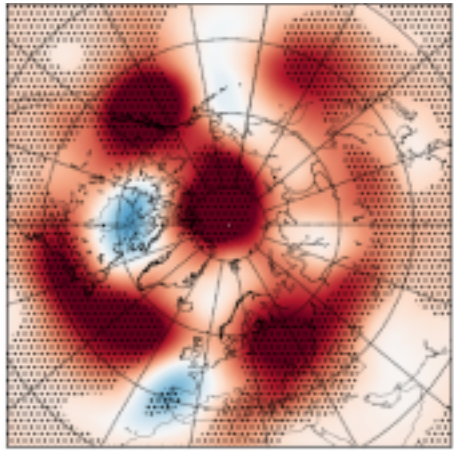


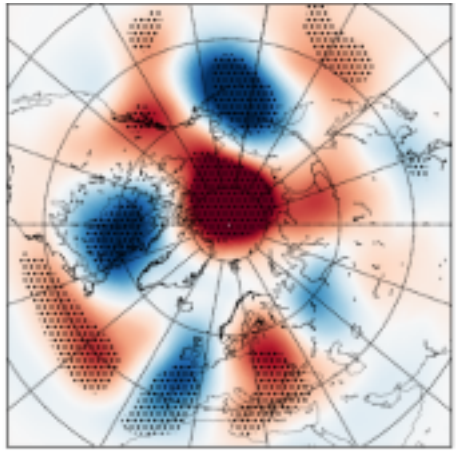
Comparing 500 hPa Geopotential height

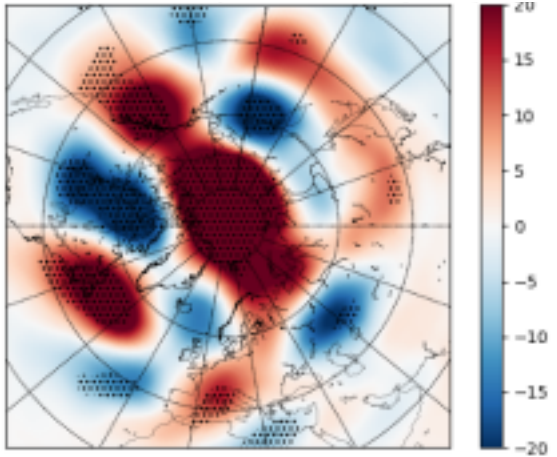








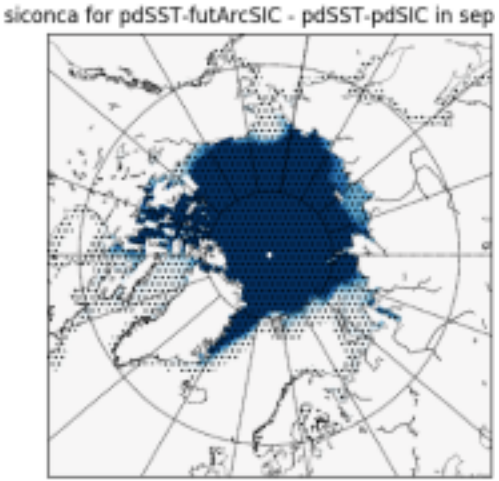


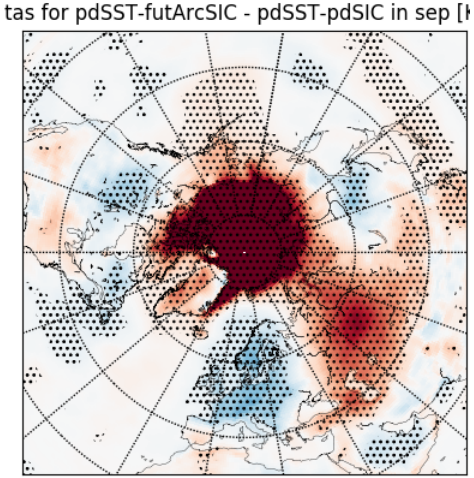


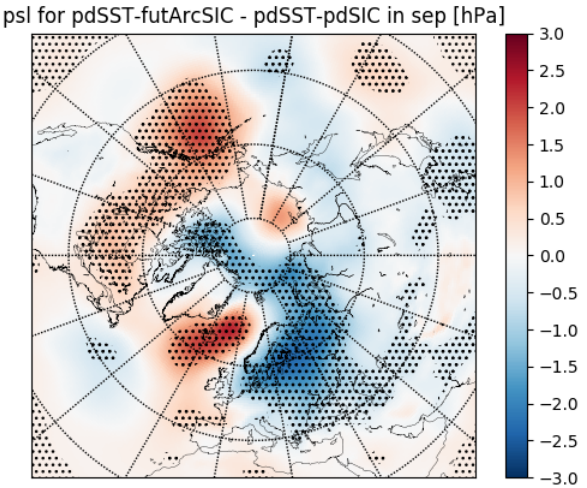
PAMIP (september)

Let's compare climate patterns associated with natural Arctic SIC anomalies (from the PRIMAVERA runs) with those from forced SIC changes (from PAMIP runs)

We run 50 members of fixed present-day SST and SIC (pdSST-pdSIC) and compare them to 50 members of fixed present-day SST and future Arctic SIC (pdSST-futArcSIC)

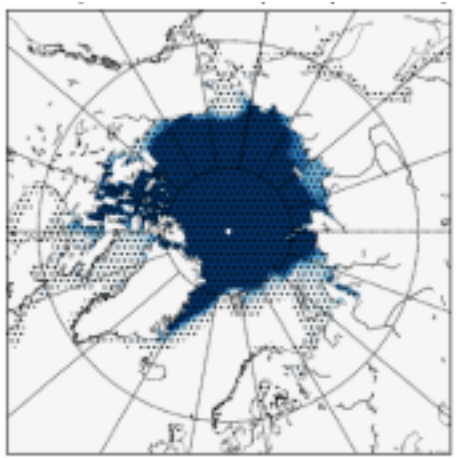




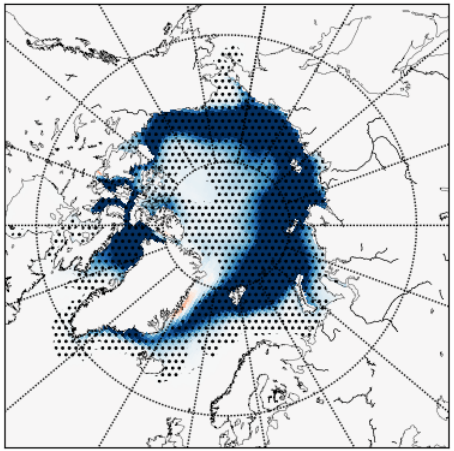


PRIMAVERA vs PAMIP (September): SIC [%]

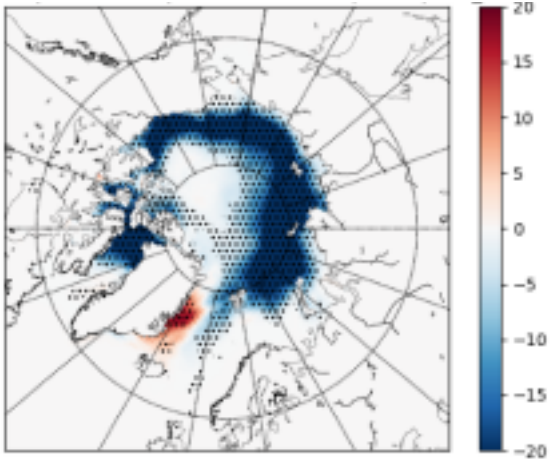
PAMIP



PRIMAVERA (LR)

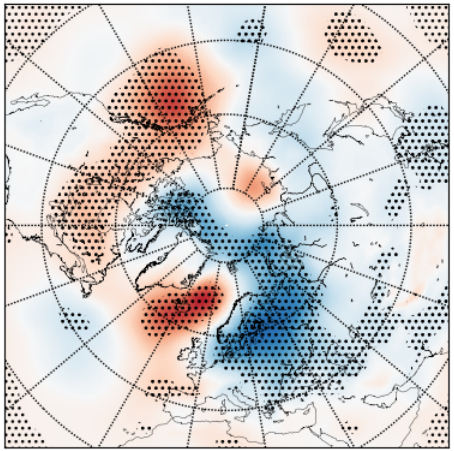


HF-FLT PRIMAVERA (LR)

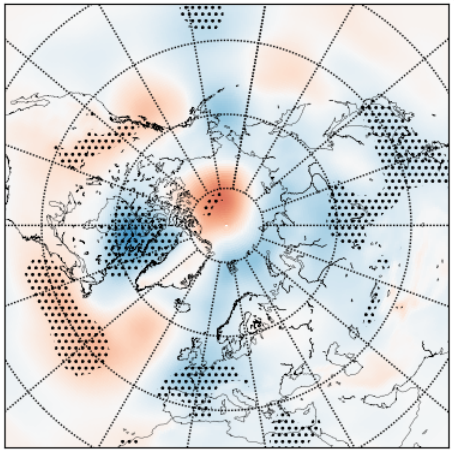


PRIMAVERA vs PAMIP (September): surface pressure [hPa]

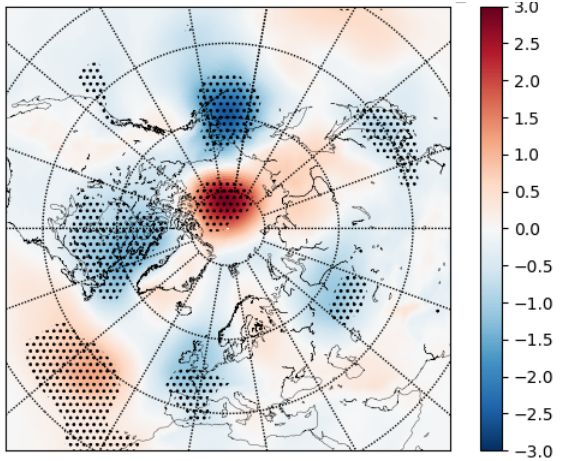
PAMIP



PRIMAVERA (LR)



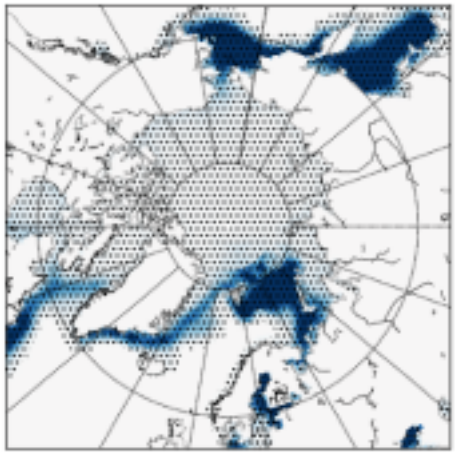
HF-FLT PRIMAVERA (LR)



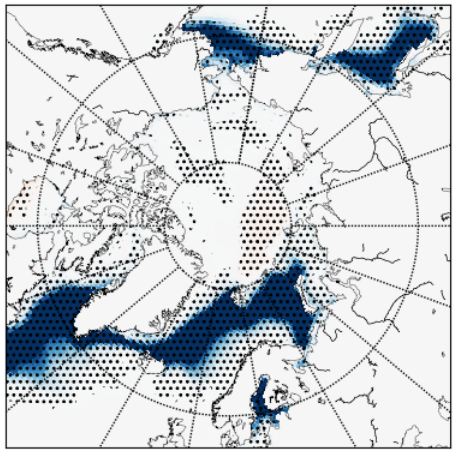
For September, there is poor agreement between PAMIP and PRIMAVERA circulation patterns

PRIMAVERA vs PAMIP (March)
SIC [%]

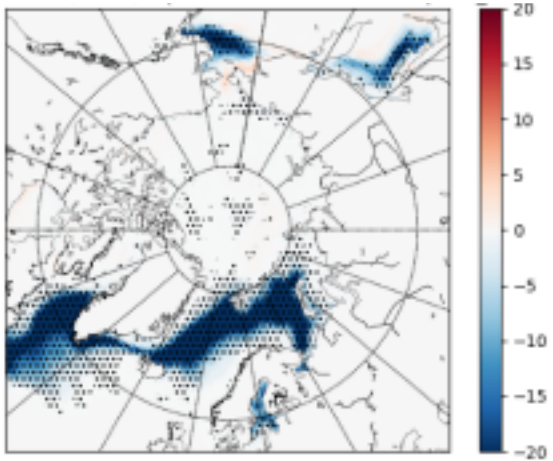
PAMIP



PRIMAVERA (LR)

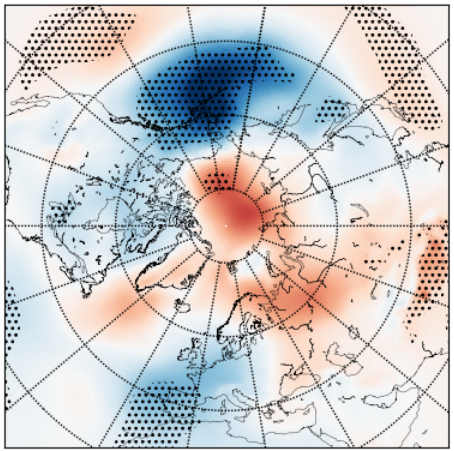


HF-FLT PRIMAVERA (LR)

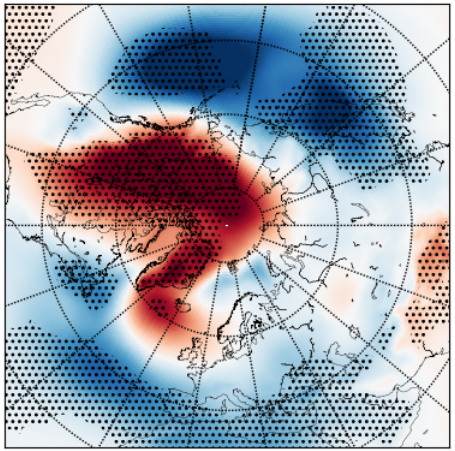


PRIMAVERA vs PAMIP (March): surface pressure [hPa]

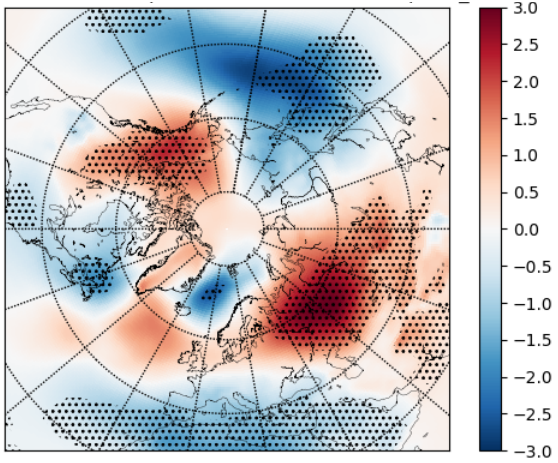
PAMIP



PRIMAVERA (LR)



HF-FLT PRIMAVERA (LR)



For March, there is better qualitative agreement between PAMIP and PRIMAVERA circulation patterns (mostly over the Atlantic and Eurasian sectors)

Summary

- SIE shows strong inter-annual variability in fully coupled EC-Earth model run at standard resolution, but not at high-resolution.

- A strong coupling of Arctic sea ice with the AMOC explains large variability amplitude at multi-decadal timescales in the lower resolution simulation.

- The overall patterns of climate anomalies associated with years of low/high SIE is quite different between LR and HR simulations. Removing this low-frequency component from the LR simulation provides a picture more consistent with HR.

- PAMIP simulations with fixed present-day SST and reduced SIE show spatial patterns in surface climate (e.g. temperature and surface pressure) response at least qualitatively comparable to the climate associations found in the PRIMAVERA runs.

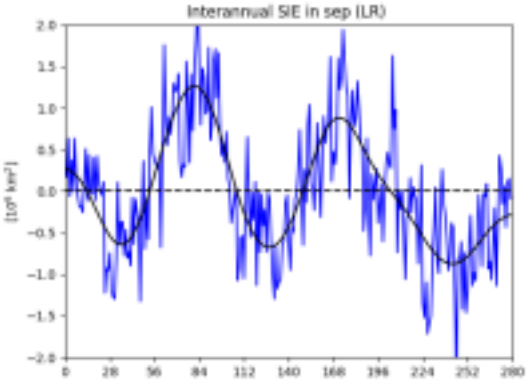
- Agreement in climate patterns associated with SIE in PAMIP and PRIMAVERA experiments could potentially be improved by using fixed SIC masks that better match natural SIC variability patterns.

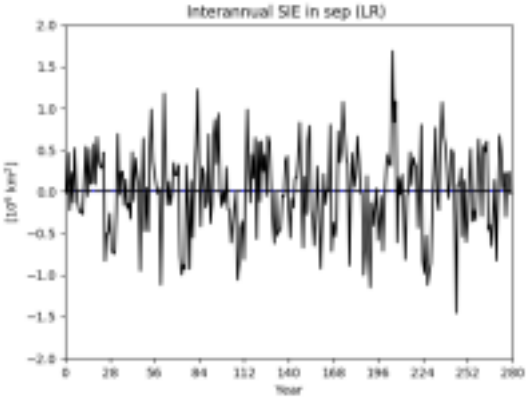
Thank you!

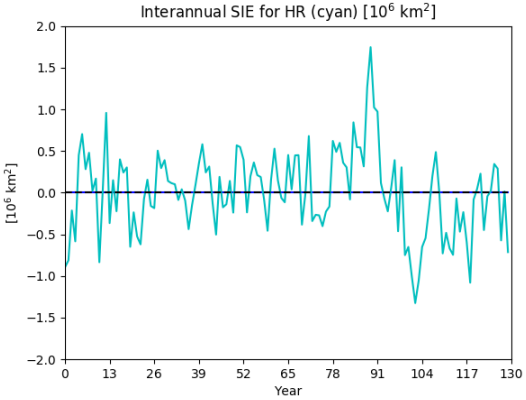
Question?

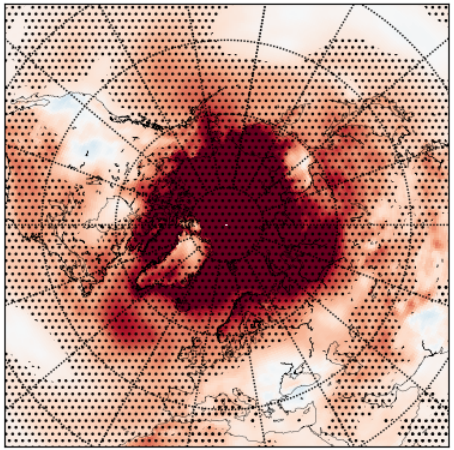
"*This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement H2020-MSCA-COFUND-2016-754433*".

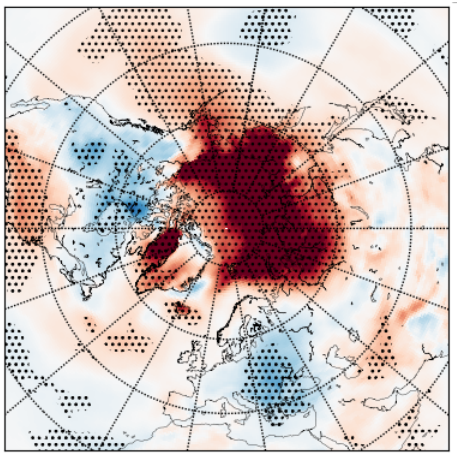
SIC pattern

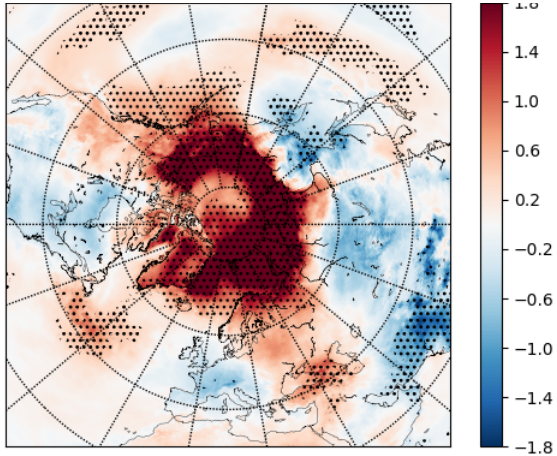

Interannual SIE in sep (LR)
[10⁶ km²]


Interannual SIE in sep (LR)
[10⁶ km²]
Year

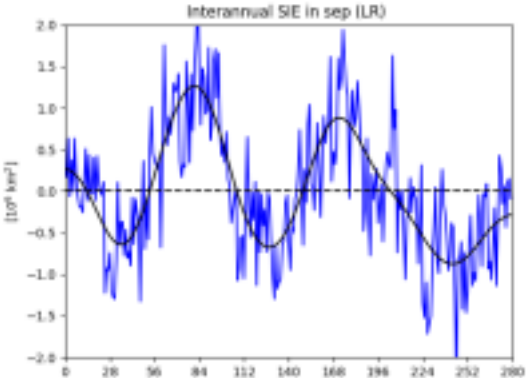

Interannual SIE for HR (cyan) [10⁶ km²]
[10⁶ km²]
Year

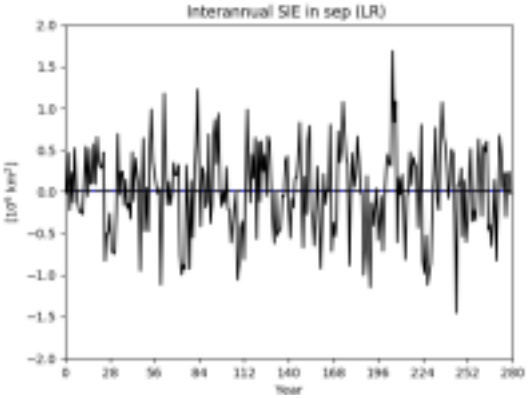


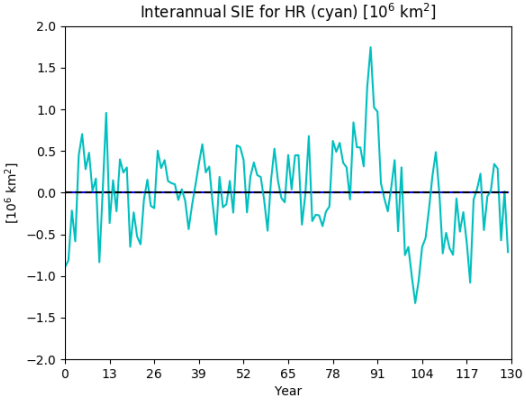


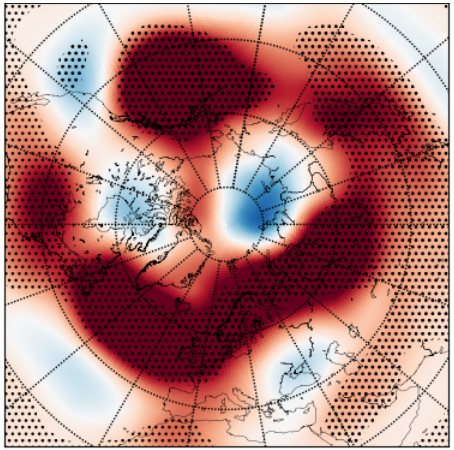

1.4
1.0
0.6
0.2
−0.2
−0.6
−1.0
−1.4
−1.8

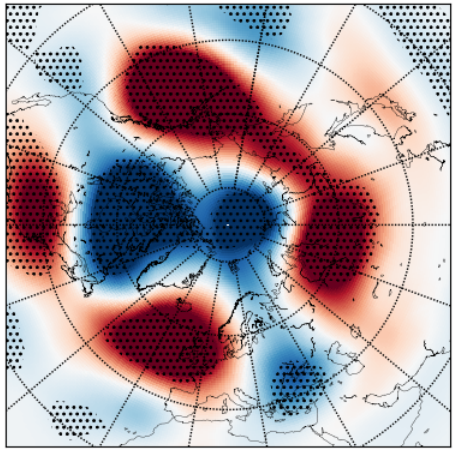
September climatological pattern associated with SIE across timescales

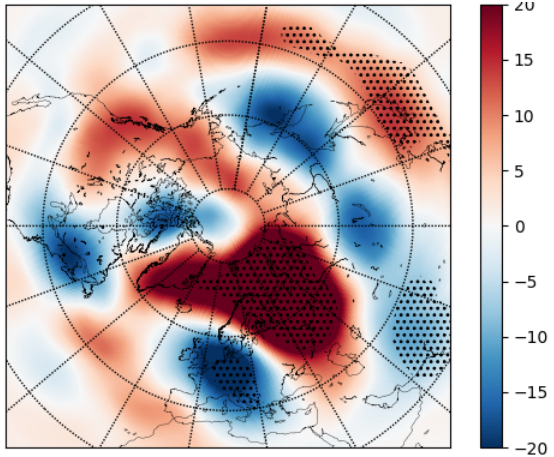






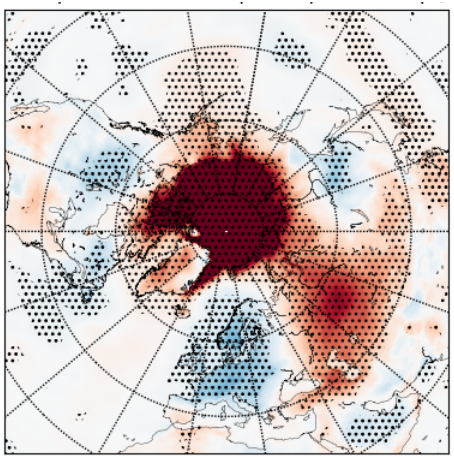




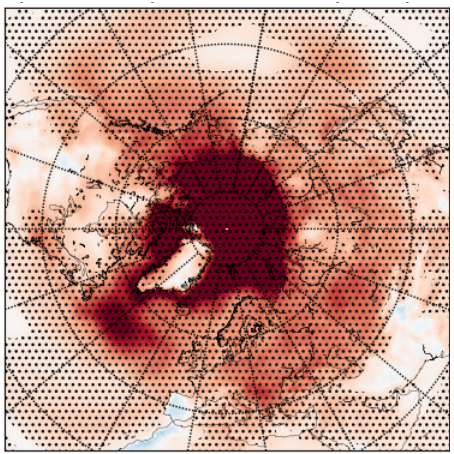


PRIMAVERA vs PAMIP (September): 2-m temperature [K]

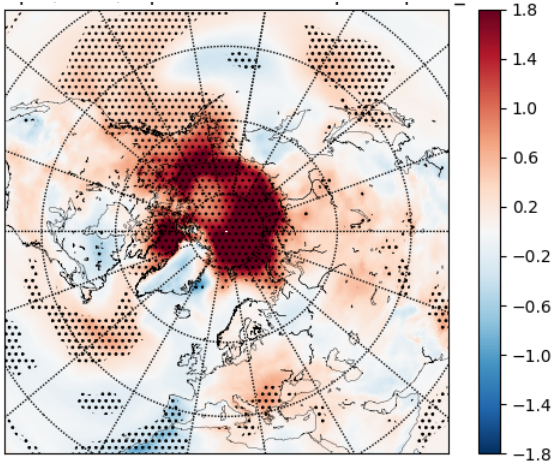
PAMIP



PRIMAVERA (LR)

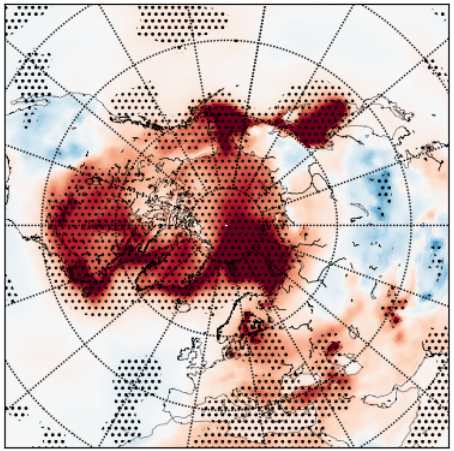


HF-FLT PRIMAVERA (LR)

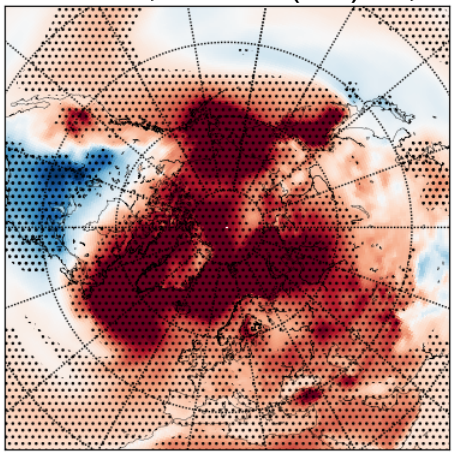


PRIMAVERA vs PAMIP (March): 2-m temperature [K]

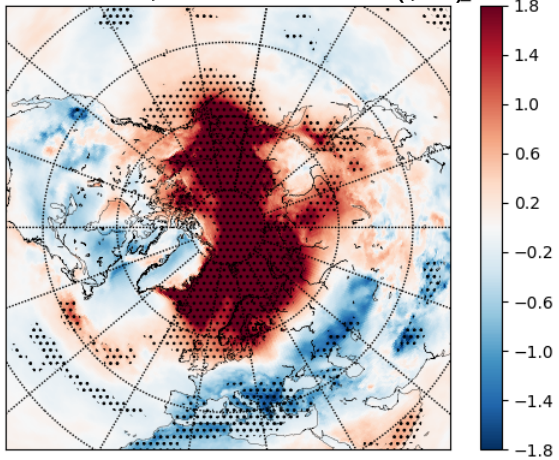
PAMIP



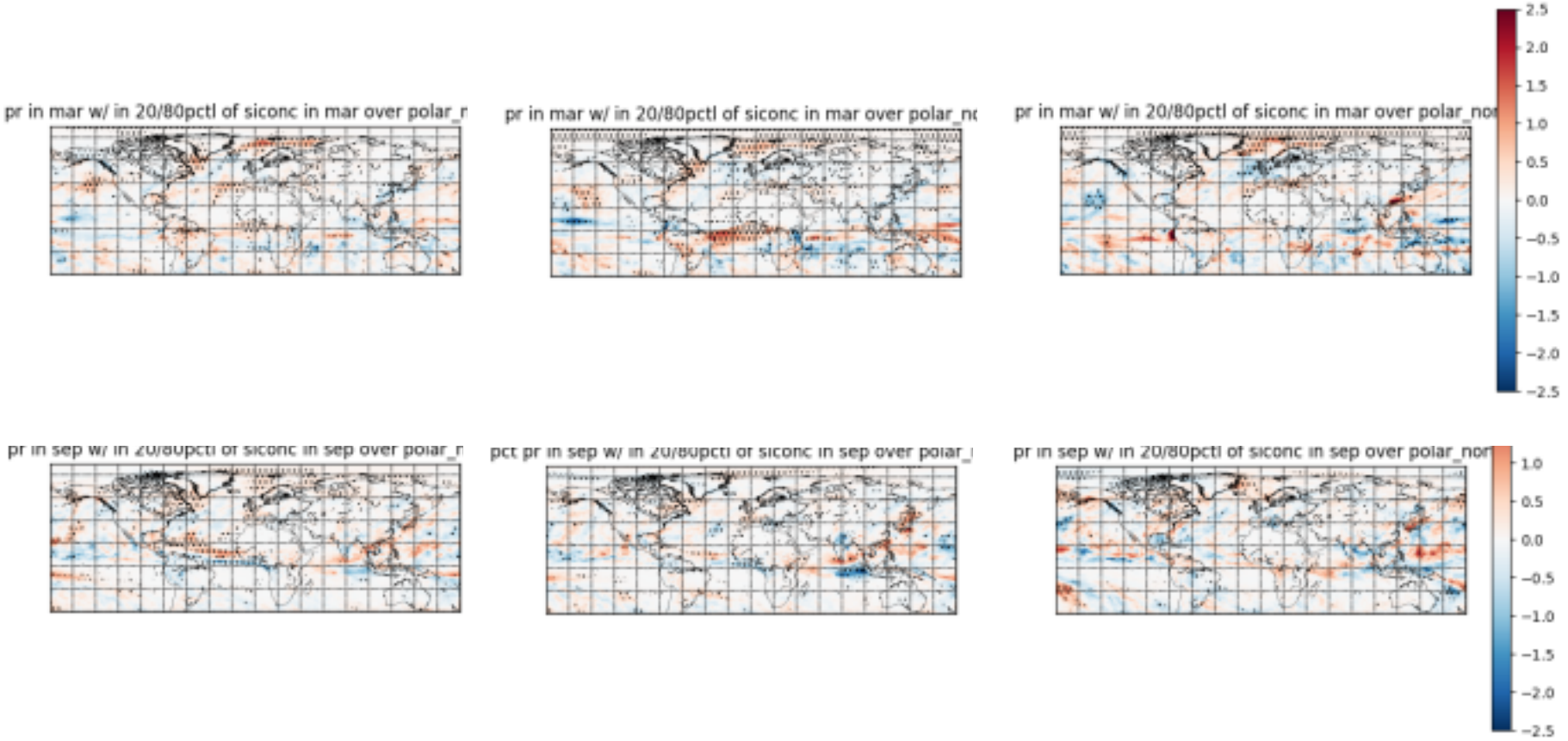
PRIMAVERA (LR)



HF-FLT PRIMAVERA (LR)



rainfall pattern in LR and HR

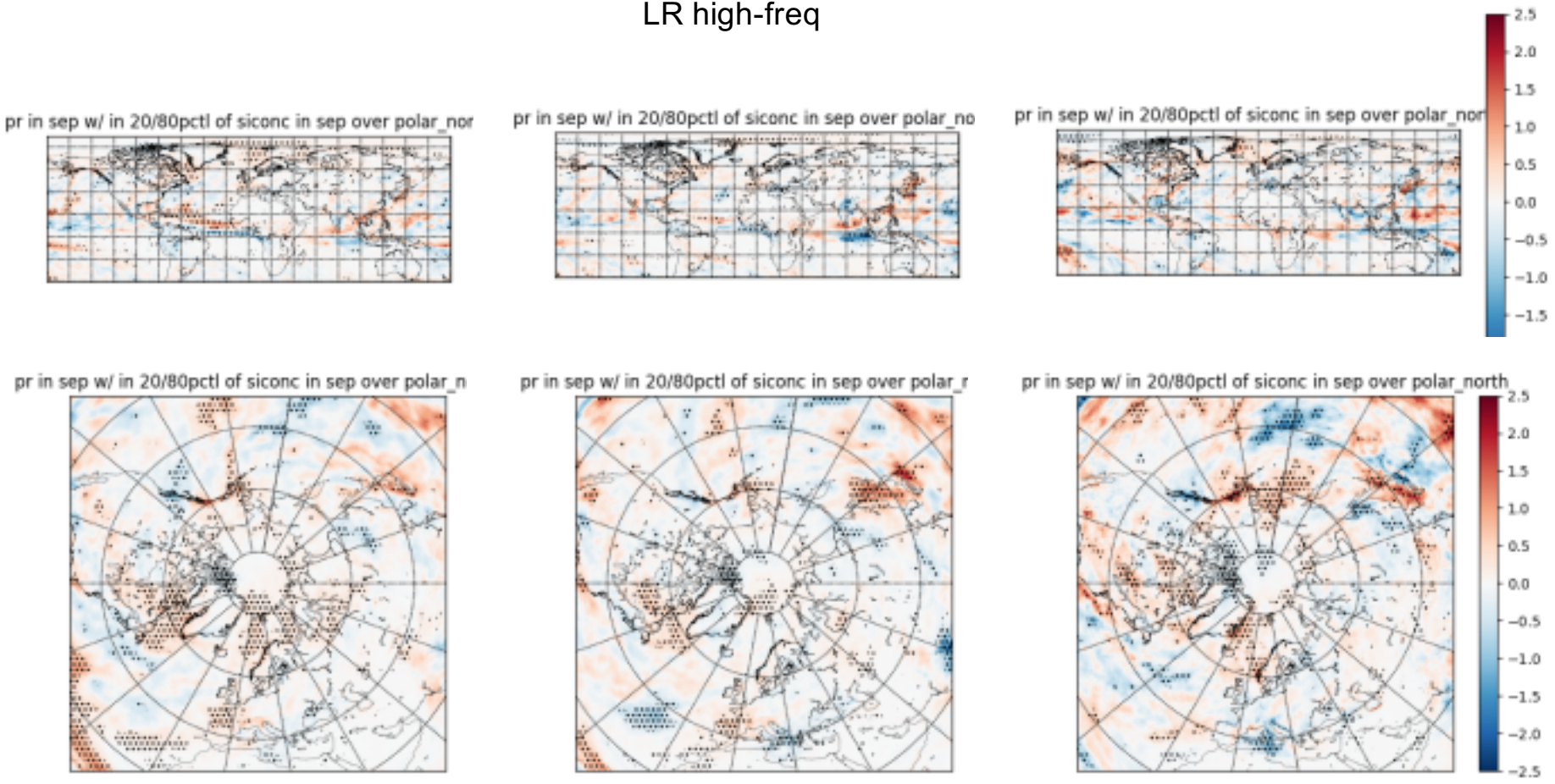


LR

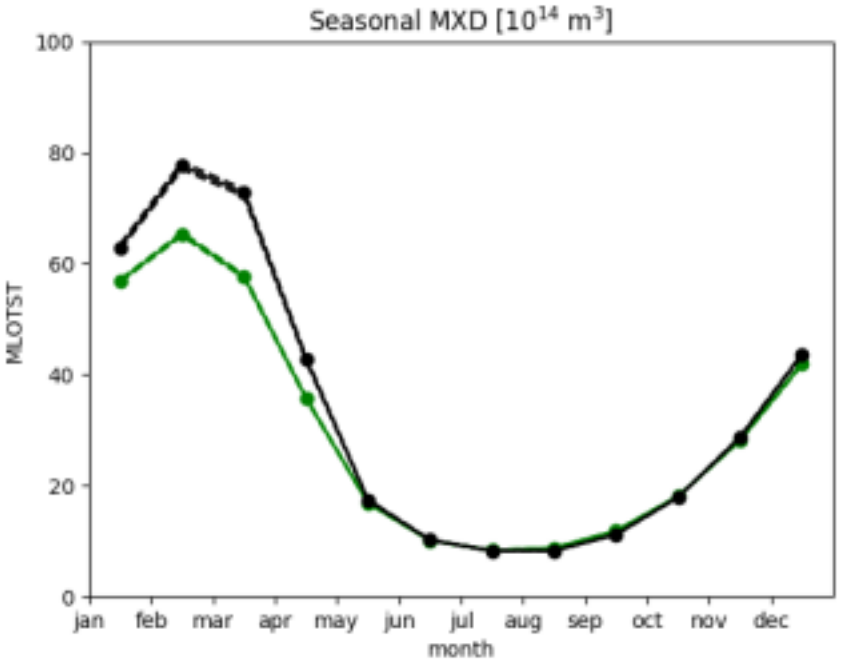
Rainfall pattern in LR and HR

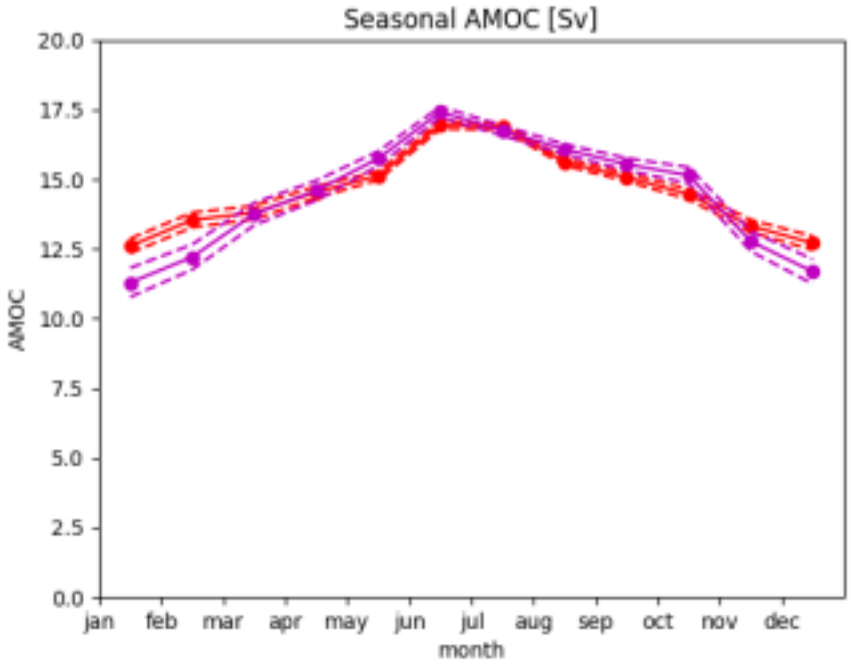
HR

LR high-freq



Climatology AMOC in LR and HR





- Issue: a number of studies have looked at whether years or periods of low sea ice extent are good proxies for the potential influence of sea ice on the Northern Hemisphere climate. Inter-annual variability in SIC and its association with climate is heavily influenced by the AMOC; climate pattern associated with those changes are different from those found in forced Sea ice experiments. What happens if you look at SIC variability and its associated climate pattern at different temporal timescales?

- Hypothesis: Isolating the component of SIE natural variability NOT associated with AMOC in a set of fully coupled climate simulations (part of the PRIMAVERA project) provides spatial patterns of changes more akin to that found in PAMIP experiments in which sea ice changes are forced.