The role of ocean heat transport from the Atlantic into the Arctic Ocean on sea ice variability

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Motivation

- Decrease of Arctic sea ice affects future climate in the Arctic and beyond
- Important to understand drivers of sea ice variability and trend
- Previous model studies:
  - summer sea ice mainly driven by atmospheric processes (incoming radiation and albedo feedback, e.g. *Serreze MC & Stroeve J. Philos Trans A Math Phys Eng Sci 2015*)
  - winter sea ice extent by ocean processes (ocean heat transport from Atlantic into Arctic Ocean, e.g. *Auclair, G. & Tremblay, L. B., JGR 2018; Årthun, M., T. Eldevik, and L. H. Smedsrud, J. Climate 2019*).

Method

We analyse a historical simulation with the UK Earth System Model (UKESM1) performed for CMIP6 from 1850 to 2014 and ocean – sea ice simulations forced by atmospheric reanalysis data with the same ocean model NEMOv3.6 and sea ice model CICEv5.1.

Focus on 3 parameters:

- Sea Ice: Annual (July-June) mean Barents Sea Ice extent
- Ocean: Winter (Nov-Apr) mean of ocean heat transport trough Barents Sea Opening (BSO)
- Atmosphere: Annual (July-June) mean incoming longwave radiation over Barents Sea

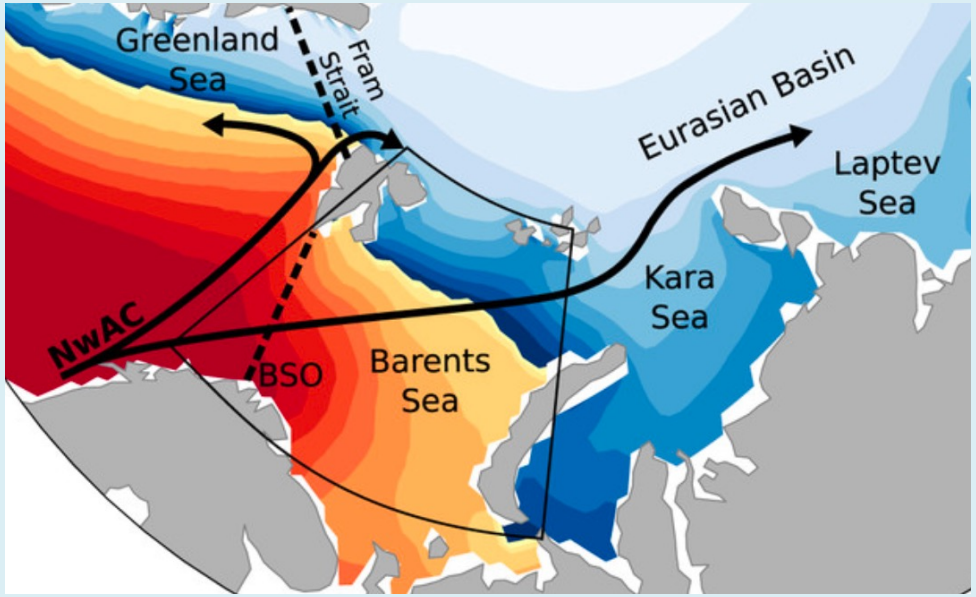
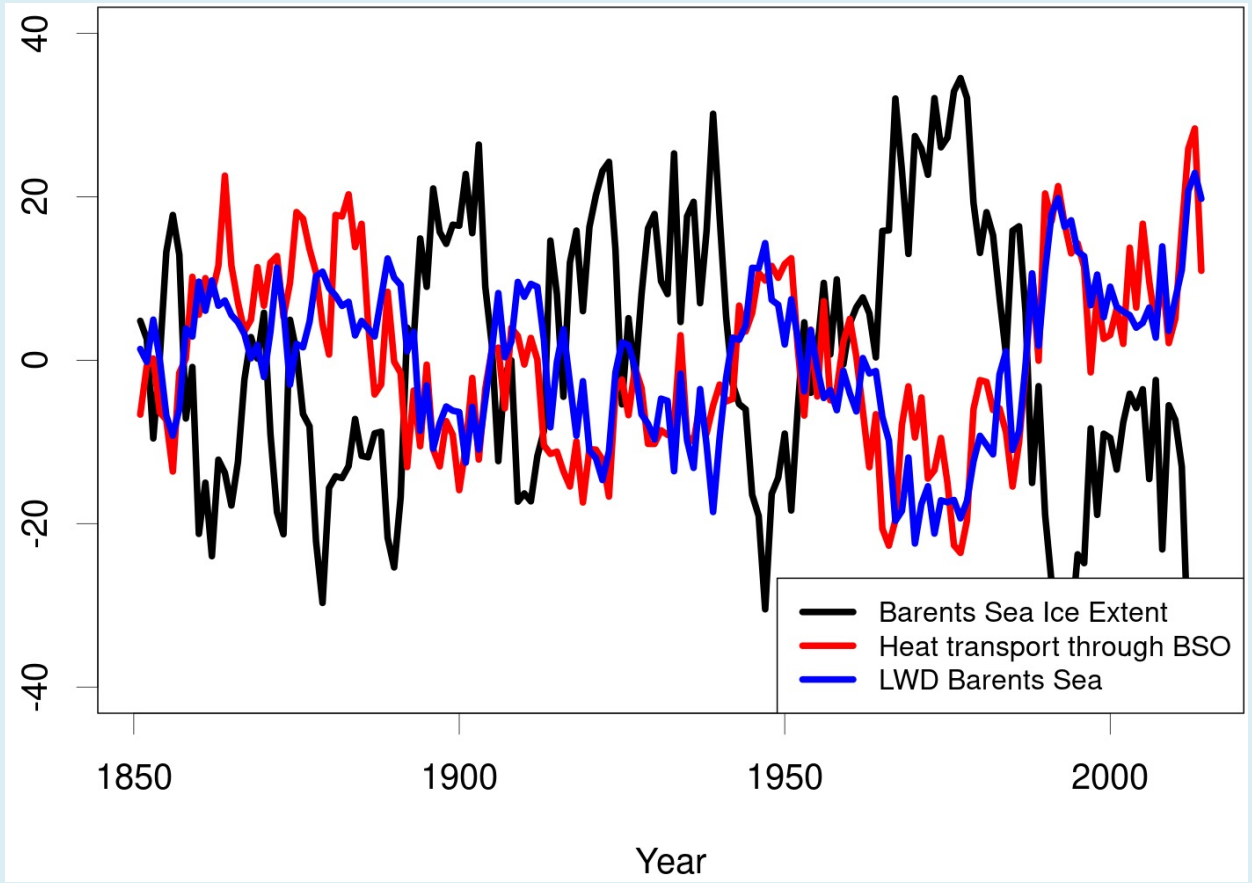


Figure from *Årthun, M., T. Eldevik, and L. H. Smedsrud, J. Climate 2019*

UKESM1 historical simulation

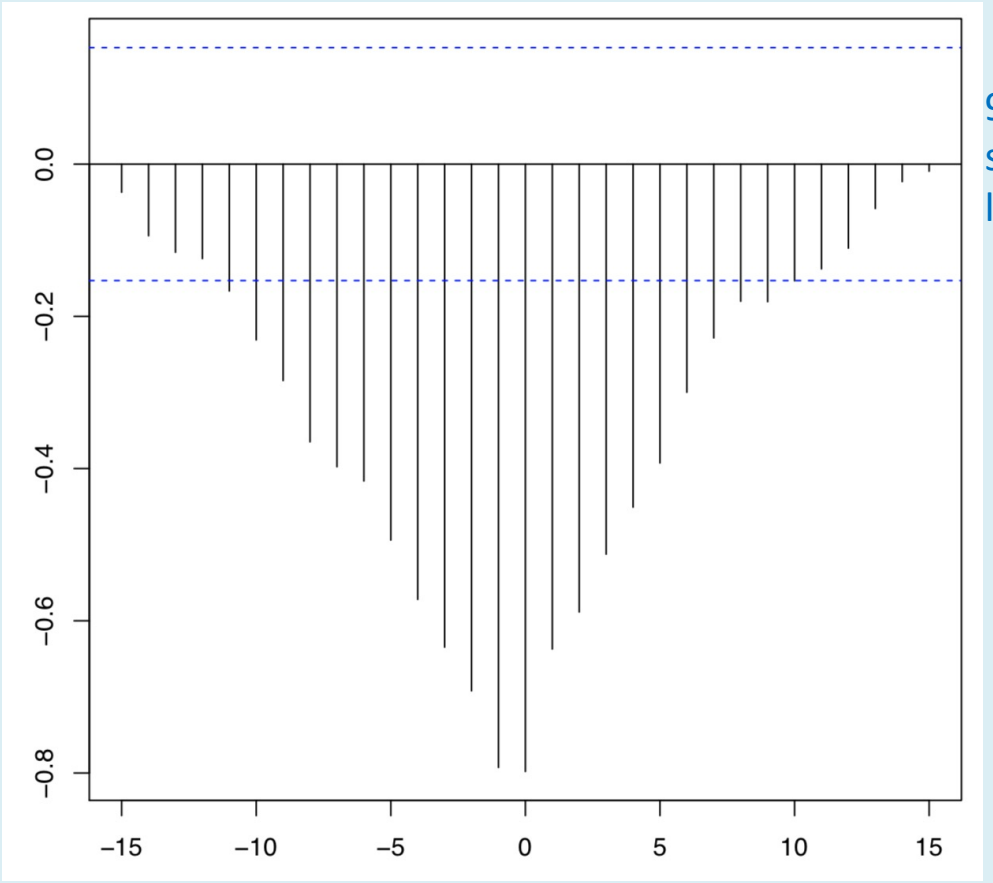
- **Strong negative correlation between BSO and Barents Sea Ice Extent for 164y time series (consistent with literature)**

Detrended time series



Anomalies in 10,000 km^2 (Extent), TW (BSO) and Wm^{-2} (LWD)

Lag correlation between BSO and Ice Extent

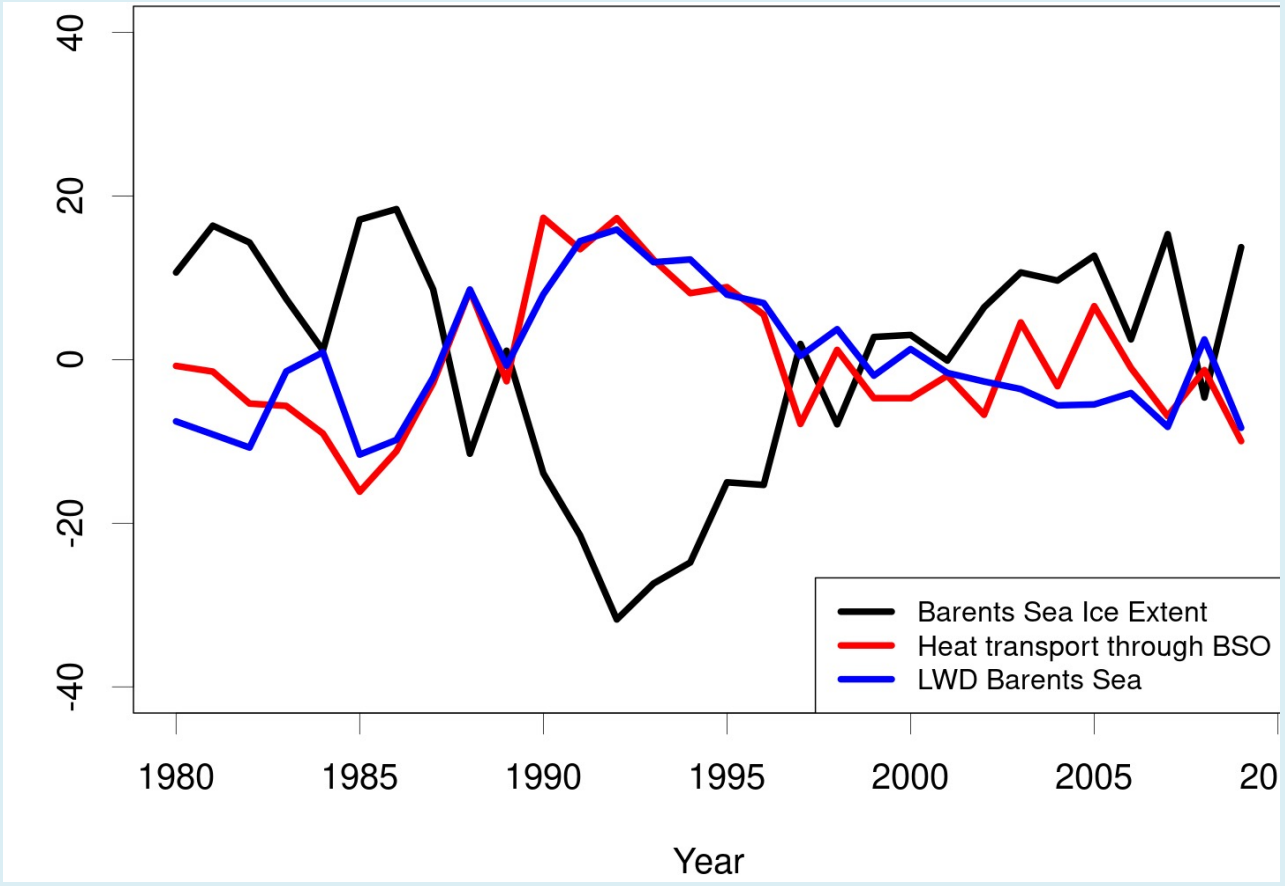


Lag in years

UKESM1 historical simulation

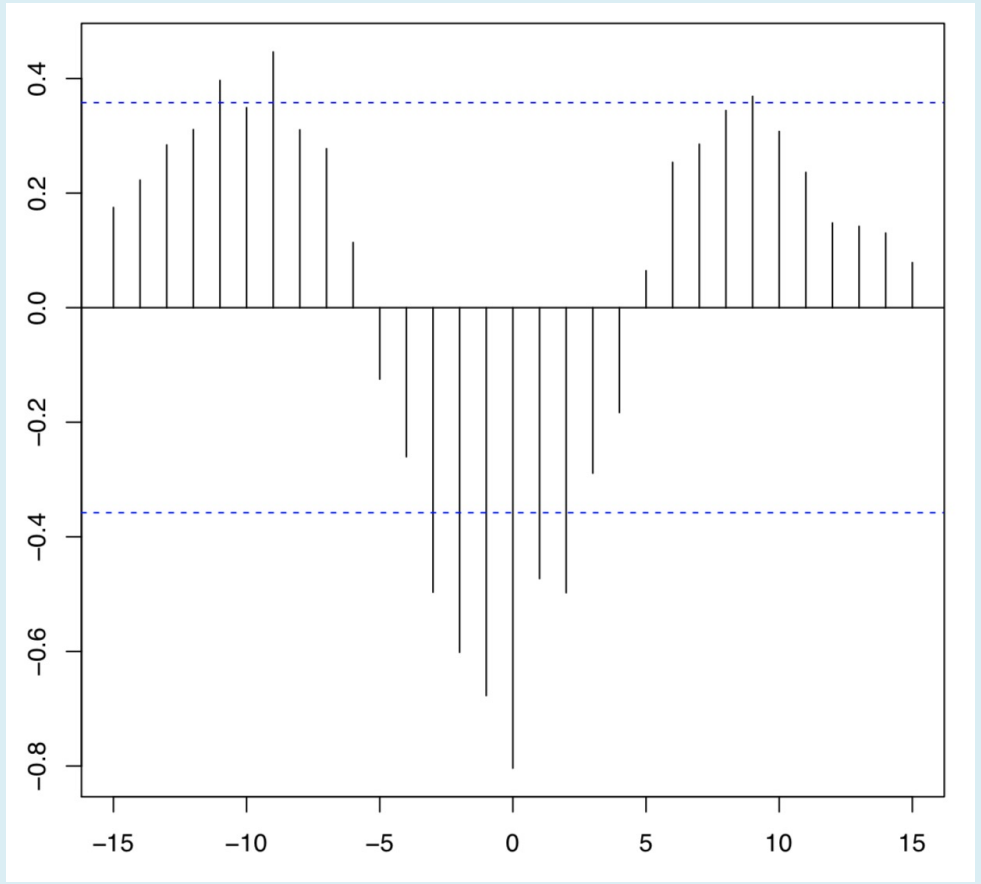
➢ **Similar results for 30y time series**

Detrended time series



Anomalies in 10,000 km^2 (Extent), TW (BSO) and Wm^{-2} (LWD)

Lag correlation between BSO and Ice Extent



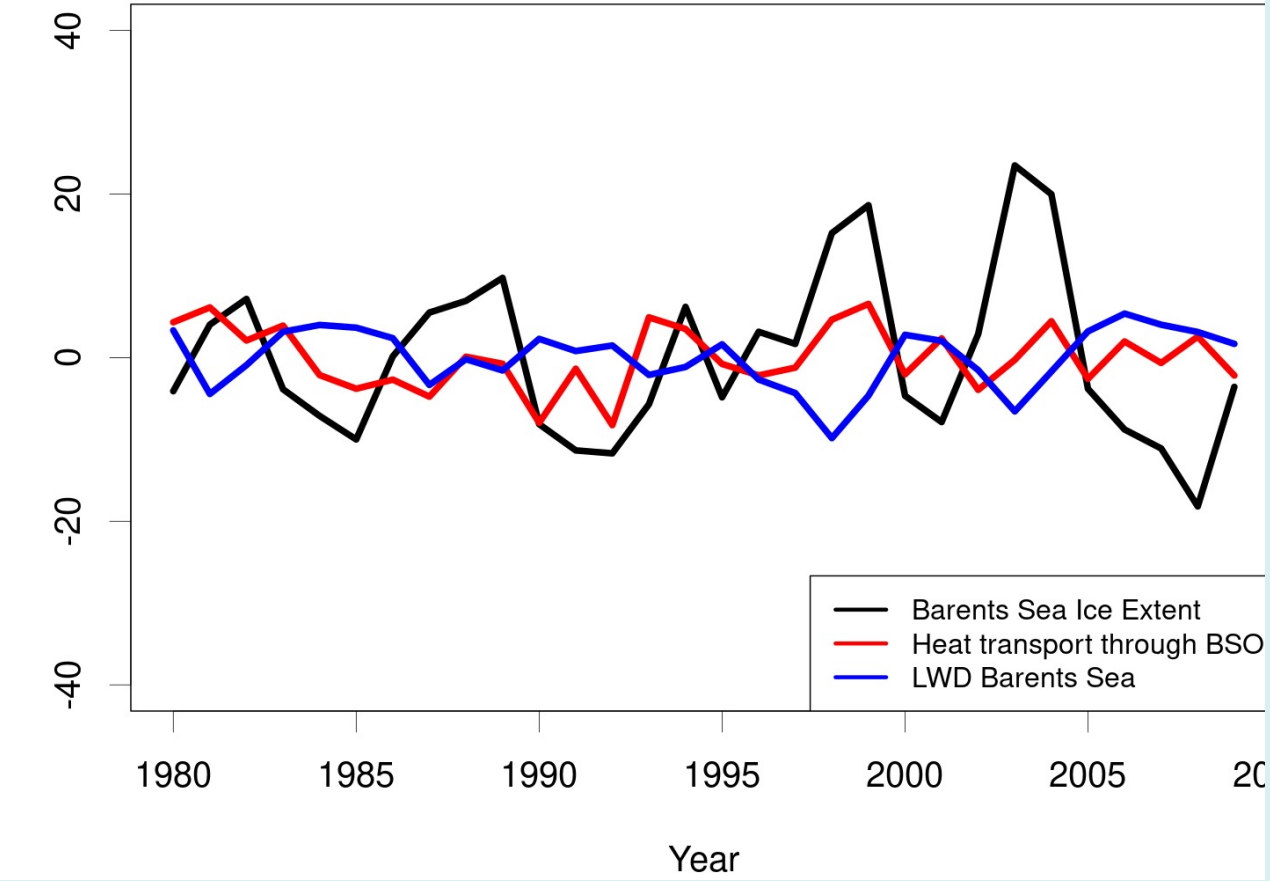
95% sig lev

Lag in years

Forced ocean – sea ice simulation (DFS5.2 atmospheric reanalysis data)

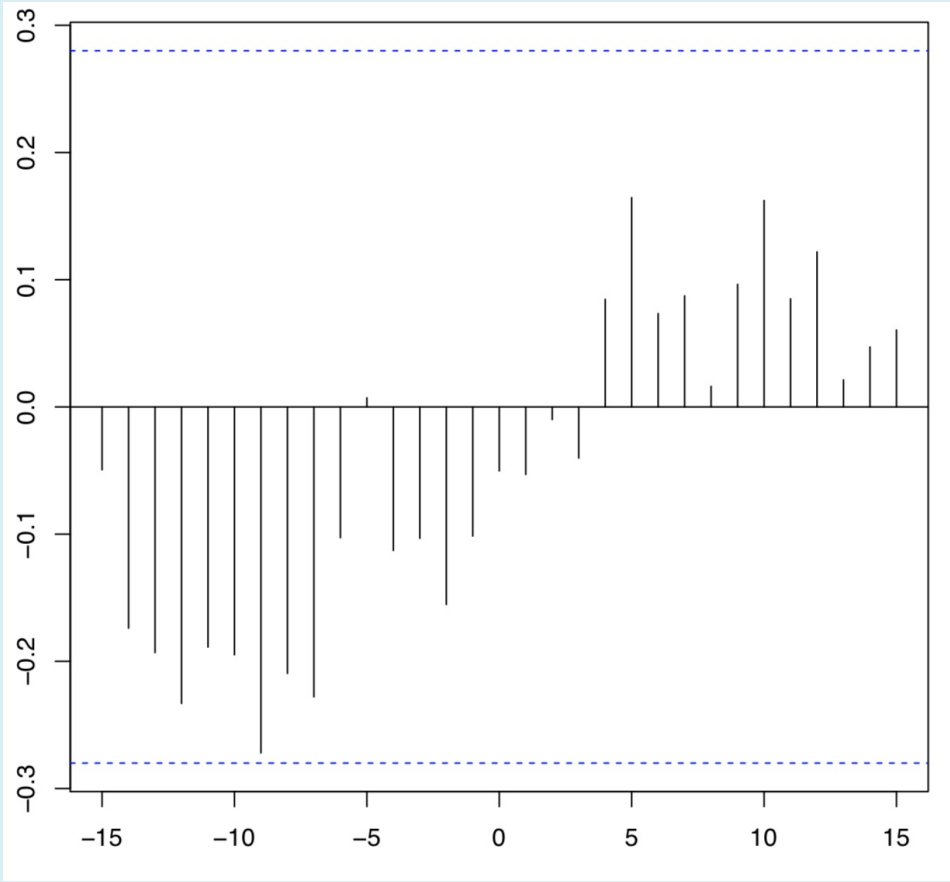
➢ **No correlation between BSO and Barents Sea Ice Extent in forced simulation**

Detrended time series



Anomalies in 10,000 km^2 (Extent), TW (BSO) and Wm^{-2} (LWD)

Lag correlation between BSO and Ice Extent



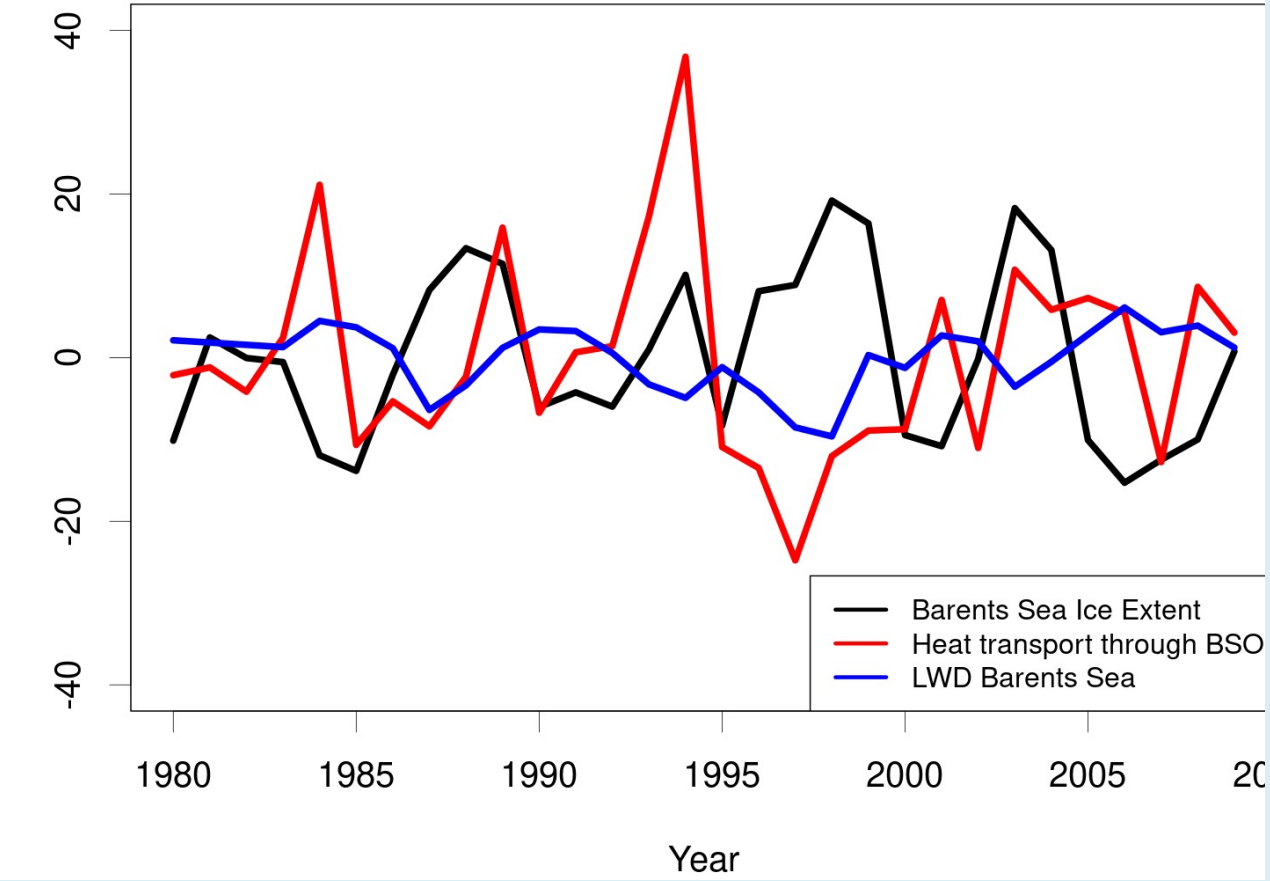
95% sig lev

Lag in years

Forced ocean – sea ice simulation (CORE atmospheric reanalysis data)

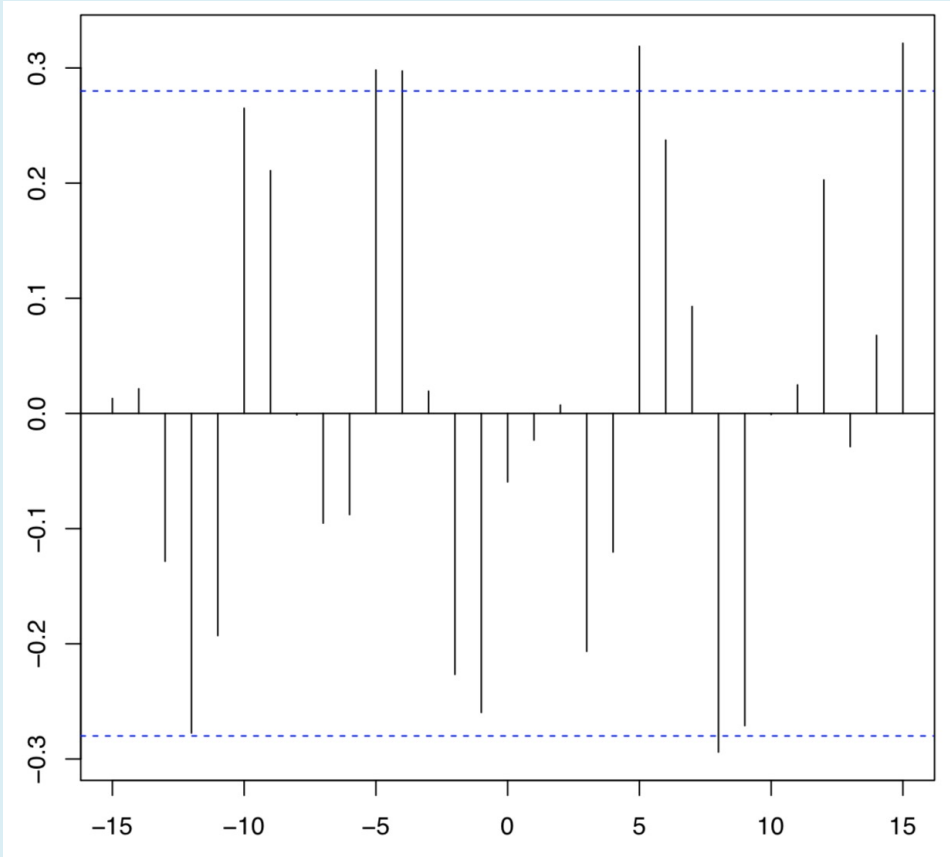
- **No correlation between BSO and Barents Sea Ice Extent in forced simulation (DFS and CORE forcing)**

Detrended time series



Anomalies in 10,000 km^2 (Extent), TW (BSO) and Wm^{-2} (LWD)

Lag correlation between BSO and Ice Extent



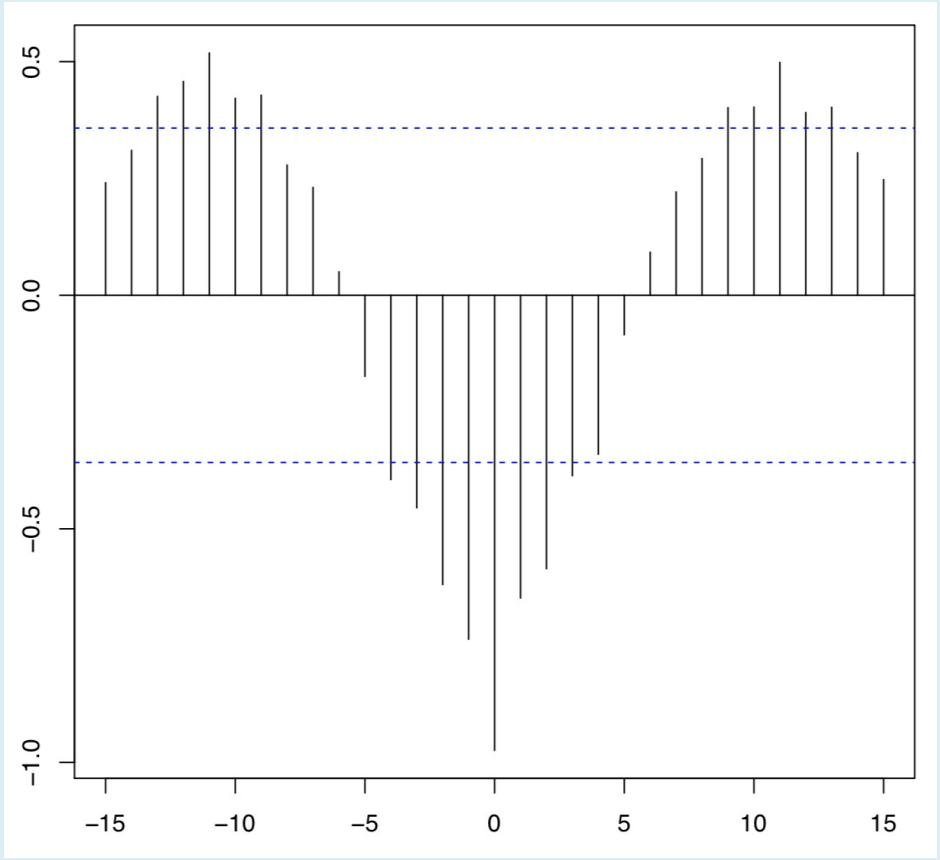
95% sig lev

Lag in years

Lag correlation between LWD (Incoming longwave radiation) and Ice Extent

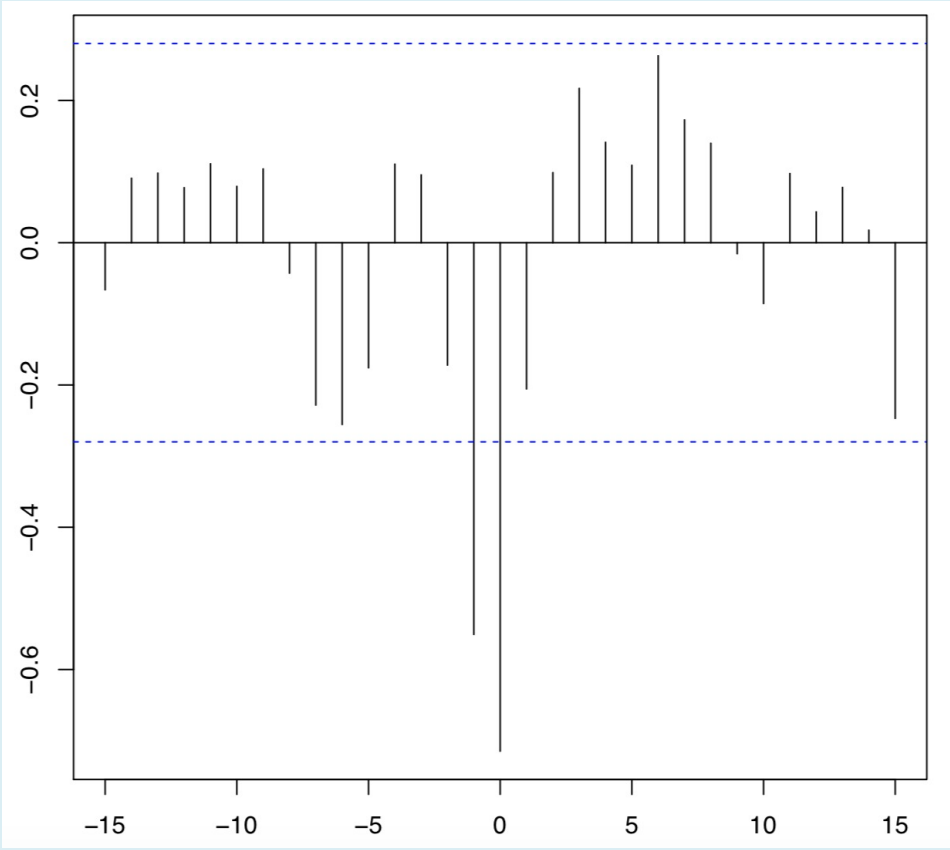
- **Strong negative correlation between LWD and Barents Sea Ice Extent for coupled and forced simulation for lag = 0 years**

UKESM 1 historical simulation

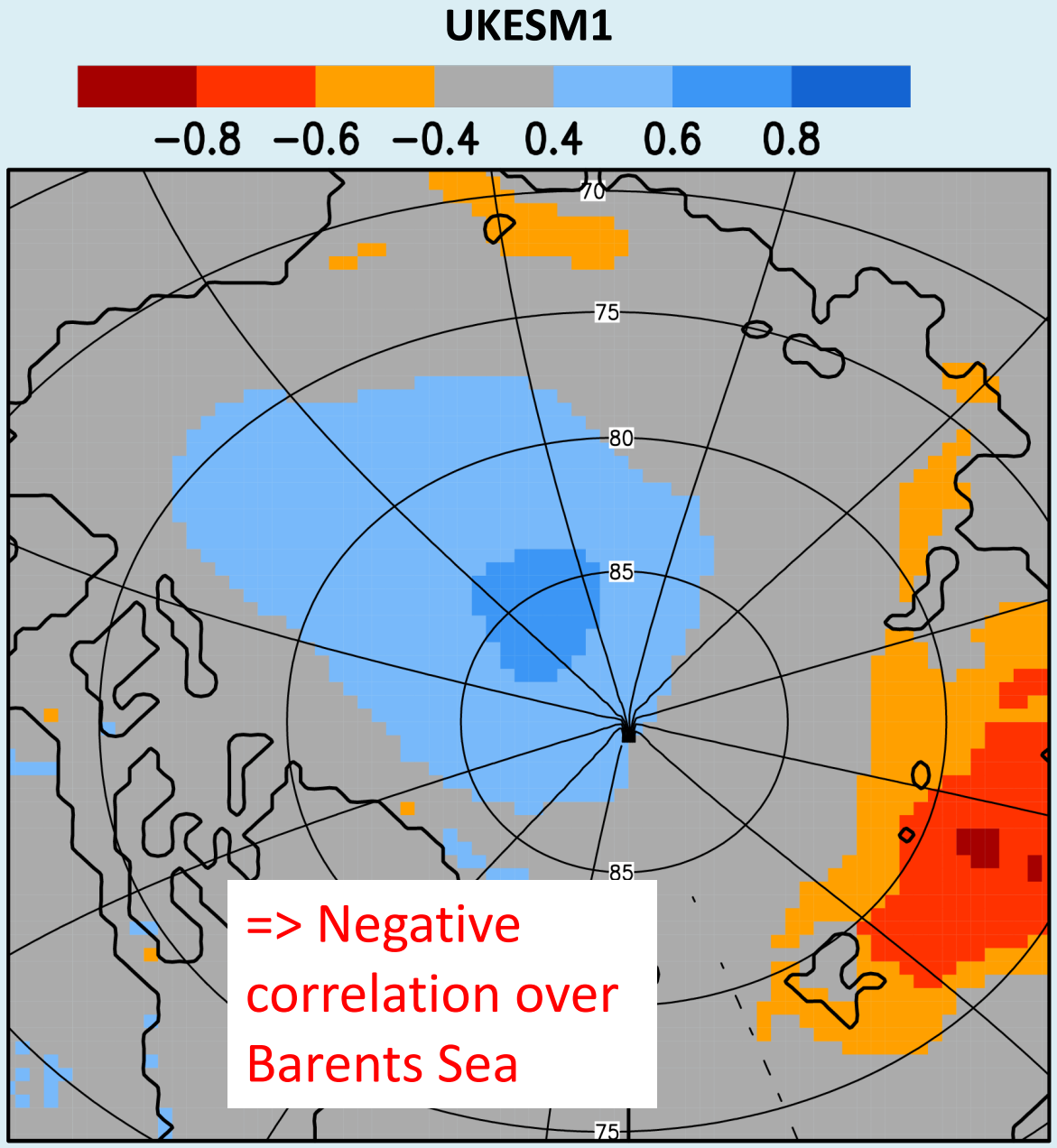


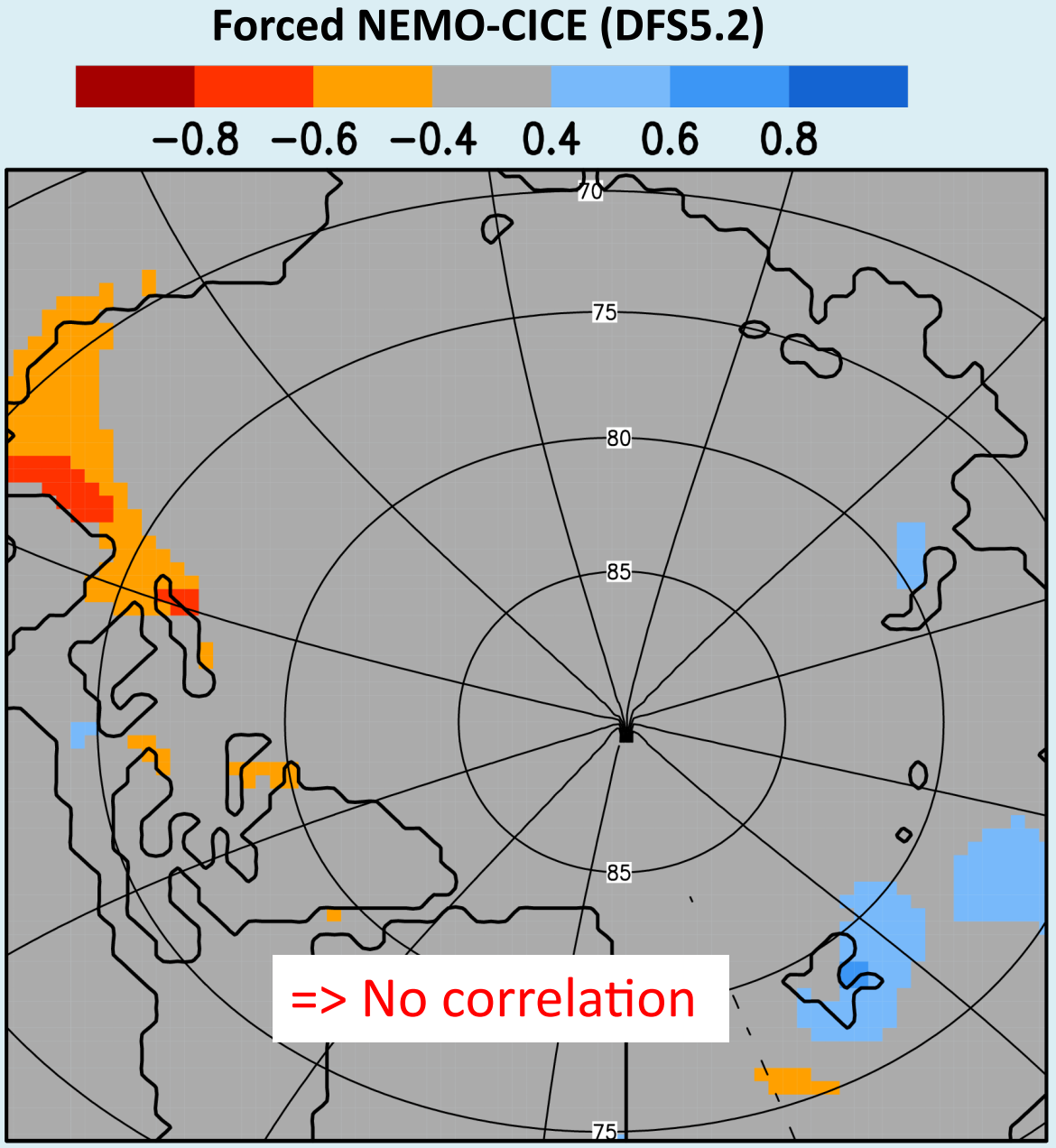
95% sig lev

Forced ocean – sea ice simulation
(DFS52 atmospheric reanalysis data)

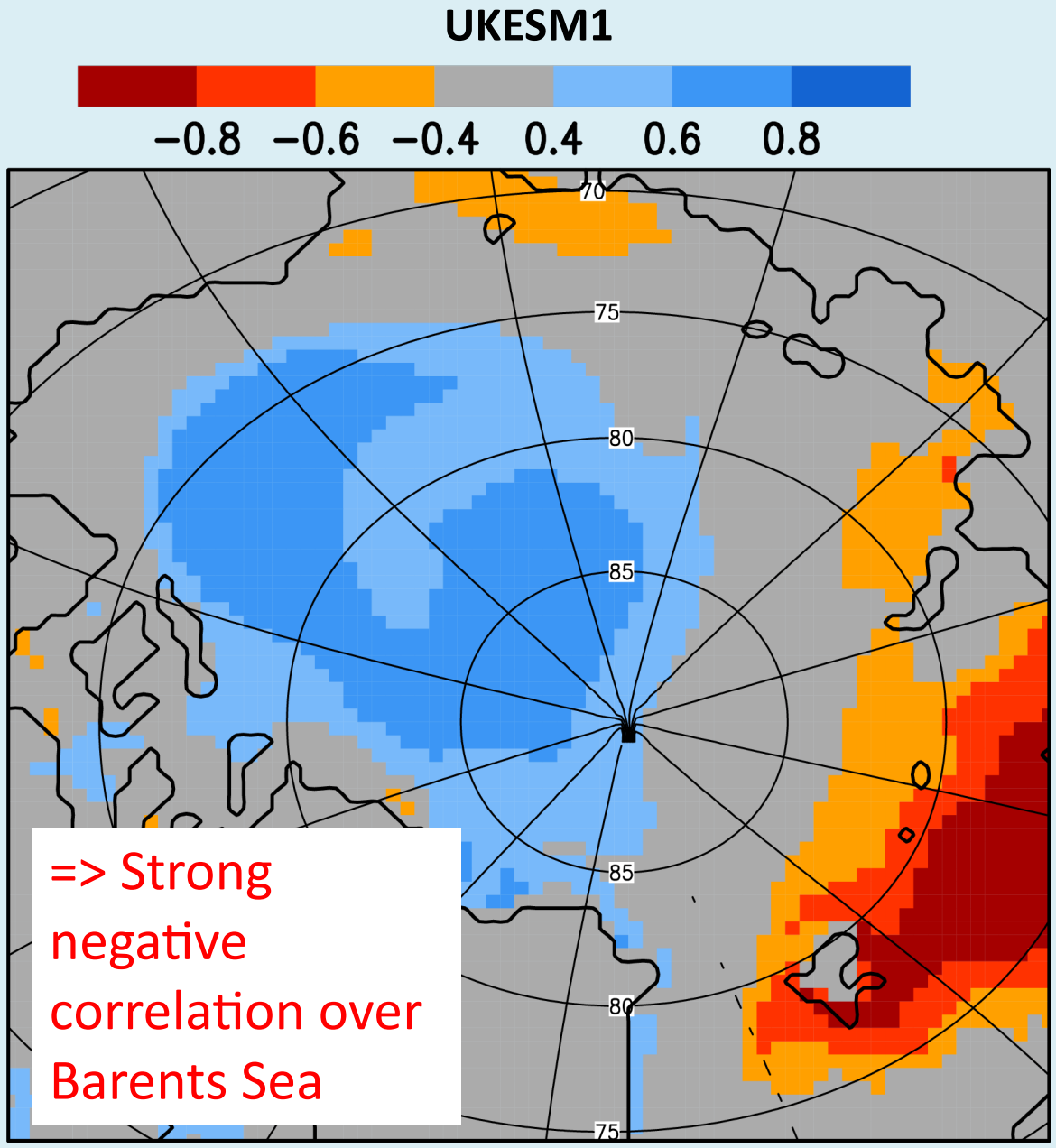


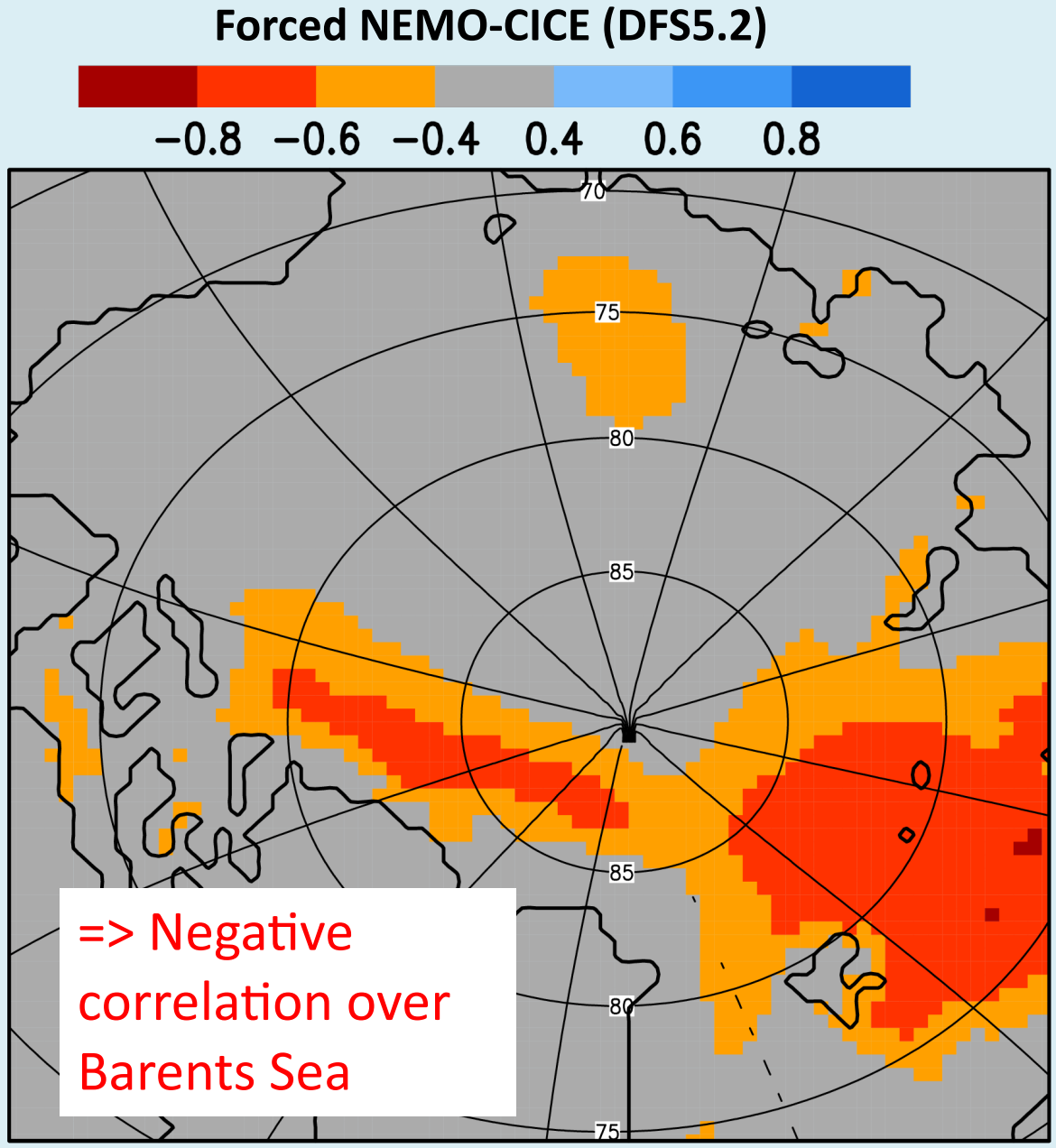
Correlation between BSO and local sea ice thickness (1980-2009)





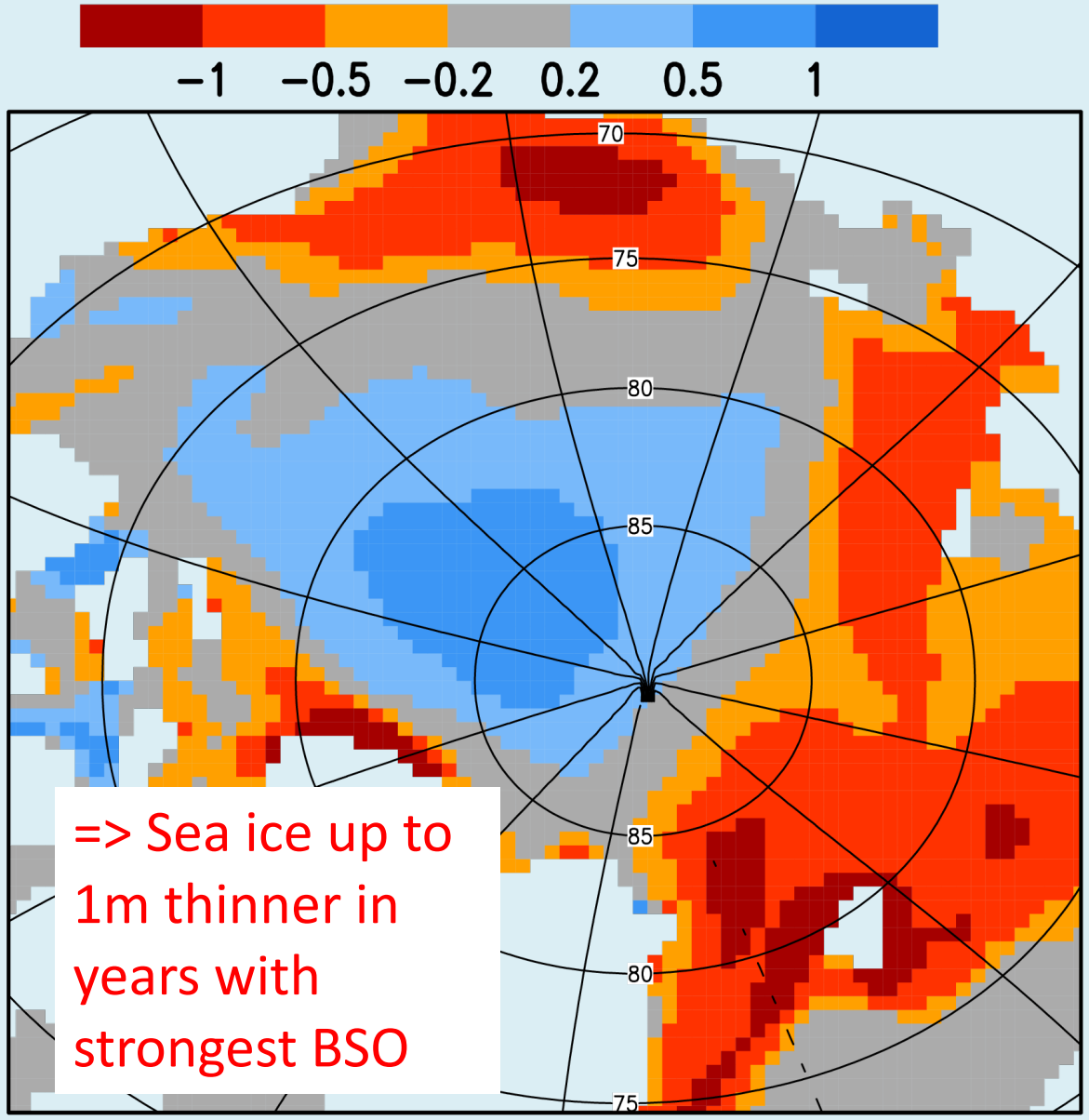
Correlation between LWD and local sea ice thickness (1980-2009)





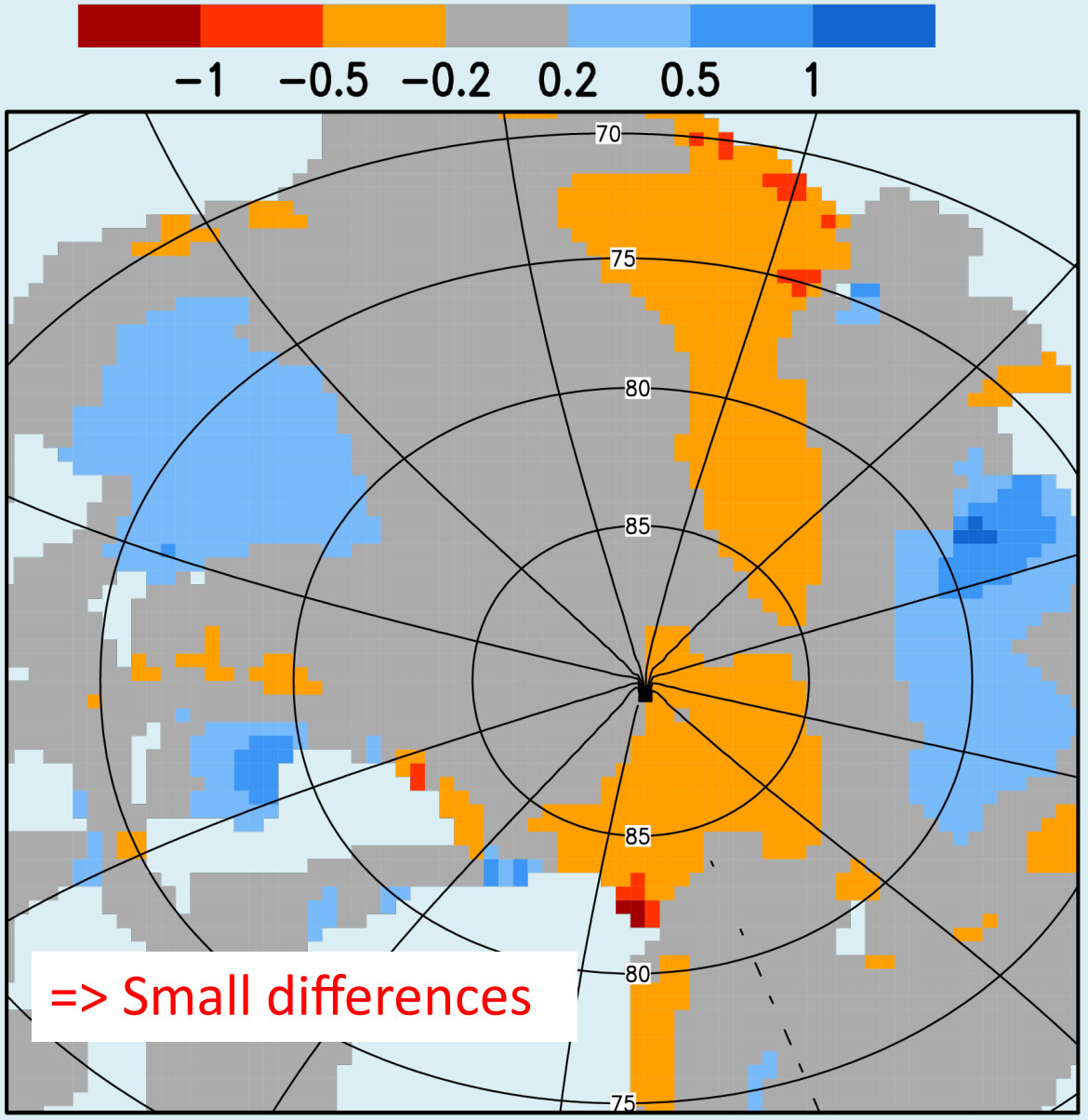
Difference in sea ice thickness: 5y with max BSO minus 5y with min BSO

UKESM1



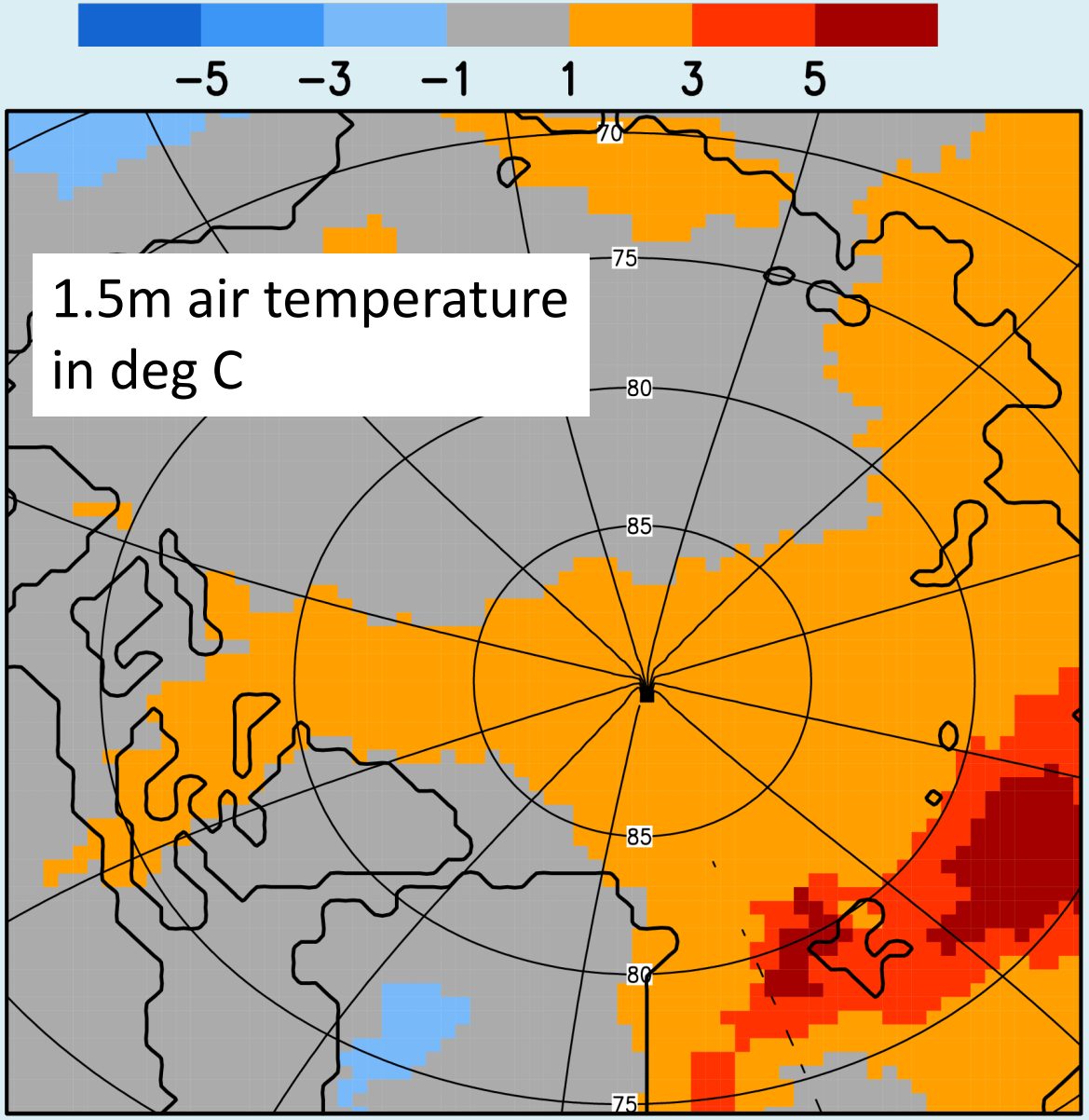
=> Sea ice up to 1m thinner in years with strongest BSO

Forced NEMO-CICE (DFS5.2)



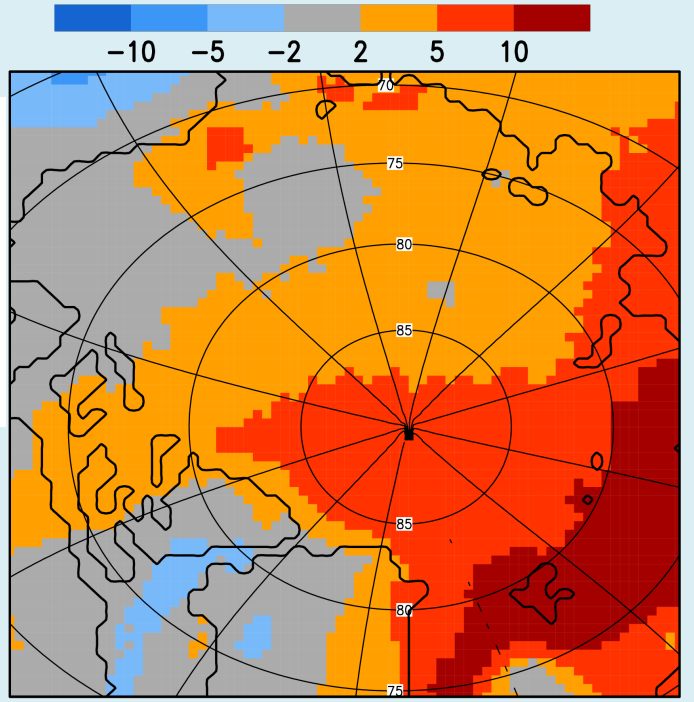
=> Small differences

Impact on atmosphere (UKESM1):
5y with max BSO minus 5y with min BSO

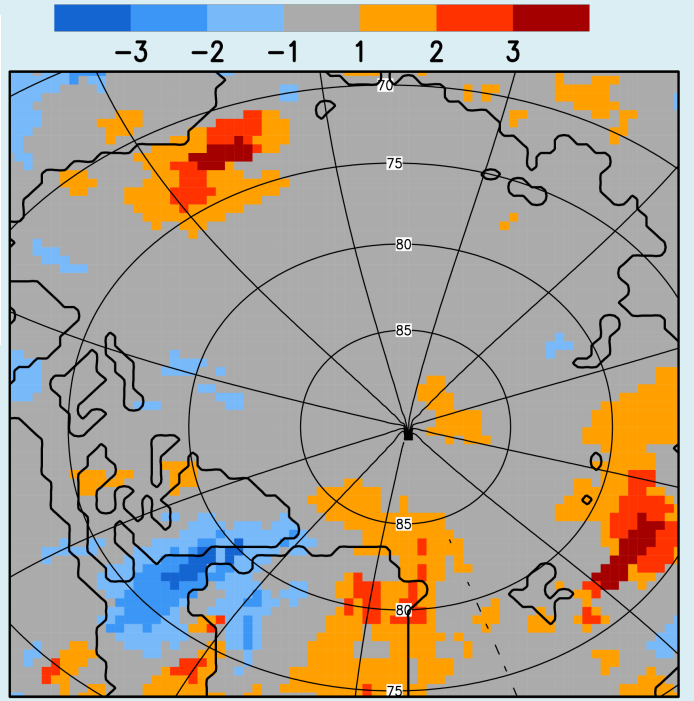


1.5m air temperature in deg C

Incoming longwave radiation in Wm^{-2}



Total cloud cover in %



=> 1.5m air temp up to 6K higher in years with strongest BSO

Summary

- UKESM1 simulation confirms previous findings: annual ocean heat transport between Norway and Svalbard is strongly correlated with the winter sea ice extent and thickness in the Barents Sea.
- Correlation does not exist for ocean-ice simulations forced with atmospheric reanalysis data.
- Strong correlation for annual mean incoming longwave radiation with winter sea ice extent and thickness in the Barents Sea in all simulations.
- **BSO ocean heat transport does not affect sea ice directly, but only via interaction with atmosphere.**