The weakening AMOC shapes future Euro-Atlantic atmospheric circulation

Workshop on Blocking and Extreme Weather in a Changing Climate

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Politecnico di Torino 1859

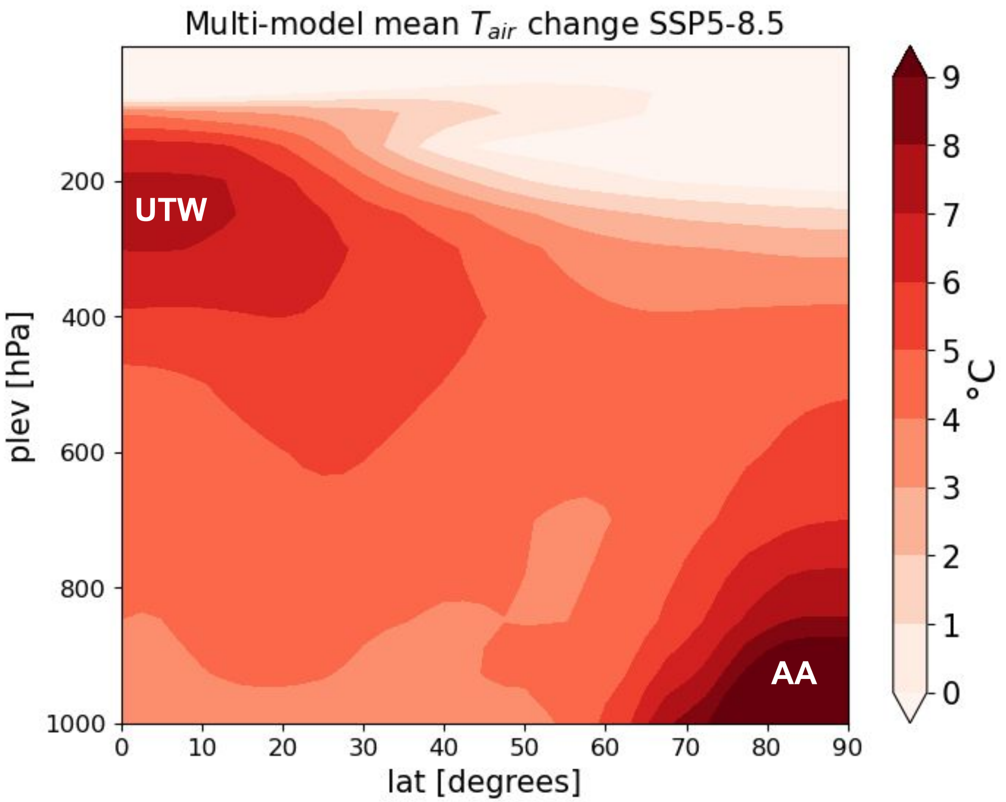
PhD SDC

Uncertain future Euro-Atlantic circulation

Tug-of-war between Arctic and Tropical warmings determines the evolution of the **meridional temperature gradient**

→ Projected squeezing of the North Atlantic jet and intensification of the storm track

(e.g. Barnes and Screen, 2015; Shaw et al., 2016, Peings et al., 2018)



2071-2100 minus 1950-2015

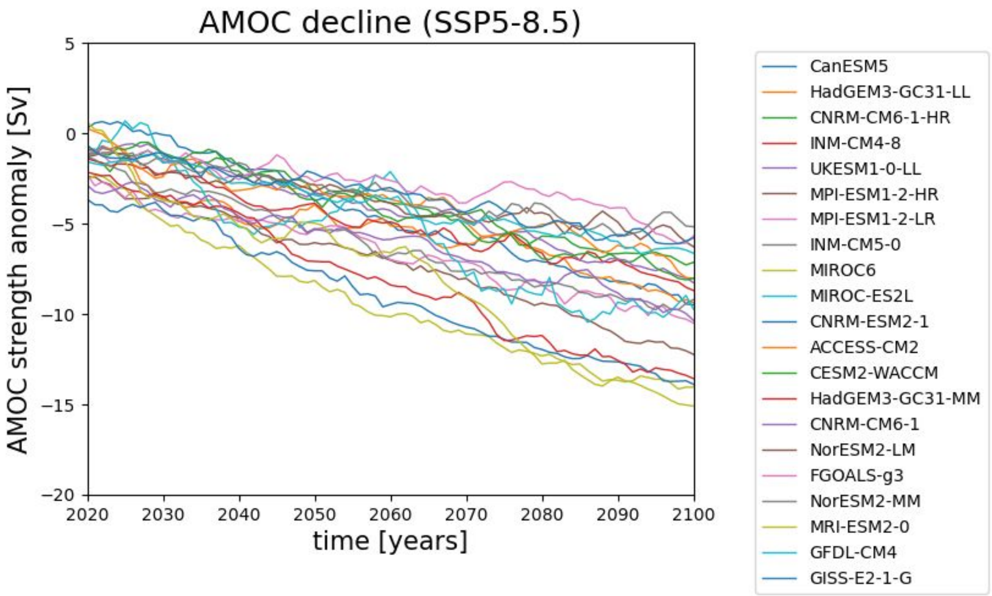
The role of the Atlantic Meridional Overturning Circulation

The AMOC is predicted to weaken under GHG forcing *(Weijer et al., 2020)*

The reduced oceanic poleward heat transport (~0.5 PW/year) impacts the atmospheric circulation in the North Atlantic

(Woolings et al., 2012; Gervais et al., 2019, Bellomo et al., 2023)

How does AMOC weakening affect the uncertainty of future wintertime Euro-Atlantic large-scale circulation?

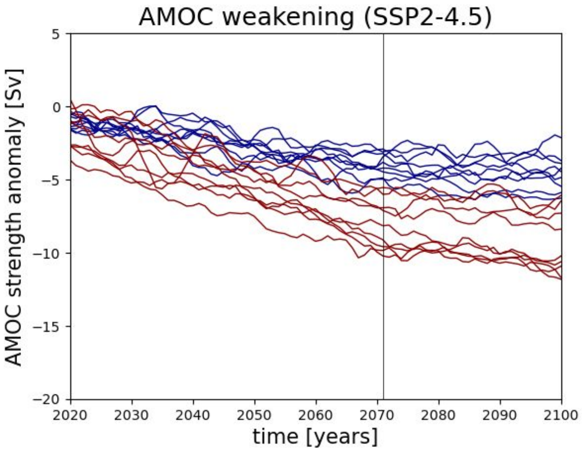


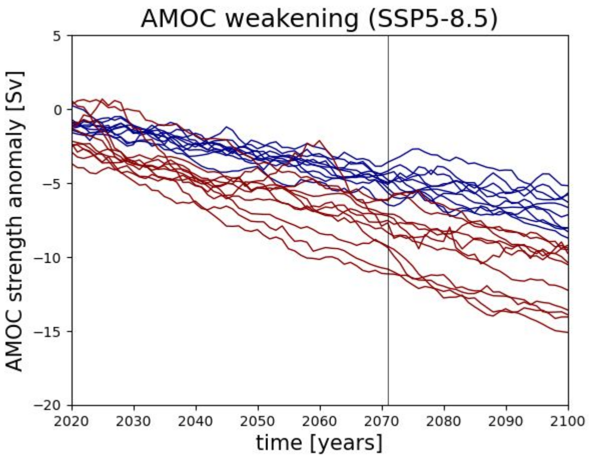
Data and Methods

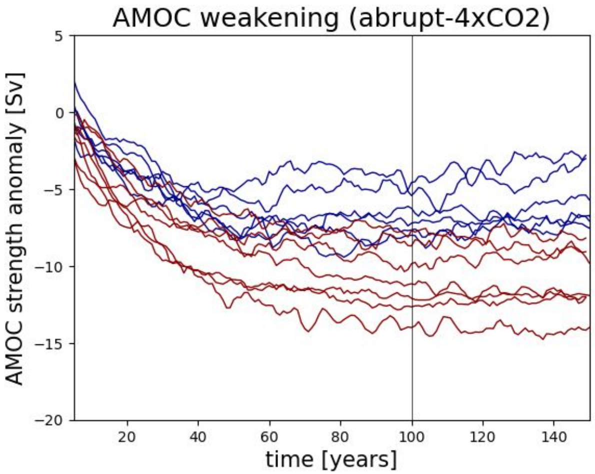
Three experiments from the CMIP6 archive

Models are splitted into **Large-AMOC Decline (LAD)** and **Small-AMOC Decline (SAD)** groups

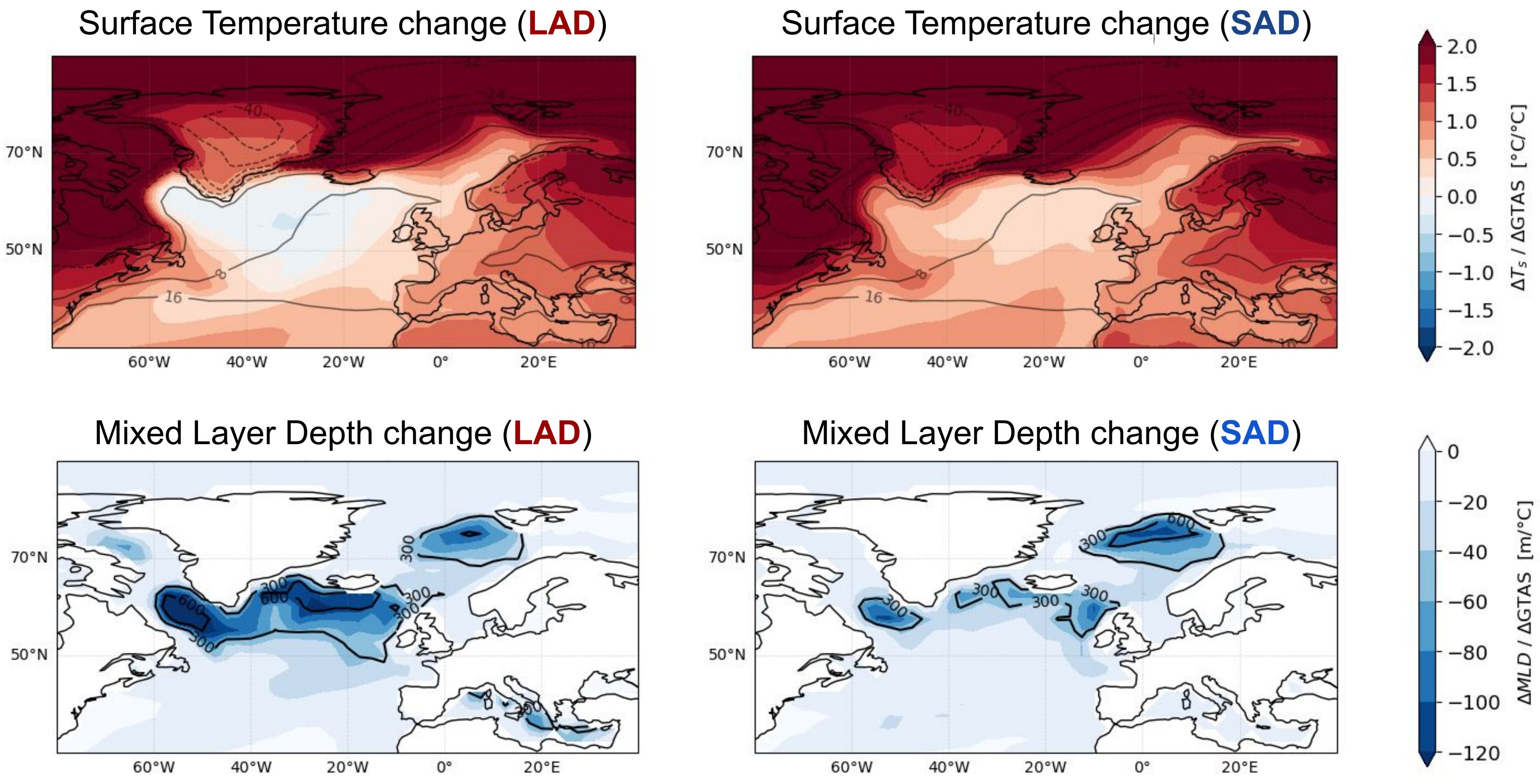
The difference in the atmospheric circulation response between the two groups is the effect of the AMOC weakening *(Bellomo et al., 2021)*







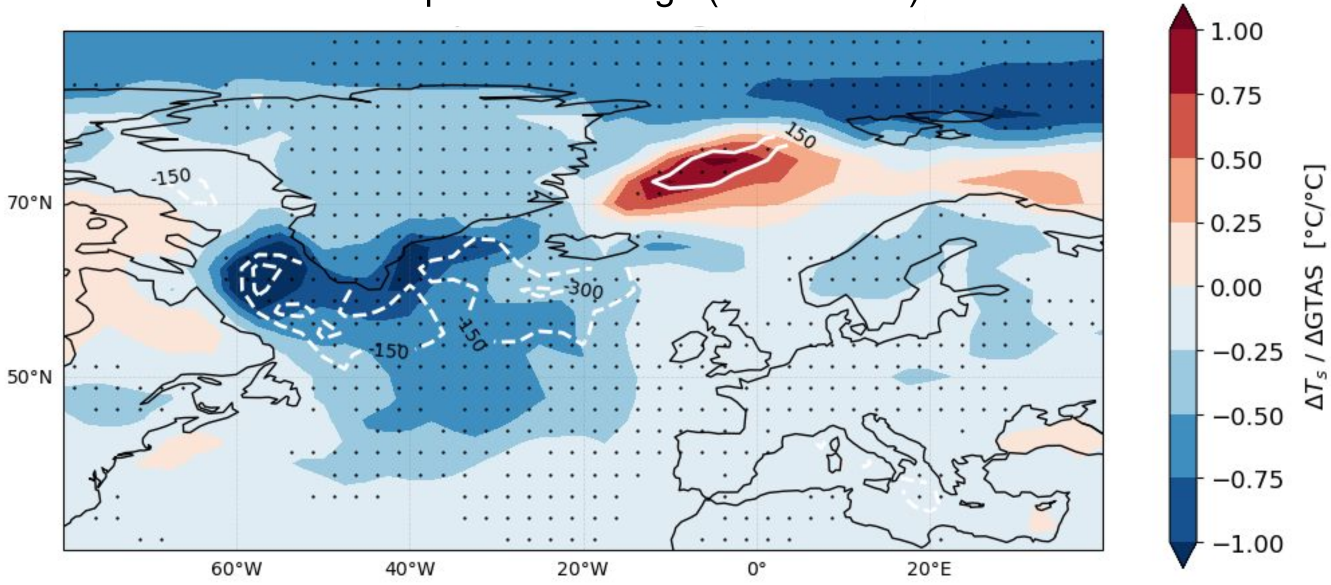
Changes in surface temperature (SSP5-8.5)



2071-2100 minus 1950-2015

Surface temperature response to AMOC weakening

Surface Temperature change (LAD - SAD)



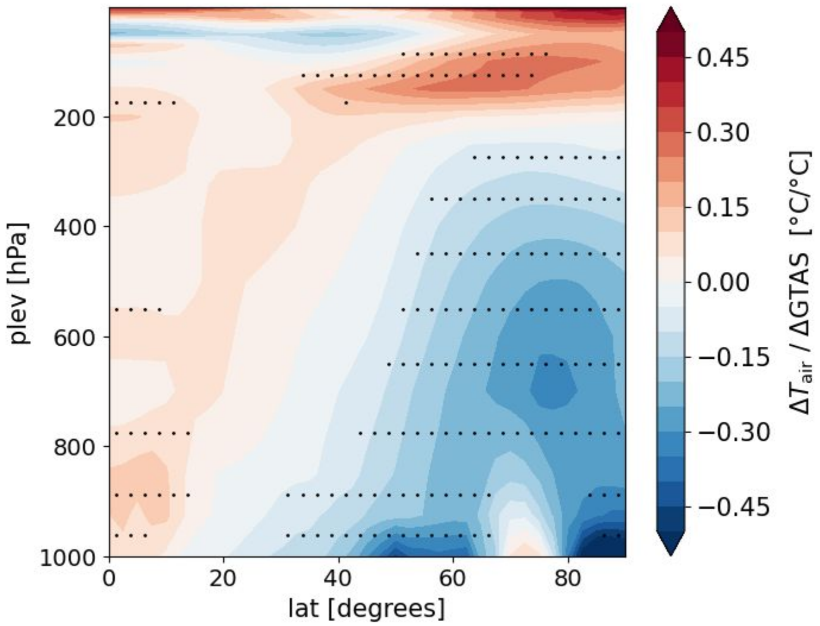
- Surface cooling
- North Atlantic Warming Hole
- Reduced heat convergence in the Deep Convection regions

- **White contours** represent the Mixed Layer Depth change (LAD-SAD)
- **Stipplings** represent statistical significance of the different responses at the 95% level

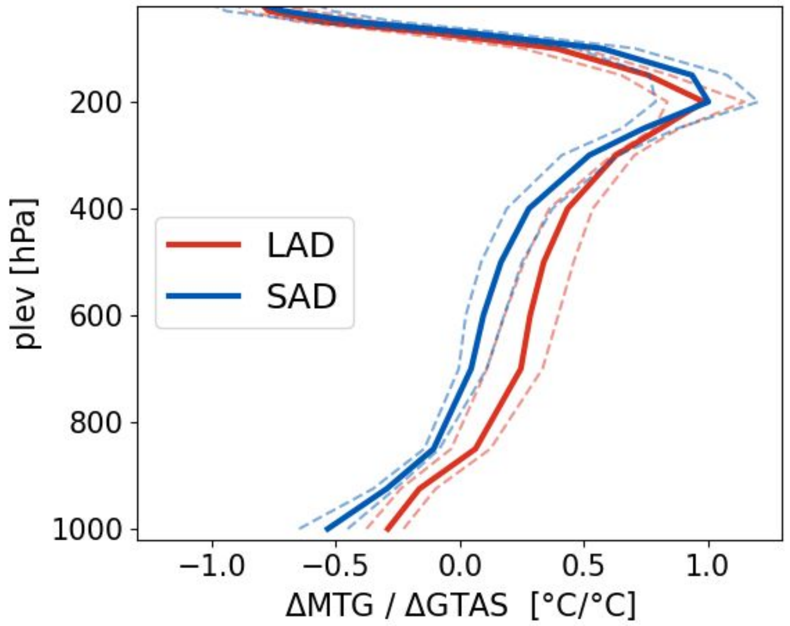
Atmosphere thermal structure response

- Reduced Arctic amplification
- Increased low-level meridional temperature gradient (20°- 40° minus 50°-70°)

Zonal mean temperature change (**LAD** - **SAD**)



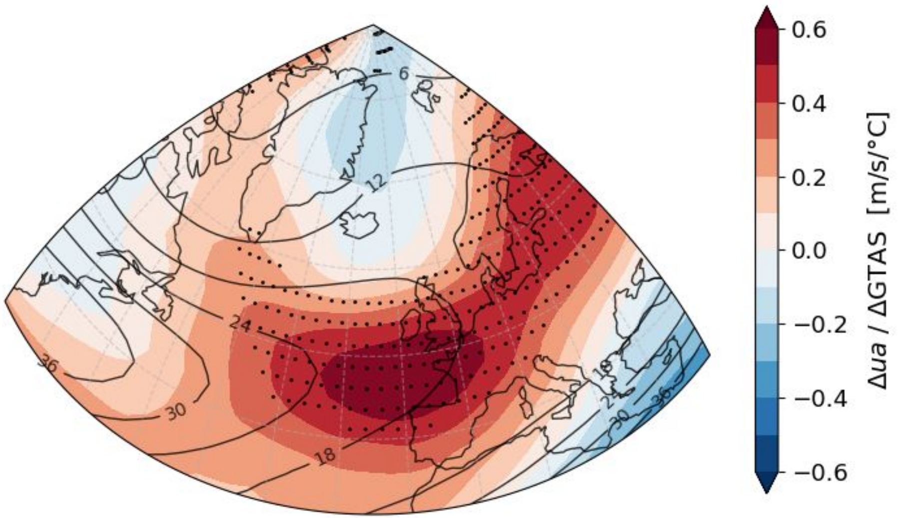
Meridional Temperature Gradient (MTG) change



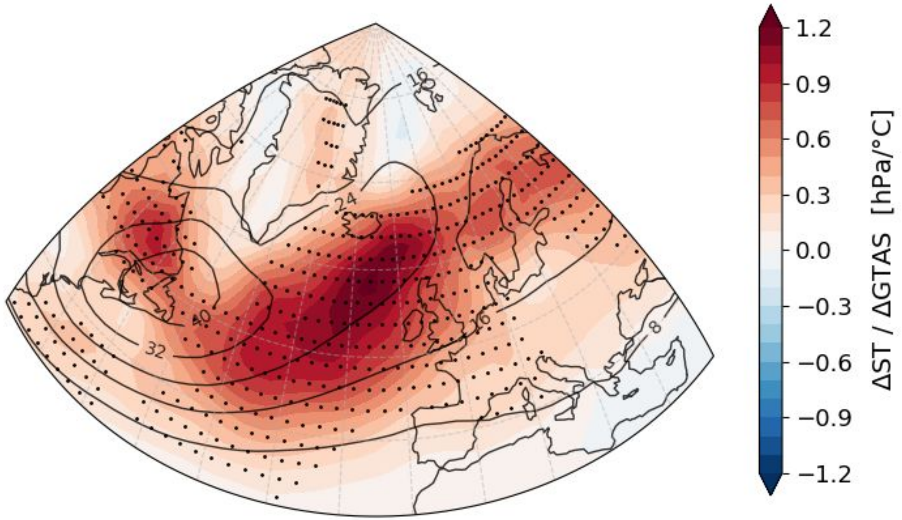
Mean circulation response

- Strengthening of the mean westerly flow, elongated towards Europe
- Intensification of the storm track in its downstream region

Zonal wind change at 250 hPa (**LAD** - **SAD**)

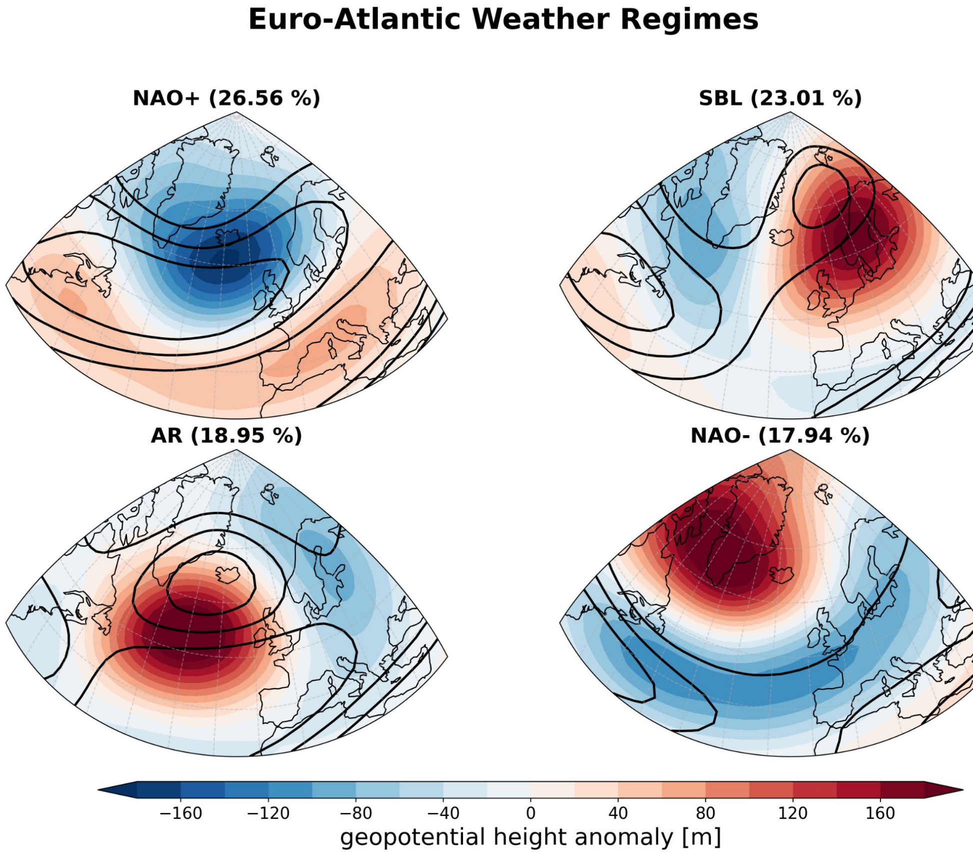


Storm track change (**LAD** - **SAD**)



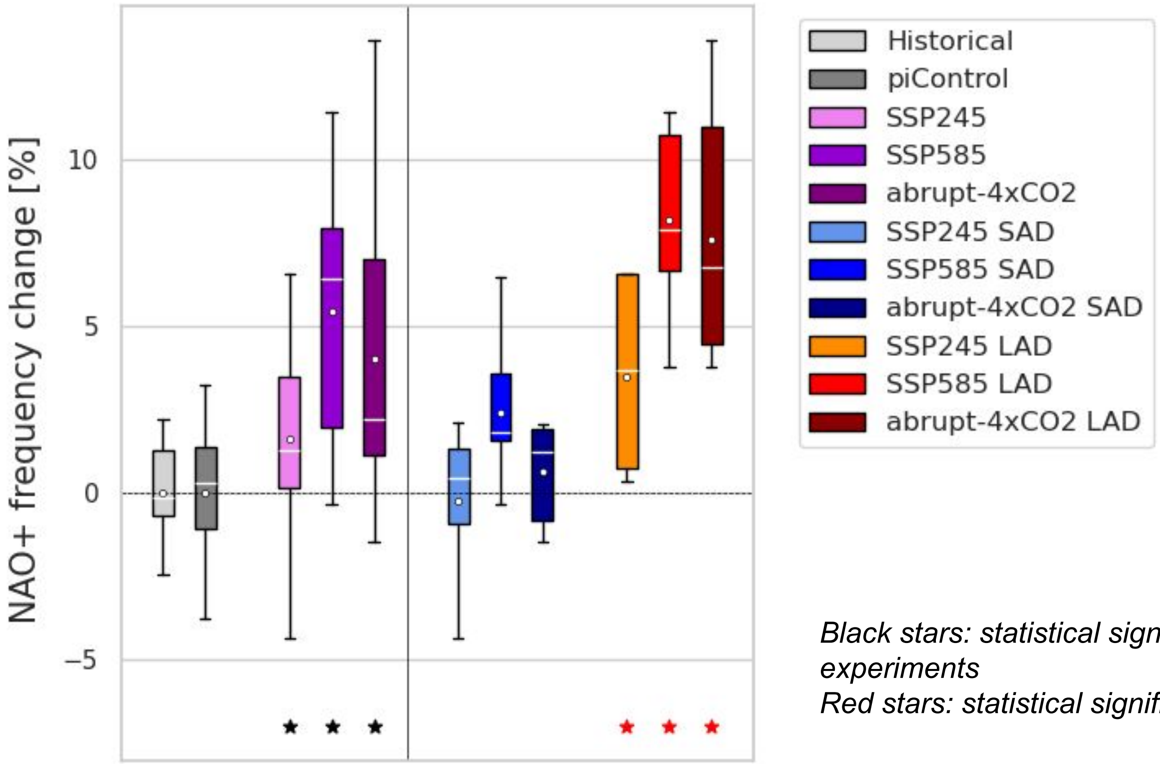
Changes in Weather Regimes frequency

- K-means clustering on wintertime 500 hPa geopotential height anomalies (ERA5)



(Vacca et al., in prep.)

Multi-model NAO+ frequency increase driven by LAD models



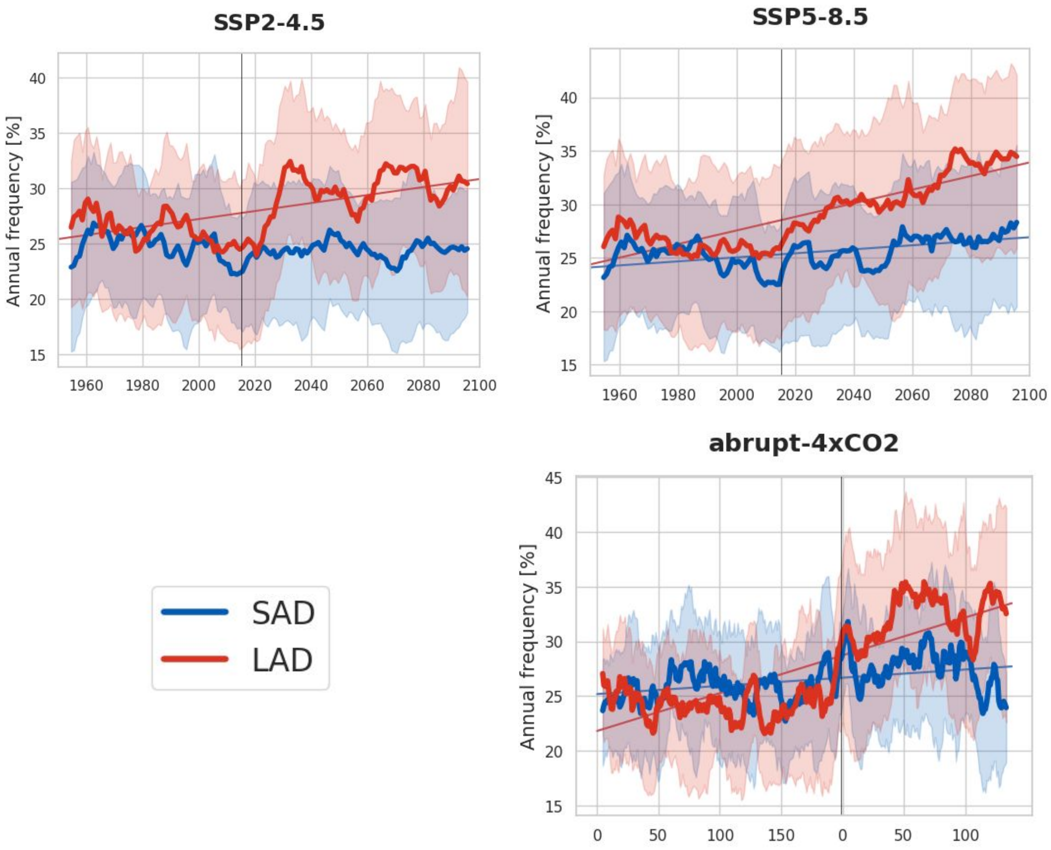
Full ensemble (purple):

- NAO+ frequency increase
- SBL and AR decrease (not shown)

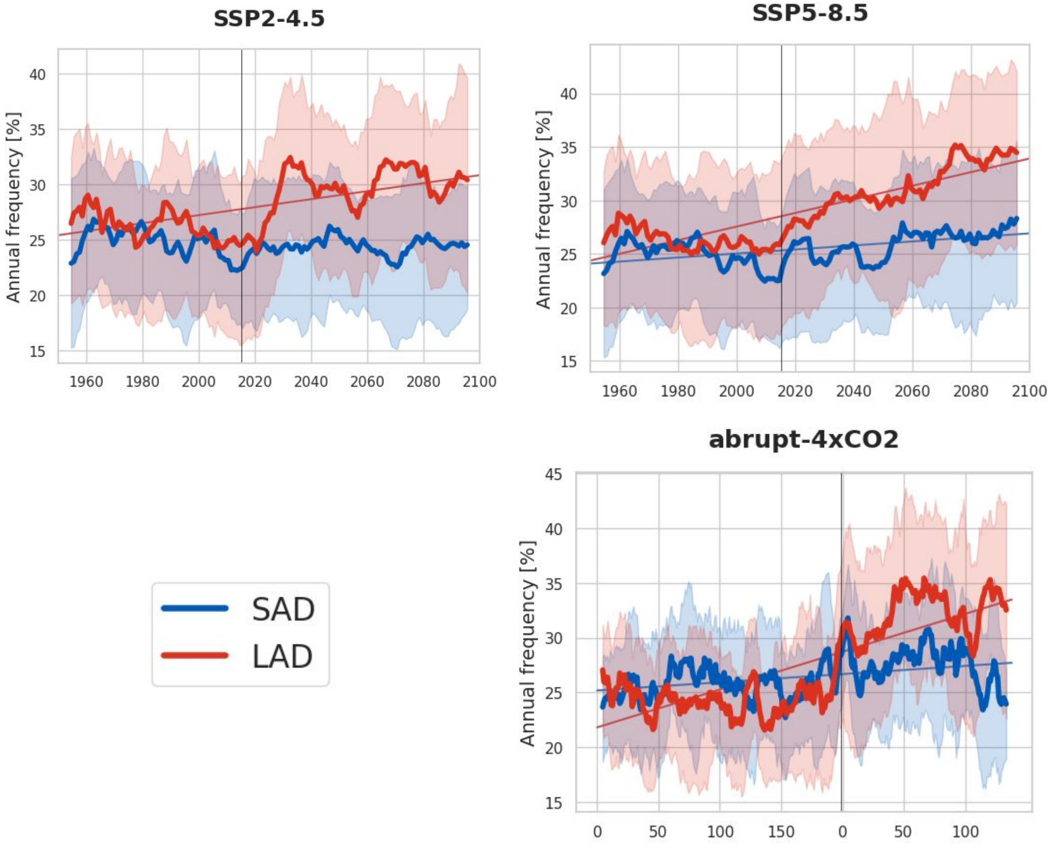
NAO+ frequency increased in LAD models

Black stars: statistical significance (5% level) between projected and control experiments
Red stars: statistical significance (5% level) between LAD and SAD groups

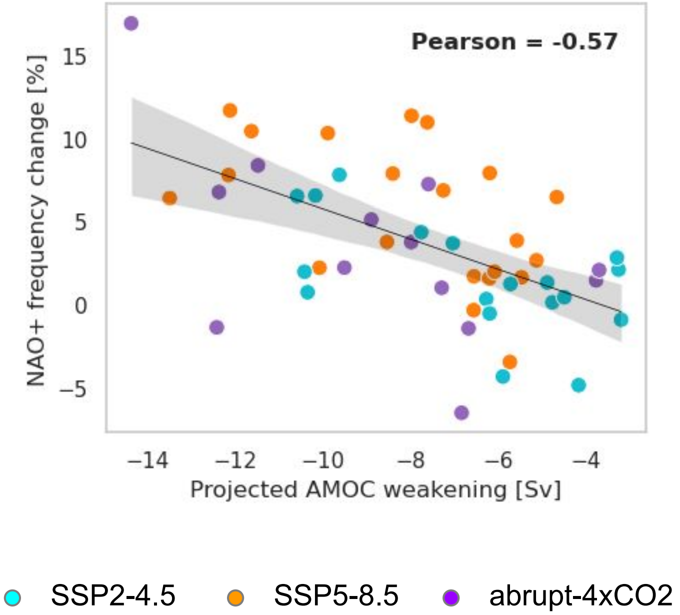
More frequent NAO+ days



More frequent NAO+ days

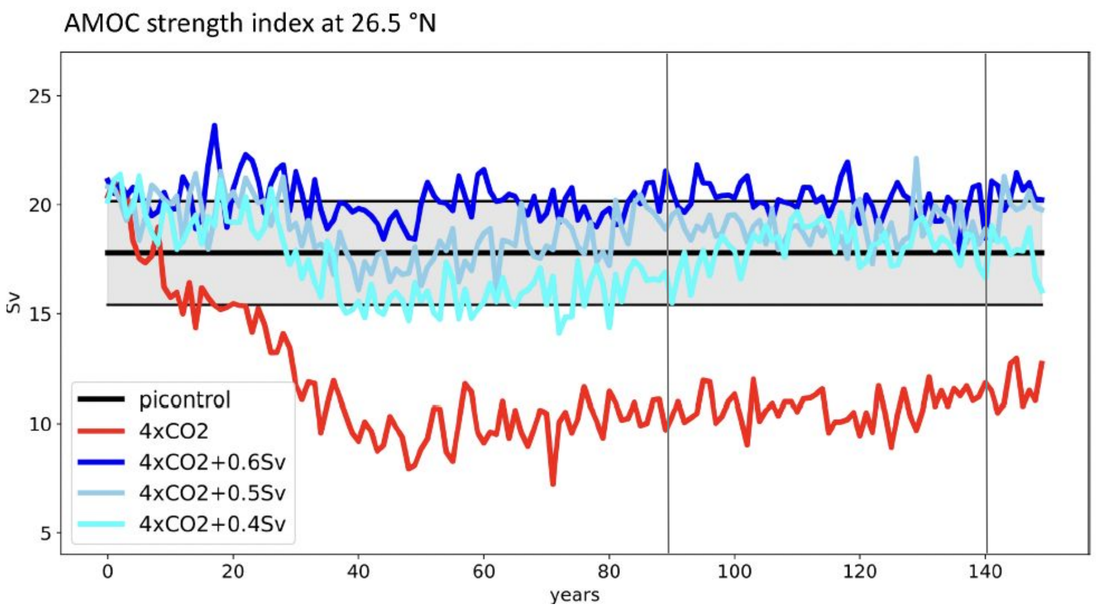


~ 0.9% per 1 Sv slowdown



Fixed-AMOC experiment with EC-Earth3

- abrupt-4xCO2 (**Weakened AMOC**)
- abrupt-4xCO2 + positive virtual salinity flux (**Fixed AMOC**)



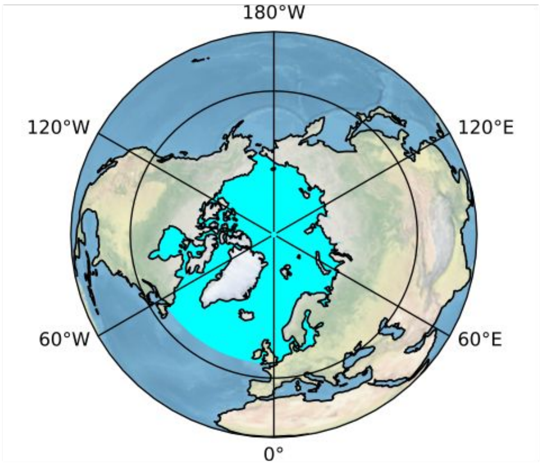
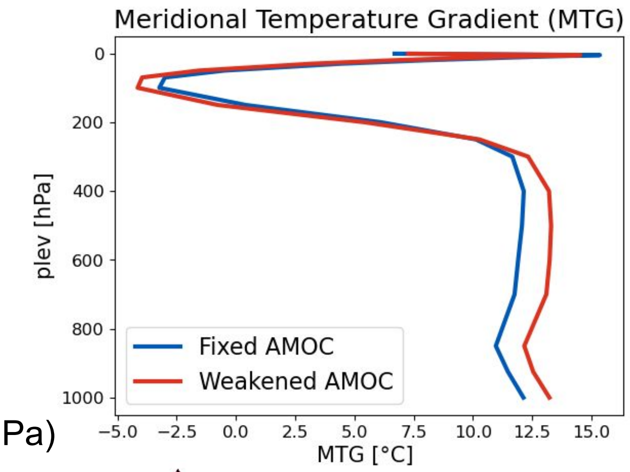


Fig. 1 Water hosing area. The cyan area shows where the surface freshwater flux anomaly is applied in the water hosing experiment

Bellomo & Mehling (under review)

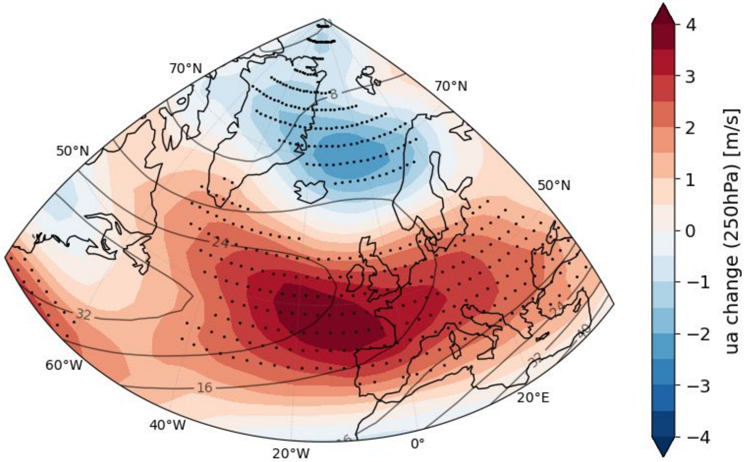
Mean circulation response



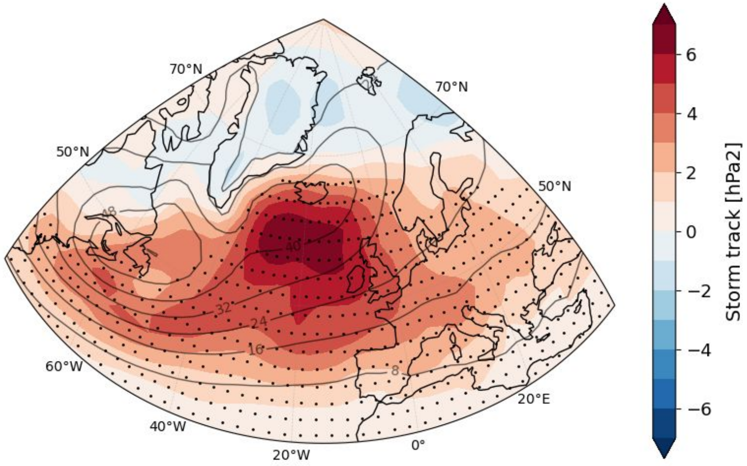
- Increased low-level MTG
- Strengthened jet stream and storm track, elongated towards Europe

Weakened AMOC - Fixed AMOC

Zonal wind change (250 hPa)

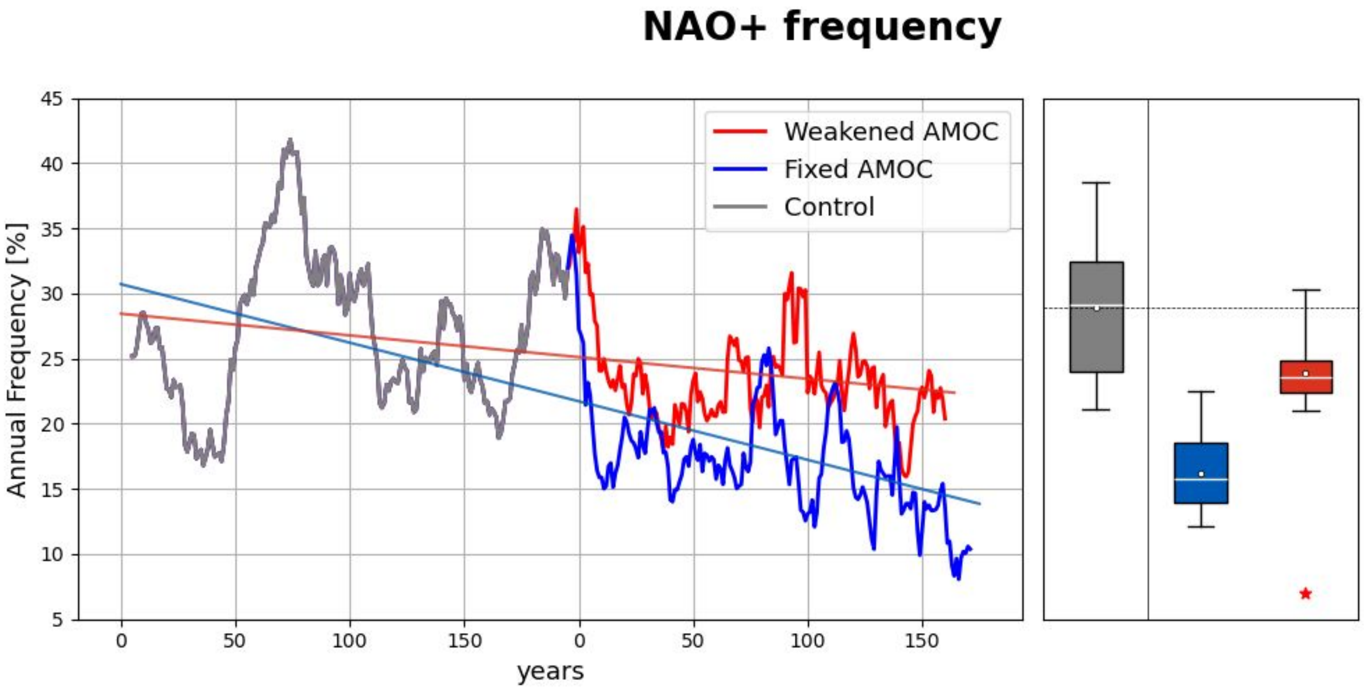


Storm track change (250 hPa)



More frequent NAO+ days

- In EC-Earth3, NAO+ frequency decreases with the forcing
- <u>NAO+ frequency decreases less with the weakened AMOC</u>

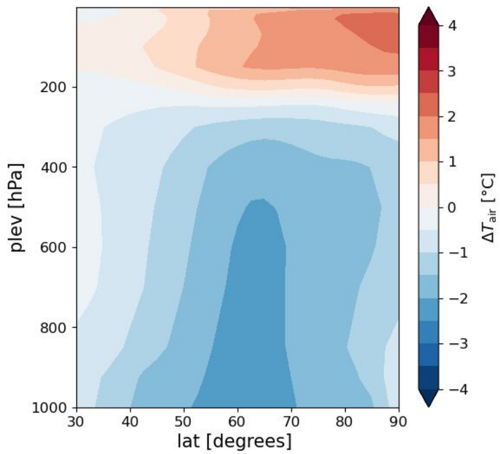


Statistical significance (5% level)

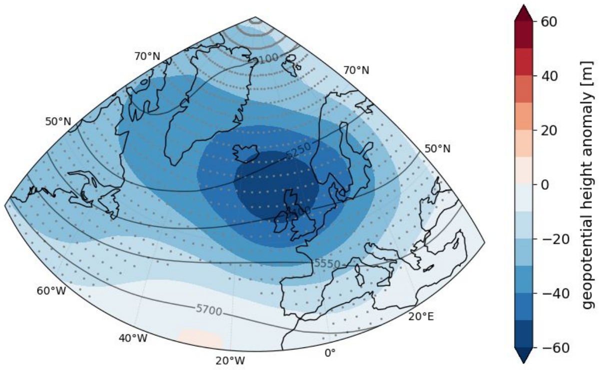
Why does the AMOC decline increases the NAO+ frequency?

Climatological temperature anomalies from the AMOC → Impact on the mean geopotential height → Increase in NAO+ days

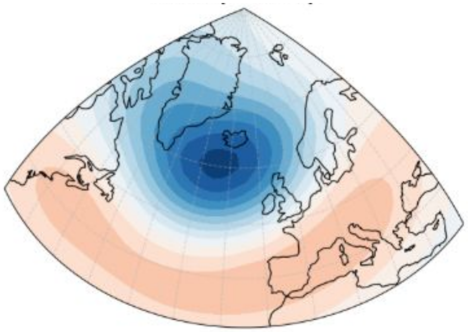
Zonal mean temperature change



Geopotential height change (500 hPa)



NAO+ regime



Weakened AMOC minus Fixed AMOC

Conclusions

- Weakening AMOC leads to a wintertime zonalization of the jet, an enhanced storm track in its northeastern flank and more frequent NAO+ days .
- AMOC decline is a key driver for the evolution of Euro-Atlantic atmospheric circulation under climate change.
- Constraints on the AMOC decline would help to reduce the uncertainty related to projections of Euro-Atlantic circulation.

Conclusions

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Thank you

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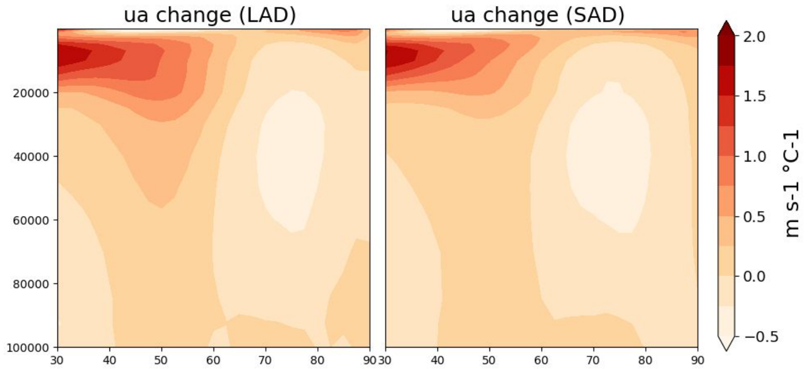
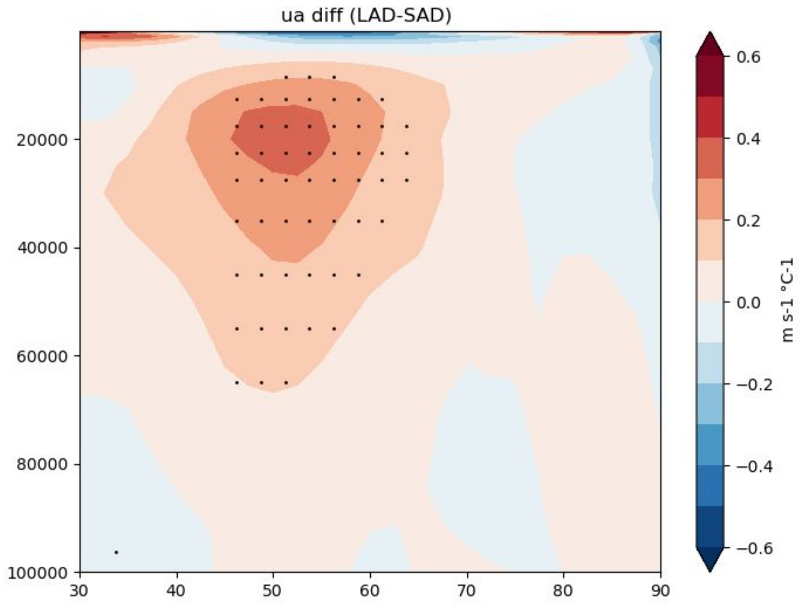
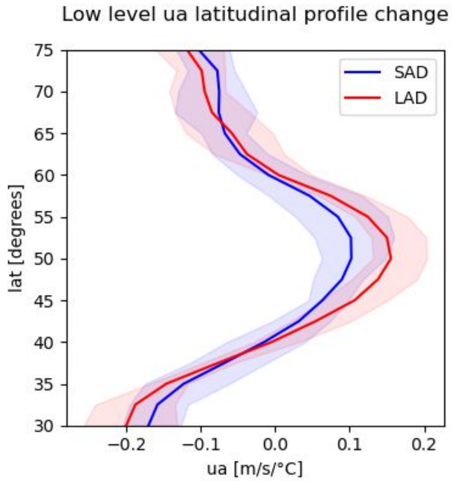
Backup slides







Backup slides