Impact of model resolution on the representation of deep-water formation and its link with the AMOC

Eneko Martin-Martinez – 22/02/2024 – EERIE Science Hour #8
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Funded by the European Union

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Personal funding

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AMOC slowdown state-of-the-art

to eddy or not to eddy?

Oceans

Atlantic Ocean circulation nearing 'devastating' tipping point, study finds

Collapse in system of currents that helps regulate global climate would be at such speed that adaptation would be impossible

Jonathan Watts
@jonathanwatts
Fri 9 Feb 2024 20.00 CET

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Physics-based early warning signal shows that AMOC is on tipping course

RENÉ M. VAN WESTEN, MICHAEL KLIPHUIS, AND HENK A. DIJKSTRA Authors Info & Affiliations

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Abstract

One of the most prominent climate tipping elements is the Atlantic meridional overturning circulation (AMOC), which can potentially collapse because of the input of fresh water in the North Atlantic. Although AMOC collapses have been induced in complex global climate models by strong freshwater forcing, the processes of an AMOC tipping event have so far not been investigated. Here, we show results of the first tipping event in the Community Earth System Model, including the large climate impacts of the collapse. Using these results, we develop a physics-based and observable early warning signal of AMOC tipping: the minimum of the AMOC-induced freshwater transport at the southern boundary of the Atlantic. Reanalysis products indicate that the present-day AMOC is on route to tipping. The early warning signal is a useful alternative to classical statistical ones, which, when applied to our simulated tipping event, turn out to be sensitive to the analyzed time interval before tipping.

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Why are eddies relevant?

≲ 100 km

≲ 1 month

- They can **transport water masses** to remote regions
- These water masses **impact the mean state and variability** of the ocean
- Those changes may **impact the deep water mixing** and, thus, the **AMOC**

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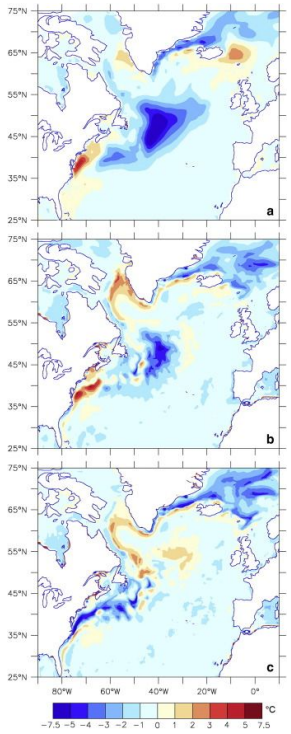
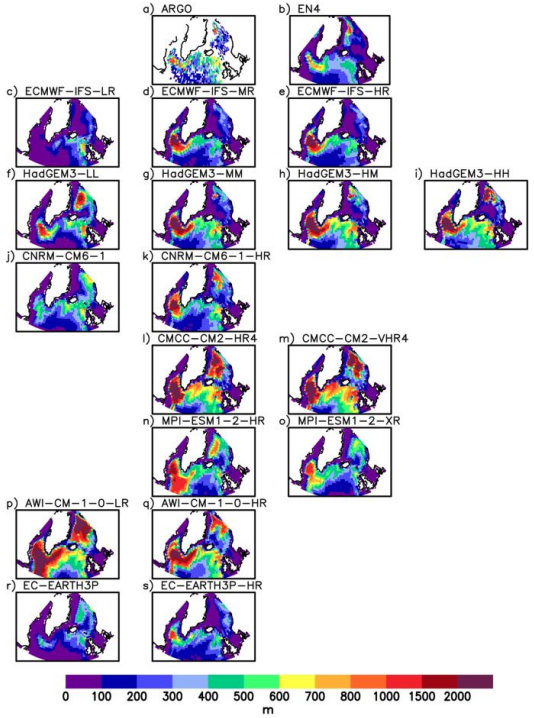
Some eddy-rich studies

Bias correction



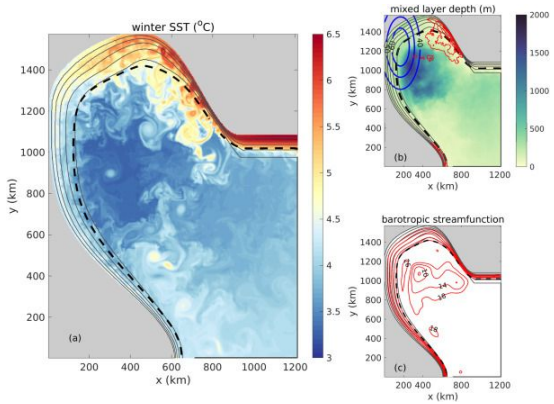
(Marzocchi et al., 2015)

Deeper mixing in the Labrador Sea



(Koenigk et al., 2021)

Eddies are essential in boundary-interior exchanges



(Georgiou et al., 2020)

Improve air-sea interactions

(Moreno-Chamarro et al., 2021)

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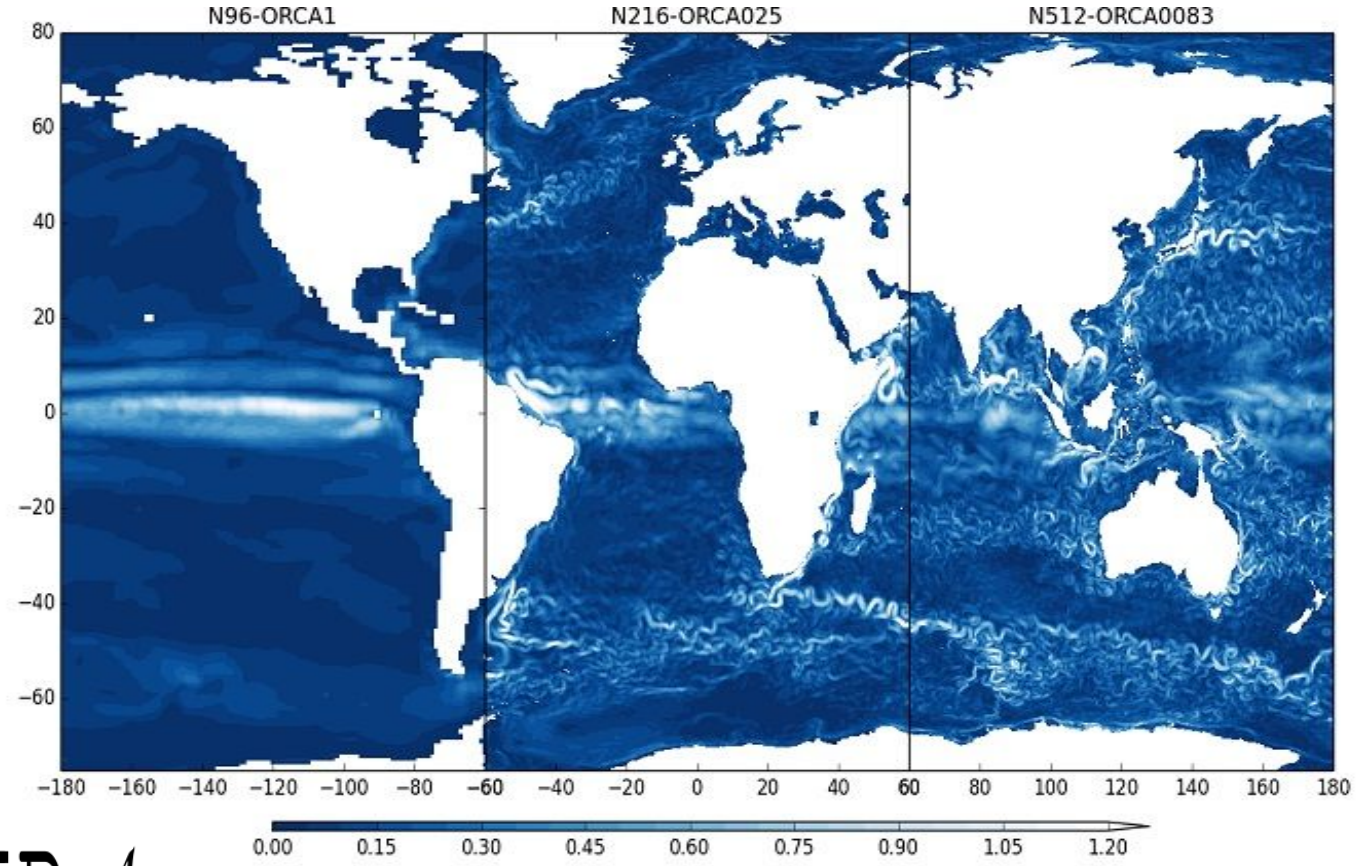
PRIMAVERA project's outputs



Source: PRIMAVERA Gallery (courtesy of Malcolm Roberts)

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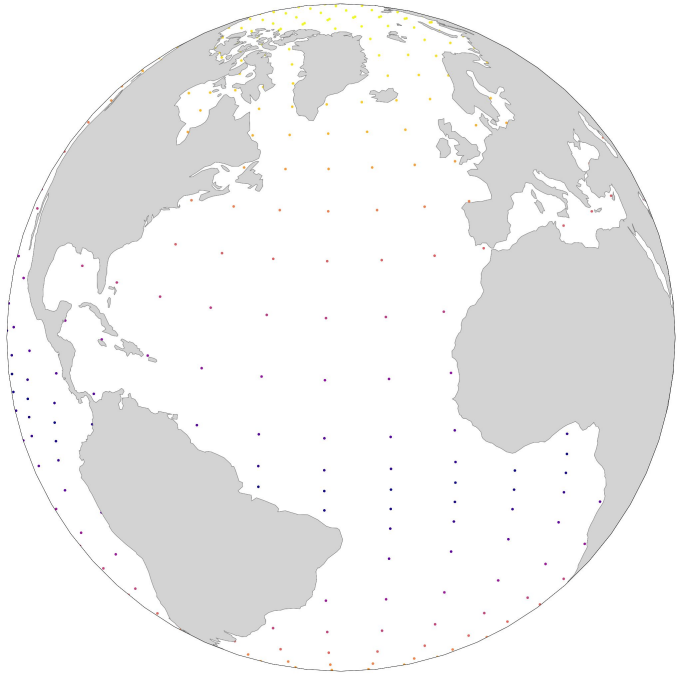
PRIMAVERA project's EC-Earth models

EC-Earth3P

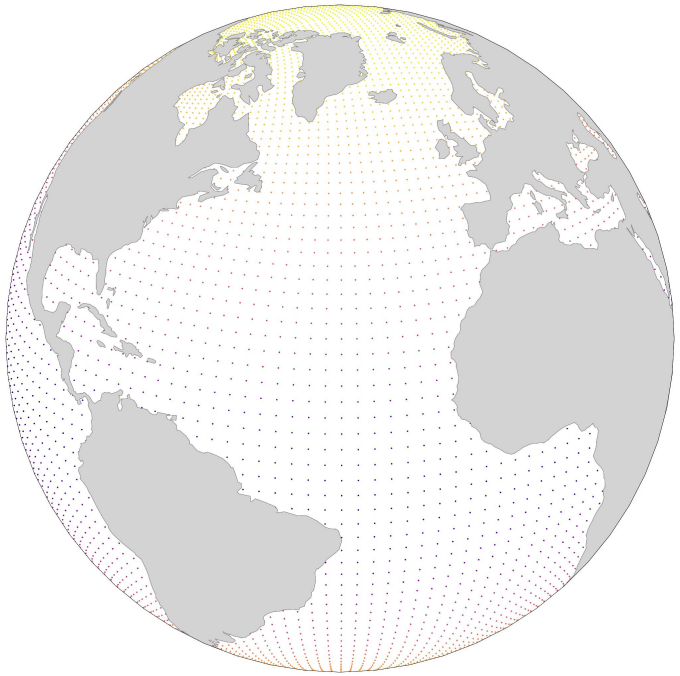
70km ~ Atmosphere
100km ~ Ocean



PRIMAVERA

EC-Earth3P-HR

35km ~ Atmosphere
25km ~ Ocean



EC-Earth3P-VHR

14km ~ Atmosphere
8km ~ Ocean

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Model set-up

1950-control

HighResMIP protocol

76 years long

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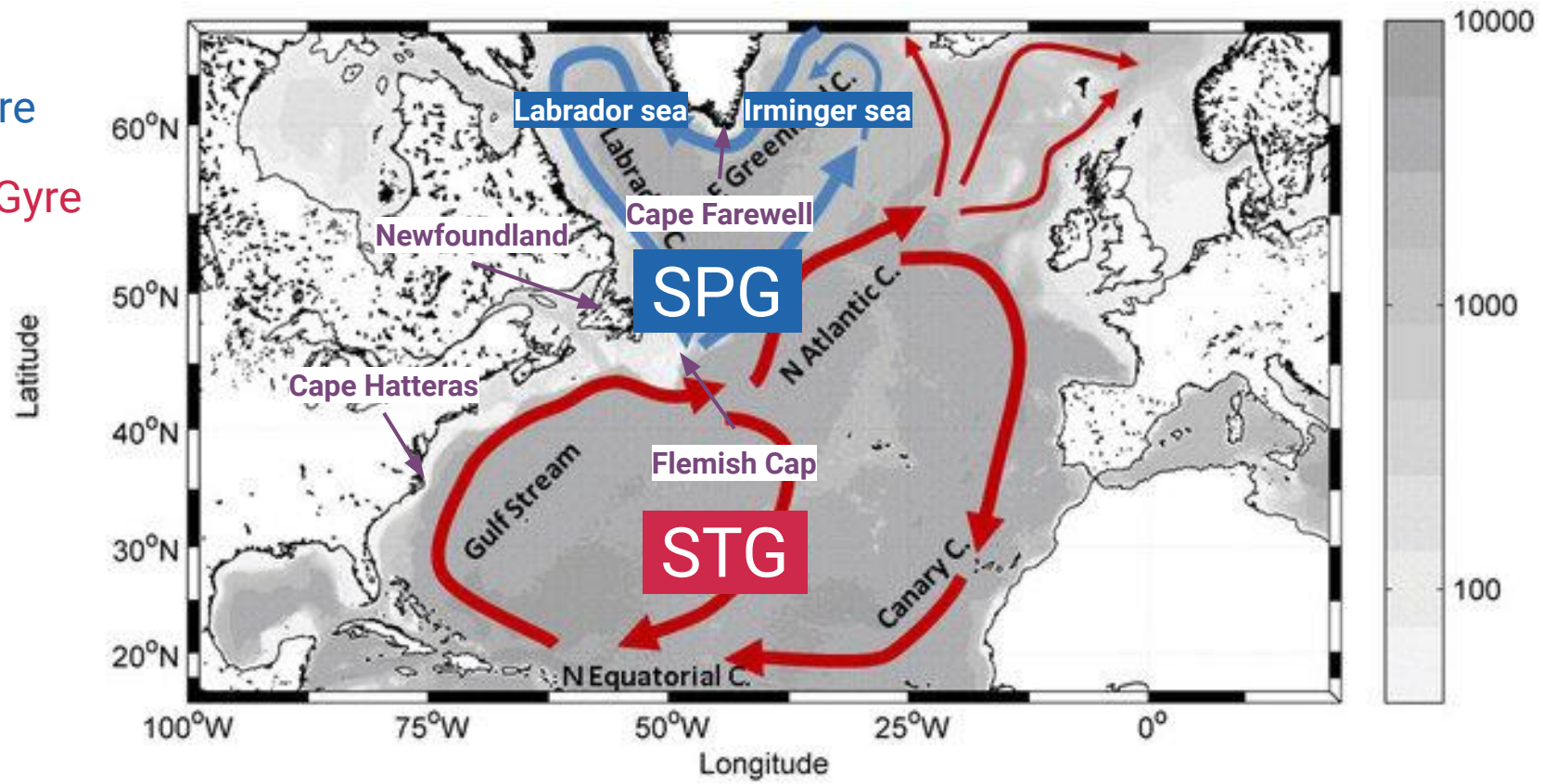
Main circulation in the North Atlantic

SPG: Subpolar Gyre

STG: Subtropical Gyre



Source: [Berx & Payne (2016)]

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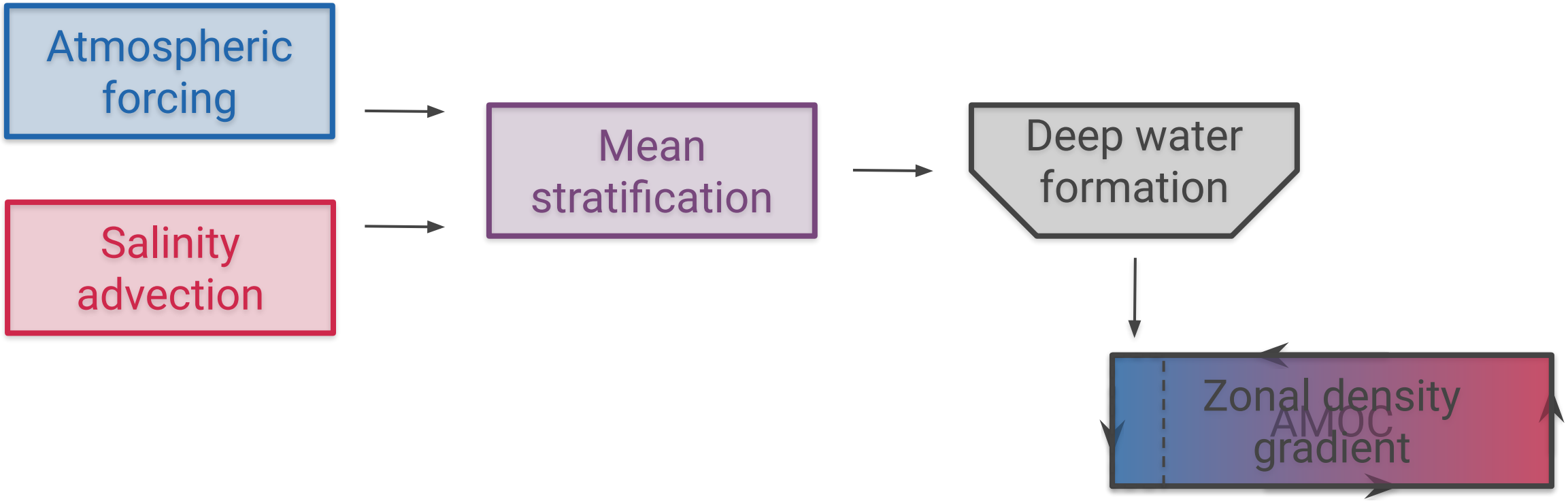
Analysis summary



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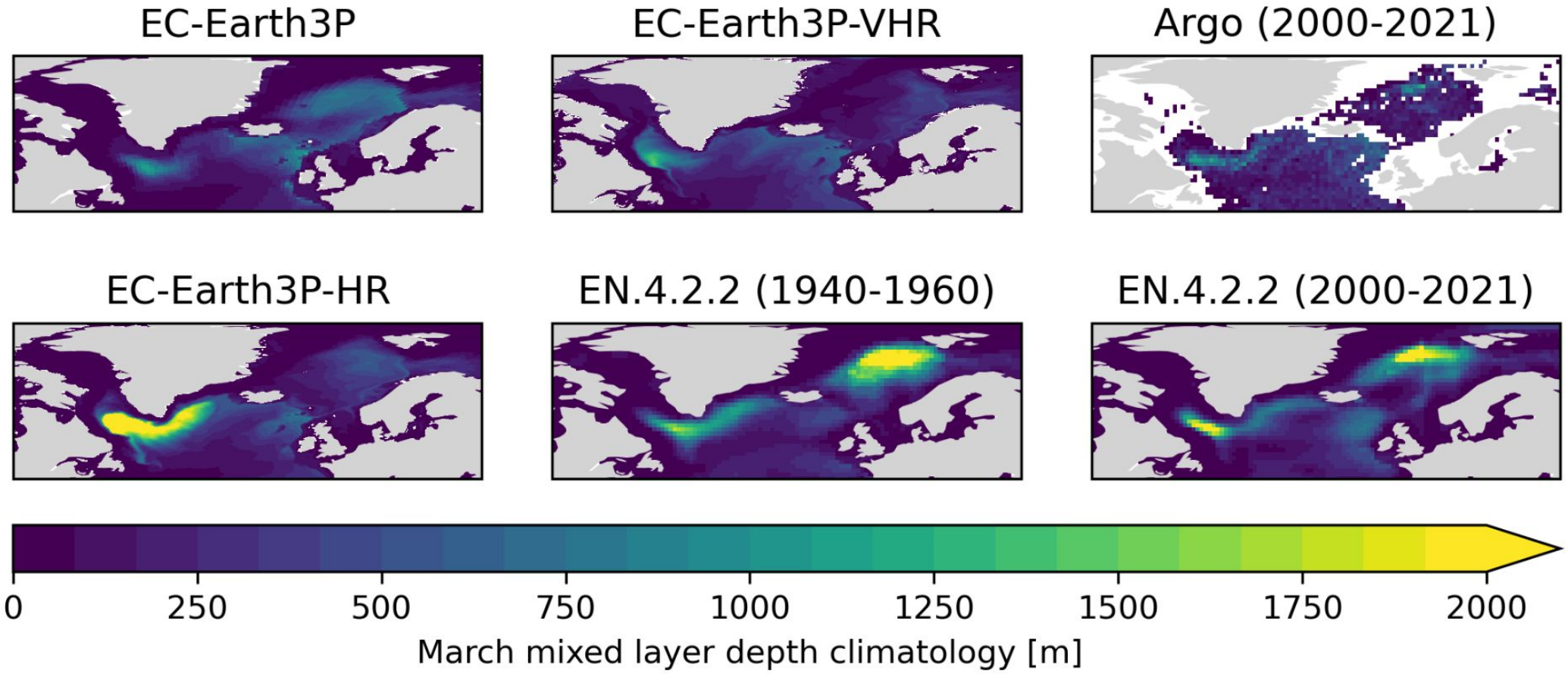
Mixing in the North Atlantic

March mixed layer (MLD) depth climatology



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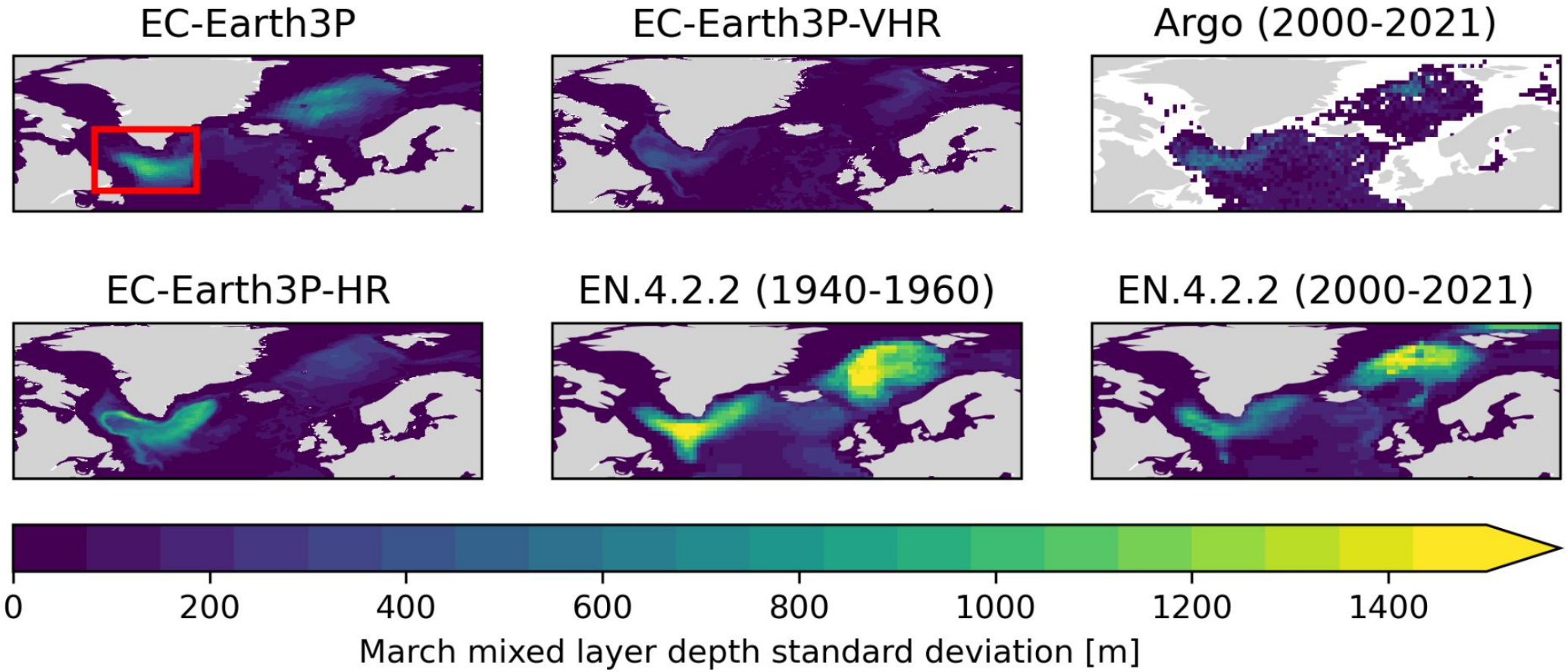
Mixing in the North Atlantic

March mixed layer depth (MLD) standard deviation



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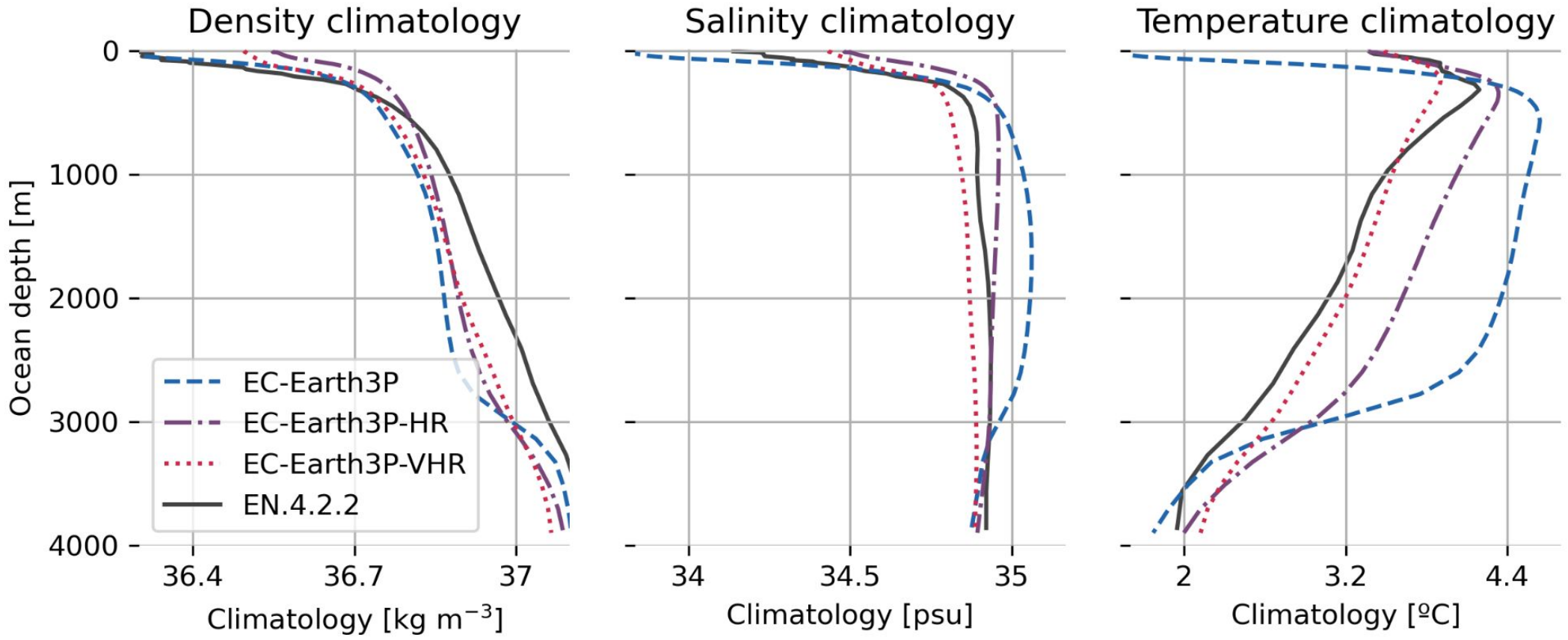
Vertical profiles in the Subpolar Gyre

Mean climatology in the Labrador sea in DJFM



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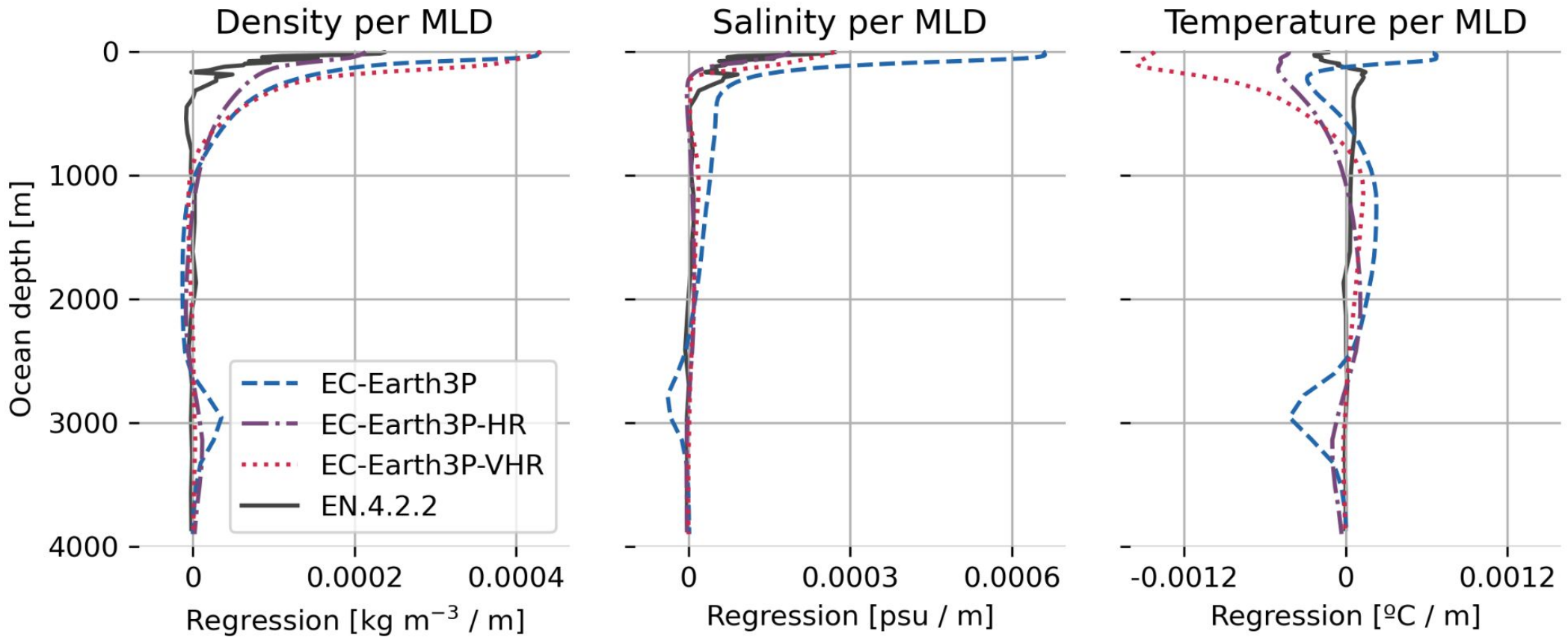
Vertical profiles in the Subpolar Gyre

Regression between March MLD series and DJFM profiles in the Labrador sea



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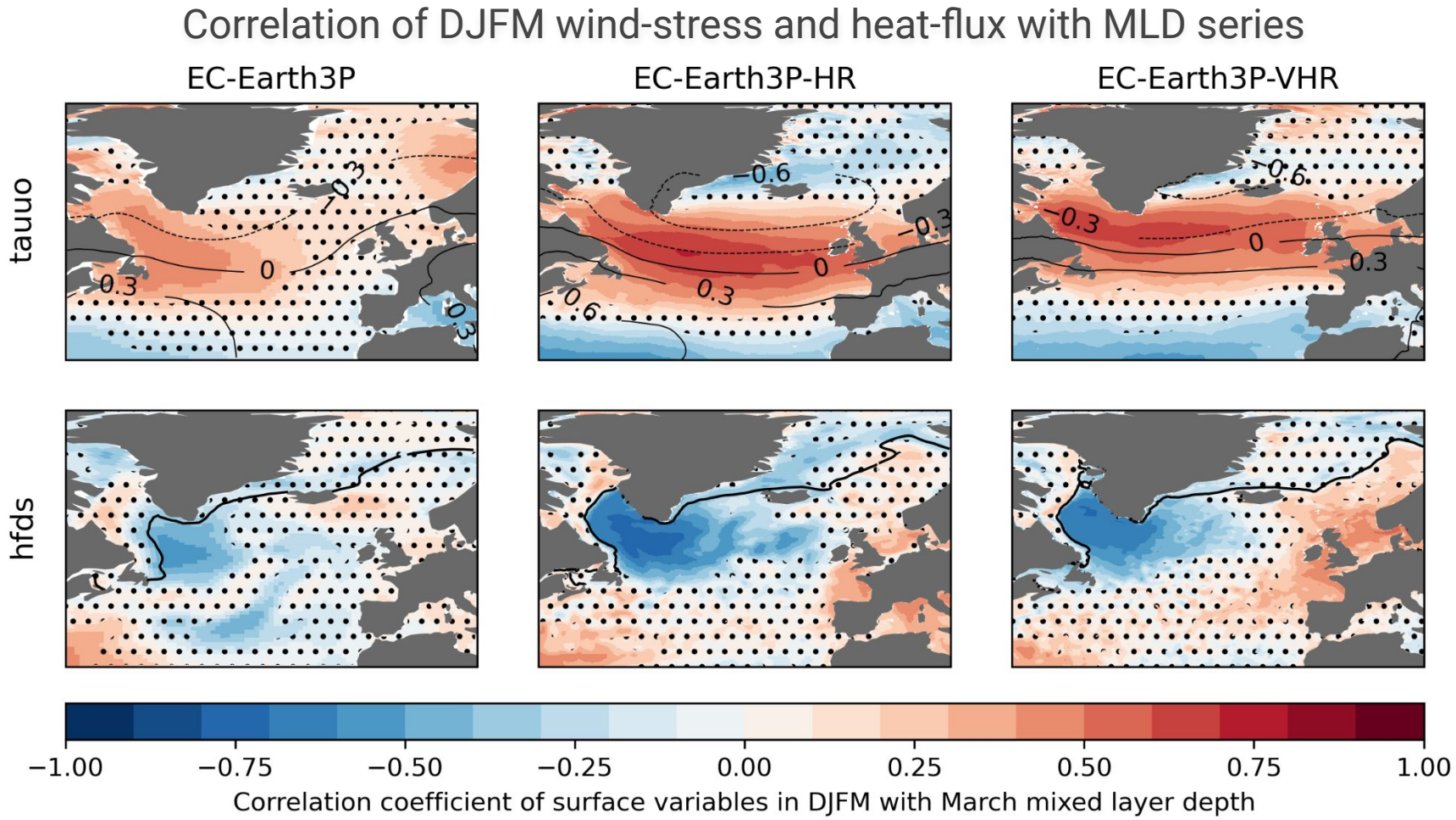
Mixing drivers in the North Atlantic



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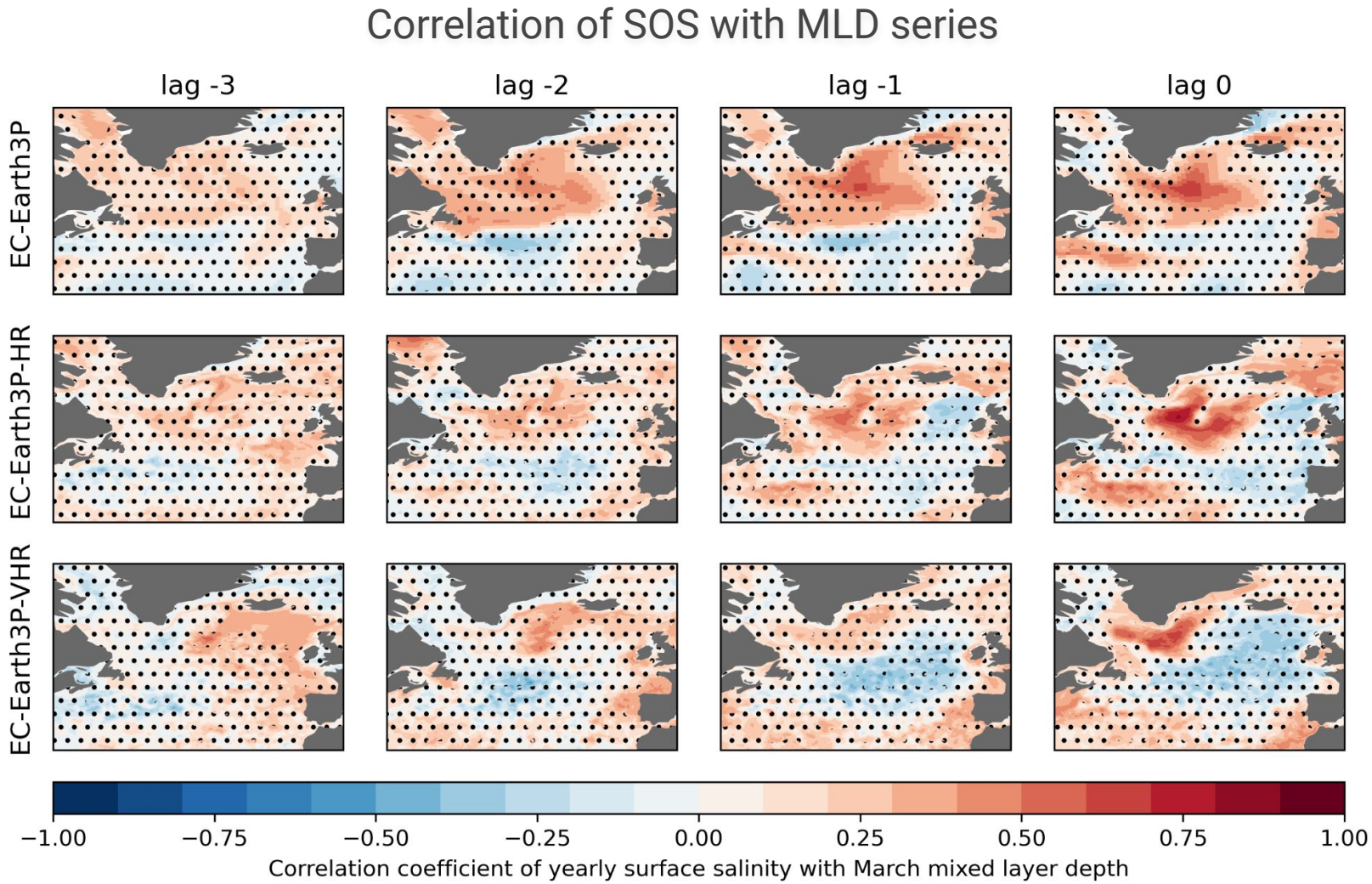

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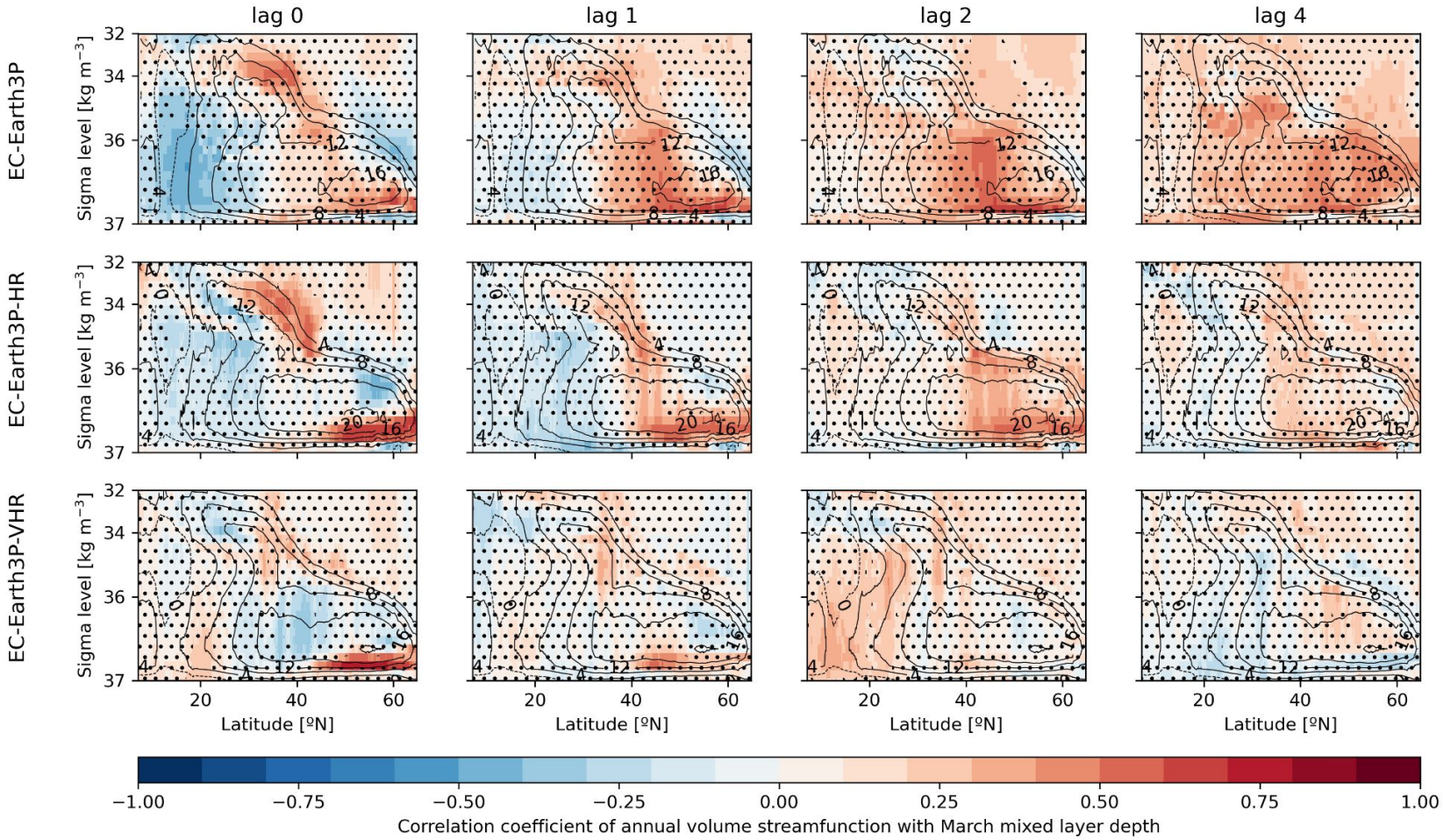
AMOC response to mixing

Correlation of MOC with MLD series



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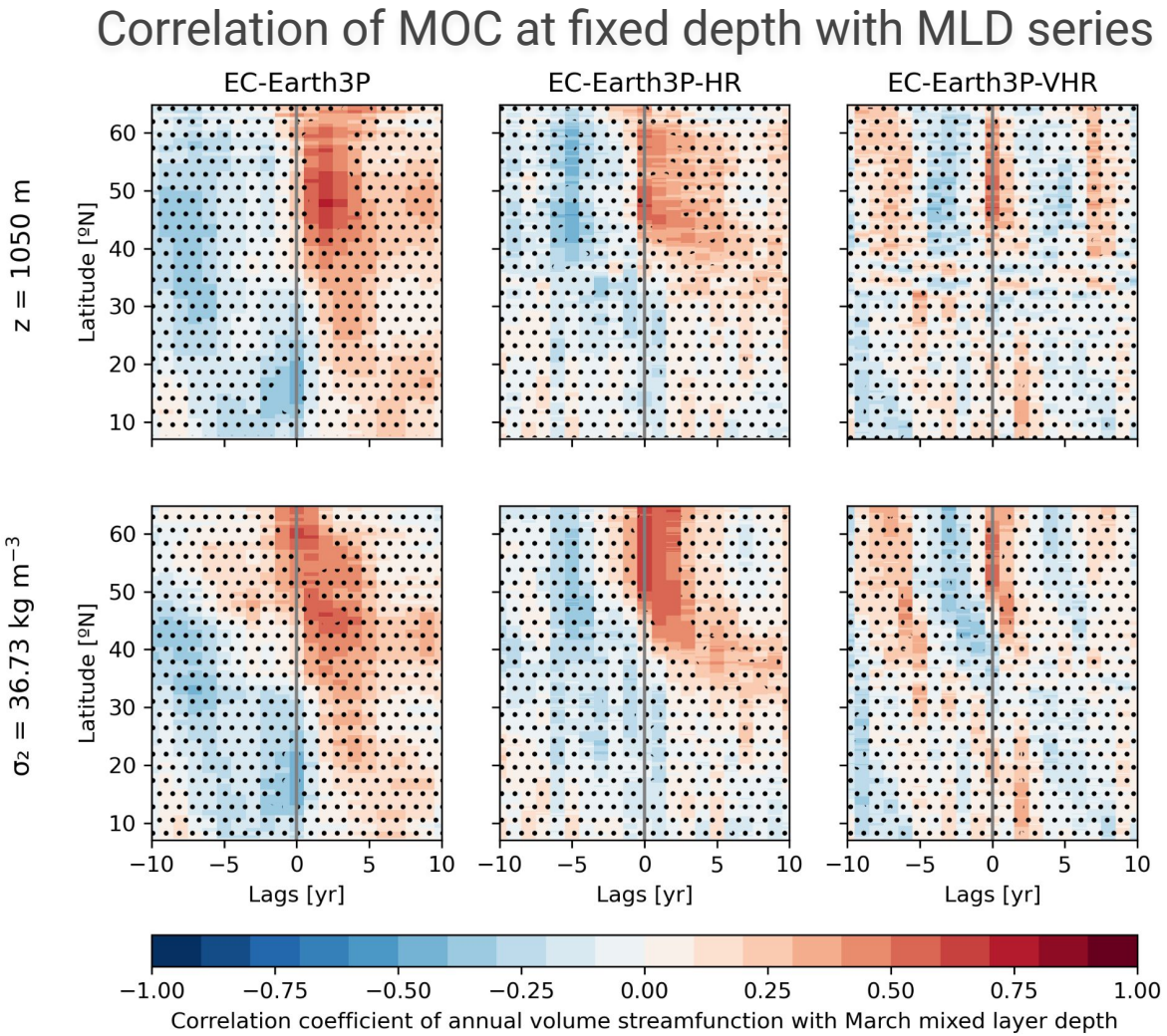

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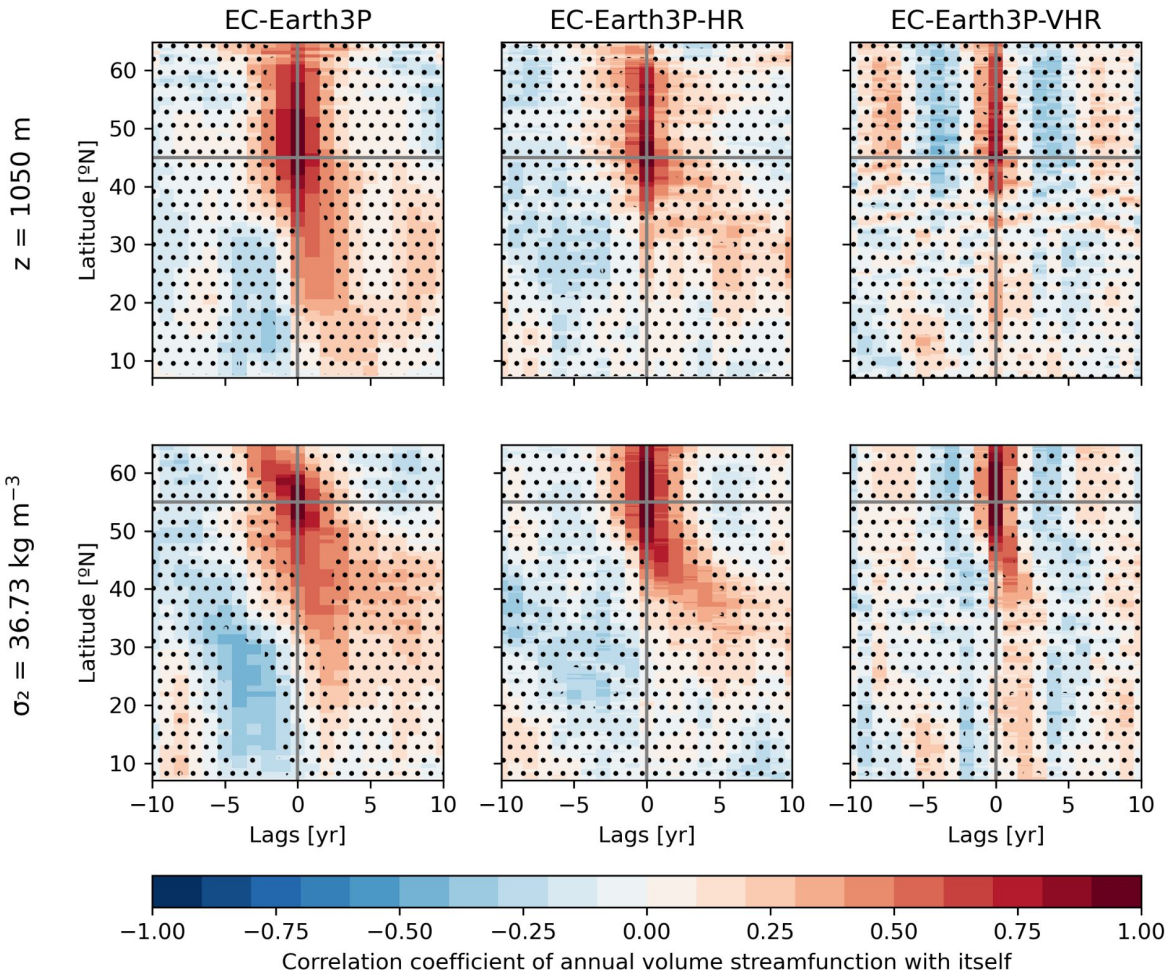
AMOC latitudinal coherence

Correlation of MOC at fixed depth with MOC at fixed depth and latitude



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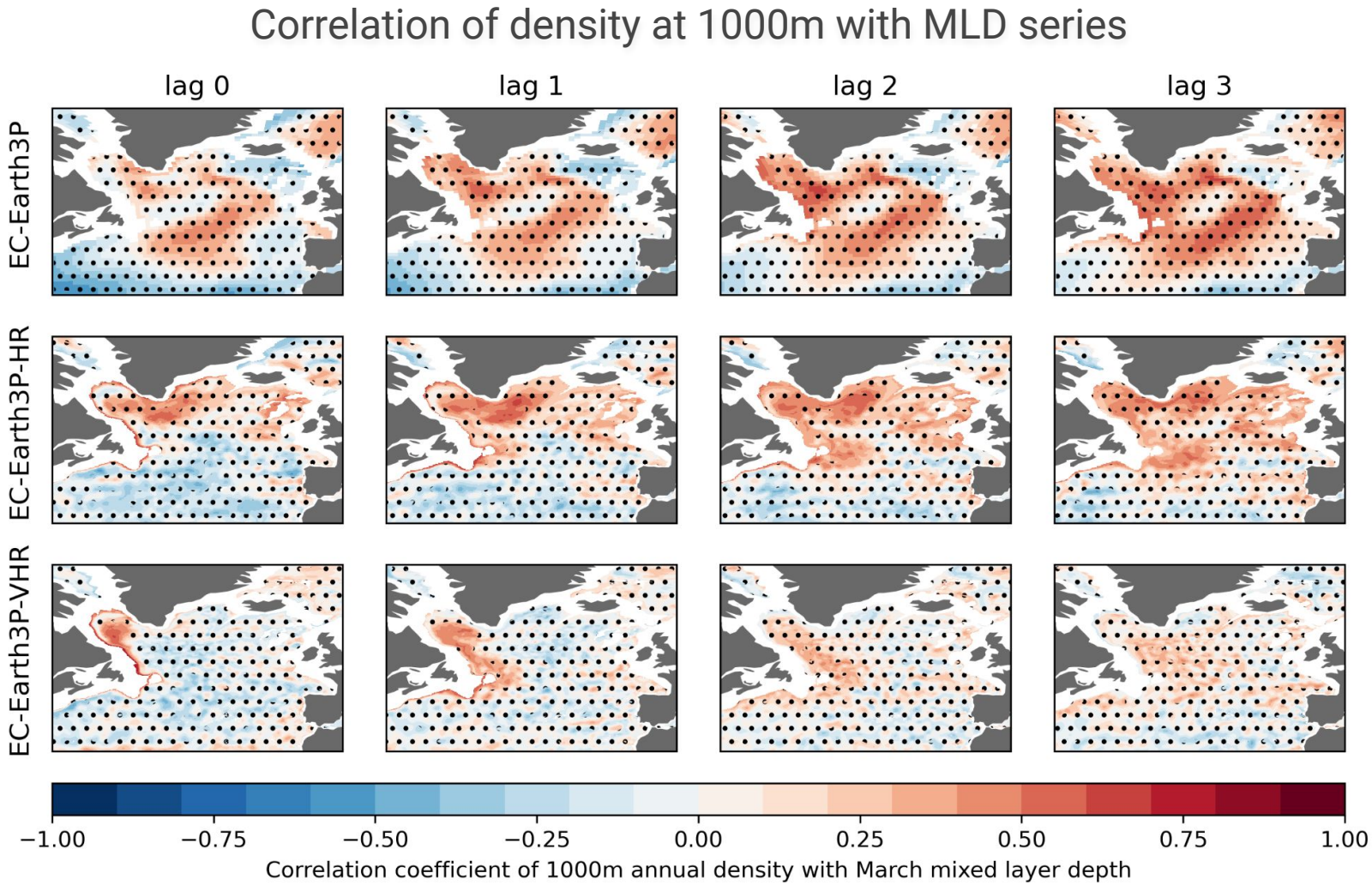
Deep ocean density anomalies propagation



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Conclusions

- The drivers and impacts of Labrador Sea convection are sensitive to the model resolution
- The mean Labrador Sea stratification and MLD are more realistic in the eddy-resolving version of EC-Earth3P
- The NAO exerts a stronger influence on Labrador MLD in the eddy-resolving and eddy-permitting versions of EC-Earth3P
- The advection of salinity anomalies by the mean SPG circulations seems to also play an important driving role in the eddy-resolving one
- We identify important differences across resolutions both in terms of speed and pathways for the propagation of Labrador Sea density anomalies along the Western Boundary Currents, which ultimately impact the coherence of the AMOC changes across latitudes

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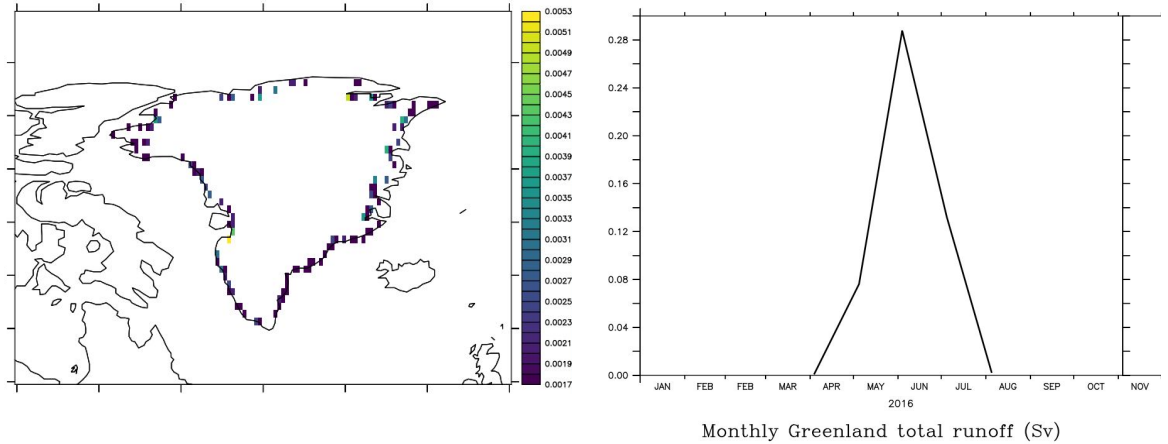
How about water-hosing?

Spatial and seasonal distribution

Based on Bamber et al. (2018)

1958–2018 climatological mean



Amount of freshwater

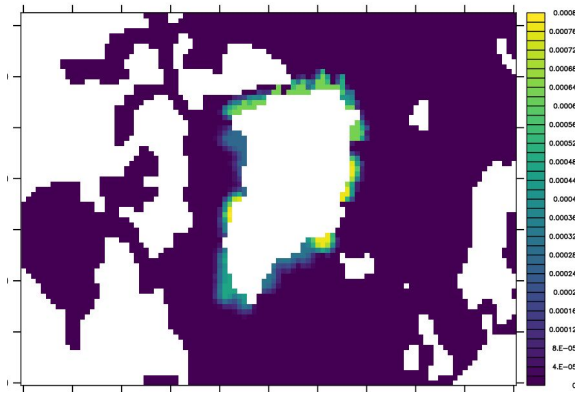
Idealized setup:

0.1 Sv distributed spatially and over the year

Three ensemble members

For 21 years, starting from different AMOC states

Branching off from a 1950-control



July runoff (Sv). Output by NEMO.

Implemented by E. Moreno-Chamarro for EC-Earth3P-VHR

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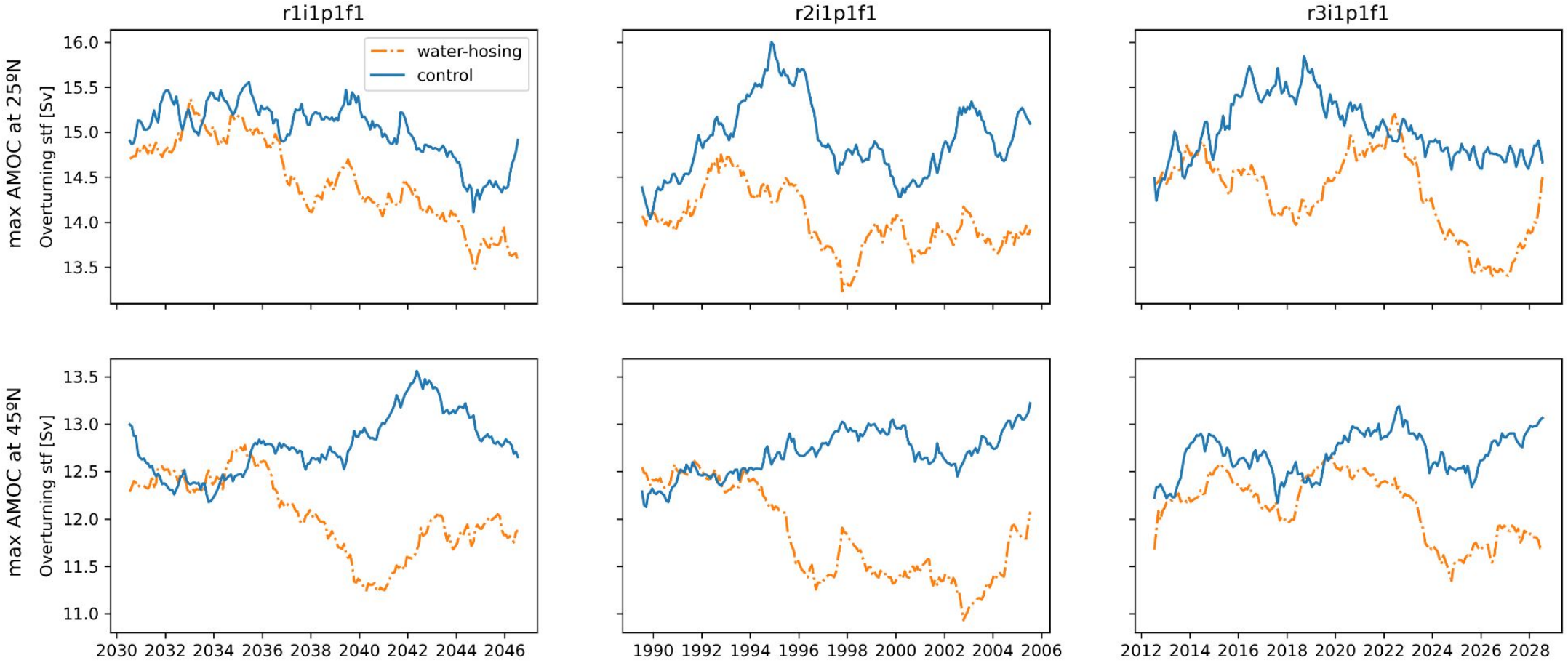
Impact of water-hosing on the AMOC

maxMOC with 5-years low-pass-filter at 25ºN and 45ºN



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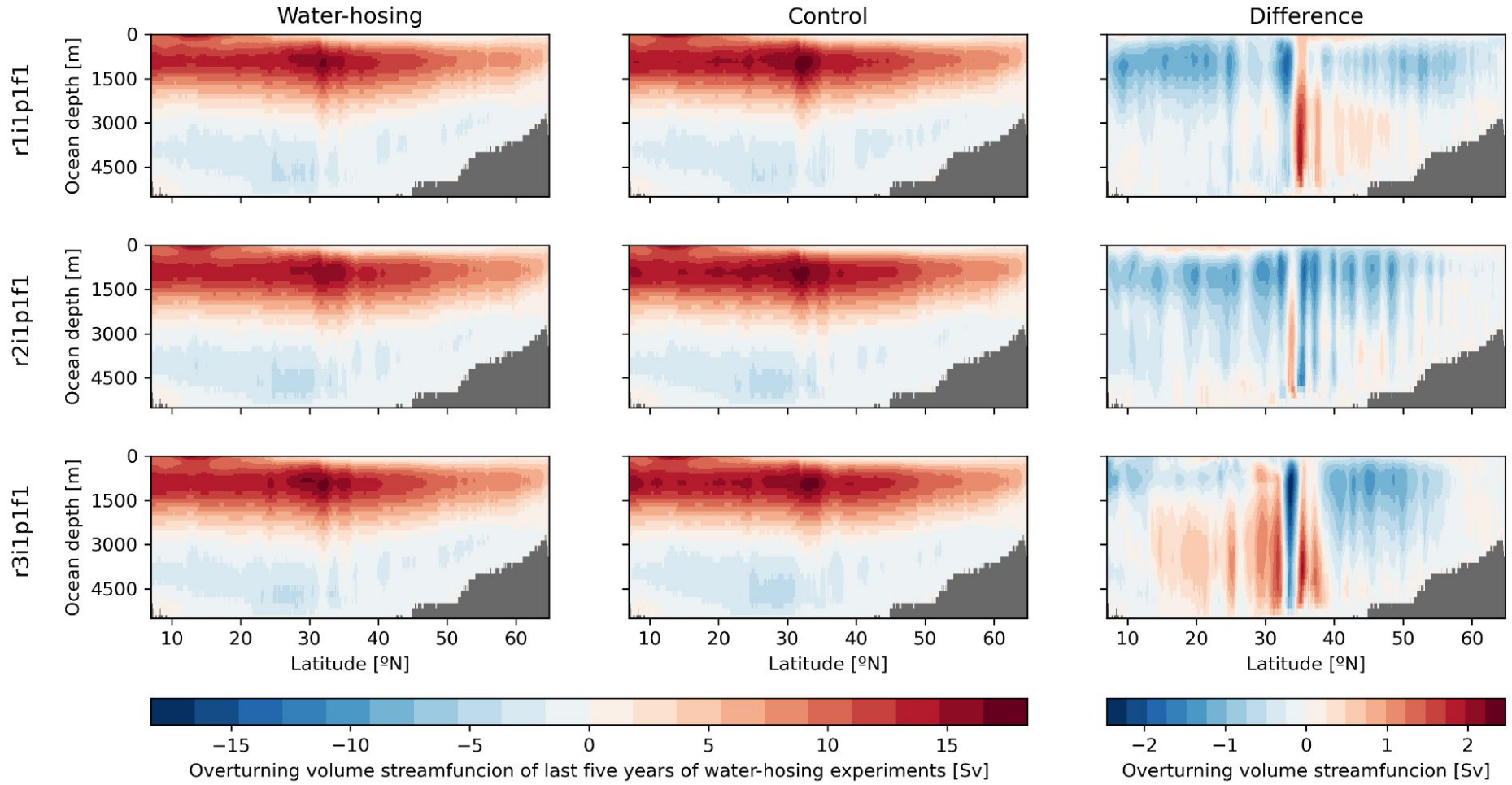
Impact of water-hosing on the AMOC

MOC of the last five years of the water-hosing experiments



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Future work

- Studying water-hosing impact on the AMOC in the sigma-space
- Investigating how the meltwater fluxes ultimately influence water mass transformation and the vertical mixing
- Studying salinity anomalies propagation in the subpolar gyre
- …

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Thank you!

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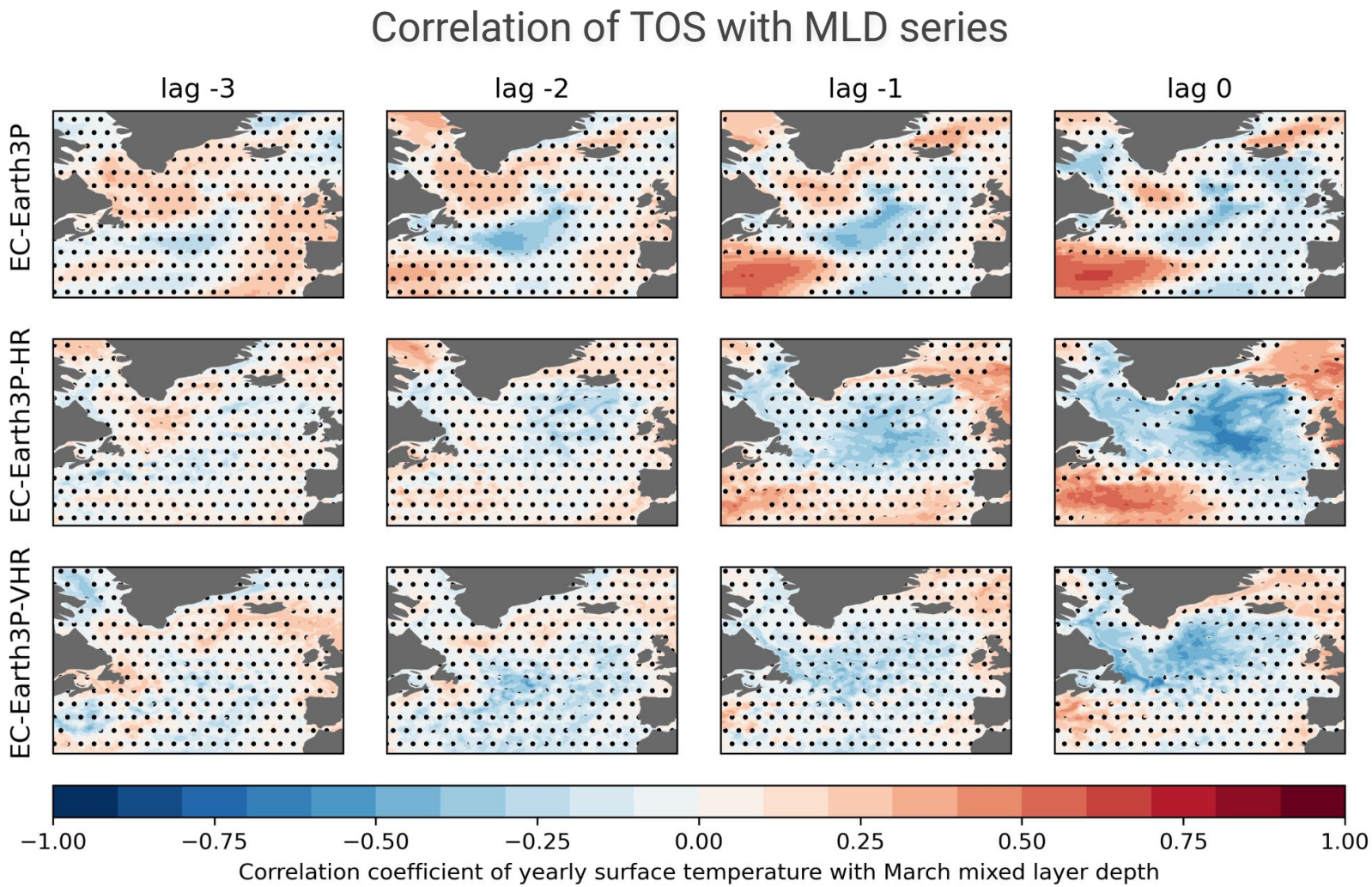
Mixing drivers in the North Atlantic



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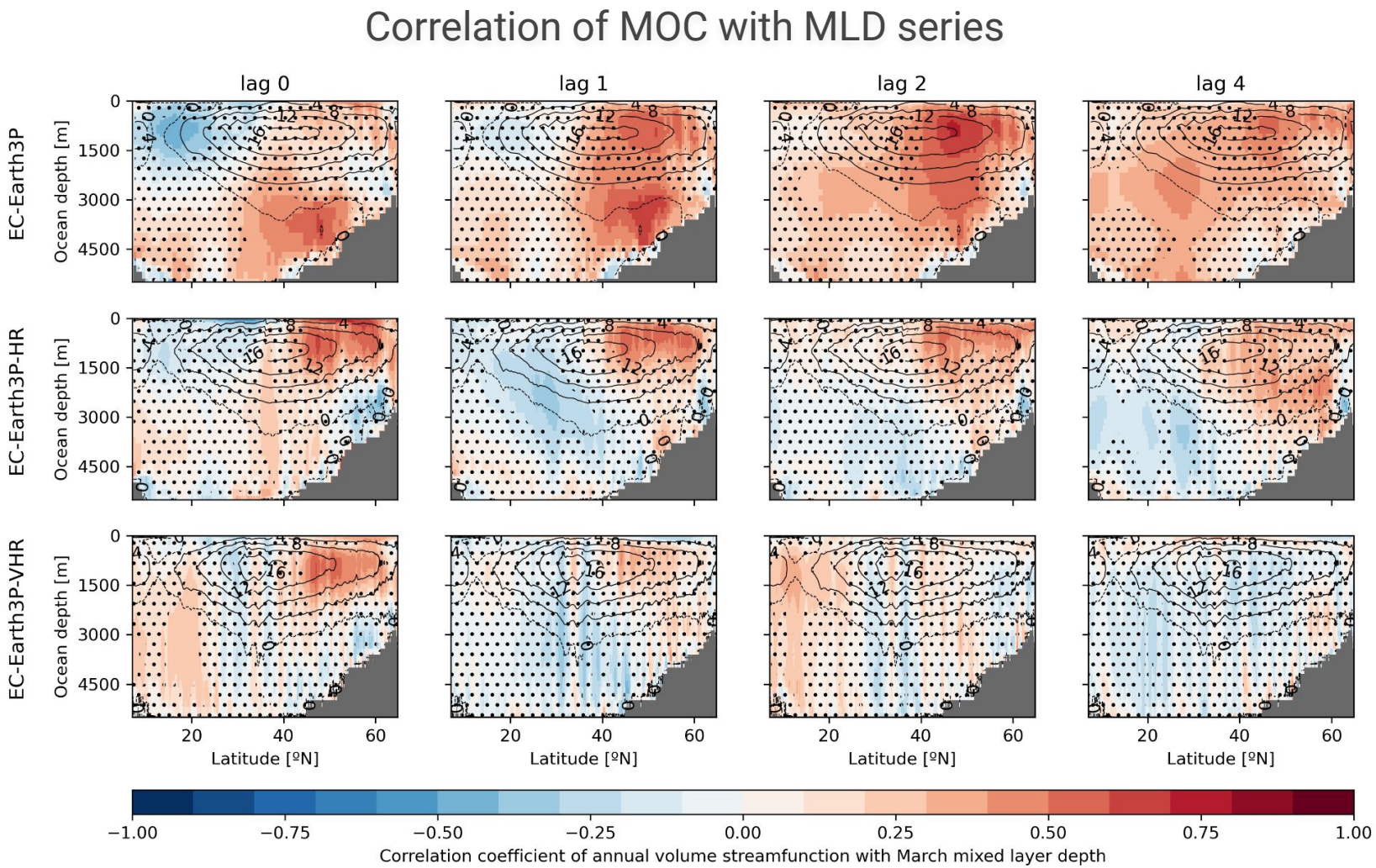
AMOC response to mixing



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