A multi-model comparison of the ocean contributions to multidecadal variability in the North Atlantic

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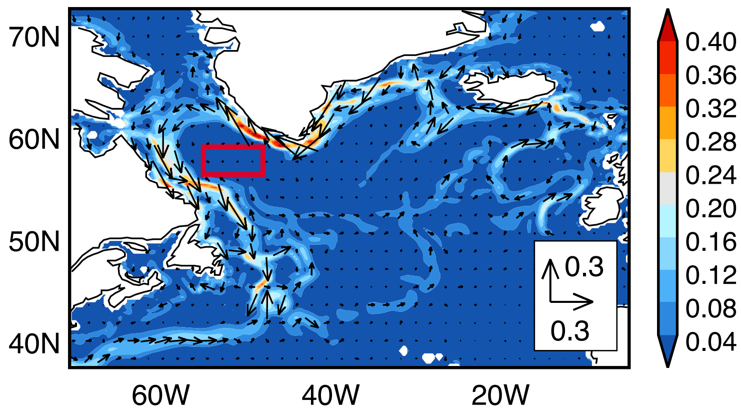
Motivation

Ortega et al (2017)

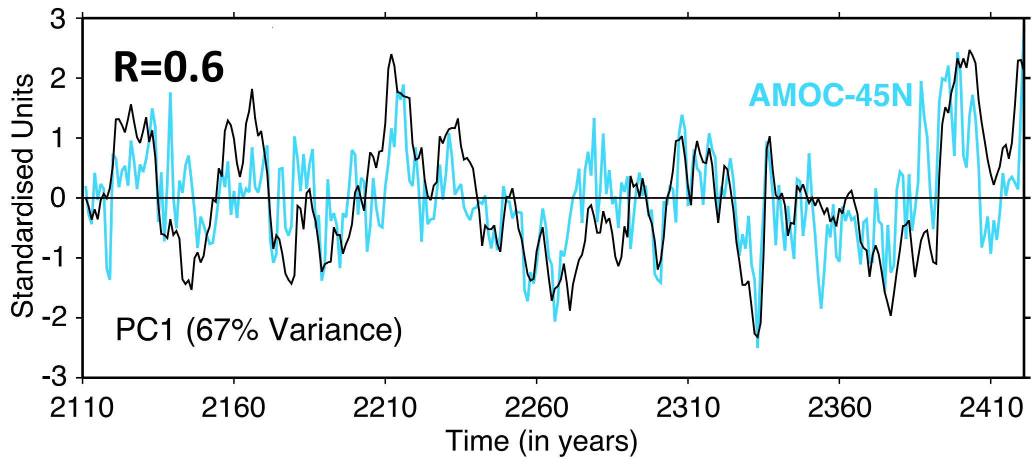
Analysis with HadGEM3-GC2 (GC2)

- Coupled control preindustrial simulation
- 310 years long
- Eddy-permitting resolution (1/4° in the ocean)

Mean current speed at 1000 m



PC1 of the spatially averaged density in Labrador Sea (PC1-LSD)



Motivation

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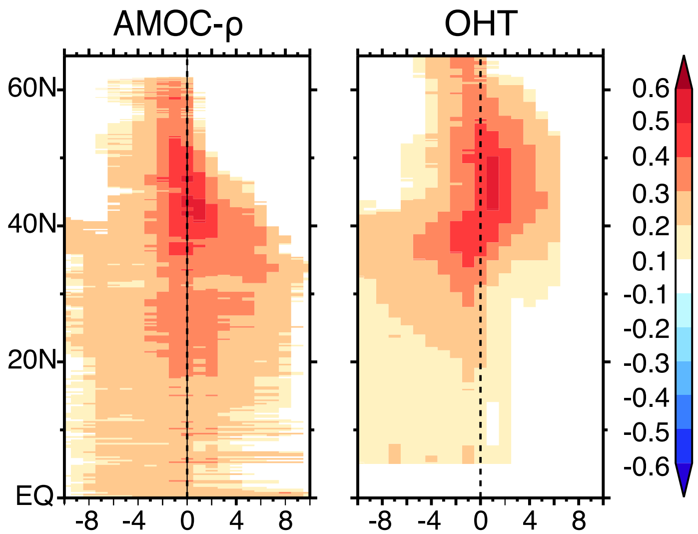
Cross-correlations with PC1-LSD



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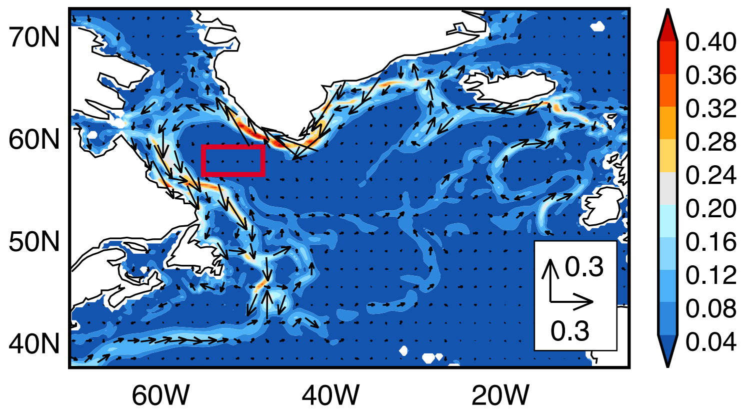

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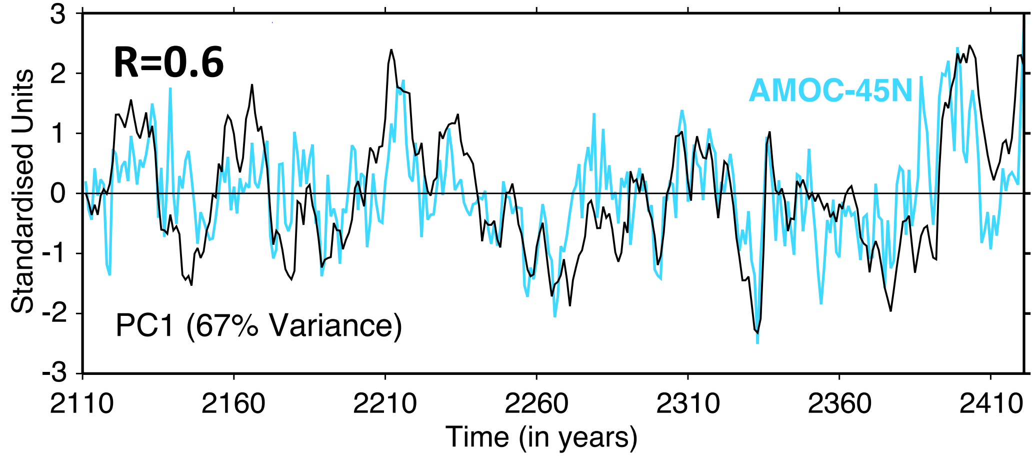

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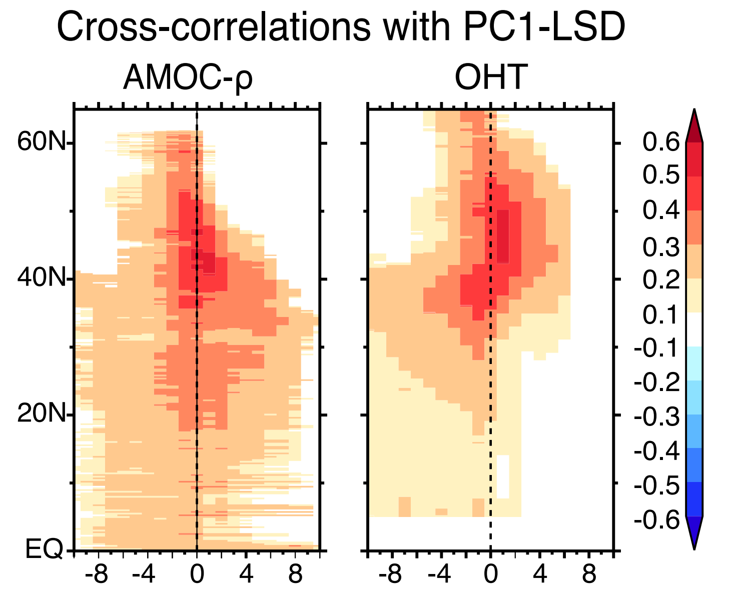
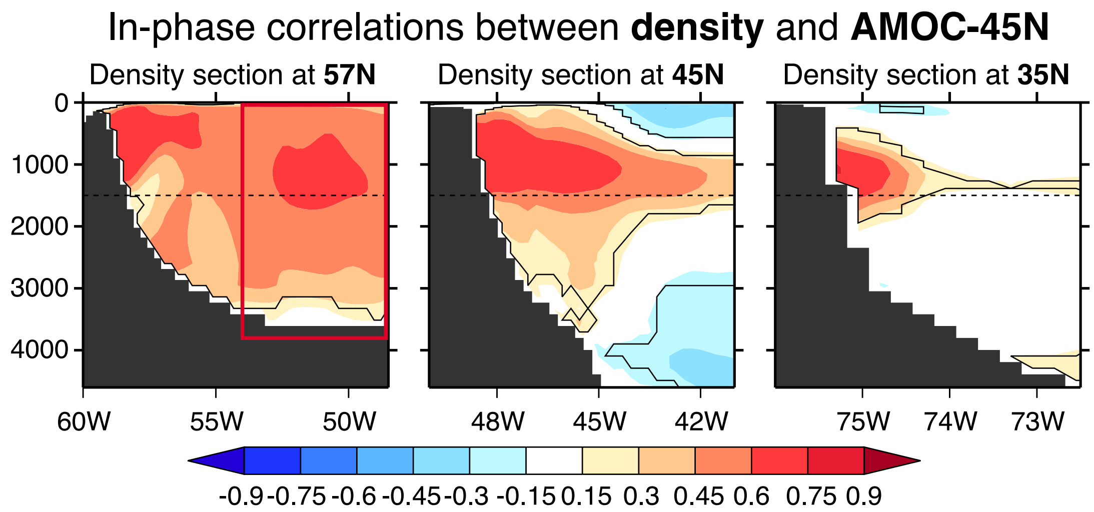
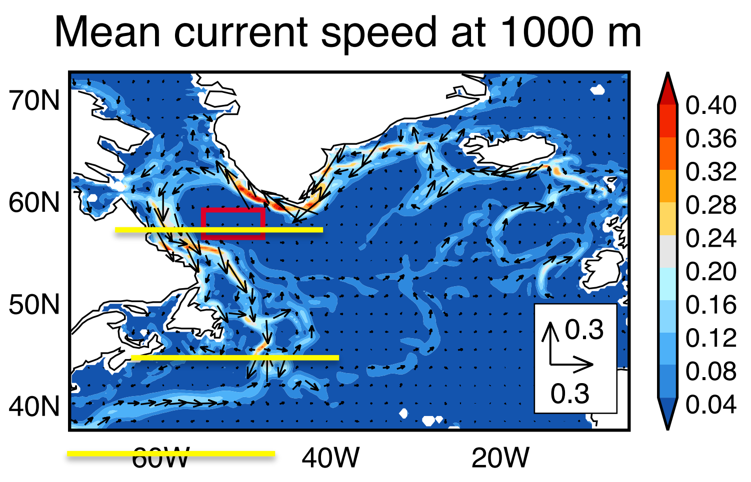
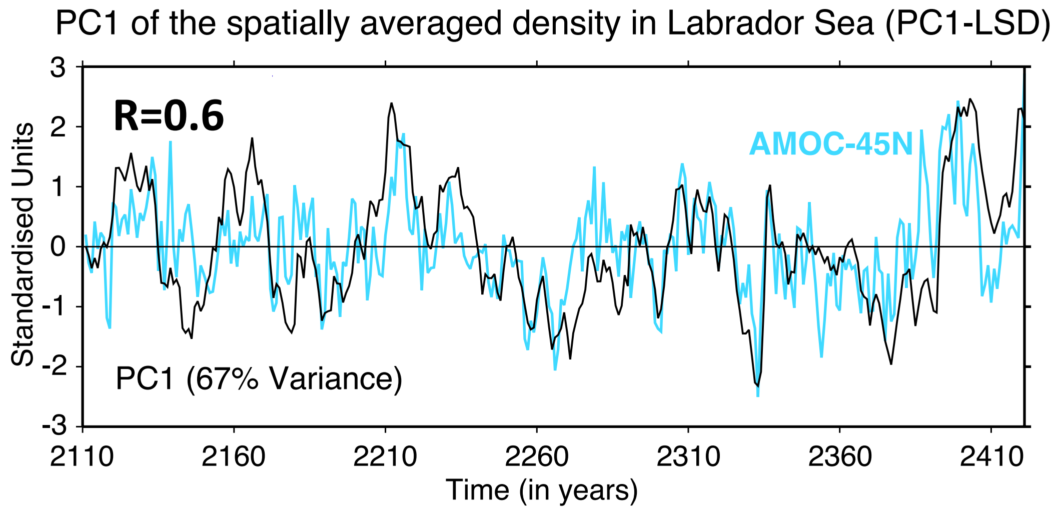




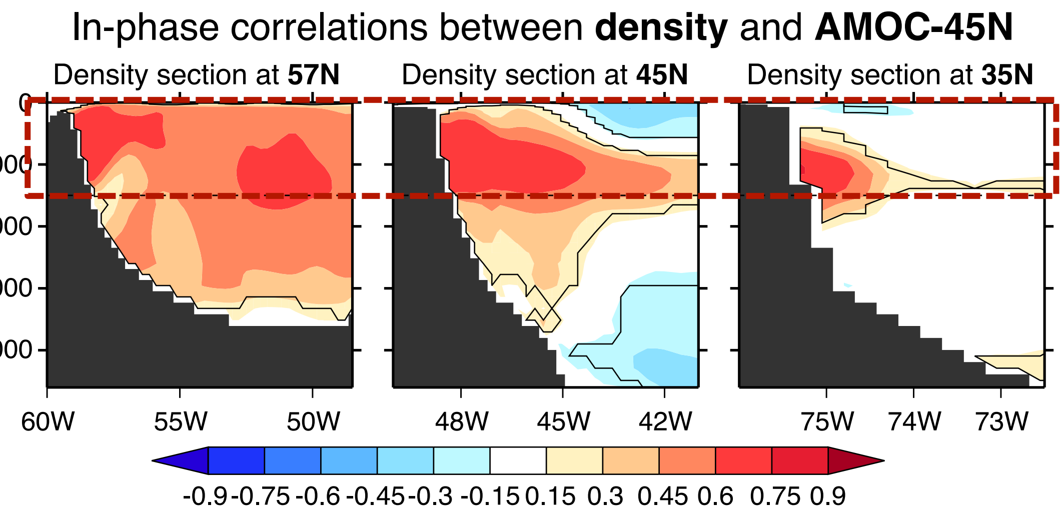




Motivation

Ortega et al (2017)

In GC2, only the **upper 1500 m** show coherent density changes along the western boundary



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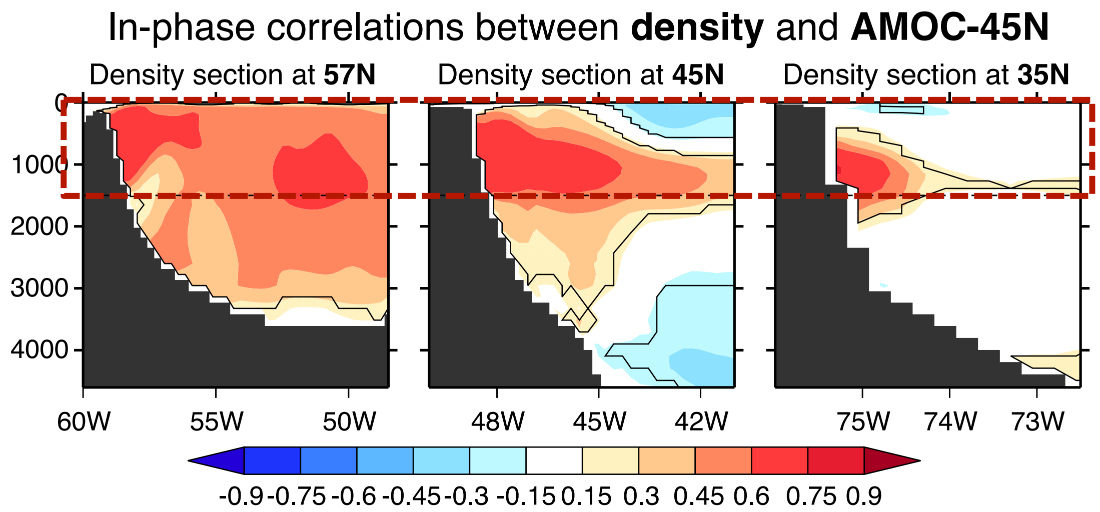
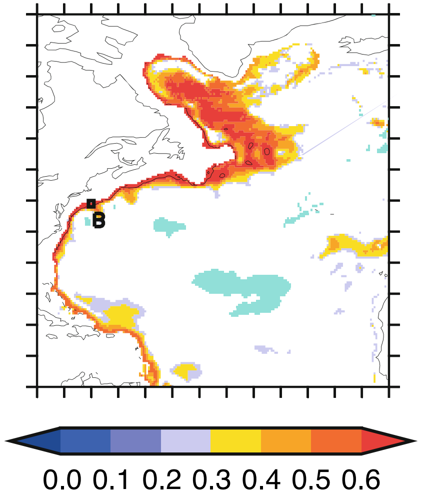
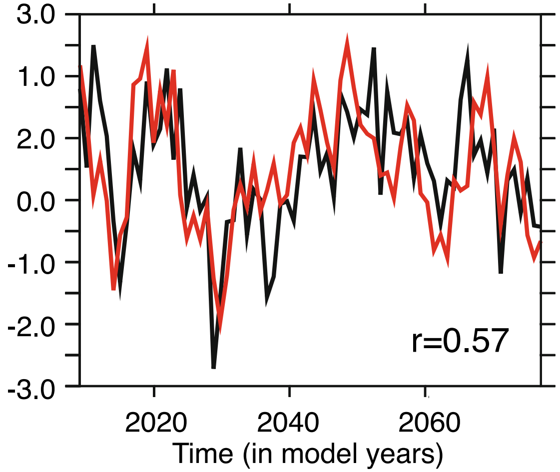


Correlation with vertically averaged 1500-3000m density



Density index at B vs AMOC-40N



Hodson et al (2012)

In HiGEM, Labrador Sea densities propagate along the boundary at deeper levels: **1500-3000m**

A cross-model analysis within DYNAMOC

Preindustrial Coupled Control Experiments	Ocean-forced Historical Experiments
HadGEM3-GC2 310 years 1/4° ORCA Grid **HiGEM** 340 years 1/3° Regular Ocean Grid	**ORCA025-IAF** **ORCA025-DFS** 1958-2009 AD 1/4° ORCA Grid **ORCA12-DFS** 1958-2015 AD 1/12° ORCA Grid

Assimilation Run
DEPRESYS3
1960-2016 AD
1/4° ORCA Grid

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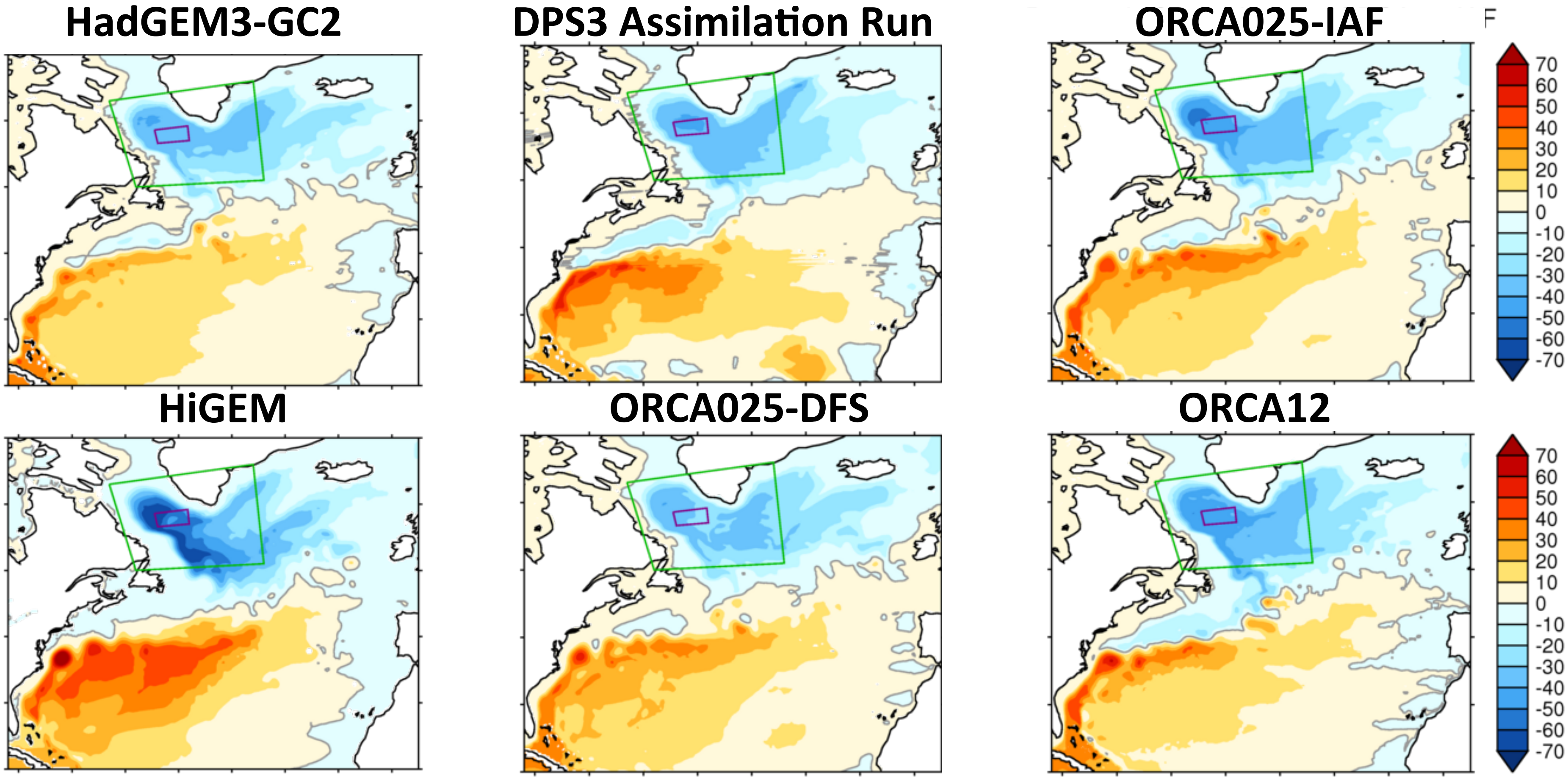
1. **How different are Labrador Sea properties** accross the models?
2. **How robust** is the **link** of **LSD with boundary densities and the AMOC**?
3. **How coherent** are AMOC variations at **subpolar** and **tropical latitudes**?

Mean climatological properties

Barotropic Streamfunction



All the simulations but the DPS3 assimilation show an **overshooting of the Gulstream separation** (less marked in GC2 and ORCA12)

Mean climatological properties

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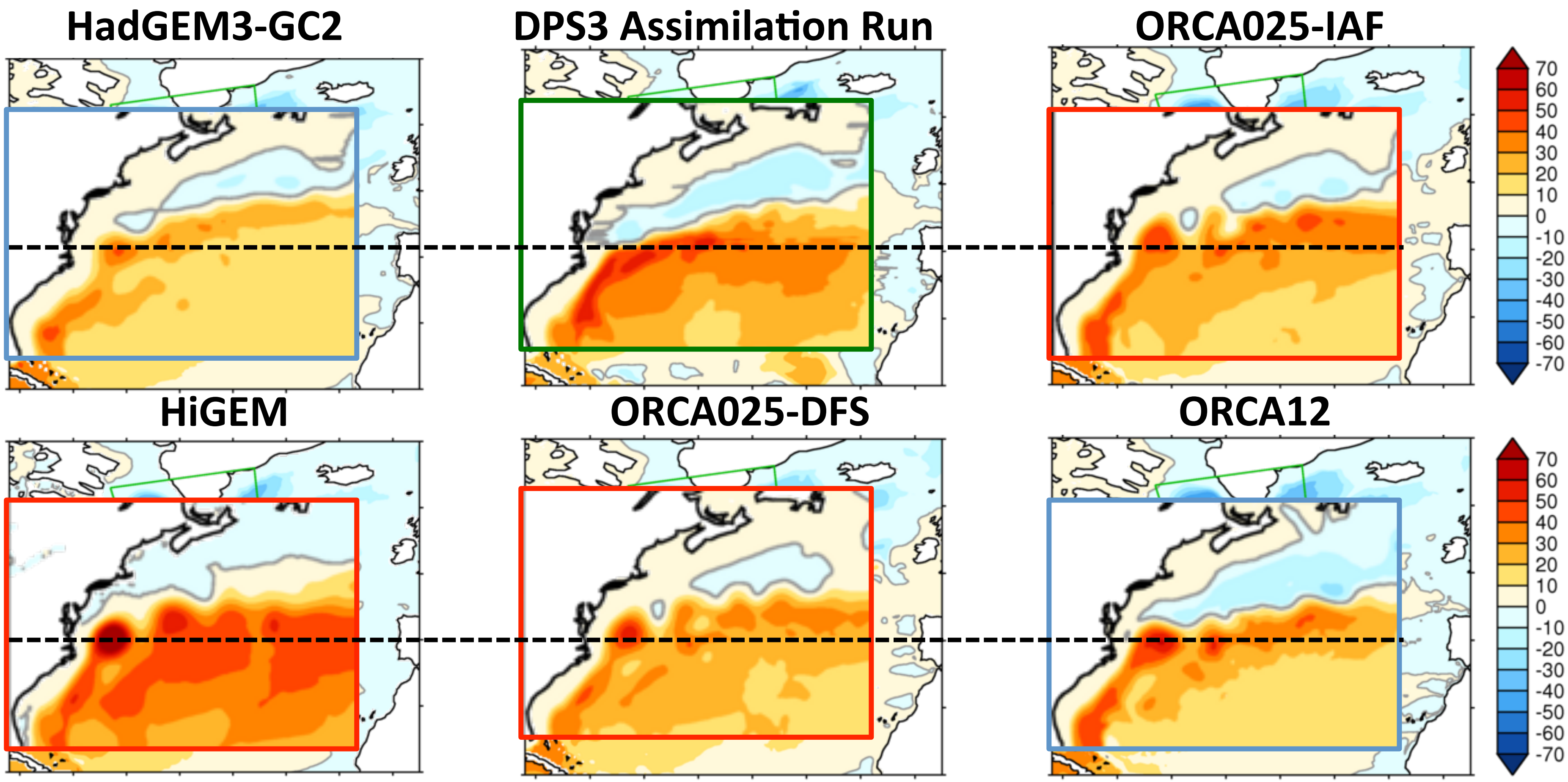

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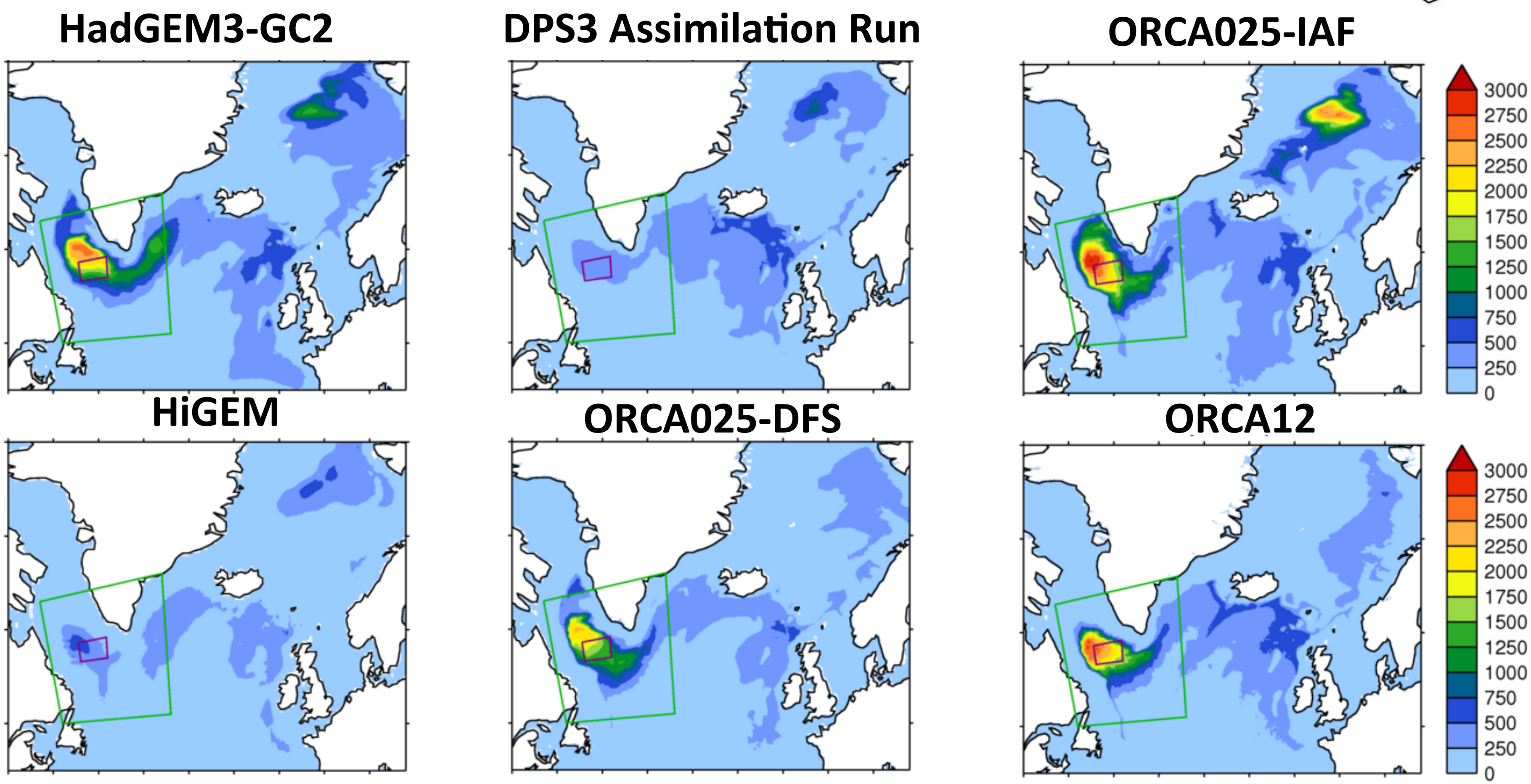
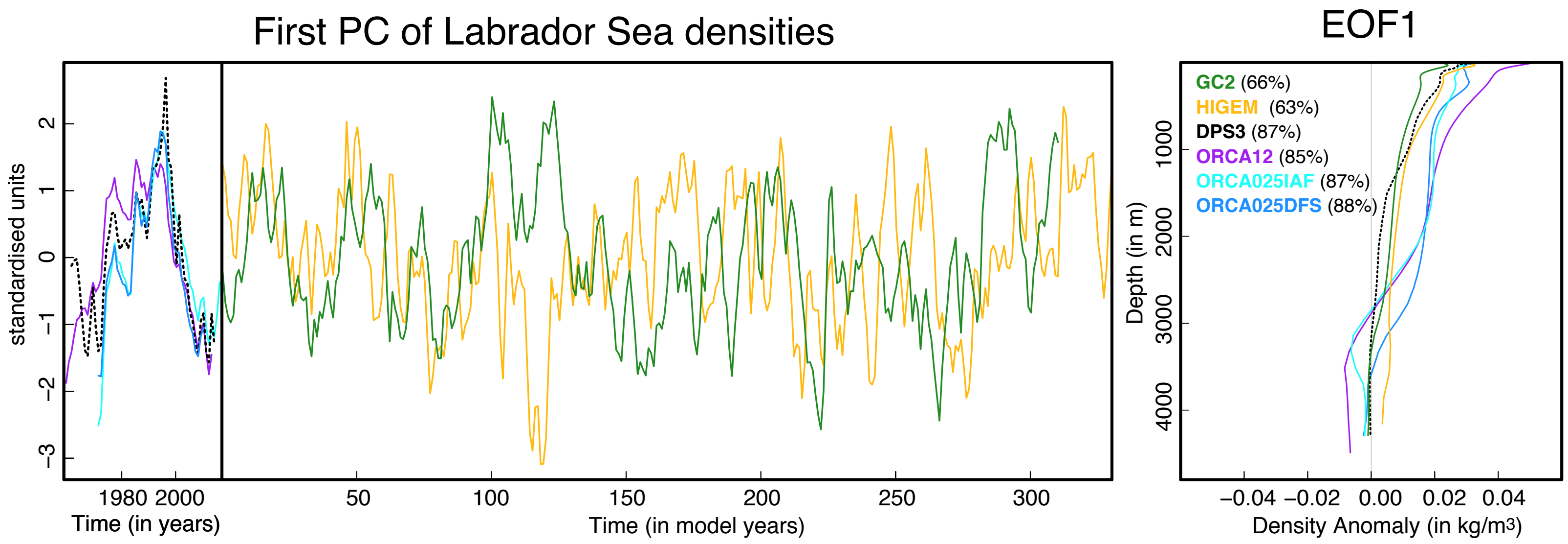
Mean climatological properties II

Mixed layer Depth (in march)



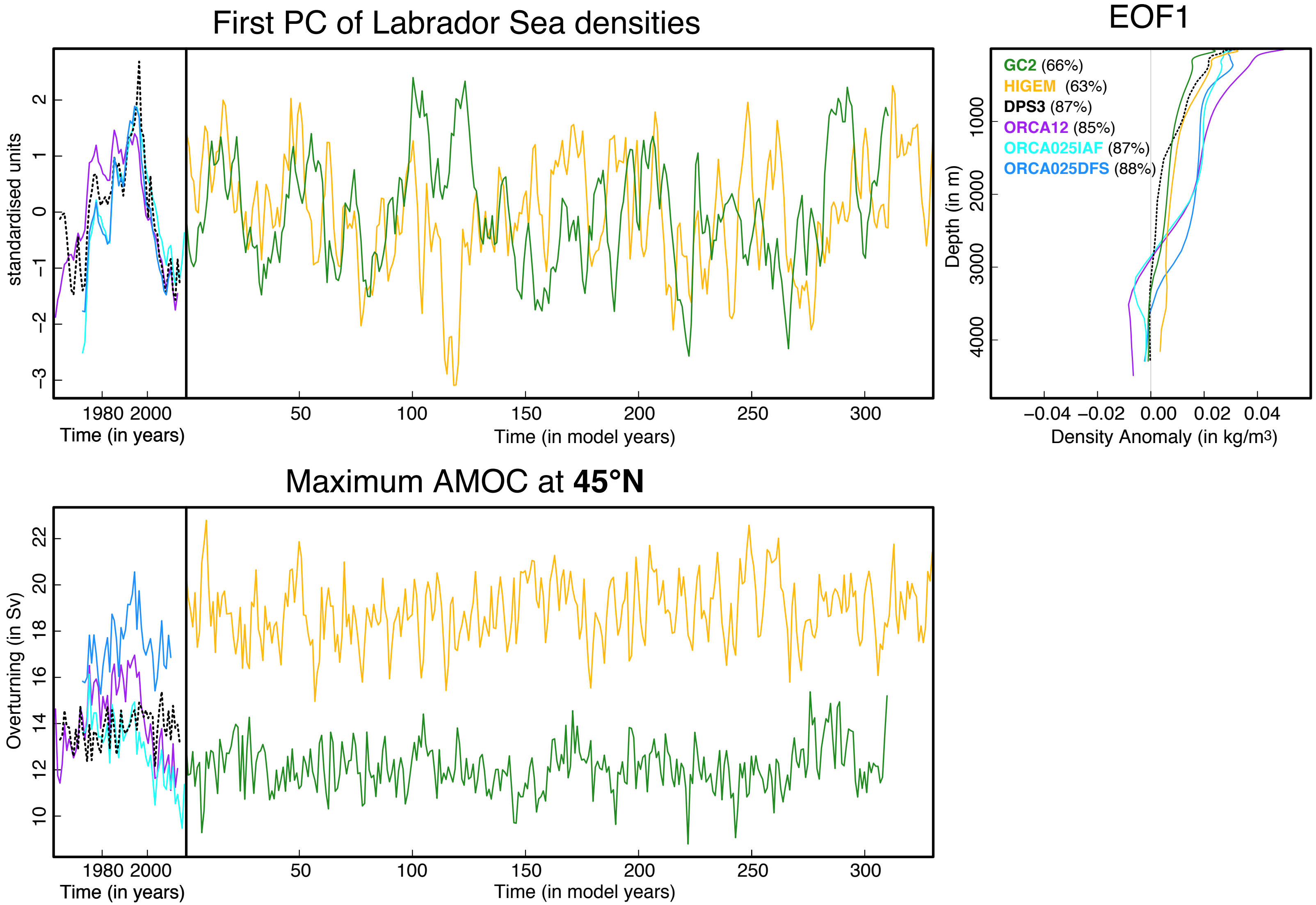
The **mixed layer depth** is generally **too strong** in the **Labrador Sea**

Leading mode of Labrador Sea densities (LSD)



The **first mode** of LSD is encouraginly **consistent across the simulations**

Leading mode of Labrador Sea densities (LSD)



There is **less consistency** regarding the associated **changes in the AMOC**

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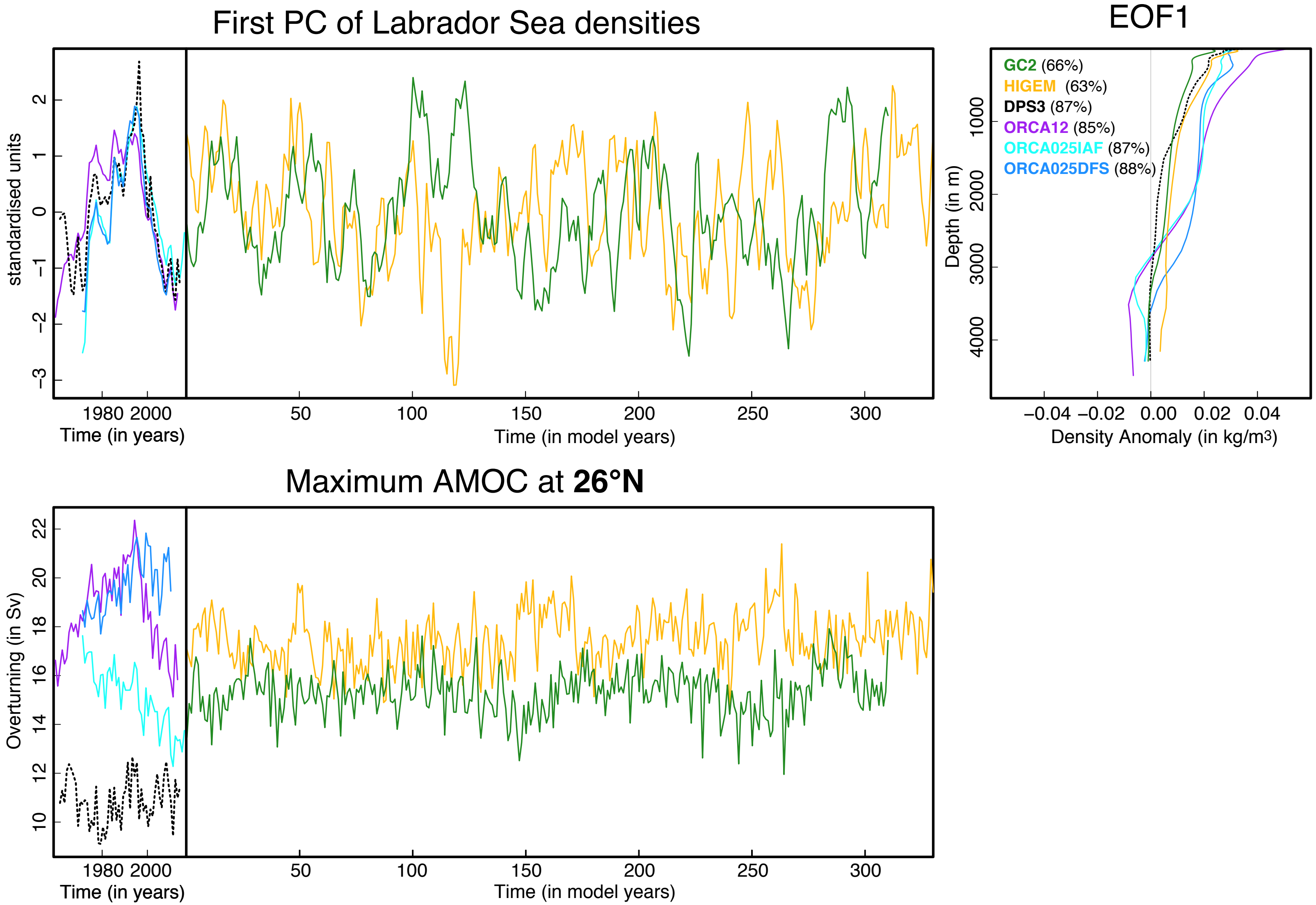

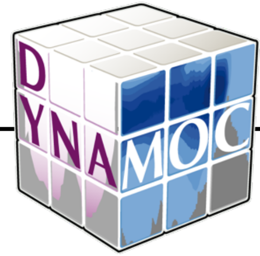

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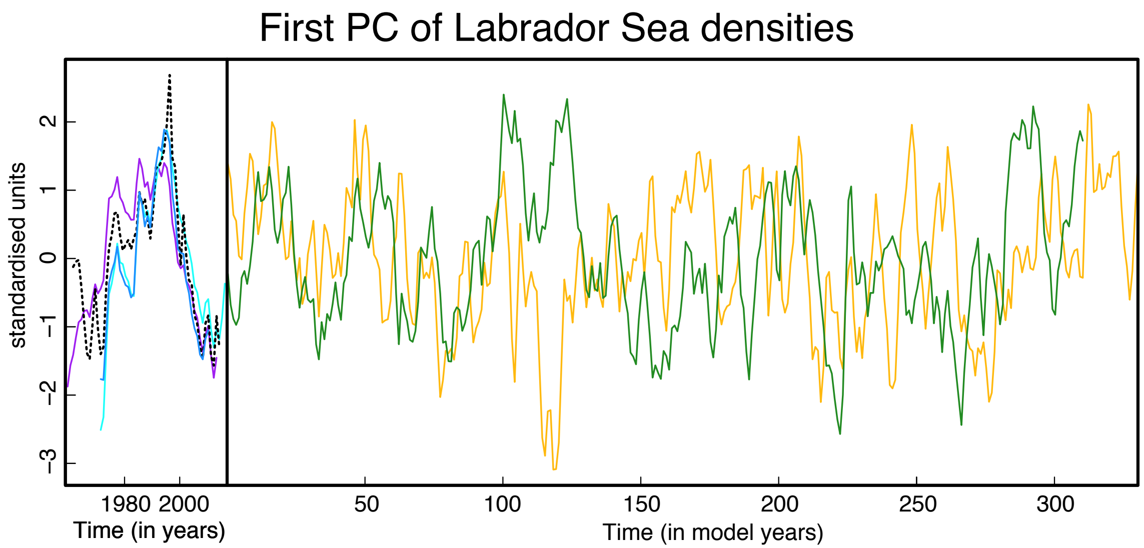
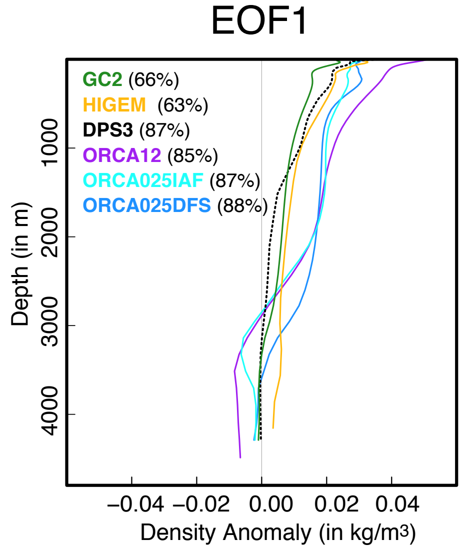
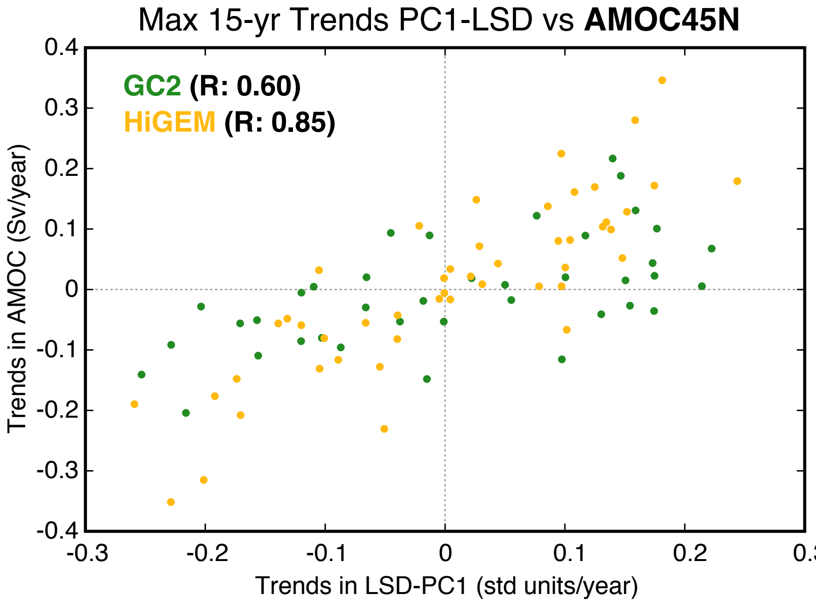
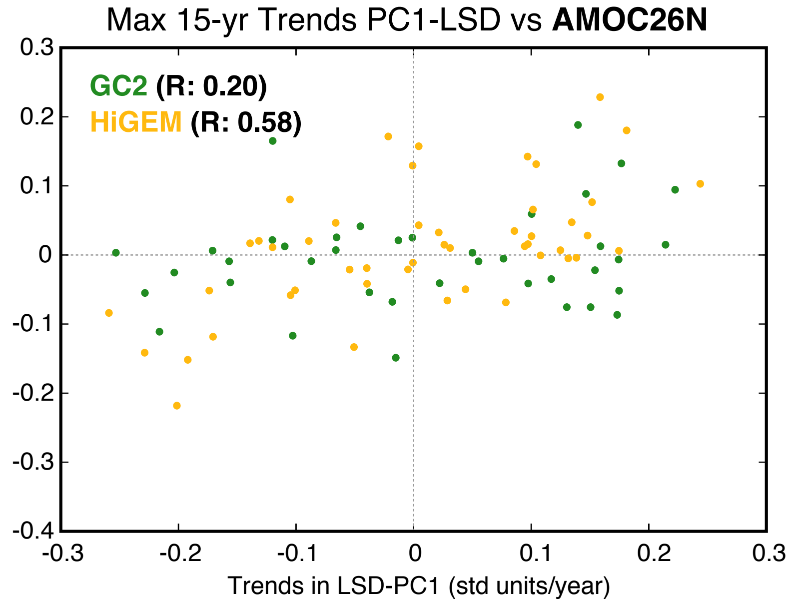




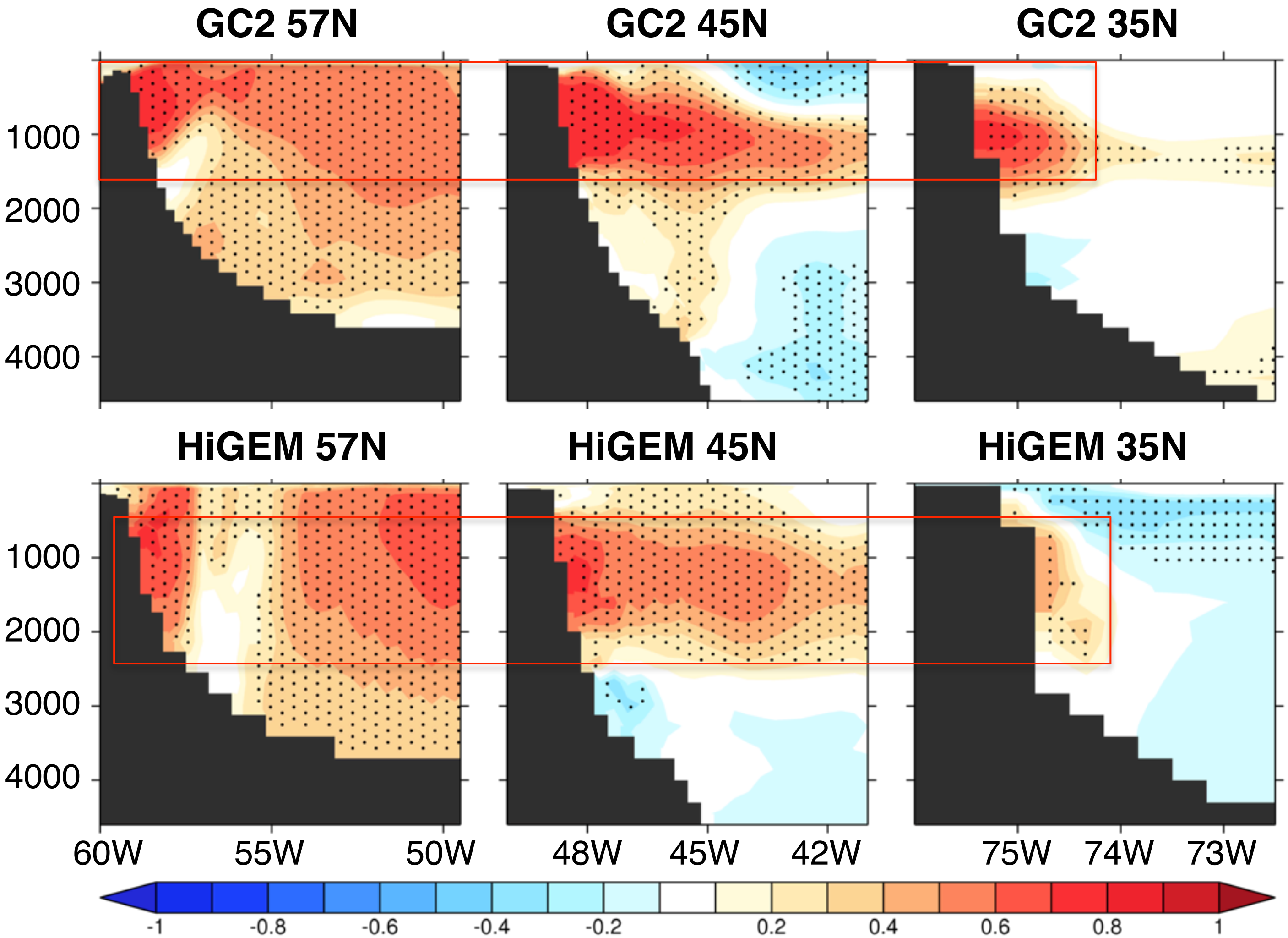




There is a **strong link** with the **AMOC45N** (and weaker with AMOC26N)

AMOC link with density changes across the WBC

Correlations AMOC45-Ekman vs boundary densities



Boundary signals are **shallower** and **correlations stronger** in **GC2**

HiGEM has a **weaker link** of the **BC** with **interior Labrador Sea**

Conclusions and further work

- All the simulations analysed show clear multidecadal variability in the Labrador Sea densities
- However, their ultimate link with the AMOC and the boundary densities seems to be model dependent
- These differences can potentially affect their link with the wider North Atlantic, and the associated climate impacts

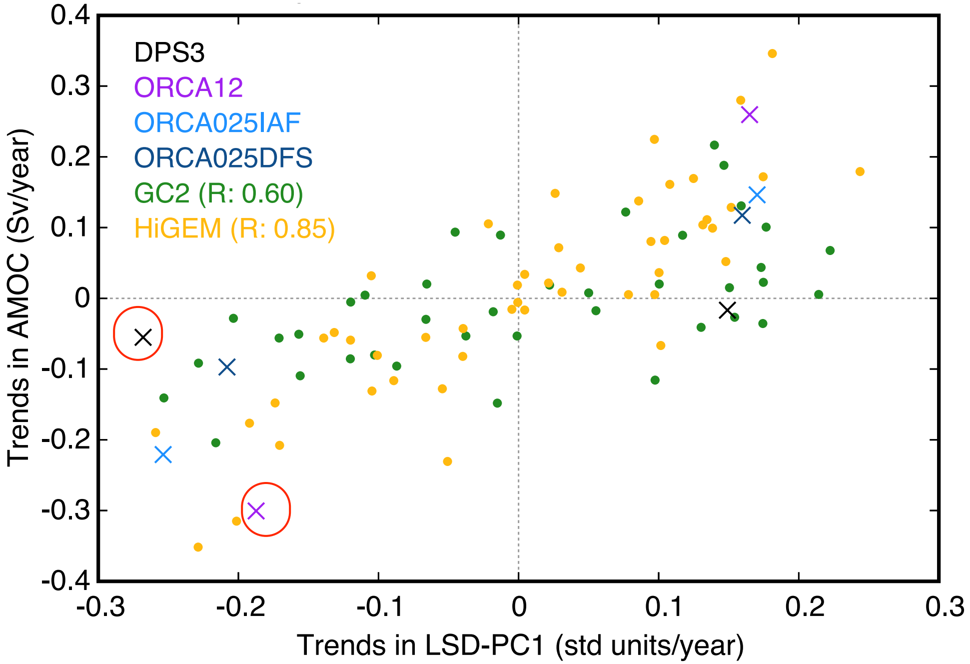
Conclusions and further work

- Evaluating the model results with observational data, when possible (e.g. RAPID, DWBC line W)
- Extending the analysis to other models (to identify the robust features as well as the key model uncertainties)
- Quantifying the atmospheric (e.g. NAO-driven) vs non-atmospheric contributions to LSD
- Exploring the effect of model biases (and resolution) on the LSD-AMOC-BC relationships

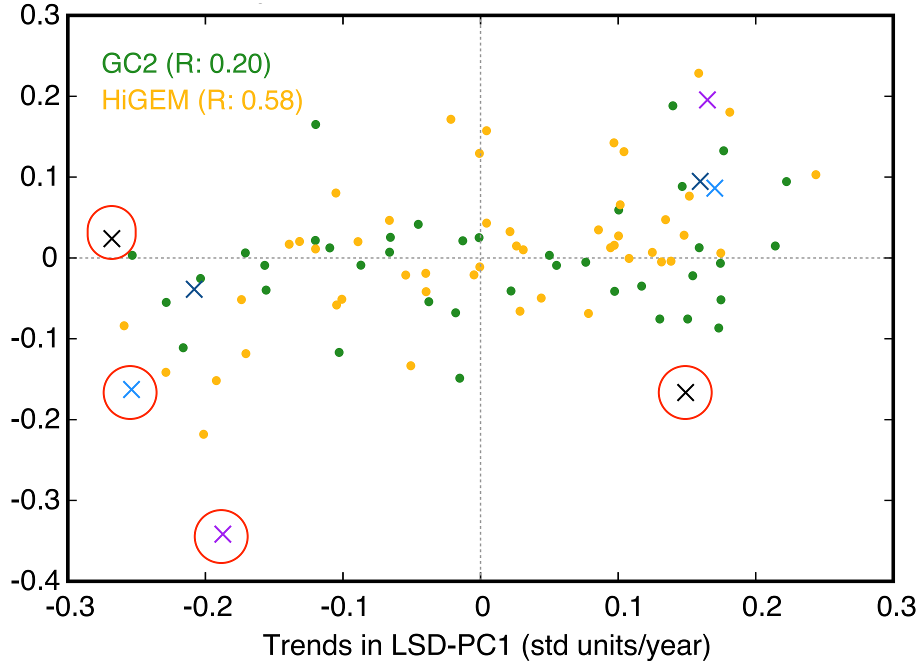
Decadal trend comparison: Historical vs Control

Scatterplot of 15-year trends

PC1-LSD vs AMOC45N



PC1-LSD vs AMOC26N

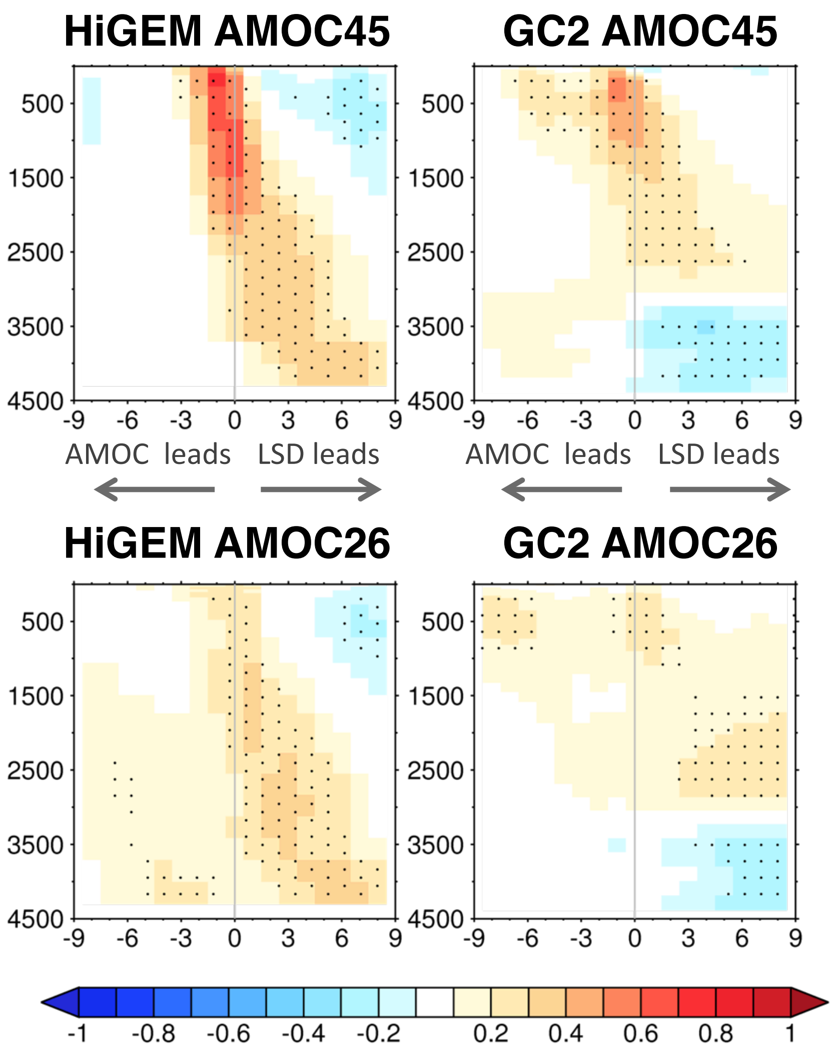


There is a **strong linear link** between **PC1-LSD** and **AMOC45N** trends

Trends in the **forced ocean runs** tend to fall **outside the spread** in the **control** experiments, potentially due to the effect of **initial drifts**

Depth of LSD changes linked to the AMOC

AMOC indices vs LSD

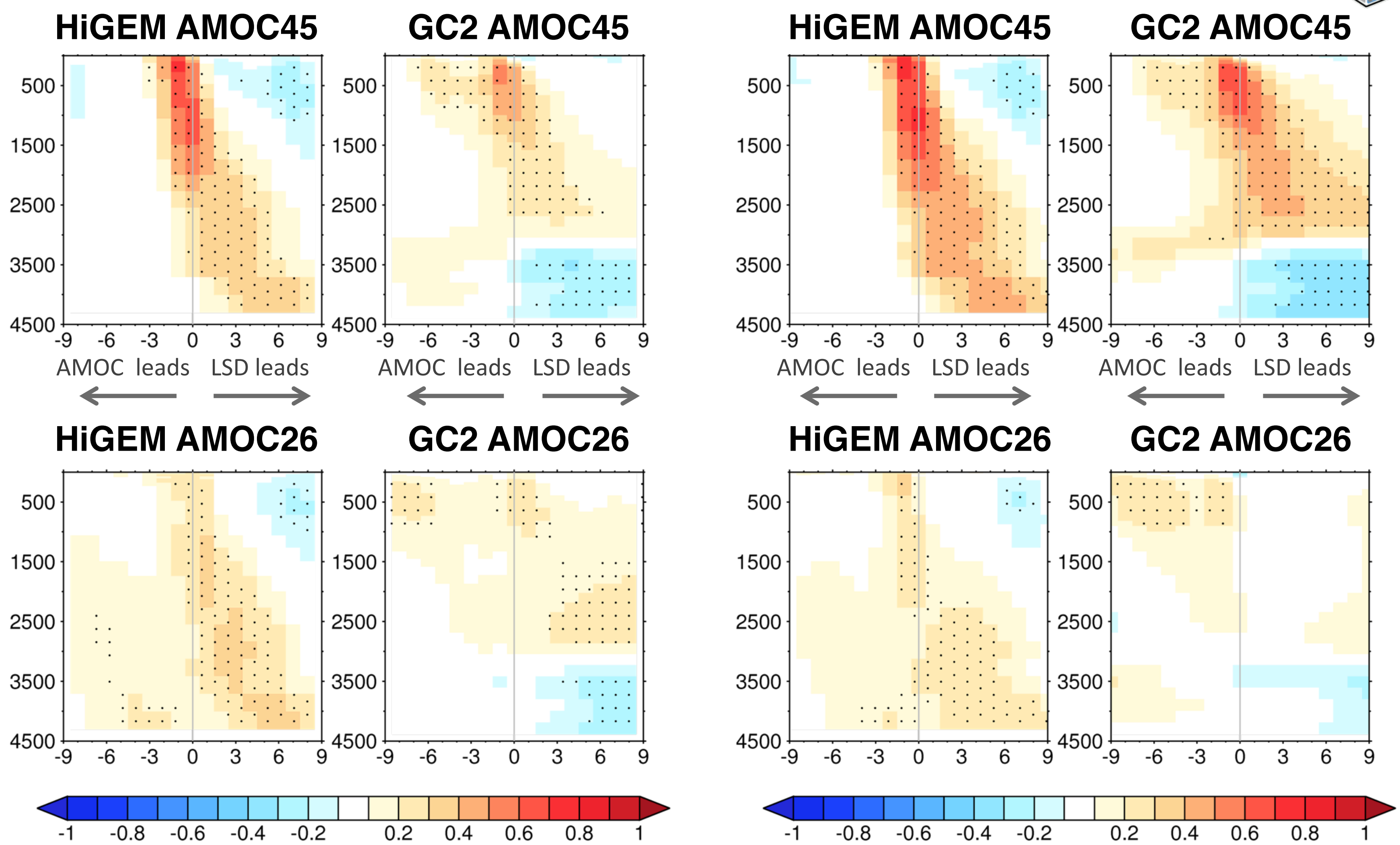


HiGEM shows a link of **deeper LSD** anomalies with the **AMOC**

Depth of LSD changes linked to the AMOC

AMOC indices vs LSD

[AMOC-Ekman]



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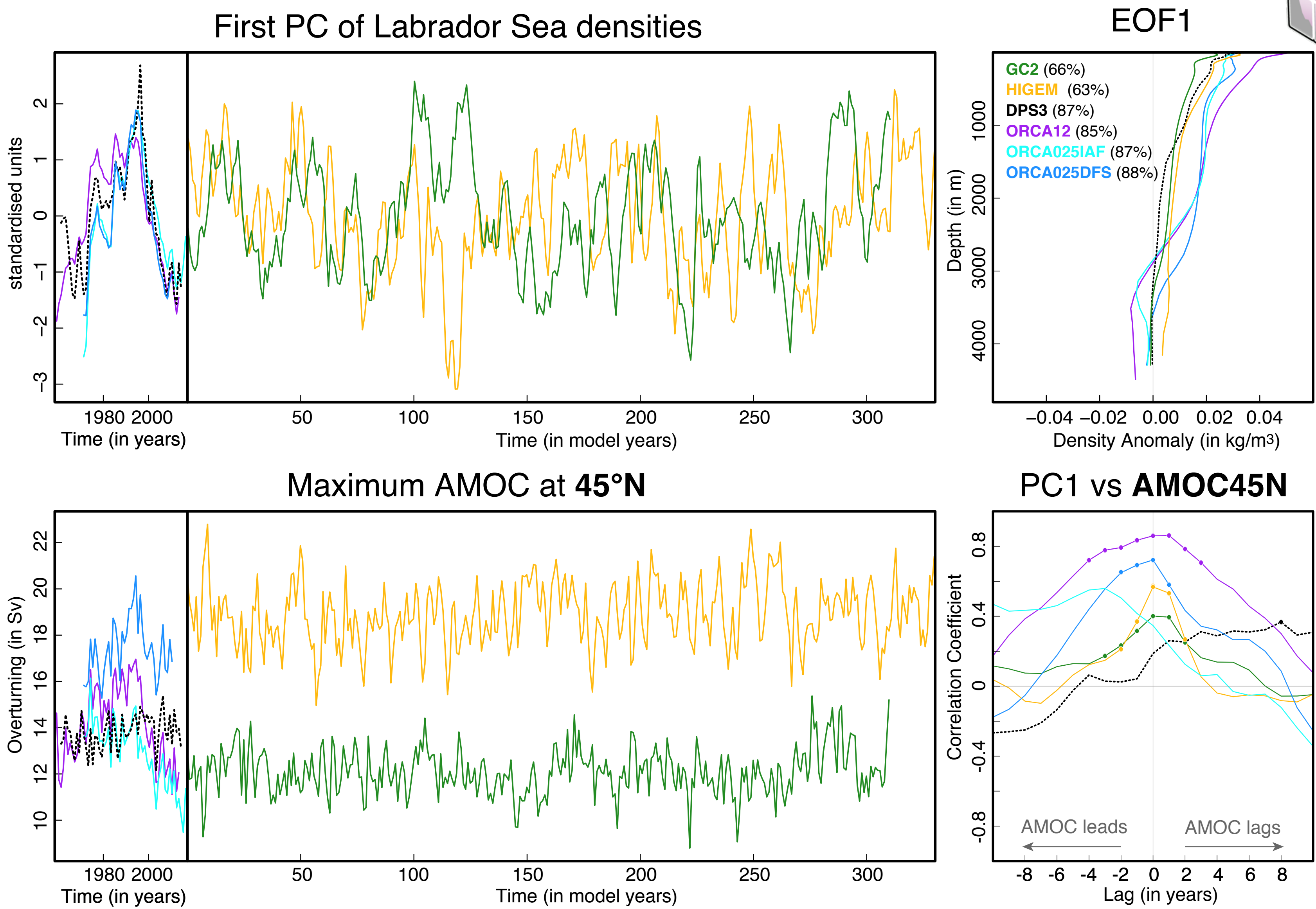
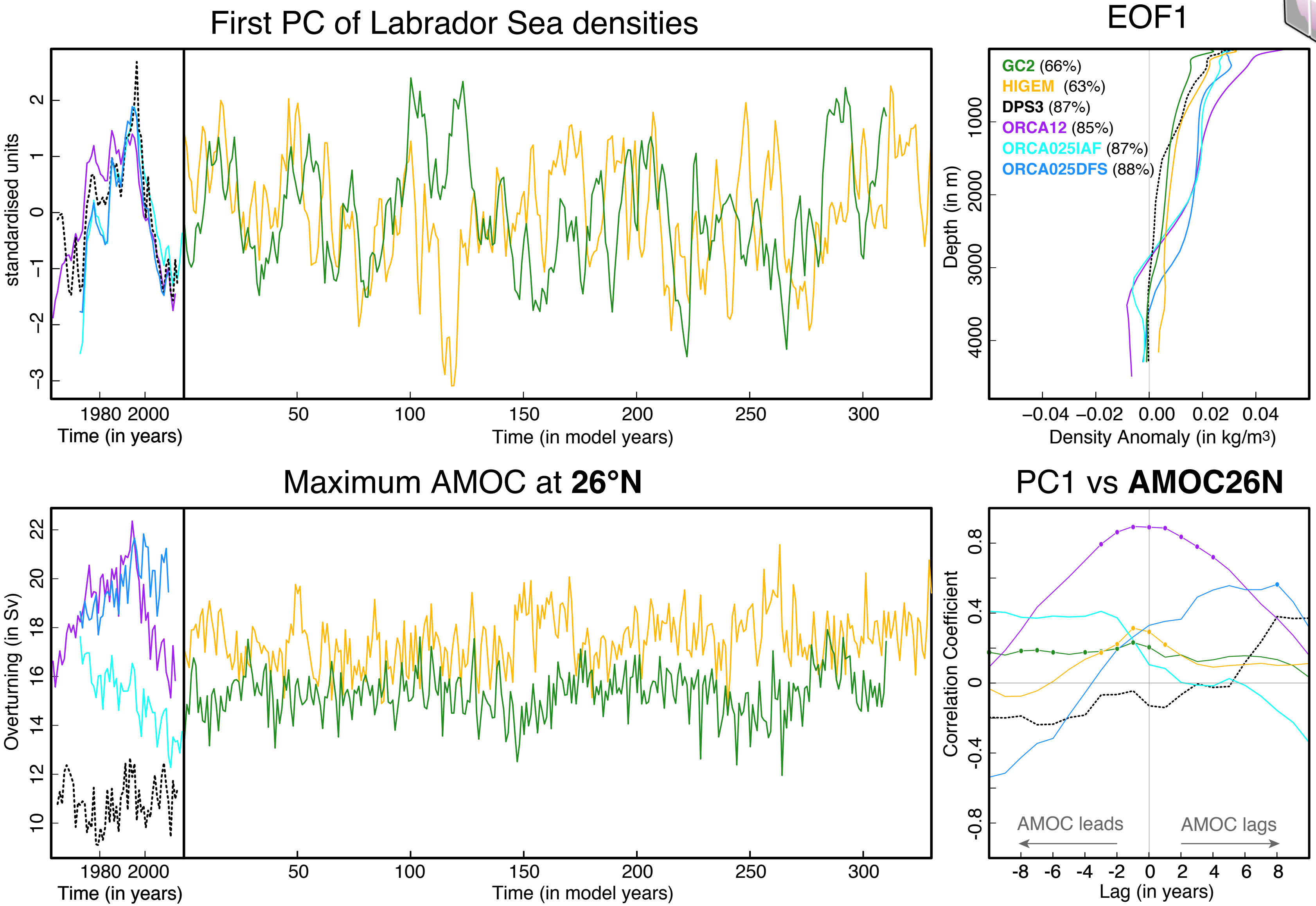
Link with the AMOC at 45°N



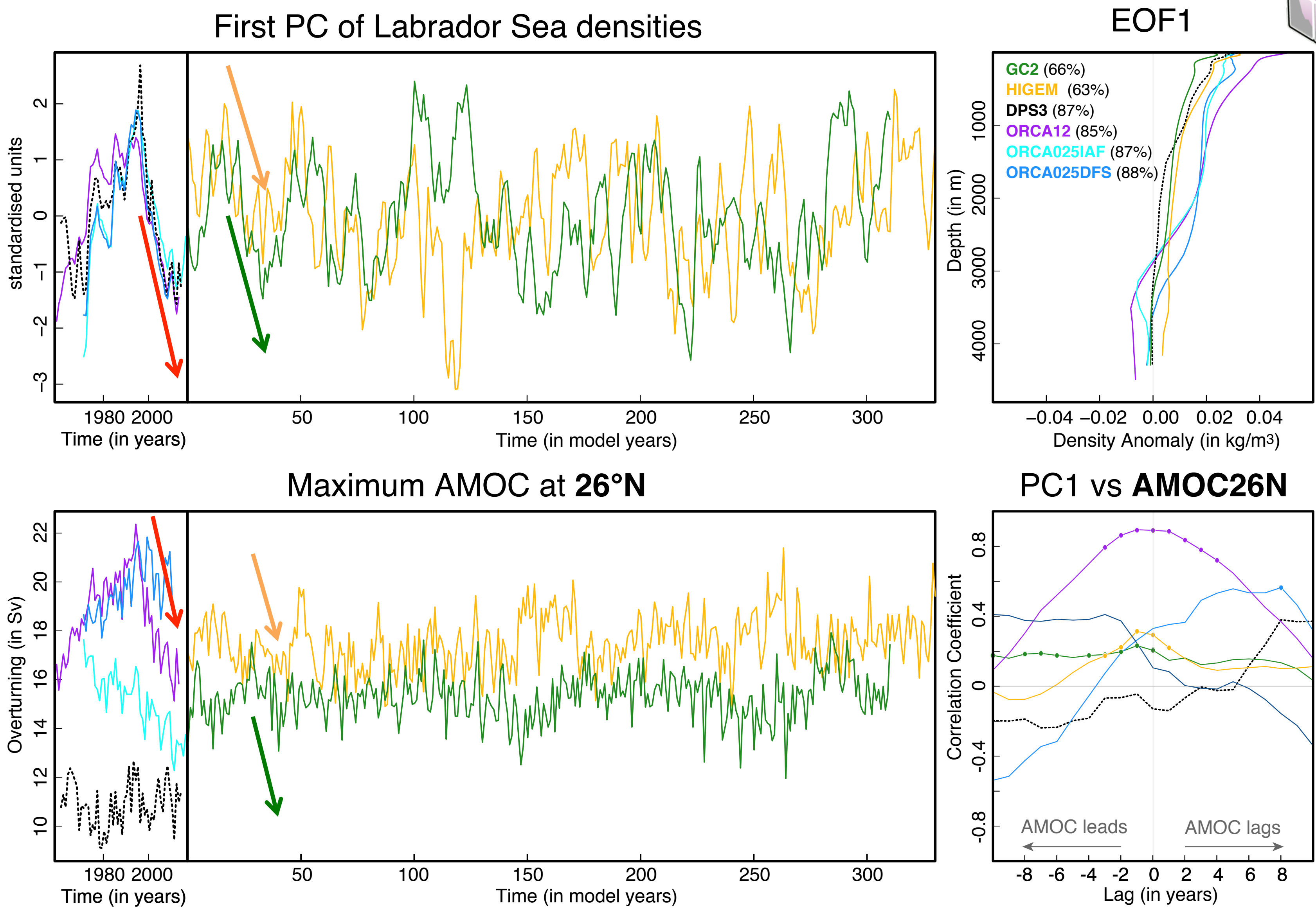
PC1-LSD changes are tightly **linked** to changes in the **AMOC at 45N**

Link with the AMOC at 26°N



By contrast, they show **no consistent link with** the **AMOC at 26°N**

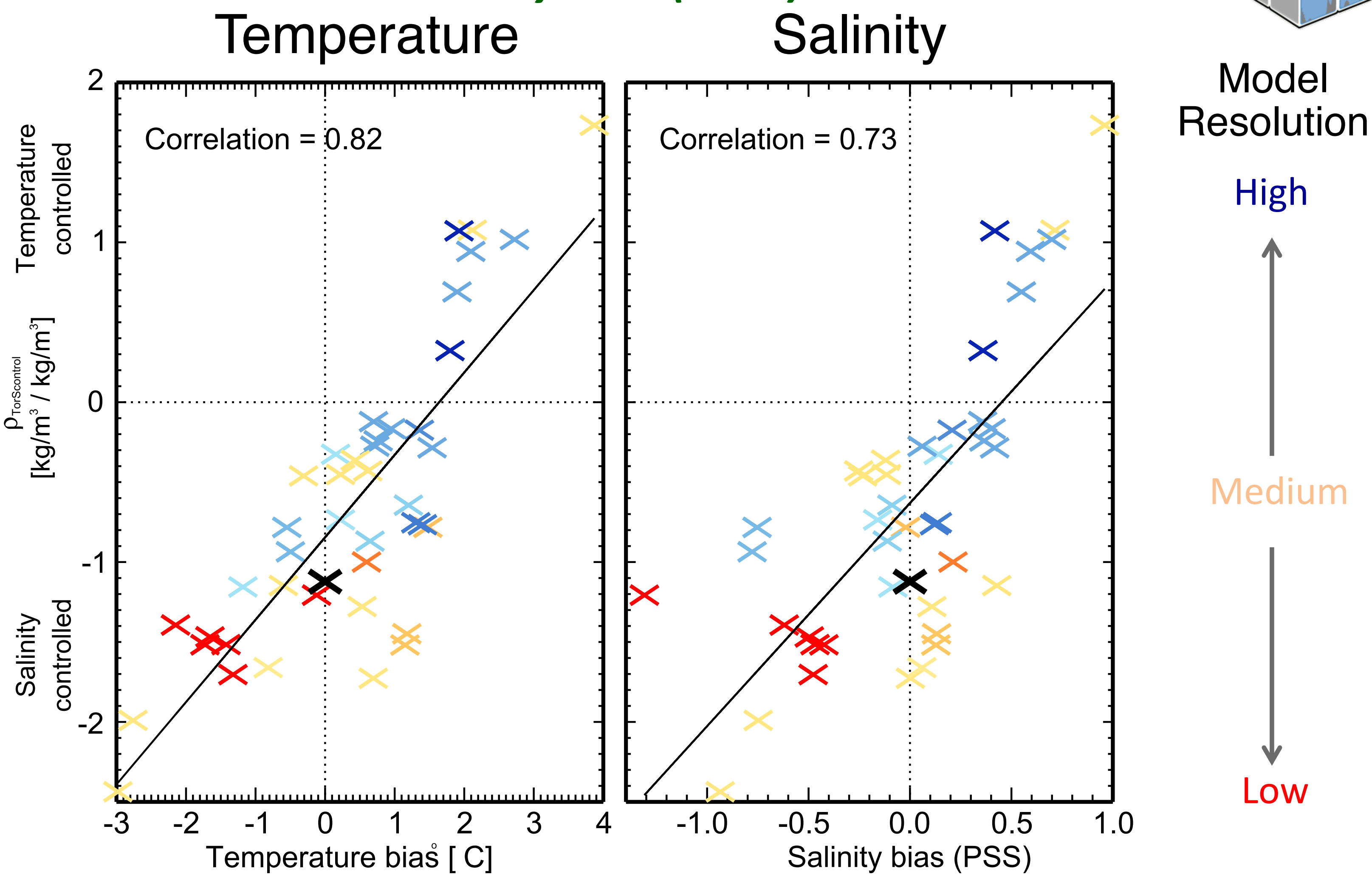
Link with the AMOC at 26°N



We can **compare decadal trends** in **PC1-LSD** and the **AMOC** Indices

Effect of model biases in Labrador Sea density

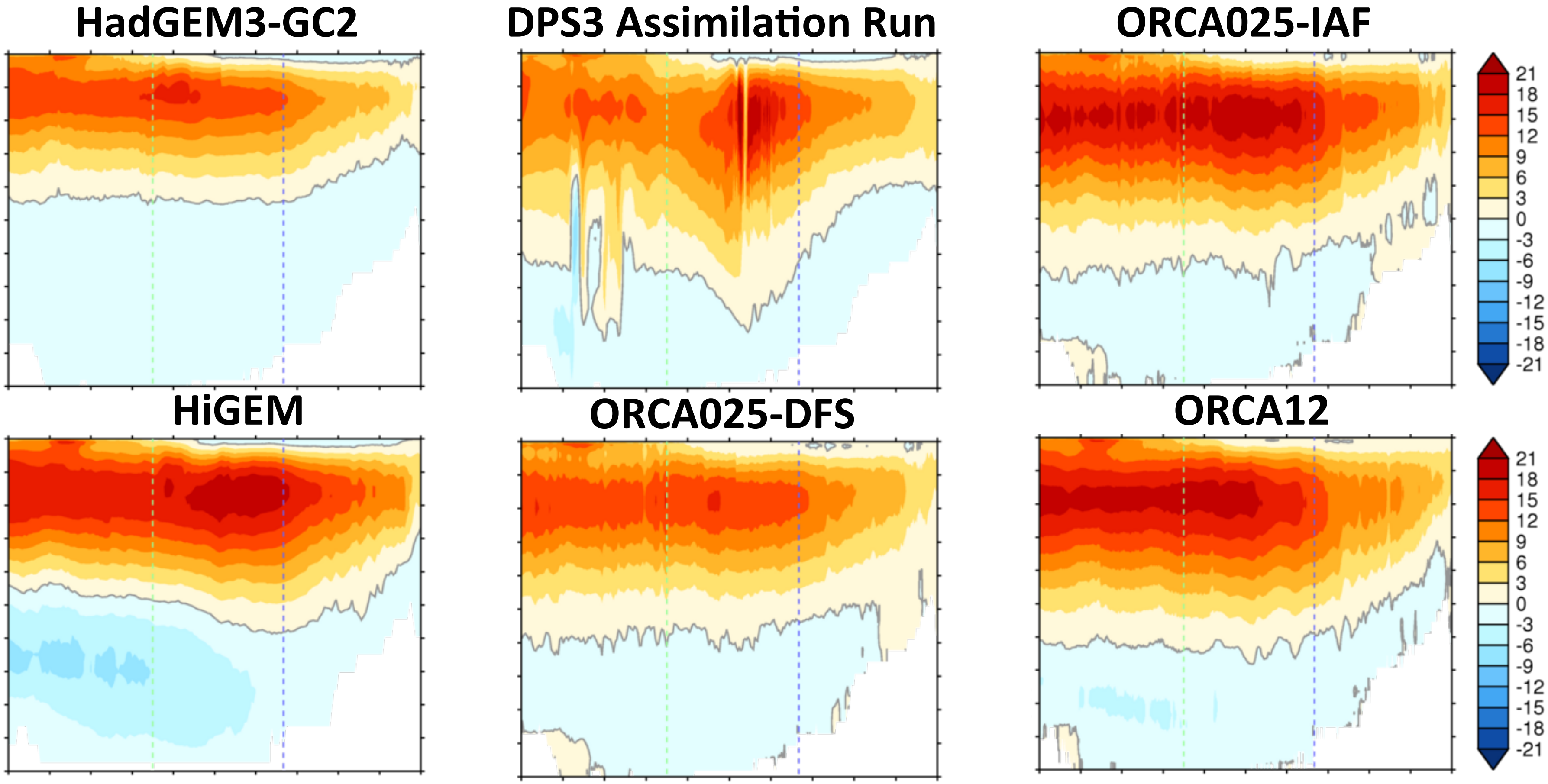
Menary et al (2015)



CMIP5 model biases can affect the controls of LSD density, and potentially its variability and impacts

Mean climatological properties

AMOC Streamfunction



The **location of the maximum,** its **intensity,** and **the depth of the AMOC cell can largely vary** from one model to another