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

P. Ortega[1], J. Robson[1], R. Sutton[1], M. Menary[2], A. Blaker[3], A. Germe[3], J. Hirschi[3], B. Sinha[3], L. Hermanson[2] & S. Yeager[4]

(1) NCAS-Climate, University of Reading, UK (2) Met Office Hadley Centre, UK (3) National Oceanography Centre, UK (4) NCAR, Boulder, US

MOTIVATION

Previous studies with the HadGEM3-GC2 model (Robson et al 2016, Ortega et al 2017) have identified the Labrador Sea density (LSD) as a key indicator of multidecadal decadal variability, linked to important changes in the Atlantic Meridional Overturning Circulation (AMOC) and the western boundary densities (WBD) and, more generally, to the climate of the wider North Atlantic (Fig. 1). These results show a great potential for decadal climate prediction. For example, decadal decreasing trends in the Labrador Sea densities lead 4-10 years later to decadal coolings in the Eastern Subpolar Gyre, and to positive phases of the North Atlantic Oscillation (NAO).

However, it remains yet to be determined if these relationships are also reproduced in other models.

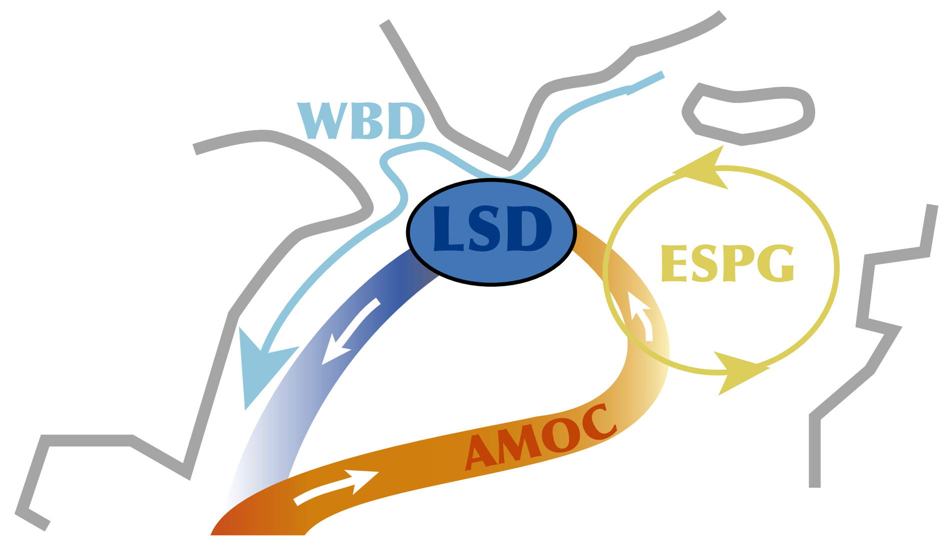


Fig. 1 Schematic of the major LSD influences across the North Atlantic in HadGEM3-GC2

Main Goal:

To test the consistency of the LSD relationships across an ensemble of climate models

1. EXPERIMENT SELECTION

PiControl Simulations

HadGEM3-GC2	310 years, 1/4° ORCA Grid
HiGEM3	340 years, 1/3° ORCA Grid
CMIP5 ensemble	(19 experiments)

Ocean-forced & Historical

ORCA025-IAF/DFS	1958-2009AD, 1/4° ORCA Grid
ORCA12-DFS	1958-2015AD, 1/12° ORCA Grid
NCAR-IAF	1948-2007AD, Nominal 1° Grid
DPS3 Assimilation run	1960-2016AD, 1/4° ORCA Grid

2. LSD: AN INDEX OF MULTIDECADAL VARIABILITY

The 1st mode of Labrador Sea Densities (**PC1-LSD**) behaves as a **red-noise** process with enhanced variance at **12-30** yrs. Its **EOF** has a **coherent structure** across models

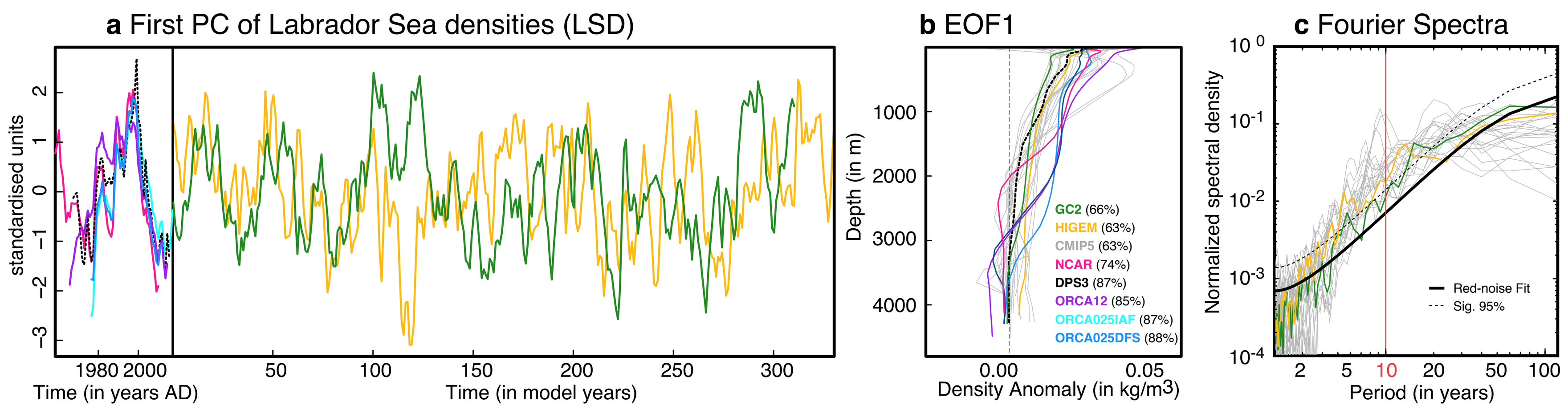


Fig. 2 **a** Evolution of the first Principal Component of the spatially-averaged LSD (PC1-LSD) in a selection of control and ocean-only forced simulations; **b** associated EOF (as a function of depth); **c** Fourier spectra of PC1-LSD in the control runs. Gray lines in b-c correspond to the control CMIP5 experiment.

3. LSD LINK WITH THE OCEAN CIRCULATION

PC1-LSD decadal trends are **strongly linked** to those of the **AMOC at 45°N** and the **Subpolar Gyre Strength** in all models, but their **connection** with the decadal trends of the **AMOC at 26°N** is **highly model dependent**, both in terms of magnitude and lag of maximum correlation (Fig. 3).

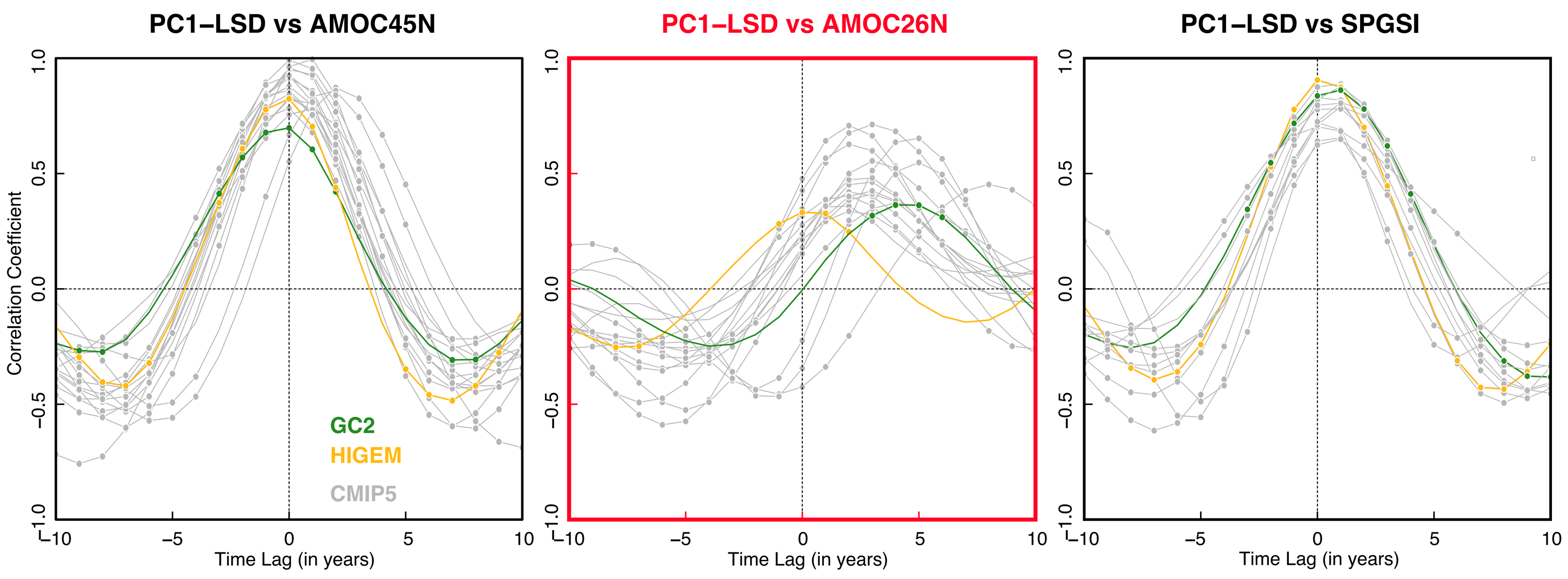
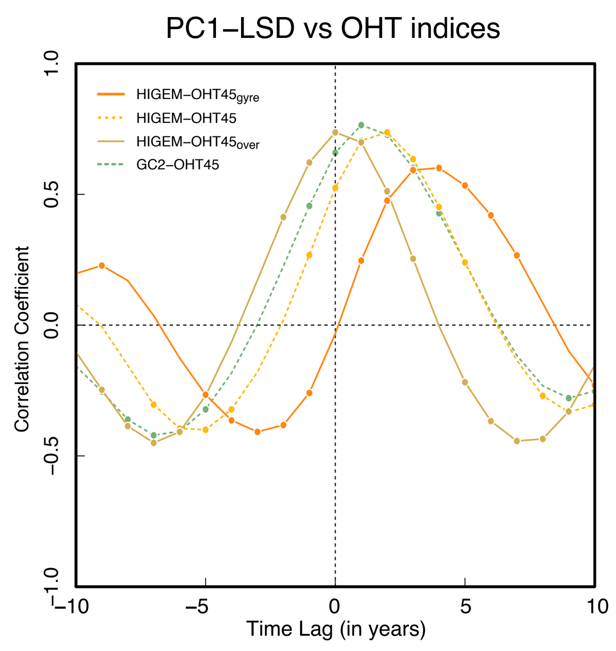


Fig. 3 Cross-correlation of the 10-yr running trends in PC1-LSD vs those in the maximum AMOC at 45°N (left), at 26°N (middle) and at a Subpolar Gyre Strength Index (rigth) in the whole ensemble of simulations. Dots indicate significant values at the 95% confidence level.



The meridional ocean heat transport (**OHT**) **at 45°N** also shows a **strong correlation** with **PC1-LSD** trends, but **with 1-2 years of delay**. In **HiGEM**, the separate OHT contributions are diagnosed online, showing an **instantaneous response to the overturning**, and a slow **delayed one to the gyre** (Fig. 4).

Fig. 4 Same as in Fig. 3 but wrt trends in Ocean Heat Transport indices at 45N, only for the simulations that they were available.

4. CAUSES OF MODEL SPREAD IN LINK WITH SUBTROPICS

The **diversity** in the simulated **links with the AMOC at 26°N** could be potentially explained **by differences** in the representation of the southgward propagation of **western boundary densities** (WBD, as illustrated in Fig. 5 for GC2 and HiGEM).

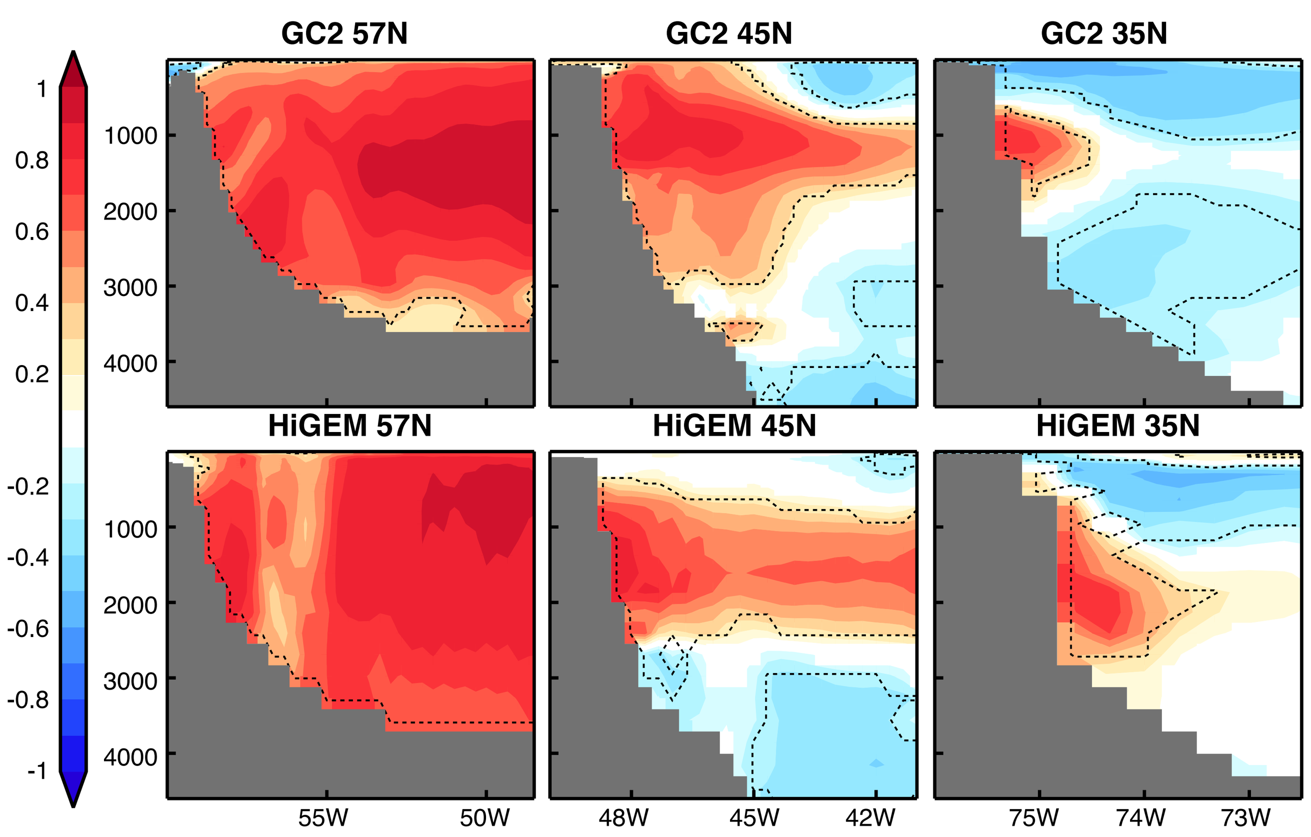


Fig. 5 Correlation between the 10-year running trends in PC1-LSD and the depth-lon density profile at 3 zonal sections along the western boundary: 57°N, 45°N and 35°N (from left to right). Results for GC2 (top) and HiGEM (bottom) control simulations are shown. Significant correlations at the 95% confidence level are enclosed by dashed contours.

The scatterplot in Fig. 6 confirms that the **strength** of the PC1-LSD **link with the AMOC-26N** is **sensitive to the depth of WBDs** propagating from Labrador Sea

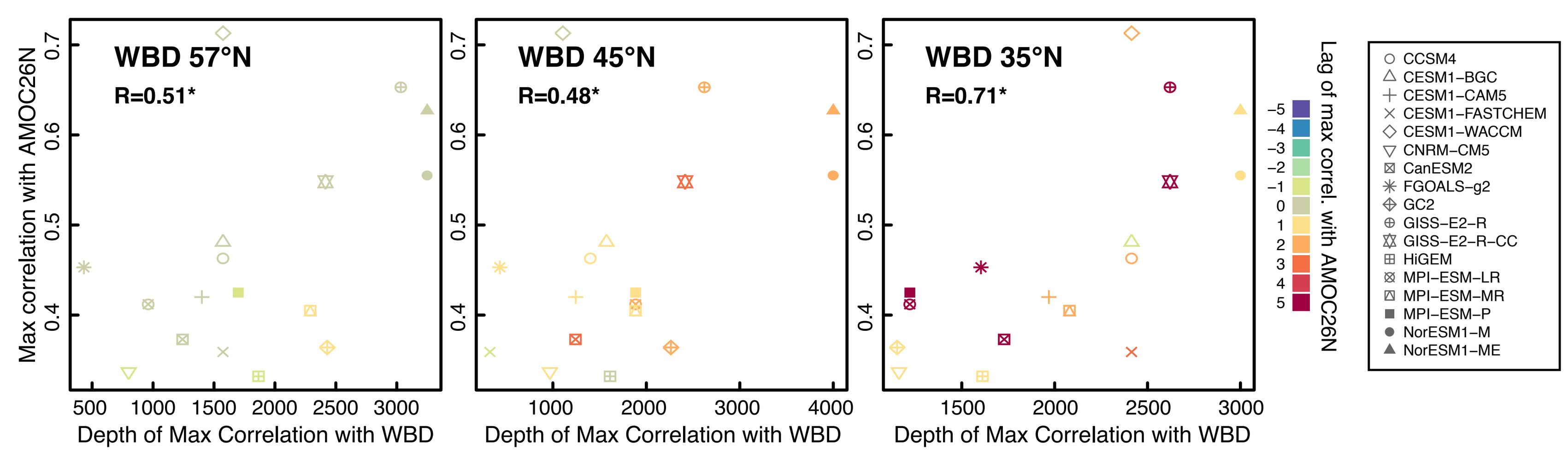
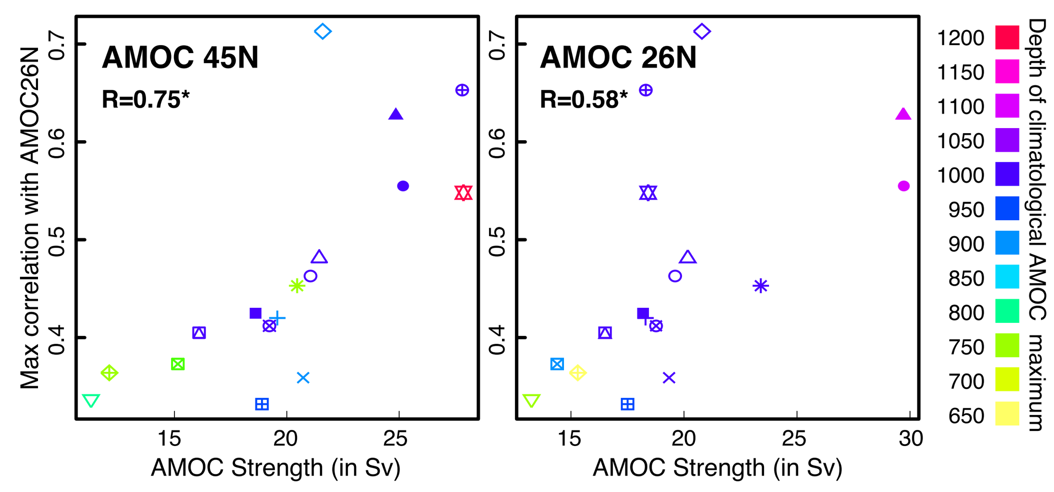


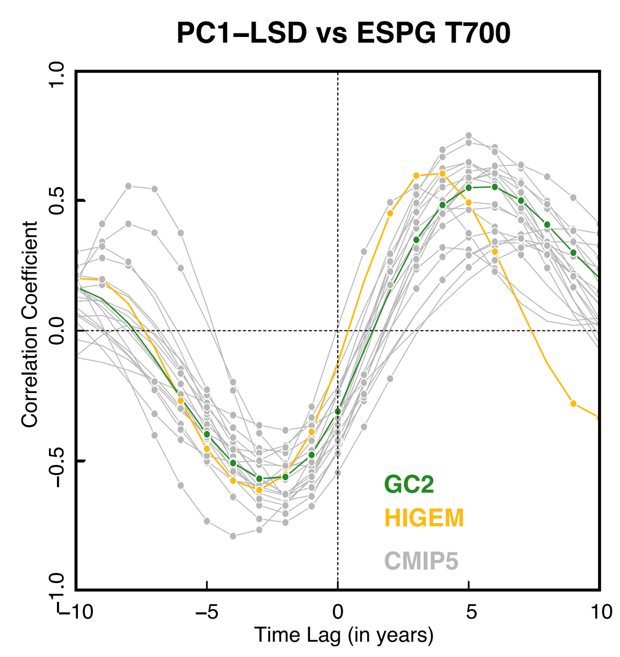
Fig. 6 Scatterplot of the maximum correlations between PC1-LSD and the AMOC at 26°N vs the depth at which the maximum correlations between PC1-LSD and the WBD at 57°N, 45°N and 35°N ocurr. Correlations between the two metrics are shown in the topleft corner.



This link with the subtropics is **stronger** in models with a **stronger and deeper climatological AMOC**.

Fig. 7 Similar to Fig. 6 but with respect to the climatological AMOC maximum (and depth of the maximum).

5. LAGGED CONNECTIONS WITH THE ESPG



All models support a link between the **decadal trends in PC1-LSD and** the equivalent trends in the top 700 m average ocean temperature in the Eastern Subpolar Gyre (**ESPG T700**) **delayed by 3 to 10 years** (Figure 8).

Fig. 8 Same as in Fig. 3 but between PC1-LSD and the ESPG T700.

CONCLUSIONS

- **Models consistently show a strong link between the Labrador Sea Densities and the AMOC at subpolar latitudes (45N), but show little coherence regarding their relationship with the subtropical AMOC.**
- **This model diversity relates to a different representation of the boundary densities as they propagate southwards from the Labrador Sea, as well as to the density stratification in Labrador Sea (not shown).**
- **Regardless of these differences, models show a coherent delayed LSD link with the ESPG temperatures, with encouraging prospects for predictive purposes**

REFERENCES

Ortega P, J Robson, R. Sutton & M. Andrews (2017) "Mechanisms of decadal variability in the Labrador Sea and the wider North Atlantic in a high-resolution climate model", *Clim Dyn* **49**, 2625–2647.

Robson J, Ortega P & Sutton R (2016) "A reversal of climatic trends in the North Atlantic since 2005", *Nat Geosci* **9**: 513–517.

NCAS Climate, Department of Meteorology, University of Reading, Reading, United Kingdom Mail: p.ortega@reading.ac.uk Website: http://www.met.reading.ac.uk/userpages/hb909987.php