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

P. Ortega, J. Robson, R. Sutton (NCAS-Climate, Reading)
A. Germe, A. Blaker, B. Sinha, J. Hirschi (NOC, Southampton)
L. Hermanson (Metoffice, Exeter)

US AMOC – Santa Fe 23-25 May 2017
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)

<table>
<thead>
<tr>
<th>Time (in years)</th>
<th>Standardised Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>2110</td>
<td>-3</td>
</tr>
<tr>
<td>2160</td>
<td>-2</td>
</tr>
<tr>
<td>2210</td>
<td>-1</td>
</tr>
<tr>
<td>2260</td>
<td>0</td>
</tr>
<tr>
<td>2310</td>
<td>1</td>
</tr>
<tr>
<td>2360</td>
<td>2</td>
</tr>
<tr>
<td>2410</td>
<td>3</td>
</tr>
</tbody>
</table>

R=0.6
Motivation

Ortega et al (2017)

Cross-correlations with PC1-LSD

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

Mean current speed at 1000 m

R=0.6
Motivation

Ortega et al (2017)

Cross-correlations with PC1-LSD

AMOC-\(\rho\)  
OHT

Mean current speed at 1000 m

In-phase correlations between density and AMOC-45N

Density section at 57N  
Density section at 45N  
Density section at 35N

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

*Ortega et al (2017)*

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

Ortega et al (2017)

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

Hodson et al (2012)

In HiGEM, Labrador Sea densities propagate along the boundary at deeper levels: 1500-3000m.
A cross-model analysis within DYNAMOC

<table>
<thead>
<tr>
<th>Preindustrial Coupled Control Experiments</th>
<th>Ocean-forced Historical Experiments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HadGEM3-GC2</strong></td>
<td><strong>ORCA025-IAF</strong></td>
</tr>
<tr>
<td>310 years</td>
<td>1958-2009 AD</td>
</tr>
<tr>
<td>1/4° ORCA Grid</td>
<td>1/4° ORCA Grid</td>
</tr>
<tr>
<td><strong>HiGEM</strong></td>
<td><strong>ORCA025-DFS</strong></td>
</tr>
<tr>
<td>340 years</td>
<td>1958-2015 AD</td>
</tr>
<tr>
<td>1/3° Regular Ocean Grid</td>
<td>1/12° ORCA Grid</td>
</tr>
</tbody>
</table>

Assimilation Run

**DEPRESYS3**

1960-2016 AD
1/4° ORCA Grid
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?**

### A cross-model analysis within DYNAMOC

<table>
<thead>
<tr>
<th>Preindustrial Coupled Control Experiments</th>
<th>Ocean-forced Historical Experiments</th>
<th>Assimilation Run</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HadGEM3-GC2</strong></td>
<td><strong>ORCA025-IAF</strong></td>
<td><strong>DEPRESYS3</strong></td>
</tr>
<tr>
<td>310 years</td>
<td>ORCA025-DFS</td>
<td>1960-2016 AD</td>
</tr>
<tr>
<td>1/4° ORCA Grid</td>
<td>1958-2009 AD</td>
<td>1/4° ORCA Grid</td>
</tr>
<tr>
<td><strong>HiGEM</strong></td>
<td>ORCA12-DFS</td>
<td>1958-2015 AD</td>
</tr>
<tr>
<td>340 years</td>
<td>1/3° Regular Ocean Grid</td>
<td>1/12° ORCA Grid</td>
</tr>
</tbody>
</table>

1958-2009 AD
1958-2015 AD
1960-2016 AD
All the simulations but the DPS3 assimilation show an **overshooting** of the Gulstream separation (less marked in GC2 and ORCA12)
All the simulations but the DPS3 assimilation show an **overshooting** of the Gulstream separation (less marked in GC2 and ORCA12).
The mixed layer depth is generally too strong in the Labrador Sea.
The first mode of LSD is encouragingly consistent across the simulations.
There is **less consistency** regarding the associated **changes in the AMOC**
Leading mode of Labrador Sea densities (LSD)

First PC of Labrador Sea densities

Erf6

EOF1

Maximum AMOC at 26°N

There is less consistency regarding the associated changes in the AMOC
Leading mode of Labrador Sea densities (LSD)

First PC of Labrador Sea densities

Max 15-yr Trends PC1-LSD vs AMOC45N

Max 15-yr Trends PC1-LSD vs AMOC26N

There is a strong link with the AMOC45N (and weaker with AMOC26N)
AMOC link with density changes across the WBC

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
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.
HiGEM shows a link of deeper LSD anomalies with the AMOC
HiGEM shows a link of deeper LSD anomalies with the AMOC.
PC1-LSD changes are tightly linked to changes in the AMOC at 45°N
By contrast, they show no consistent link with the AMOC at 26ºN
We can compare decadal trends in PC1-LSD and the AMOC Indices
CMIP5 model biases can affect the controls of LSD density, and potentially its variability and impacts.
The location of the maximum, its intensity, and the depth of the AMOC cell can largely vary from one model to another.