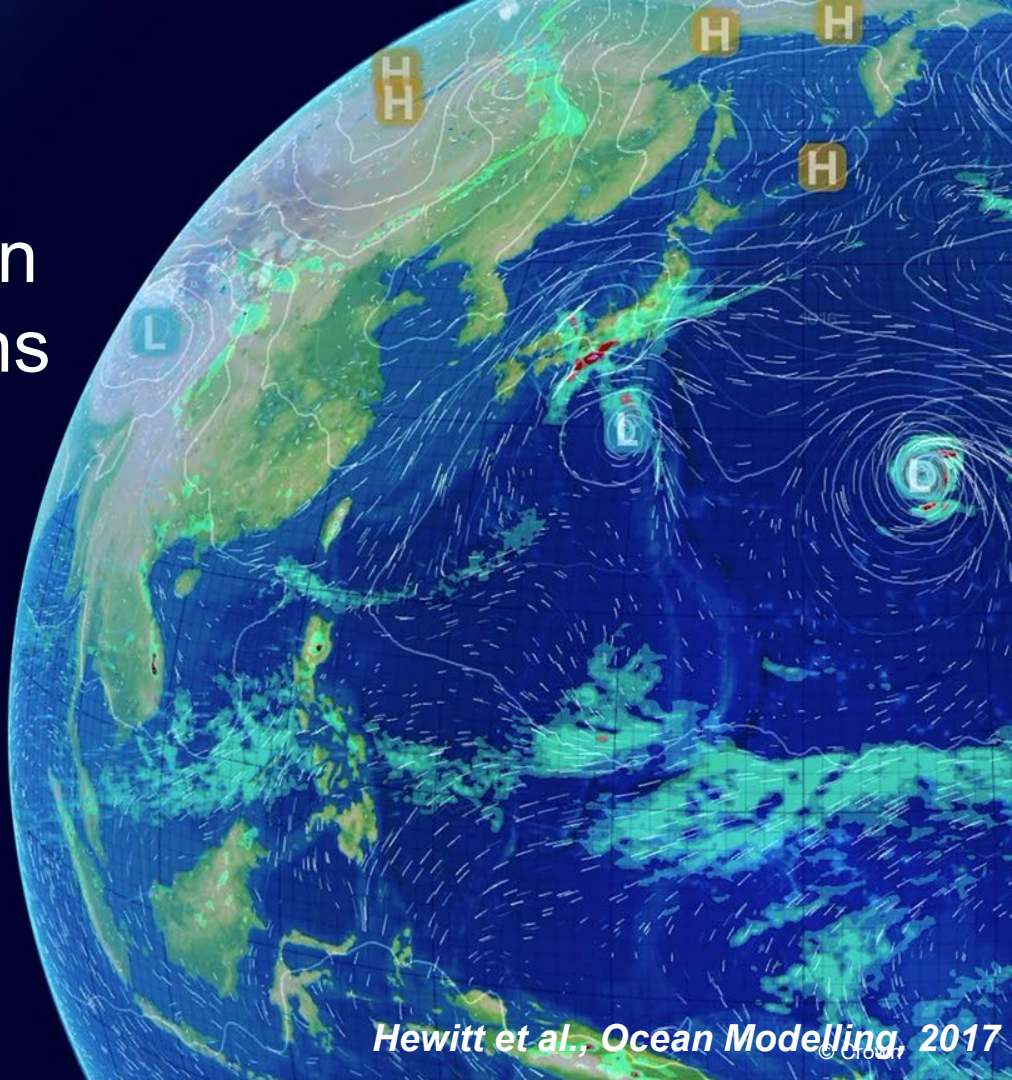
Potential benefits of high resolution ocean models in decadal climate predictions

Helene Hewitt

Malcolm Roberts, Laura Jackson, Pierre Mathiot and many others



Hewitt et al., Ocean Modelling, 2017

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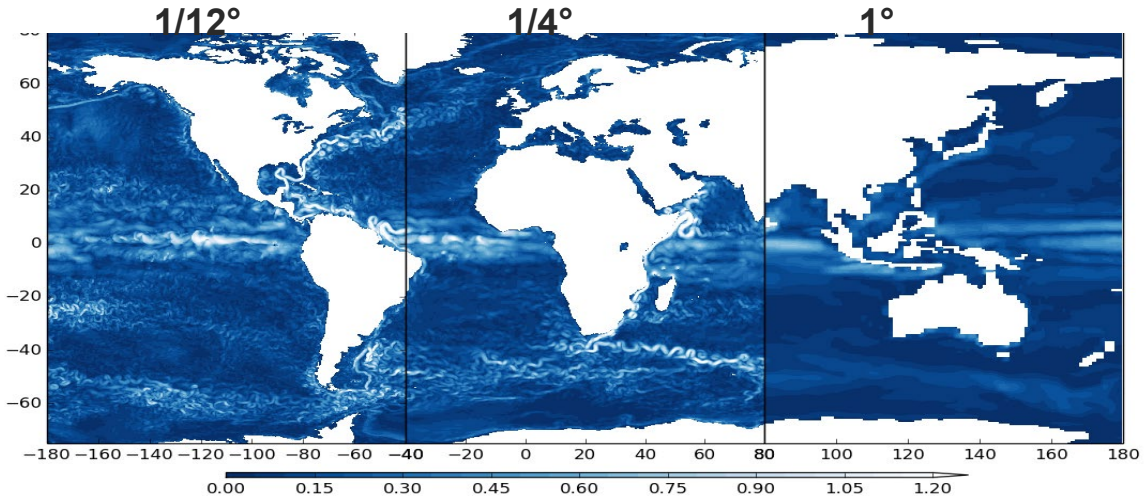
Outline

1. Introduction
2. Sensitivity to resolution in traceable model hierarchies
3. Summary and outlook

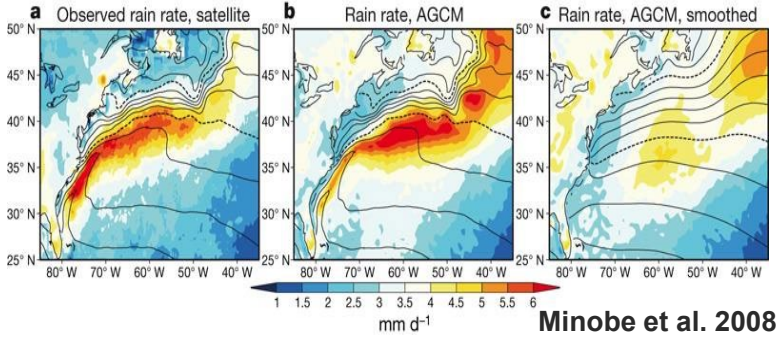


LEGO
ORCA12 model + ORCA025 bathymetry

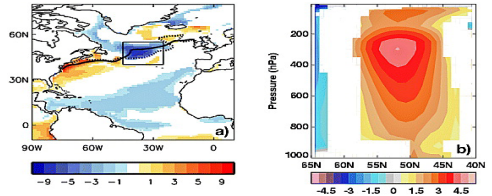
Eddy resolving (or eddy rich)	Eddy permitting (or eddy present)	Eddy parameterising
Eg, ORCA12	Eg, ORCA025	Eg, ORCA1
No GM, low isopycnal mixing	How to parameterise?	GM and isopycnal mixing

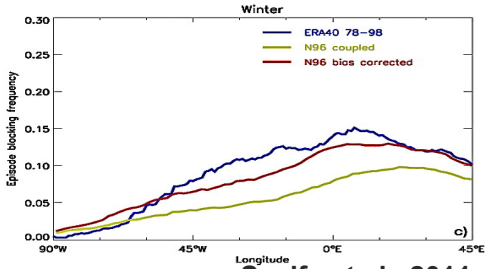
Introduction

- What are the key aspects of simulations that might be important on multiannual timescales?
- Gulf Stream position
- Northwest corner
- Eddies
- North Atlantic Deep Water

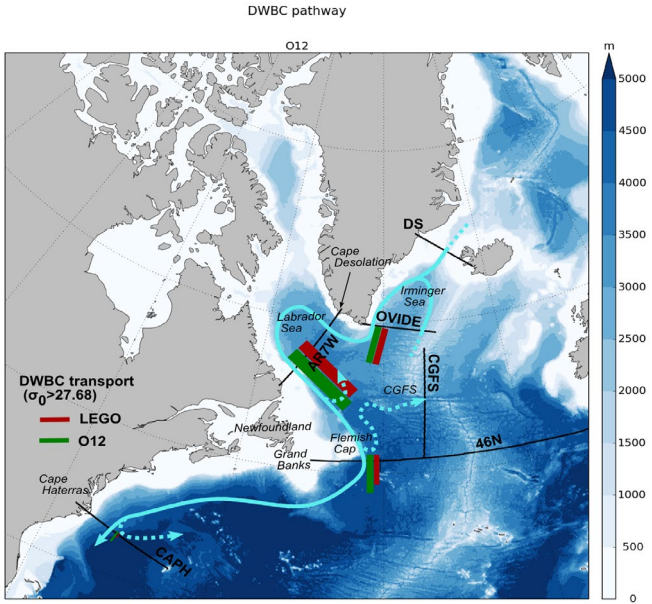


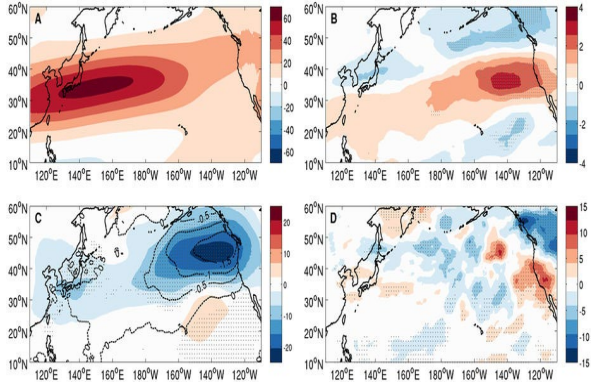
Minobe et al. 2008





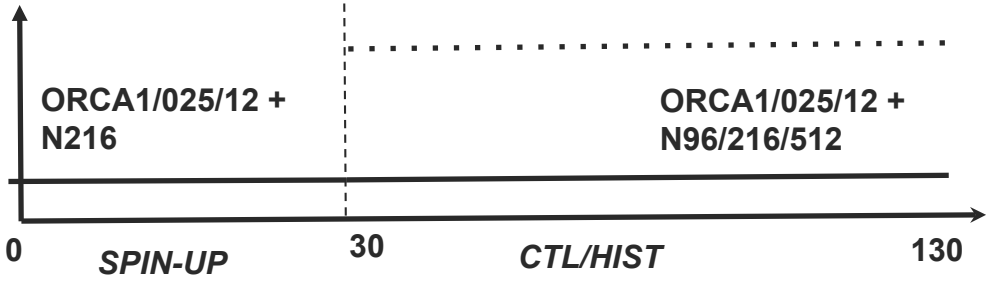
Scaife et al., 2011





Ma et al., 2015

Resolution hierarchy



- Resolution hierarchy of GC3.
- Ocean components is GO6 – NEMO at ORCA1 (L), ORCA025 (M) and ORCA12 (H).
- Atmosphere resolutions – 150km (N96; L), 60km (N216; M), 25km (N512; H).
- Control and Historical

	150km N96 L	60km N216 M	25km N512 H
ORCA1 1 deg L	*X*	*X*	
ORCA025 1/4 deg M	X	*X*	*X*
ORCA12 1/12 deg H		*X*	*X*

GC3: Williams et al., JAMES
GO6: Storkey et al., GMD
HighRes-MIP: Haarsma et al., GMD, 2016; Roberts et al., GMDD
EU-PRIMAVERA, NERC ACSIS

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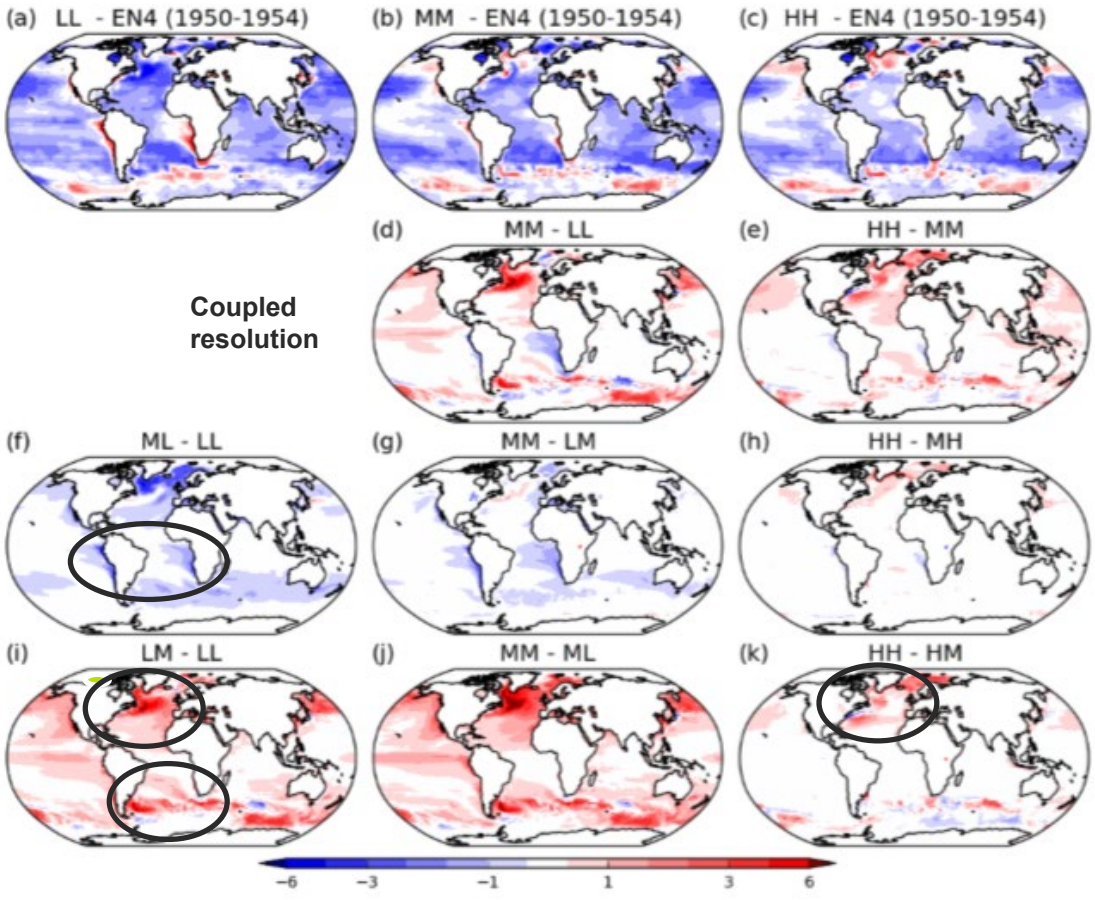
Impact of resolution on SST biases in GC3

- Large changes in SST in North Atlantic and Southern Ocean linked to ocean resolution
- Reduction in warm biases in stratocumulus regions related to atmospheric resolution



Coupled resolution

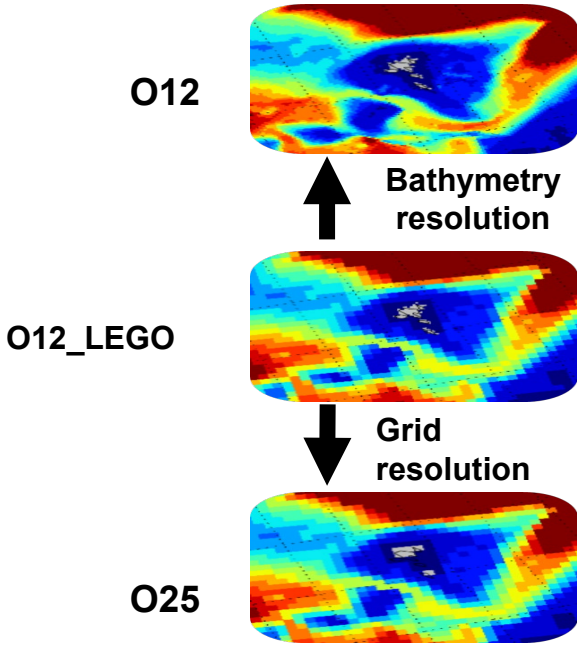
Atmosphere resolution

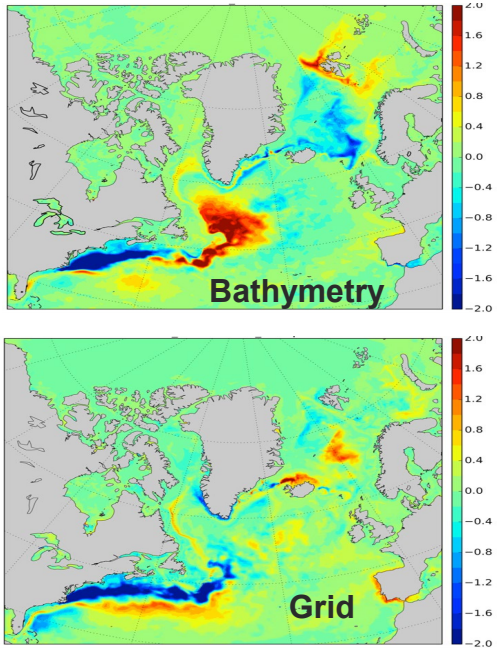
Ocean resolution

Roberts et al., GMDD

Is resolution of grid or bathymetry most important?

- Gulf Stream pathways highly sensitive to the bathymetry
- Experiment to separate grid resolution from bathymetry resolution
- Gulf Stream position ~ grid
- North West corner ~ bathymetry

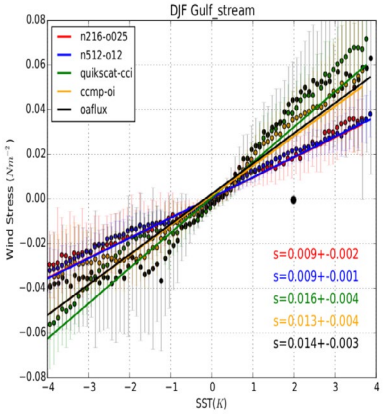


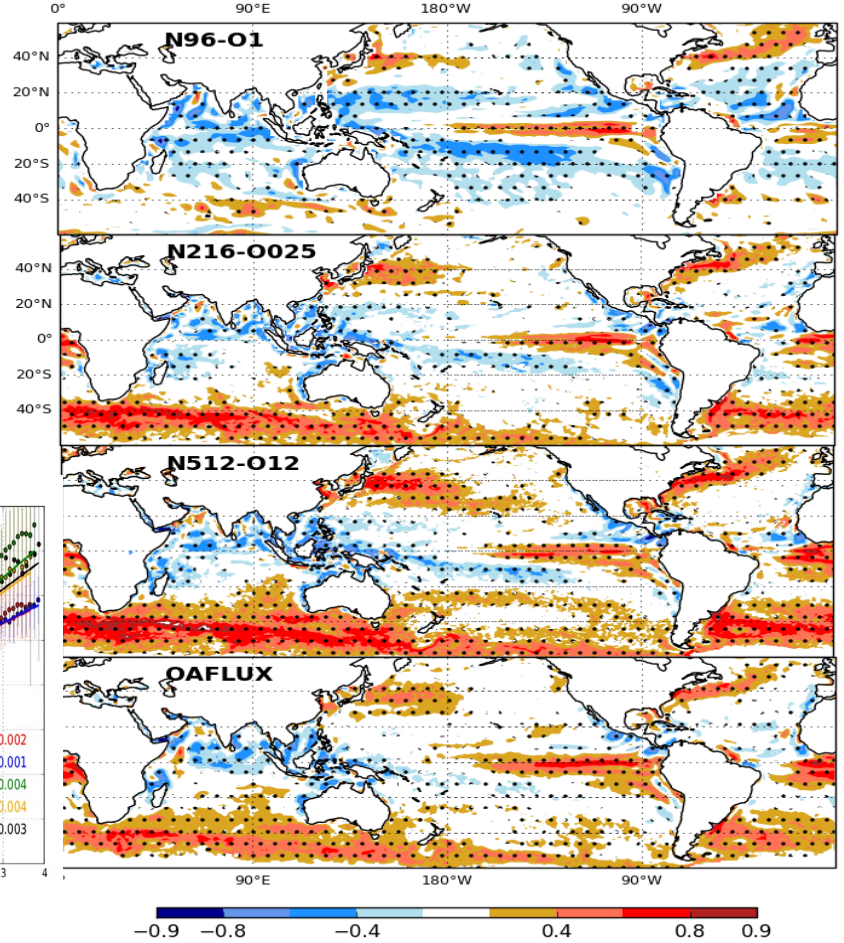


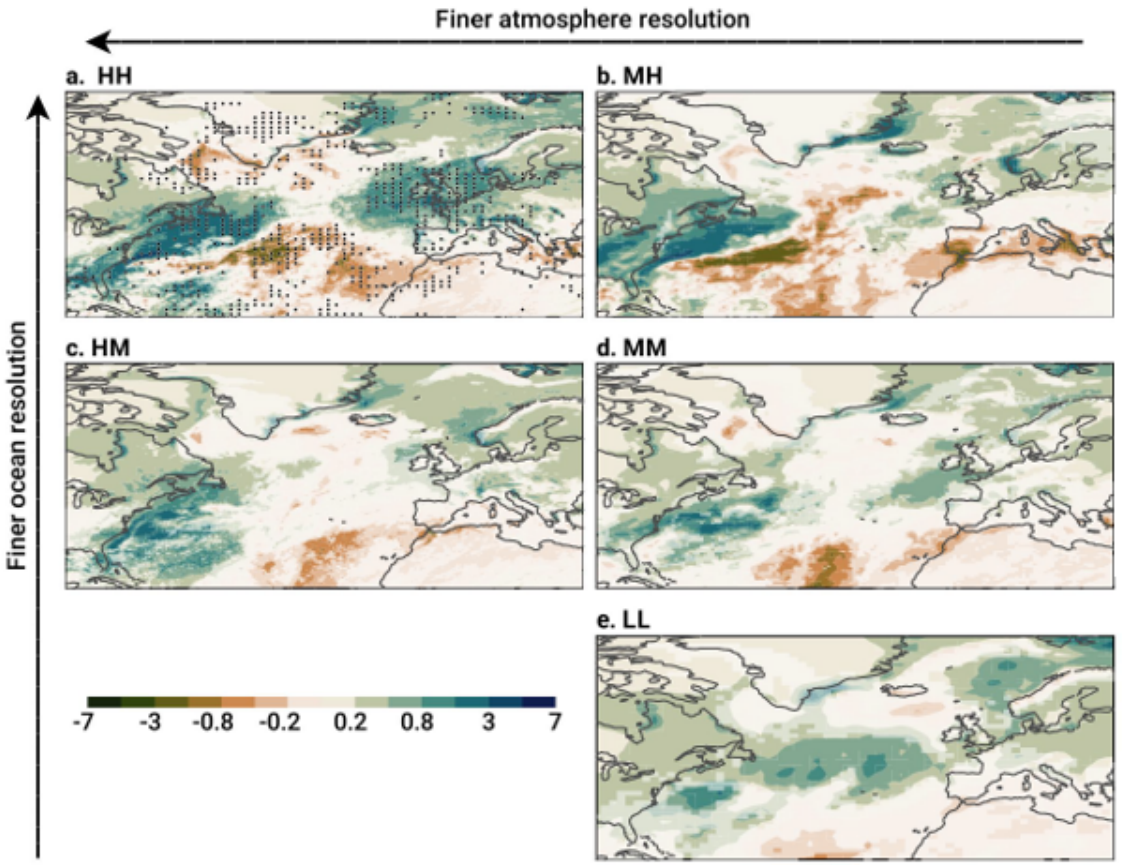
Mathiot et al., in prep.

SST-windstress relationship

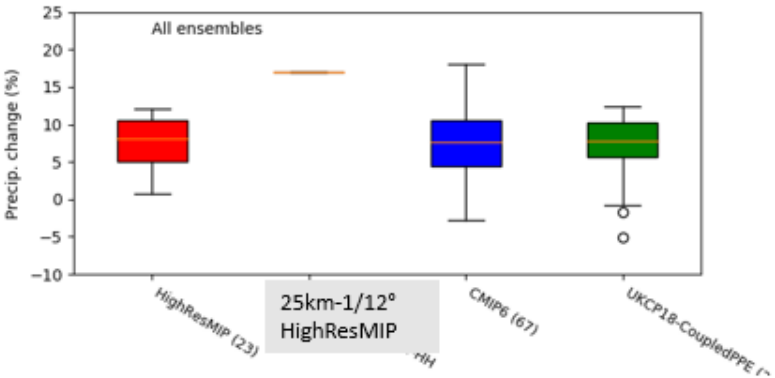
- Positive correlations indicate where ocean leads atmosphere
- Ocean becomes more important as resolution increases
- Once eddies and fronts present, not strongly sensitive to resolution
- Deficiency in physics of atmospheric boundary layer parameterisations? (Song et al., 2009)

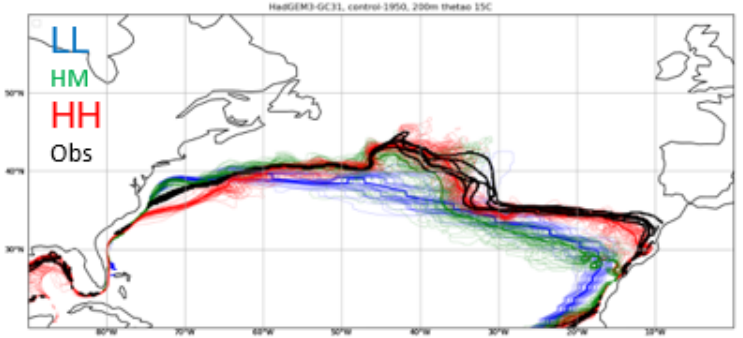






Rainfall %age change, DJF, 2030-50 - 1960-80 over Europe 20W-30E, 40-65N from different multi-model ensembles





Anomalies in winter precipitation between 2030–2050 and 1960–1980
Stippling in (a) indicates anomalies in HH falling outside a distribution including anomalies from all the other resolutions

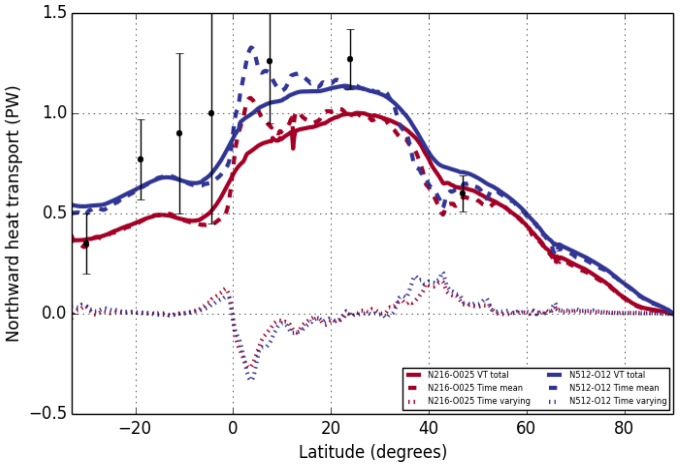
Result needs **both** atmosphere and ocean resolution

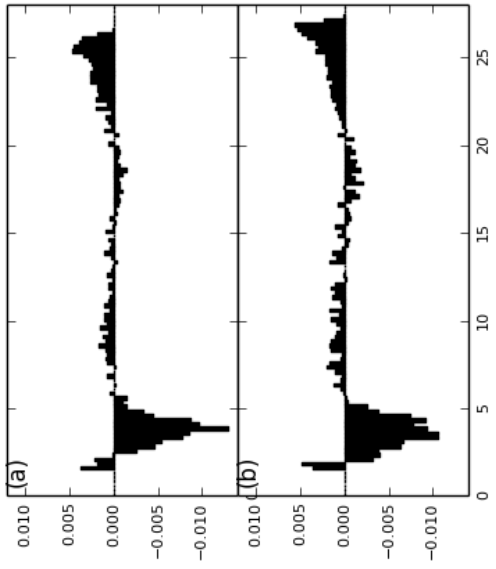
Moreno-Chamarro et al., ERL, accepted;
Grist et al., GRL, 2021.

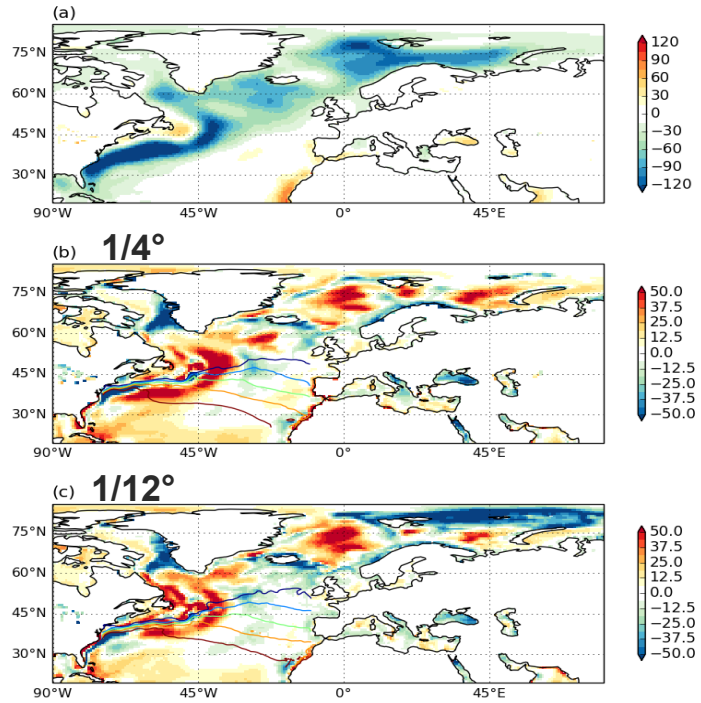
PRIMAVERA

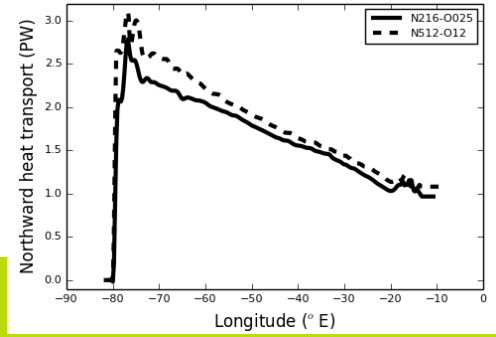
Impact on mean state

- Improved northward heat transports
- Linked to stronger Gulf Stream
- Impact on SST field reduces surface heat flux error



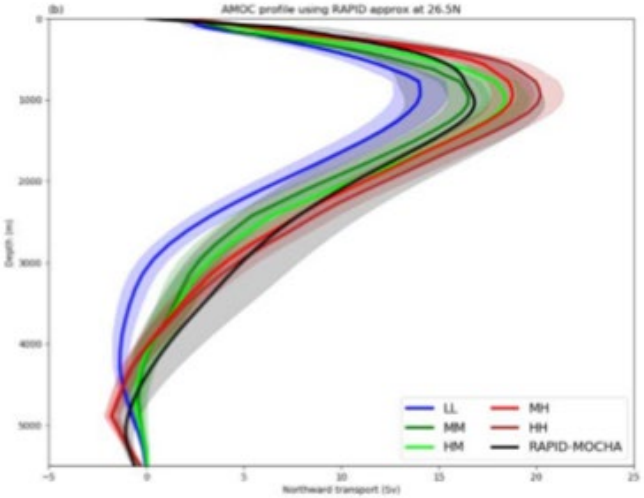


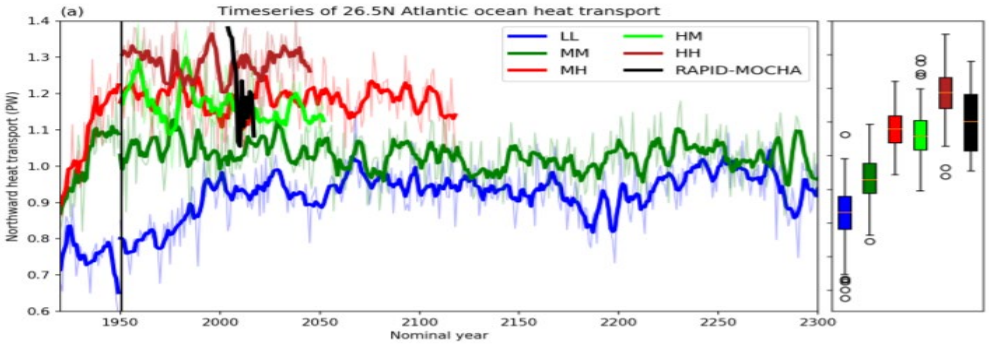


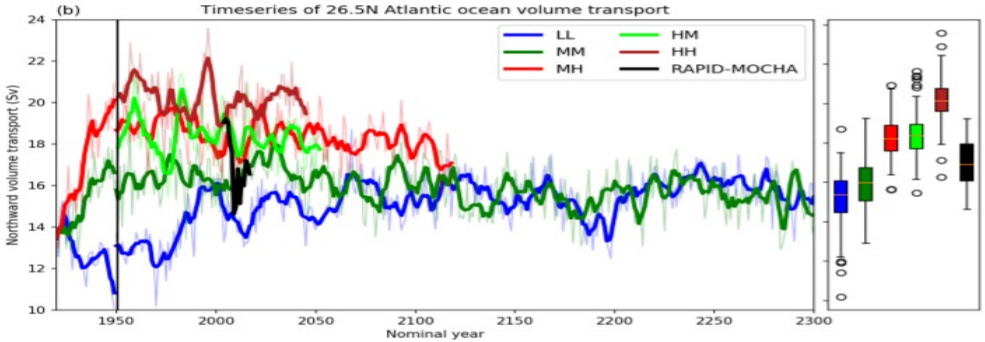


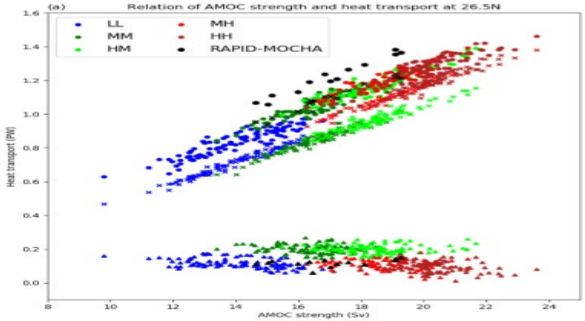
Roberts et al., 2016

AMOC in GC3 hierarchy





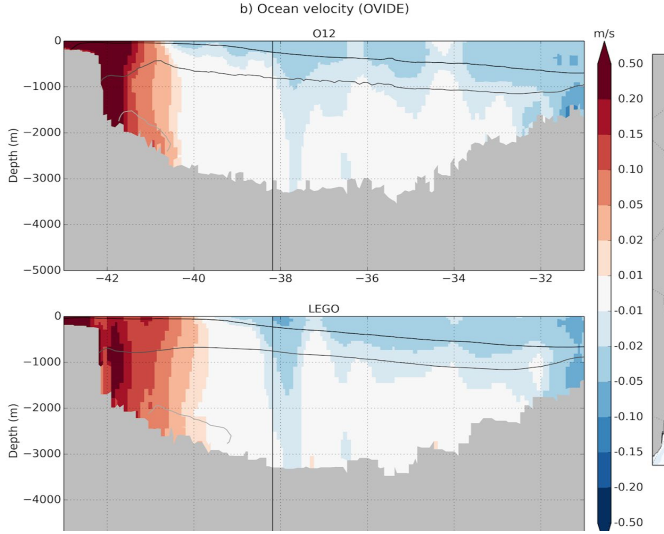


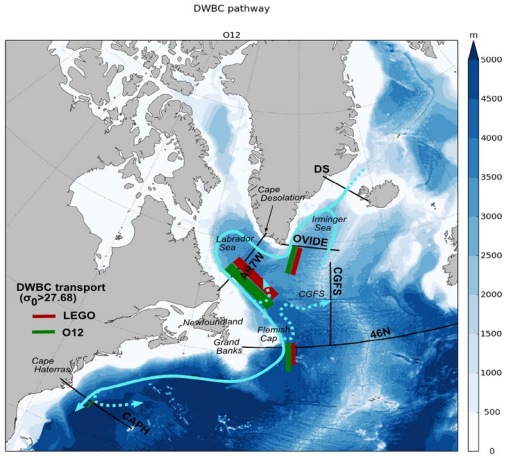


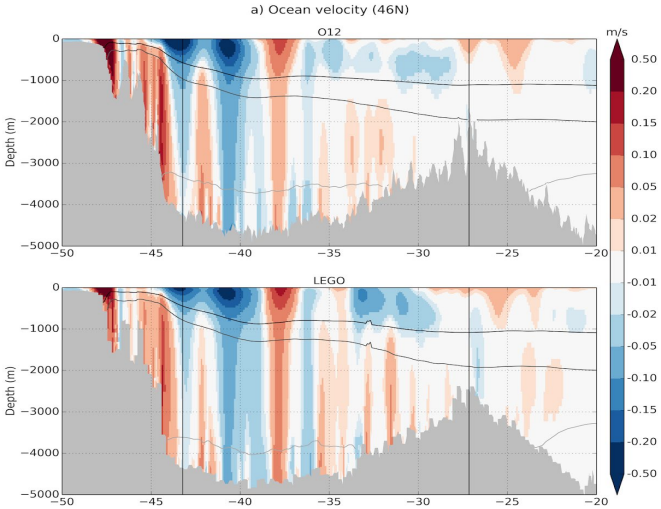
Roberts et al., 2016
Roberts et al., GMDD

Bathymetry and DWBC

- Resolution of bathymetry important for the strength of the deep western boundary current
- Seen both at OVIDE and 46N
- Not shown here but does this interact with NW corner?

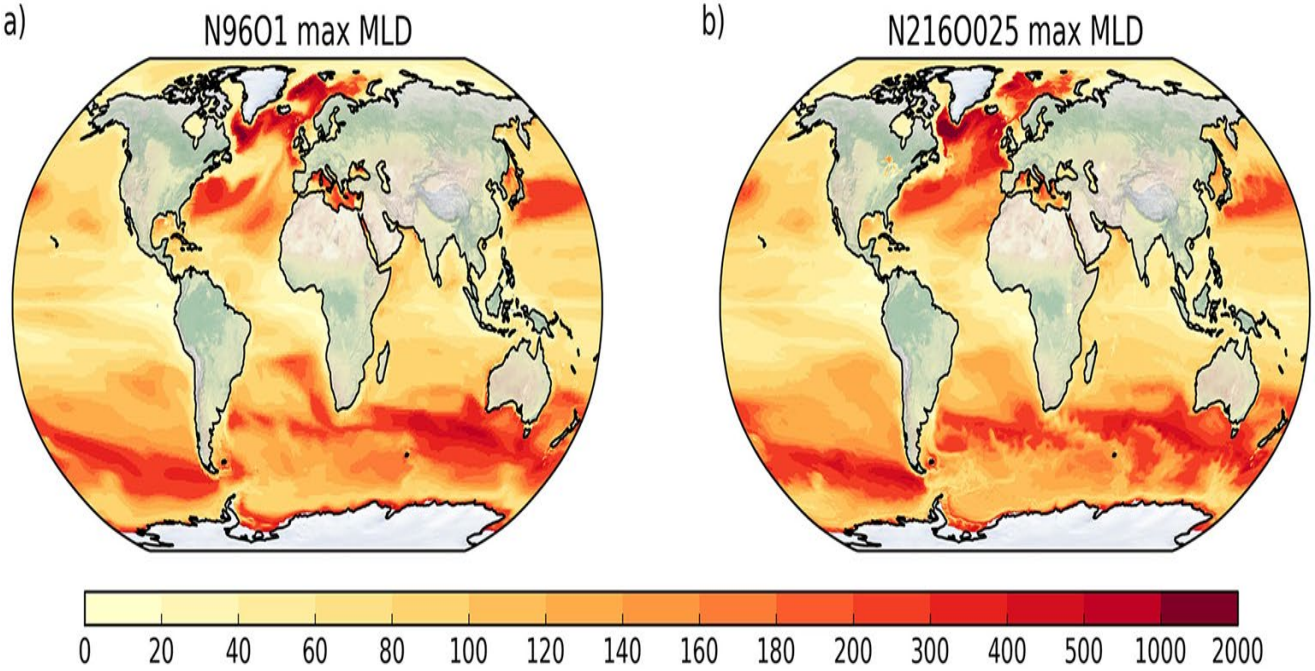






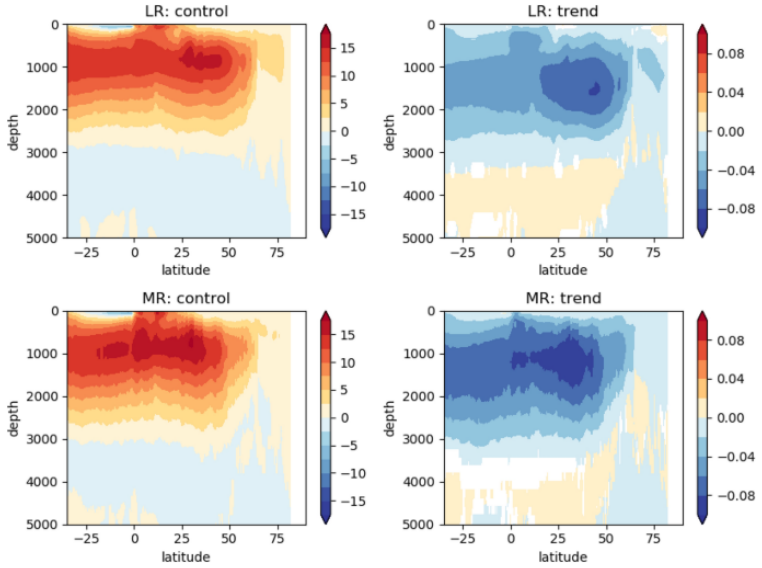
Mixed layer depths

- Convection in North Atlantic very different in ORCA1 and ORCA025
- ORCA12 similar to ORCA025
- Investigating causes of strong convections (including improving representation of overflows)

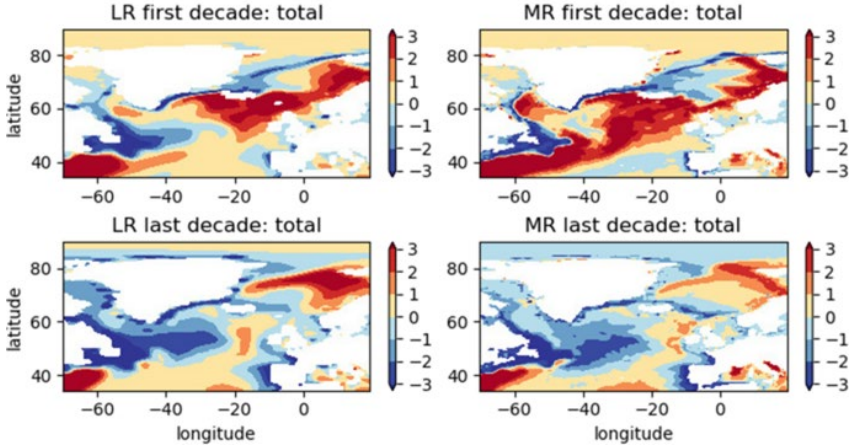


Kuhlbrodt et al, 2018

Sensitivity of AMOC response to resolution



Jackson et al., 2020



- Response of AMOC is very different between ORCA1 and ORCA025
- Related to dominance of deep water formation in western subpolar gyre
- ORCA12 similar to ORCA025 in this respect

Summary and outlook

- Both grid resolution and bathymetry resolution are critical
- Sensitivity to bathymetry resolution suggests other routes to improvements - numerics, roughness, terrain following coordinates, etc
- The sensitivity of western subpolar gyre to resolution and links to convection and climate change response requires further investigation – is NEMO particularly sensitive?
- Given push for ensembles is 1/12 degree ocean component practical? If not, how to proceed? Scale-aware parameterisations? Nesting?