The never-ending quest for resolution in marine biogeochemical modelling

K. Popova, A.G. Nurser, S. van Gennip, A. Yool, A. Coward

Once upon a time…

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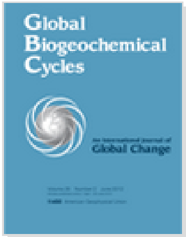

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Pages 417–450

A seasonal three-dimensional ecosystem model of nitrogen cycling in the North Atlantic Euphotic Zone

J. L. Sarmiento,R. D. Slater,M. J. R. Fasham,H. W. Ducklow,J. R. Toggweiler,G. T. Evans

First published: June 1993 Full publication history

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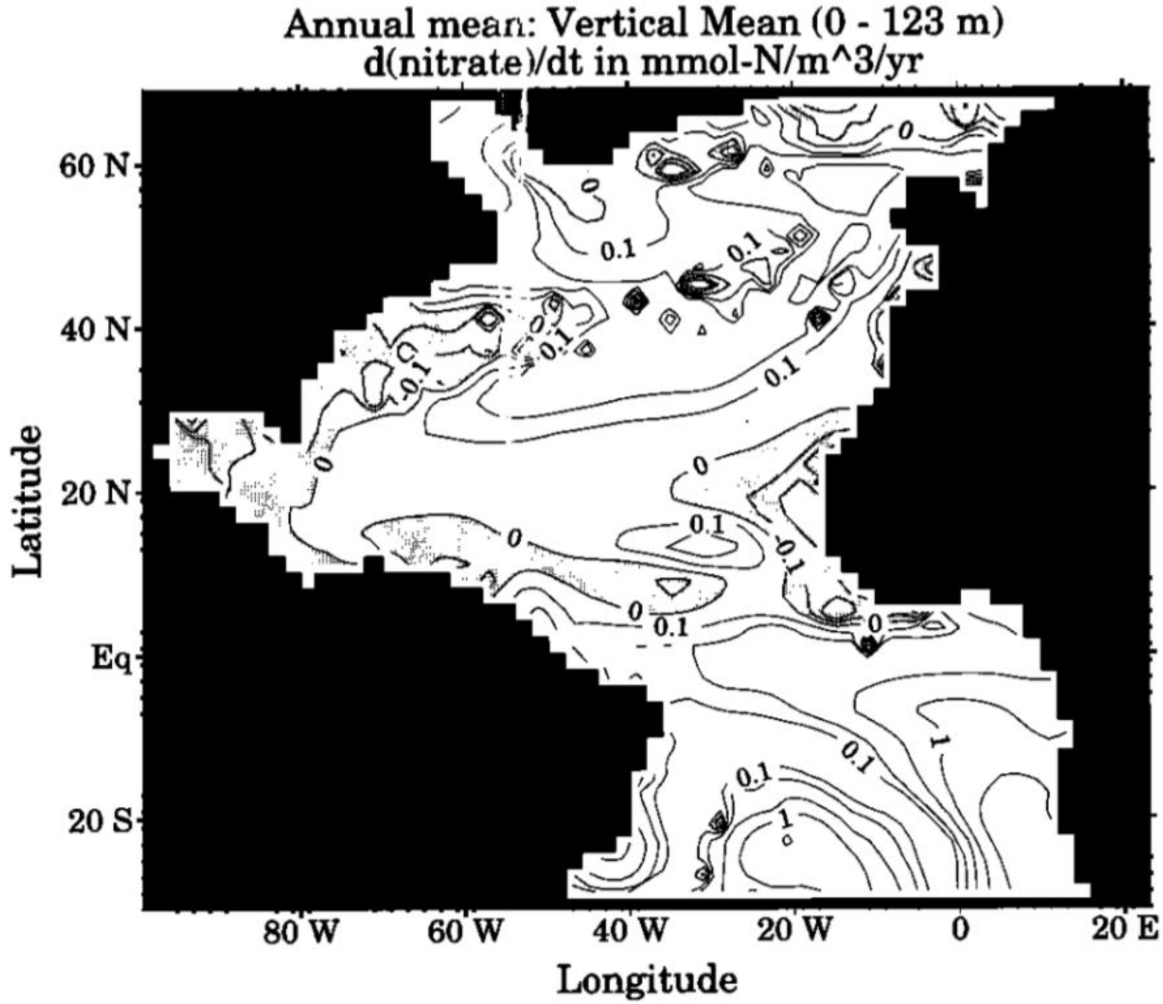
Cited by: 180 articles Refresh Citing literature

Am score 3

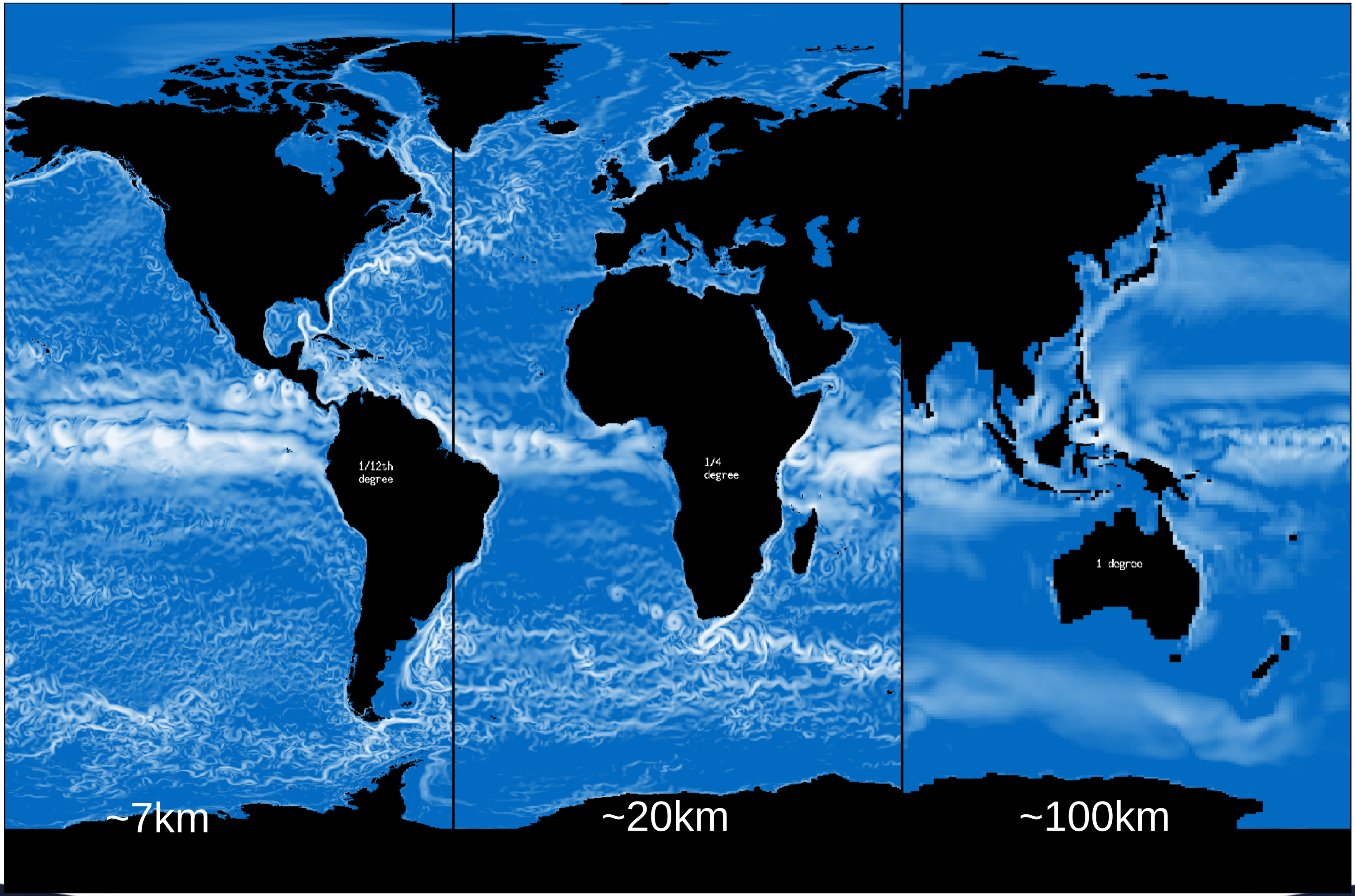
Referenced in **1** Wikipedia pages

Resolution: 2º and 25 vertical levels



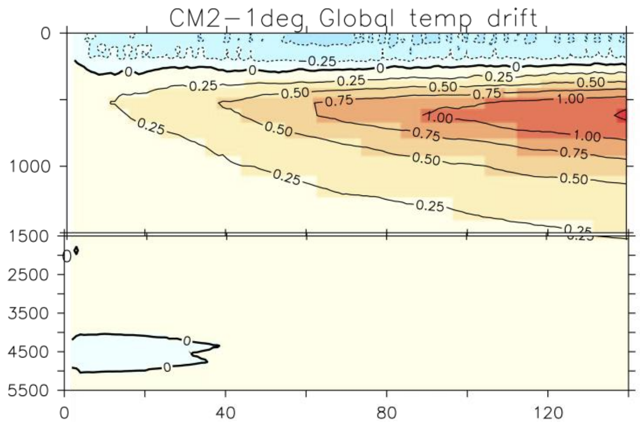
Sarmiento et al., 1993

What do we expect from increase in resolution?



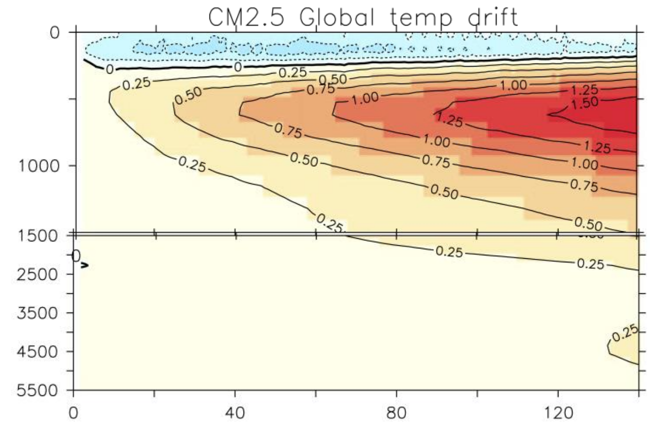
Globally-averaged 140-yr temperature drift in coupled models

CM2-1deg 1° ocean



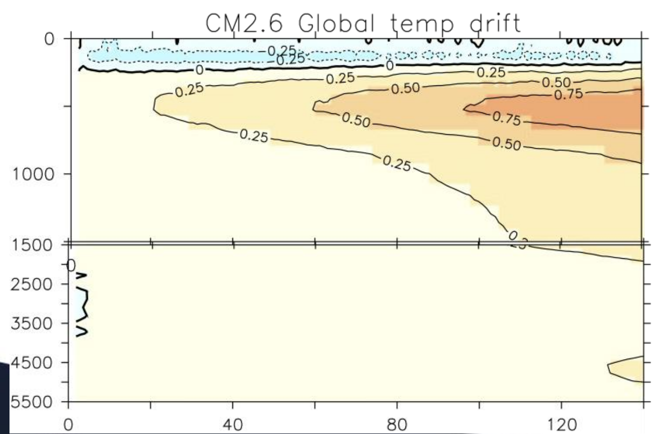
Upward heat flux by GM

CM2.5 0.25° ocean



No GM. Weak upward heat flux by weak eddies

CM2.6 0.1° ocean



No GM. Strong upward heat flux by vigorous eddies

Griffies et al., 2005, J. Clim.

Top Five

BGC-critical resolution-dependent issues

1. Subtropical gyres
   – where low resolution models traditionally underestimate nutrient availability and, thus, primary production;
2. Boundary currents
   – whose pathways and magnitudes play important roles in defining species compositions;
3. Upwelling regimes
   – pivotal in nutrient supply, deoxygenation and acidification, and associated with our most productive fisheries;
4. Upper ocean mixing
   – which controls carbon exchange between the deep ocean and the atmosphere, as well as structuring nutrient regimes throughout the world ocean;
5. Antarctic bottom water formation
   – critical for the long-term storage of anthropogenic carbon and the present-day distribution of key nutrients.

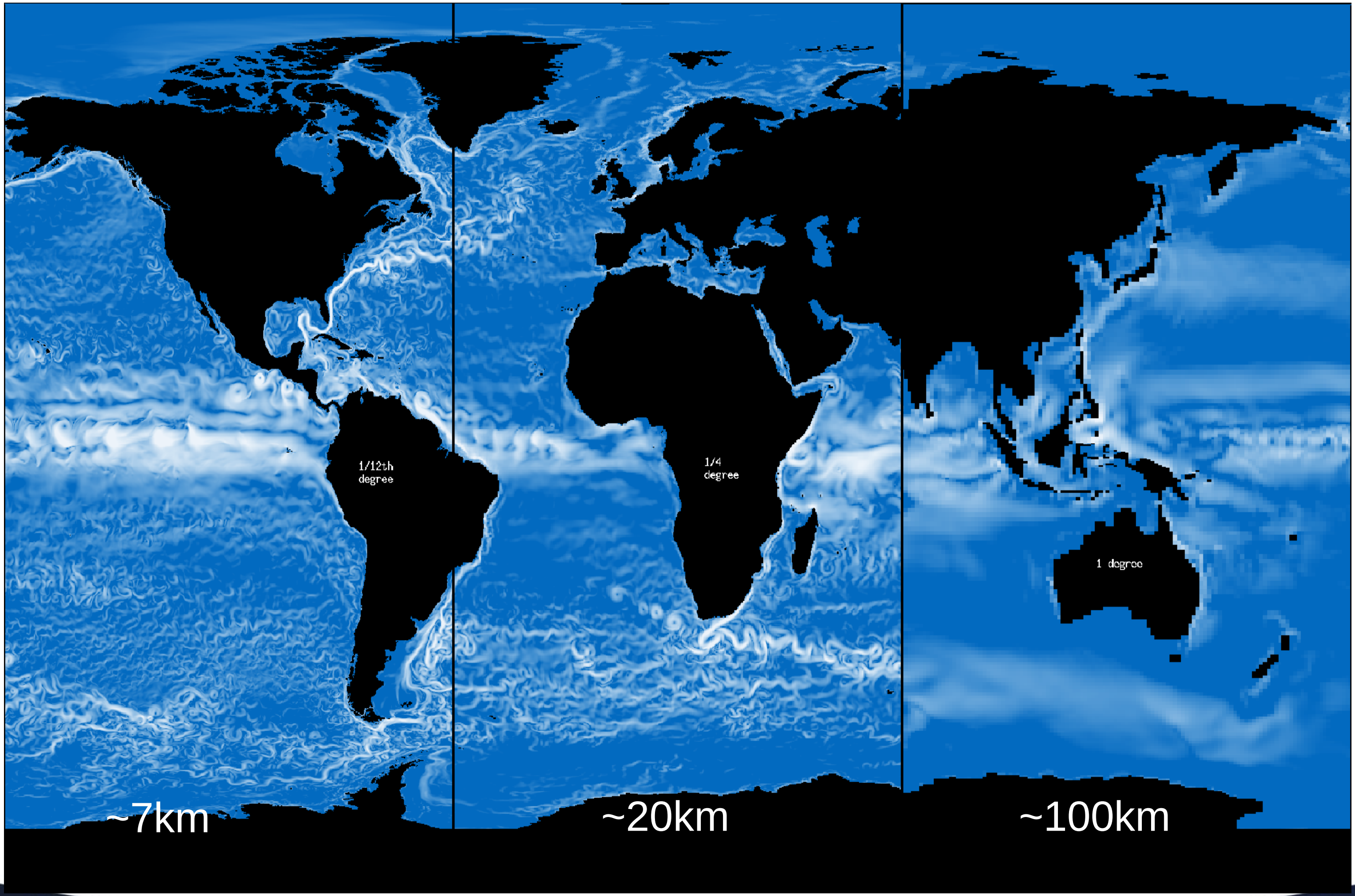
Resolution traceability and why do we care

- Computational cost dictates the use of low resolution ESM for the majority of the ensemble runs
- High resolution ensemble is desired but only a small number of high resolution runs can be afforded
- If we can "trace" the lower resolution model performance to the high one, we can extend high-res conclusions onto the low-res ensemble (or so is the idea…)

In other words (traceability hypothesis):

Increased resolution will add variability (spatial and temporal) but will not change the main state

What do we expect from increase in resolution?



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Ocean Modelling

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Large-scale impacts of submesoscale dynamics on phytoplankton: Local and remote effects

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ABSTRACT

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JOURNAL OF MARINE SYSTEMS

Impact of increased grid resolution on global marine biogeochemistry

CrossMark

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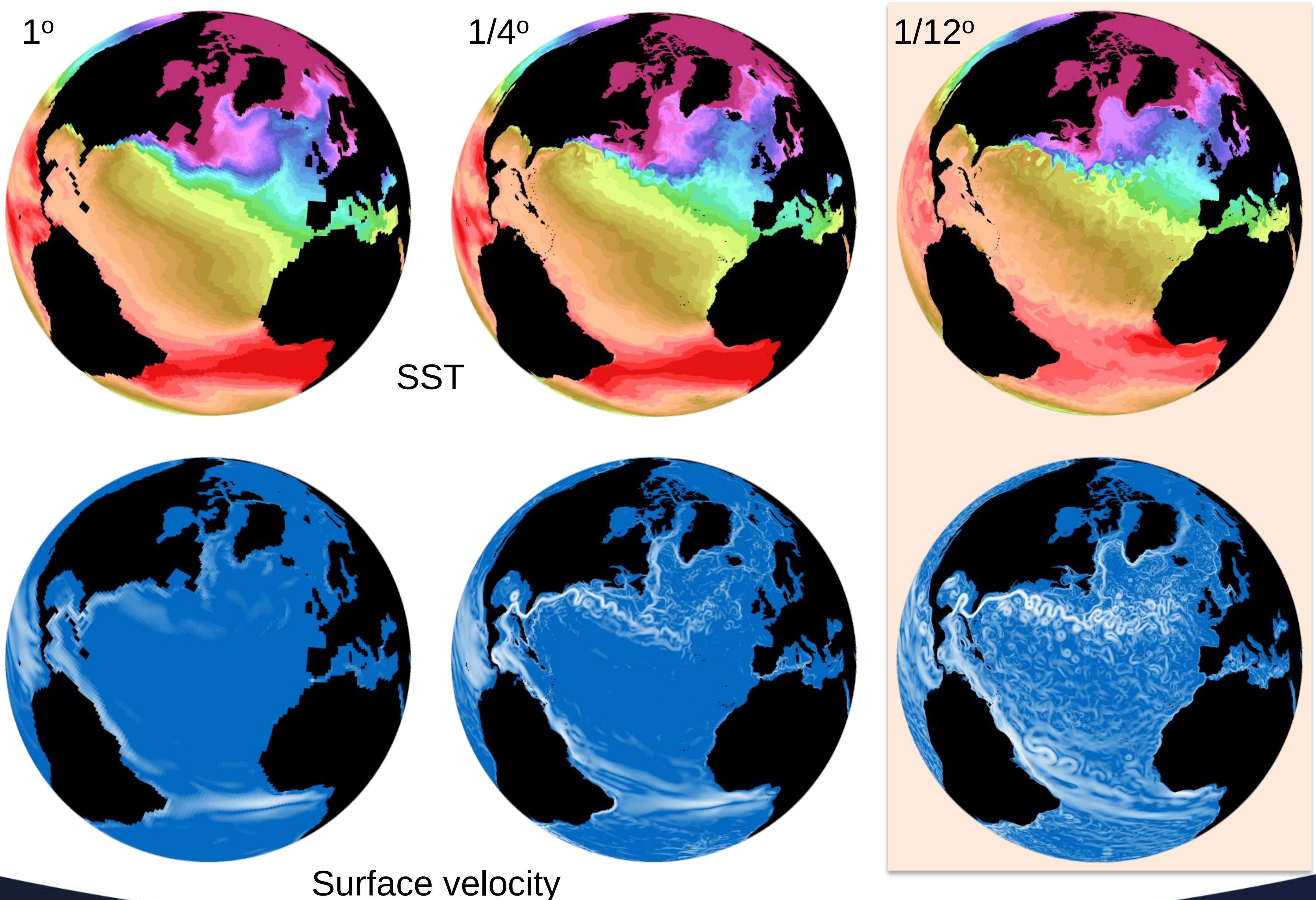
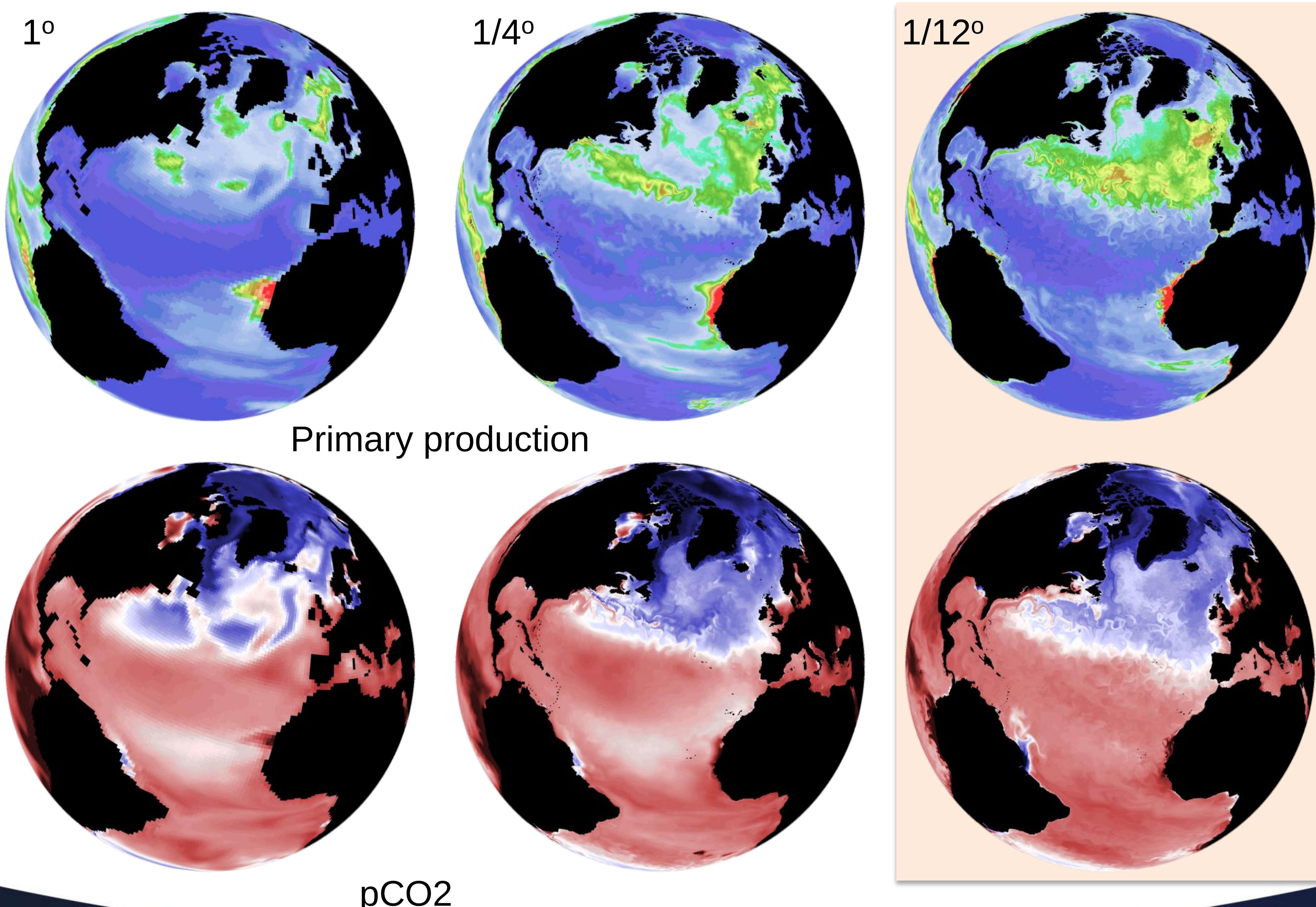
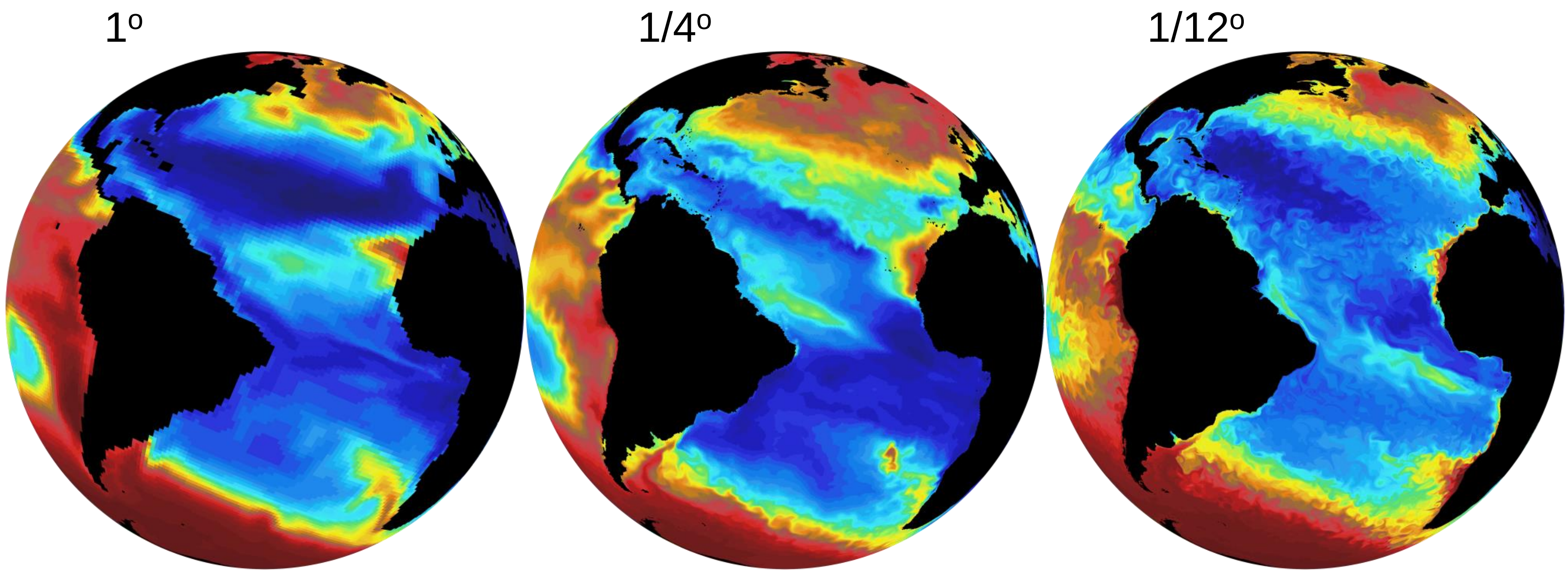
A B S T R A C T

Here we examine the impact of mesoscale processes on the global marine biogeochemical system by performing simulations at two different resolutions, 2° (LO-res) and 1/4° resolution (HI-res) using the PELAGOS model. Both the LO-res and HI-res simulations are set up with the same forcings and biogeochemical parameterizations, while the initial conditions are provided by a spinup of the LO-res simulation. This allows us to perform a direct inter-comparison of the two cases with a view to understanding how the introduction of mesoscale features affects the biogeochemical system, specifically how differences in the resolved horizontal and vertical motions are reflected in the plankton biomass and the nutrient availability. While the global large-scale oceanographic features (fronts,


1°
1/4°
1/12°
SST
Surface velocity


1°
1/4°
1/12°
Primary production
pCO2

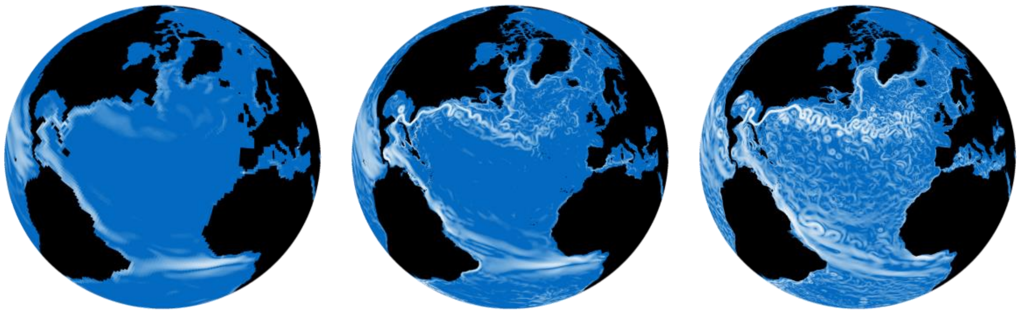
Dissolved inorganic nutrients



[Log scale]

Lagrangian experiment

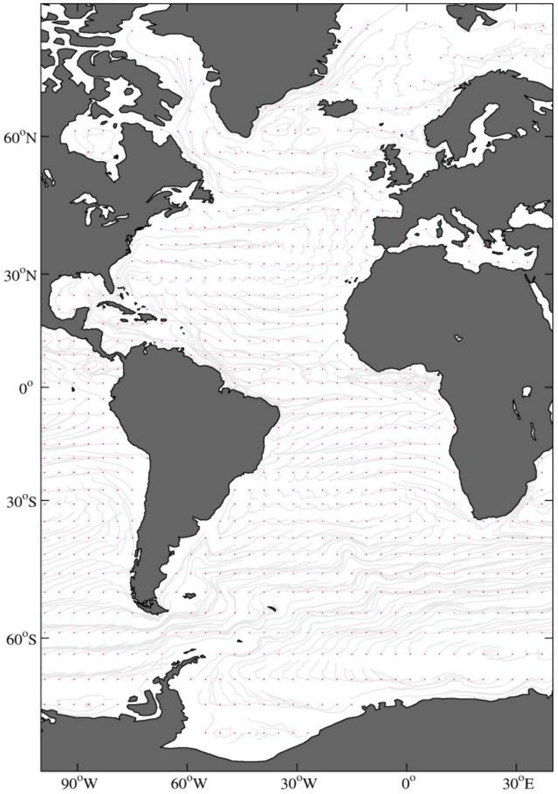
- Resolution “cascade” in NEMO-MEDUSA 1/12, ¼ and 1 degree
- 20 year runs
- Pre-cursor to the OMIP, CMIP runs



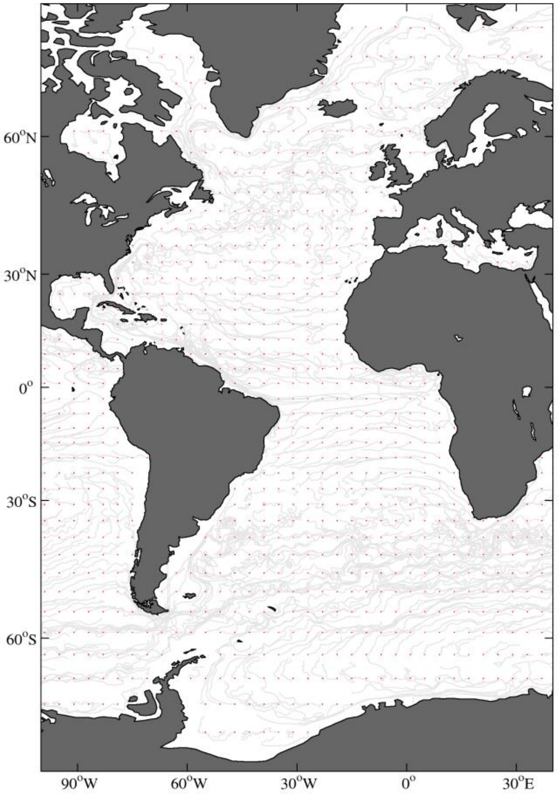
- Lagrangian particles released in every grid point at 1^o spacing
- 6 months duration (starting 1st Jan)
- ARIANE using 5 day velocity output

Lagrangian experiment

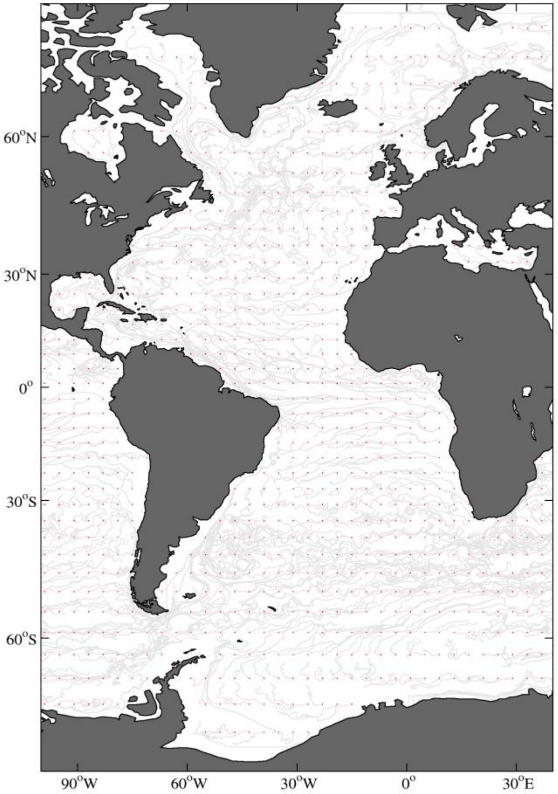
1°



1/4°



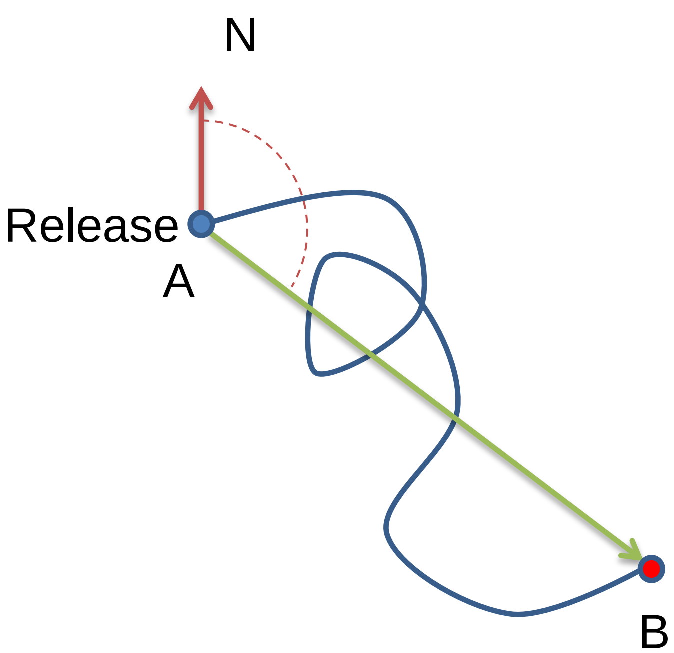
1/12°



Metrics for lagrangian motion

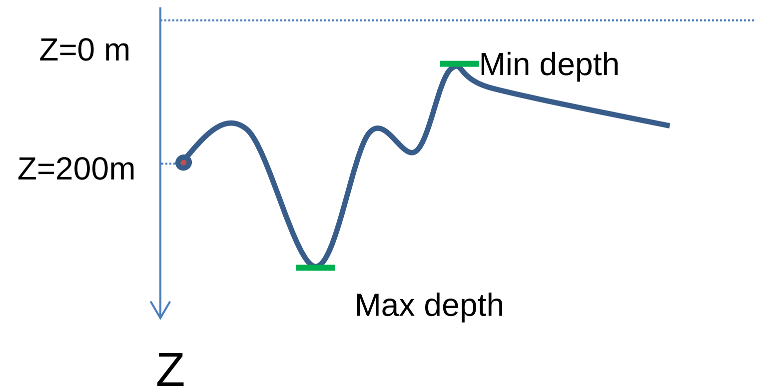
Horizontal

- distance(A,B)



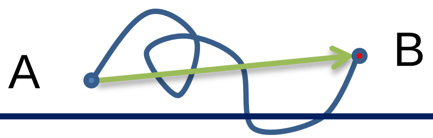
Vertical

2 metrics:
- Max depth
- Min depth

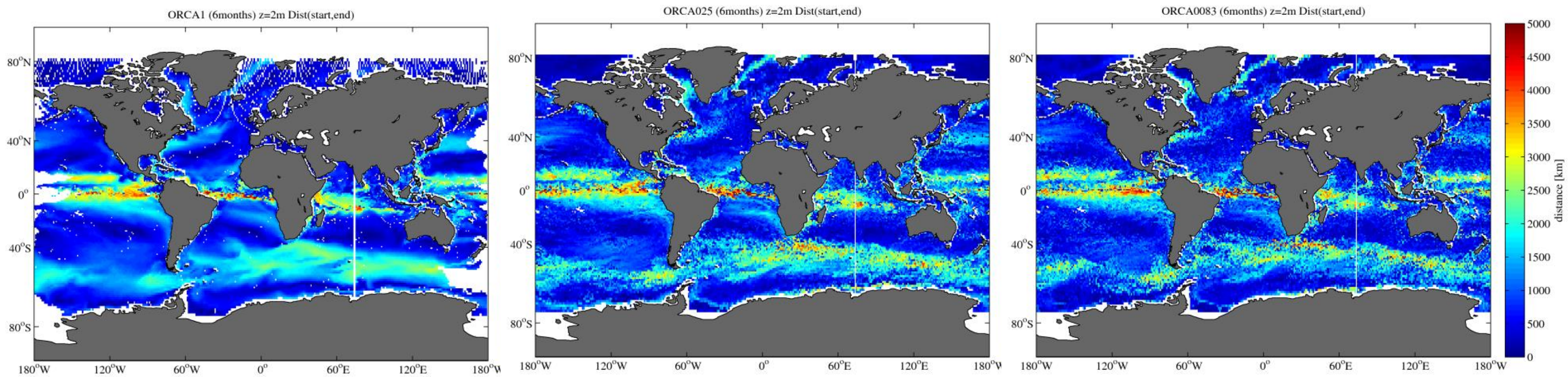


Surface

Distance (A,B),

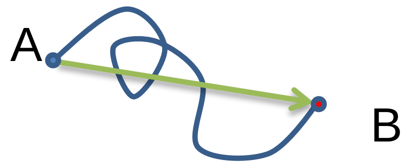


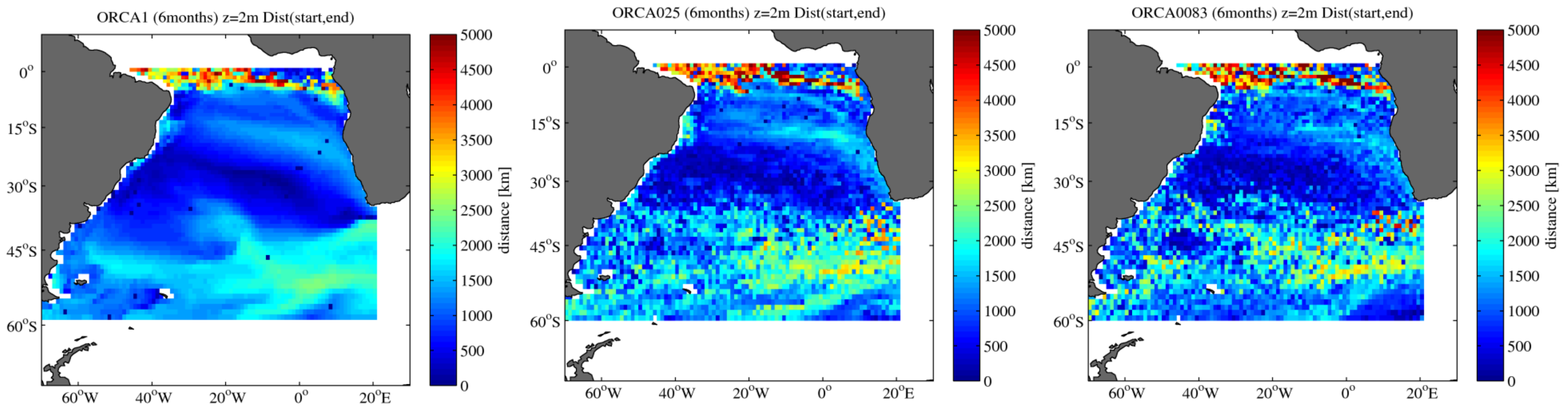
1º | 1/4º | 1/12º

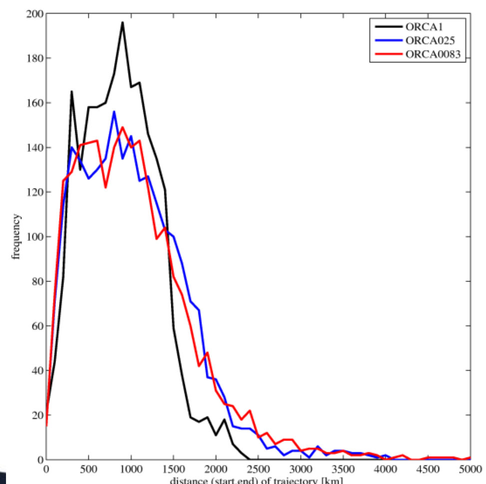


Surface

Distance (A,B),



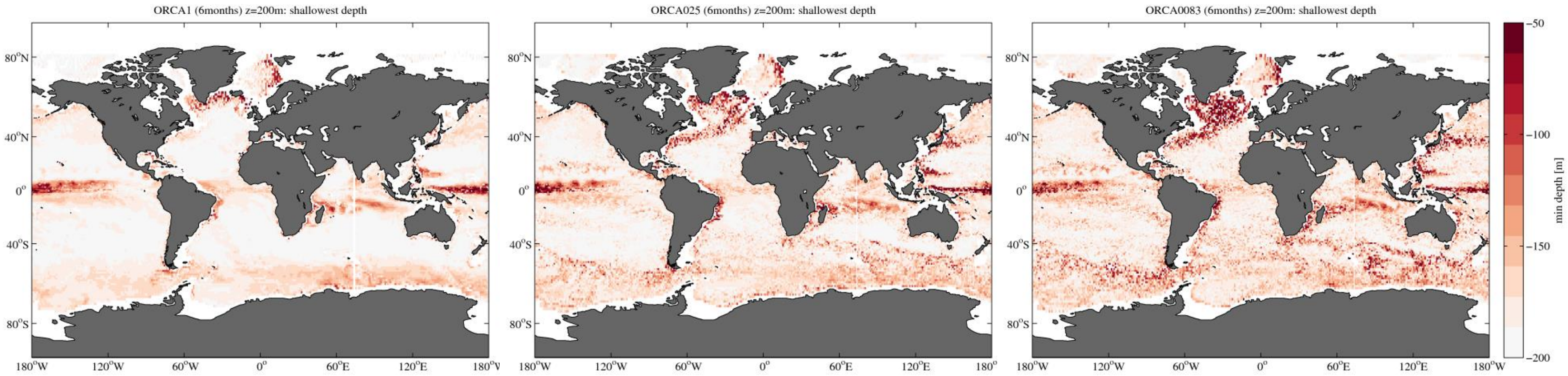




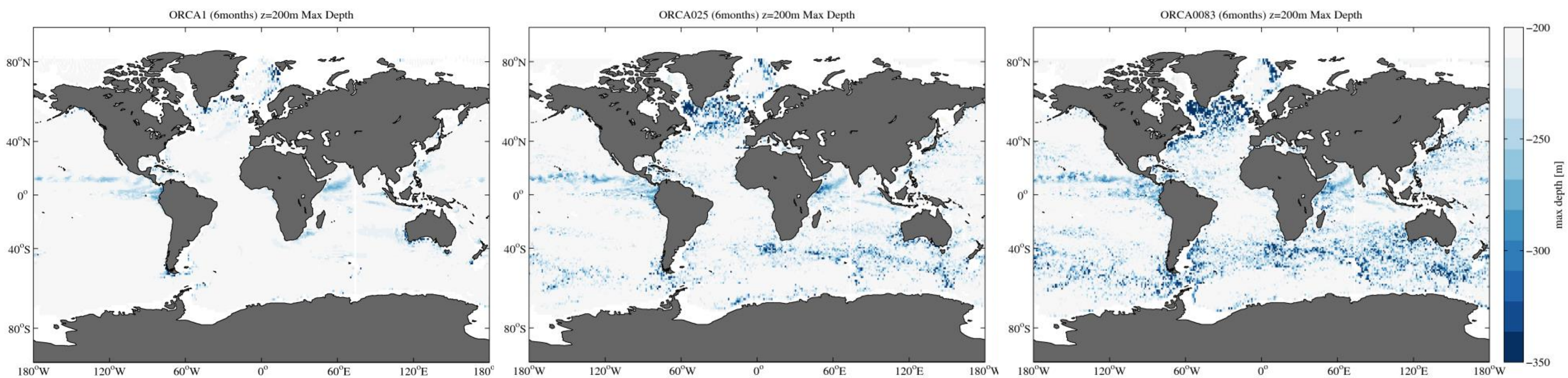
Oligotrophic gyre horizontal transfer hypothesis:

In 1/12, centres of the gyres are connected to their nutrient-rich peripheries on a much shorter timescale.
Because of much stronger mesoscale motion in 1/12, it has more intense horizontal eddy transfer of nutrients.

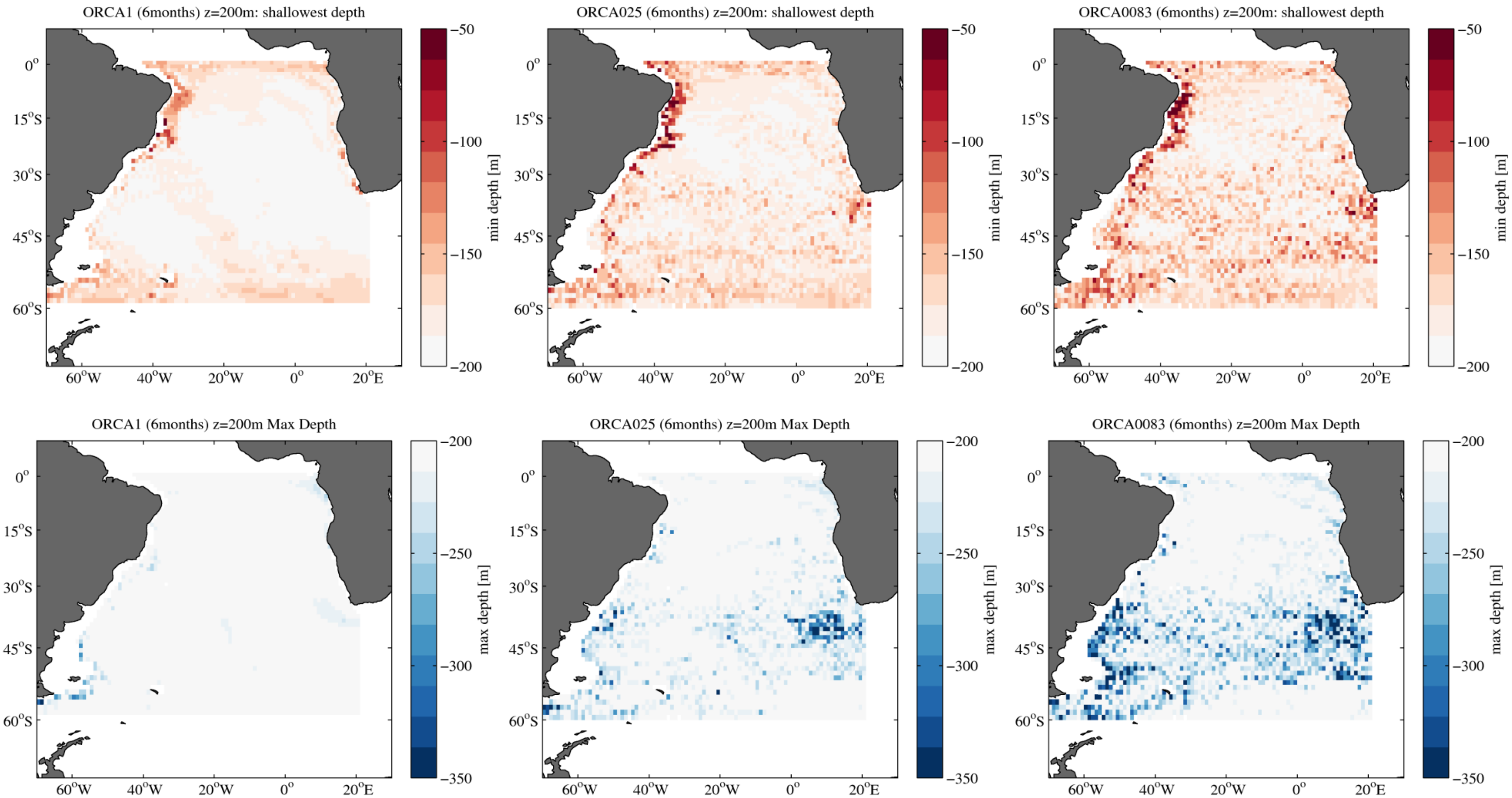
Vertical Displacement: upward / downward



1° 1/4° 1/12°



Vertical Displacement: upward / downward



[Preliminary] concluding remarks

- Lagrangian method of resolution comparison is a promising way forward to disentangle “local” and “remote” impacts of improved resolution on BGC
- In respect to horizontal pathways, ¼ and 1/12 behave very similar to each other and both are much faster than 1^o.
- In respect to the vertical motion, each step in resolution intensifies upward and downward displacement. Southern Ocean, boundary currents and NA areas of deep convection are areas where the impact is the most pronounced.
- Is $1/4^o$ the worst resolution? We don’t see any evidence of this as far as BGC is concerned