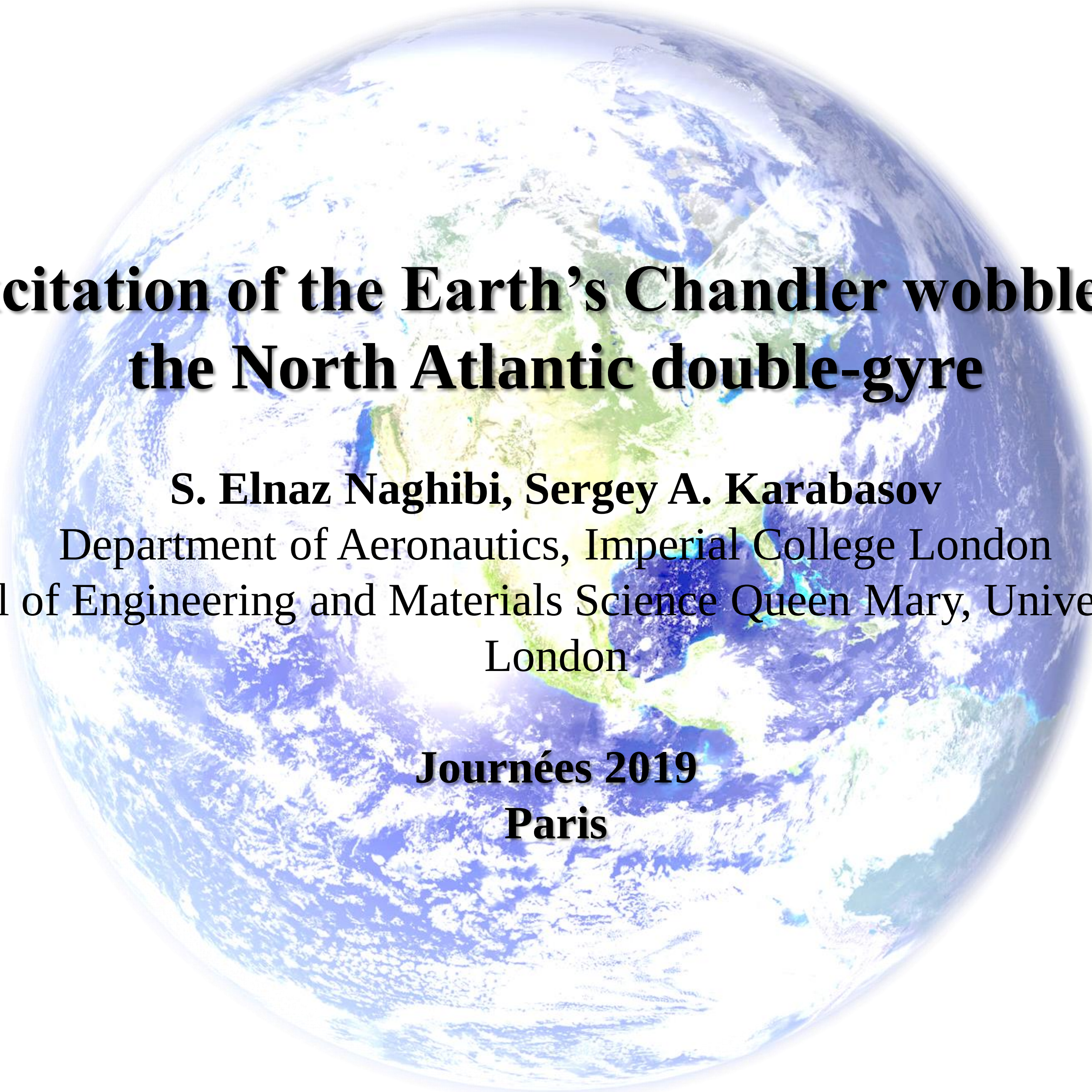

Excitation of the Earth's Chandler wobble by the North Atlantic double-gyre

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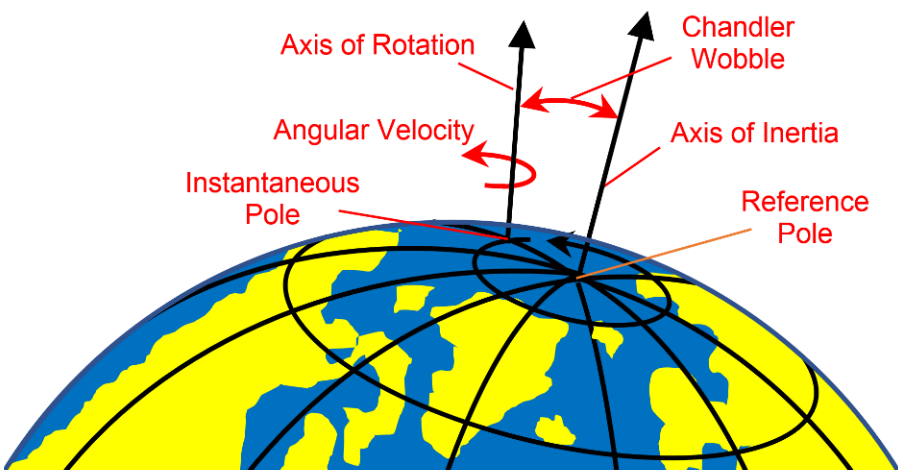
Chandler wobble

Chandler Wobble, the main component of polar motion, is a 14-month free motion, the period of which is determined by elliptic geometry and the rigidity of the Earth .

Chandler wobble equations

$$\frac{i}{\sigma_0 + i/2Q}\frac{d\mathbf{m}}{dt} + \mathbf{m} = \boldsymbol{\psi} = \left[1 - \frac{i}{\Omega}\frac{d}{dt}\right]\left\{\alpha\mathbf{c} + \beta\mathbf{h}\right\}$$

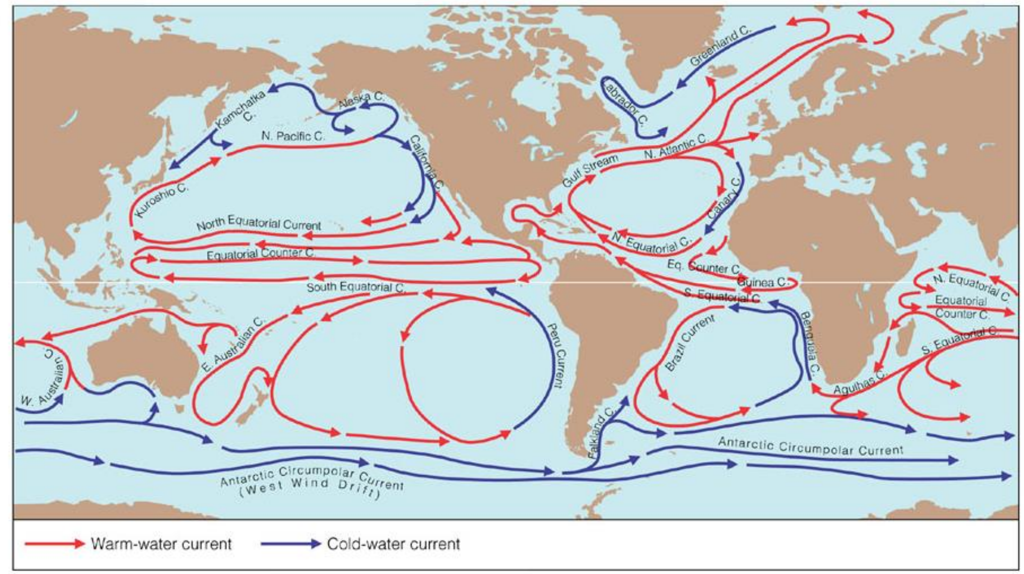
$$T_0 = \frac{2\pi}{\sigma_0} \approx 433 \text{ days}$$



Background:
general circulation ocean models & double-gyre models

General Circulation Models

- POP 2002
- NEMO 2008
- HYCOM 2002
- MITgcm 1997



double-gyre models

Munk 1950	Holland 1978	Shen et al. 1999	Berloff 2005	Karabasov et al. 2009	Maddison et al. 2015	Shevchenko & Berloff 2015

Naghibi et al., Geophysical Journal International, 2017
Naghibi et al., Applied Mathematical Modelling, 2019

Approach

HYCOM (HYbrid Coordinate Ocean Model):
A general ocean model with realistic continent boundaries, bottom topography and time varying wind forcing

Quasi-geostrophic model (QG):
A mid-latitude approximation of the double-gyre problem with steady wind forcing, flat bottom topography and longitudinal-latitudinal boundary walls

HYbrid Coordinate Ocean Model:

Conservation laws for momentum, energy, salinity, mass and the equation of state

$$\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}.\nabla)\mathbf{v} + 2\boldsymbol{\omega}\times\mathbf{v} = -\frac{\nabla M}{\rho} + \frac{\nabla.\boldsymbol{\tau}}{\rho},$$

$$\frac{\partial(\Delta h T)}{\partial t} + \nabla.(\Delta h T\mathbf{v}) = \nabla.(\nu\,\Delta h\nabla T) + F^T,$$

$$\frac{\partial(\Delta h S)}{\partial t} + \nabla.(\Delta h S\mathbf{v}) = \nabla.(\nu\,\Delta h\nabla S) + F^S,$$

$$\frac{\partial}{\partial t}(\Delta h) + \nabla.(\mathbf{v}\Delta h) = 0,$$

$$\rho = \rho(T,S,P),$$

The model considers 40 isopycnal layers and the outputs are provided over a uniform 2250×4500 resolution grid.

Quasi-geostrophic double-gyre model:

stratified potential vorticty eqautions with meridional gradient of planetary vorticity, lateral viscosity & bottom friction and wind forcing

$$\partial_t q_i + J\left(\psi_i, q_i\right) = \delta_{1i} F_w - \delta_{i3} \frac{a_v}{H_3^2} \nabla^2 \psi_i + a_h \nabla^4 \psi_i$$

$$q_i = \nabla^2 \psi_i + \beta y - \left(1-\delta_{i1}\right) S_{i1}\left(\psi_i - \psi_{i-1}\right) - \left(1-\delta_{i3}\right) S_{i2}\left(\psi_i - \psi_{i+1}\right)$$

(Karabasov et al. 2009, Shevchenko & Berloff 2015)

boundary conditions

$$\partial_{\mathbf{nn}} \psi_i - \alpha^{-1} \partial_{\mathbf{n}} \psi_i = 0$$

$$i = 1,2,3$$

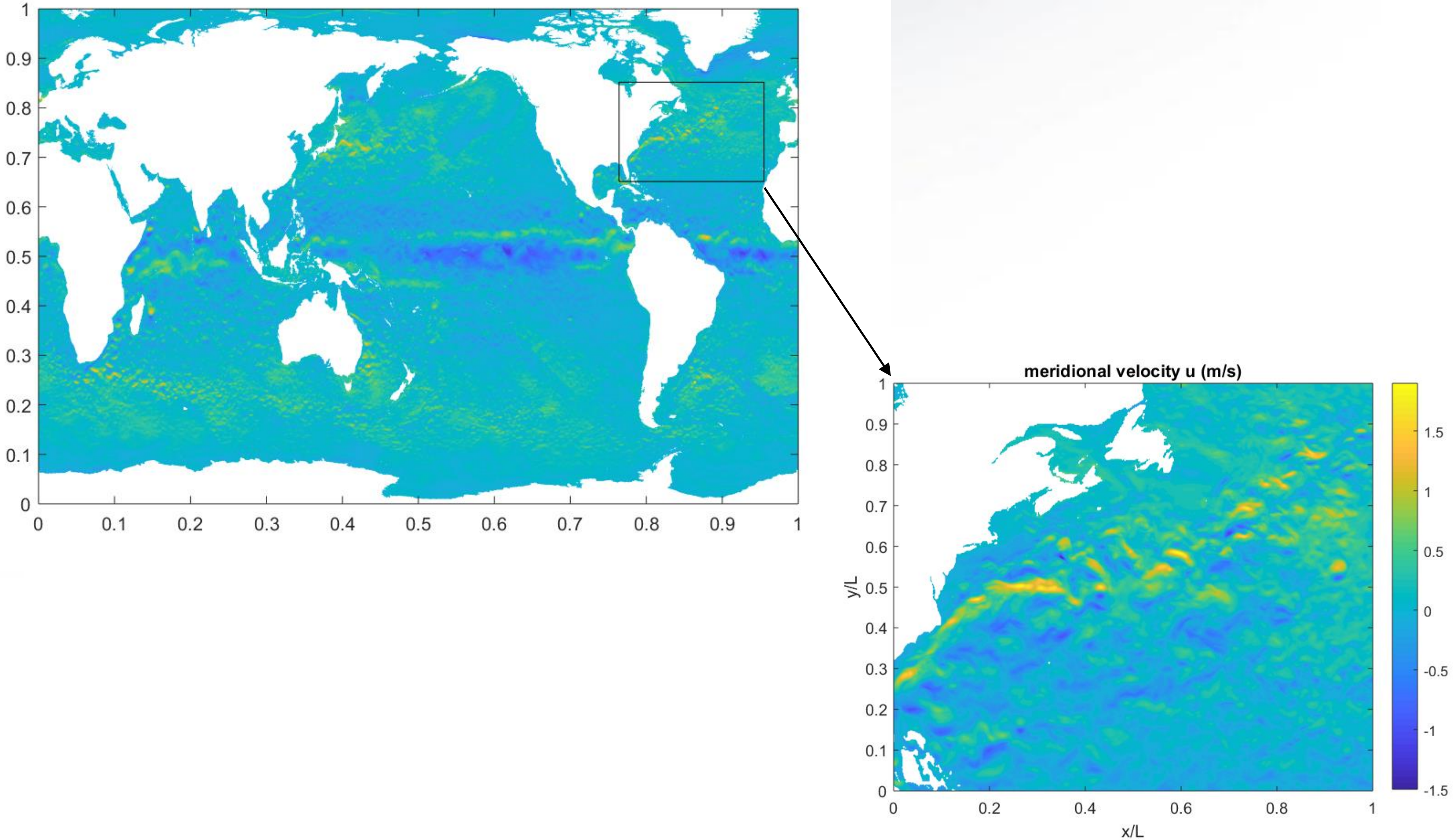
numerical solution

CABARET: Compact Accurately Boundary-Adjusting high-REsolution Technique (Karabasov & Goloviznin 2009)

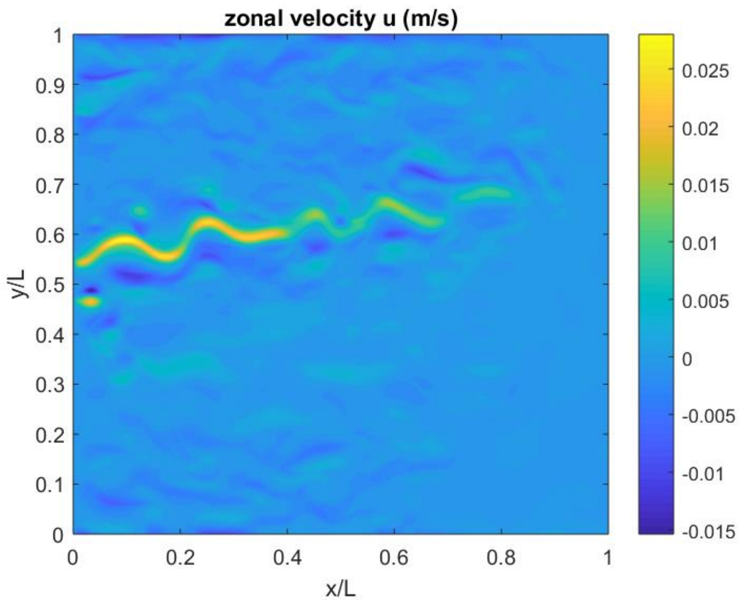
package

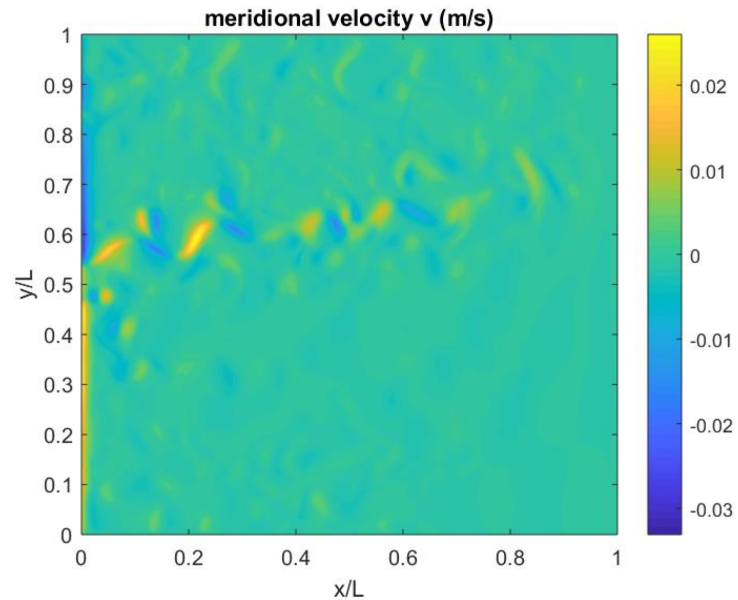
PEQUOD: Parallel Quasi-Geostrophic Model, (Maddison, Berloff & Karabasov 2014)

HYCOM outputs

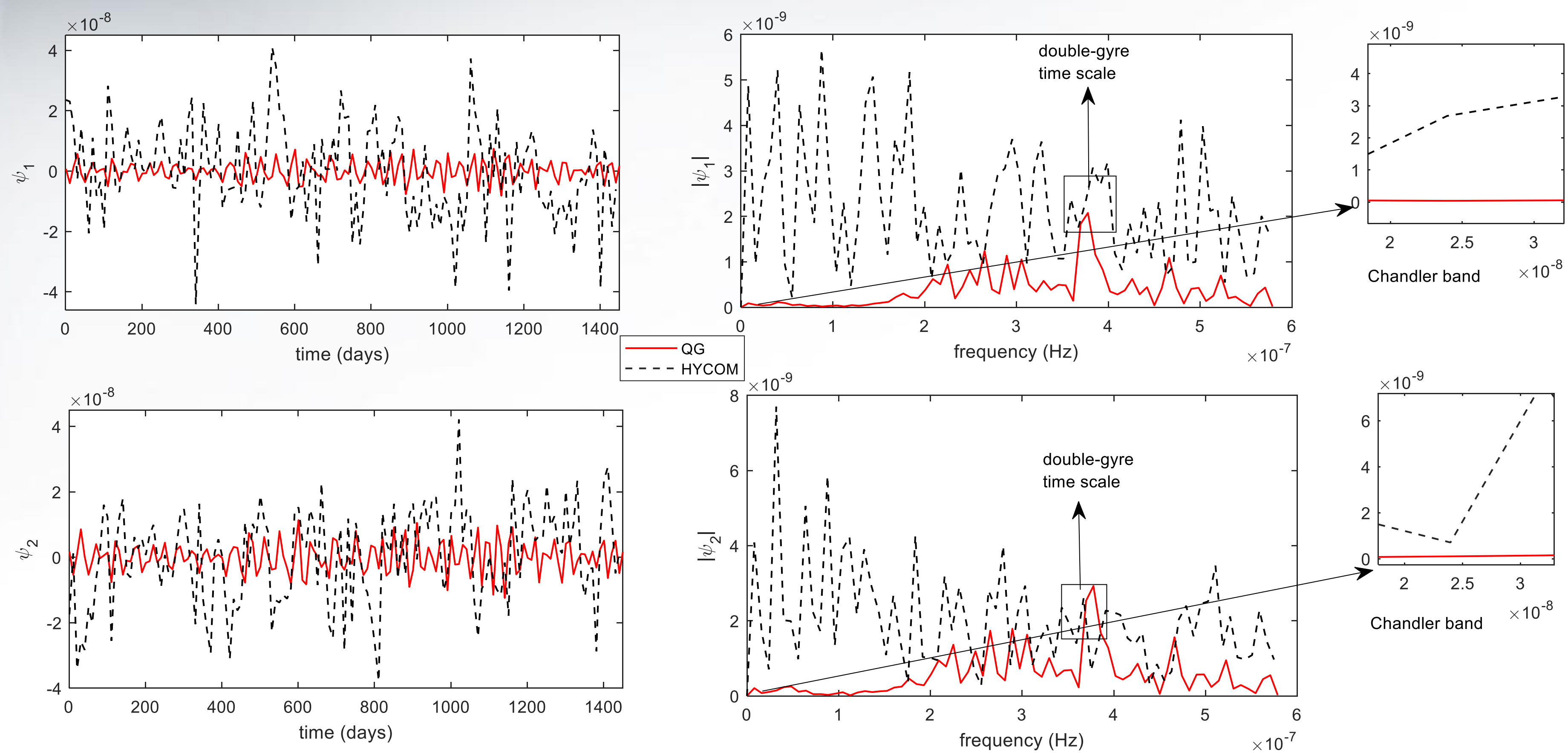


QG outputs

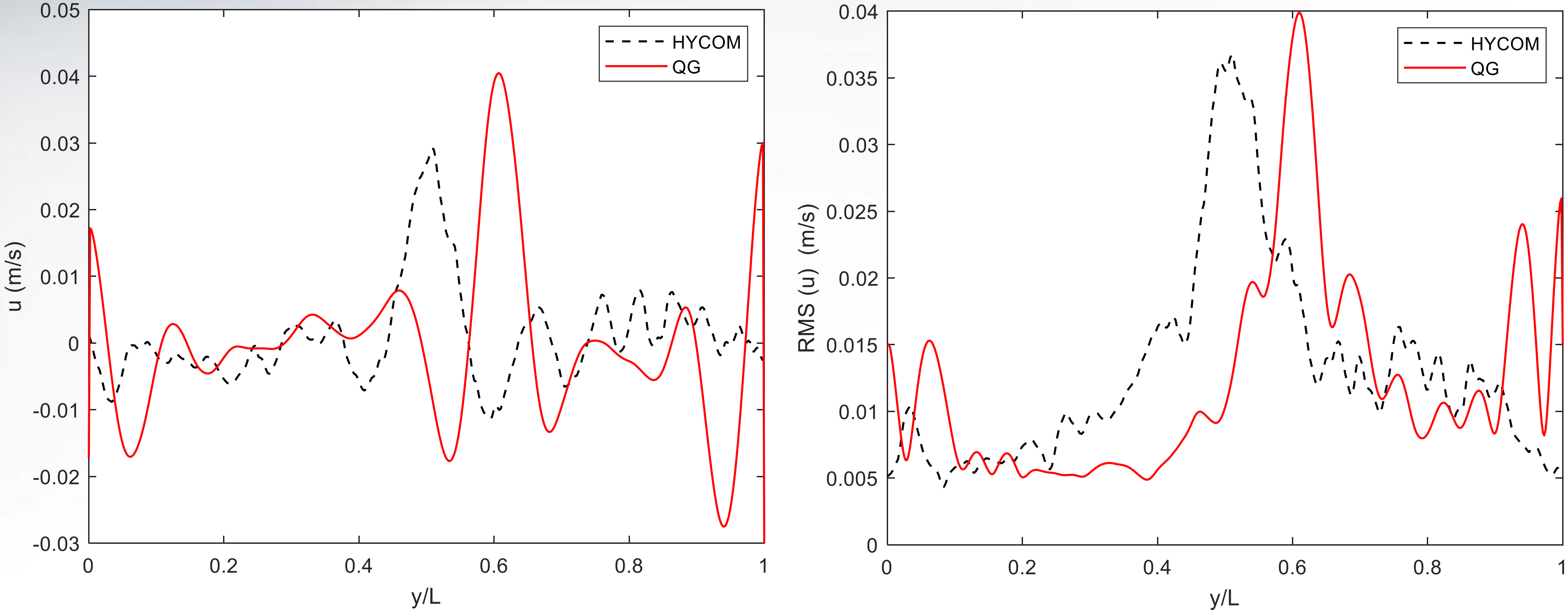

zonal velocity u (m/s)
y/L
x/L
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.2
0.4
0.6
0.8
0.025
0.02
0.015
0.01
0.005
-0.005
-0.01
-0.015


meridional velocity v (m/s)
y/L
x/L
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.2
0.4
0.6
0.8
0.02
0.01
-0.01
-0.02
-0.03

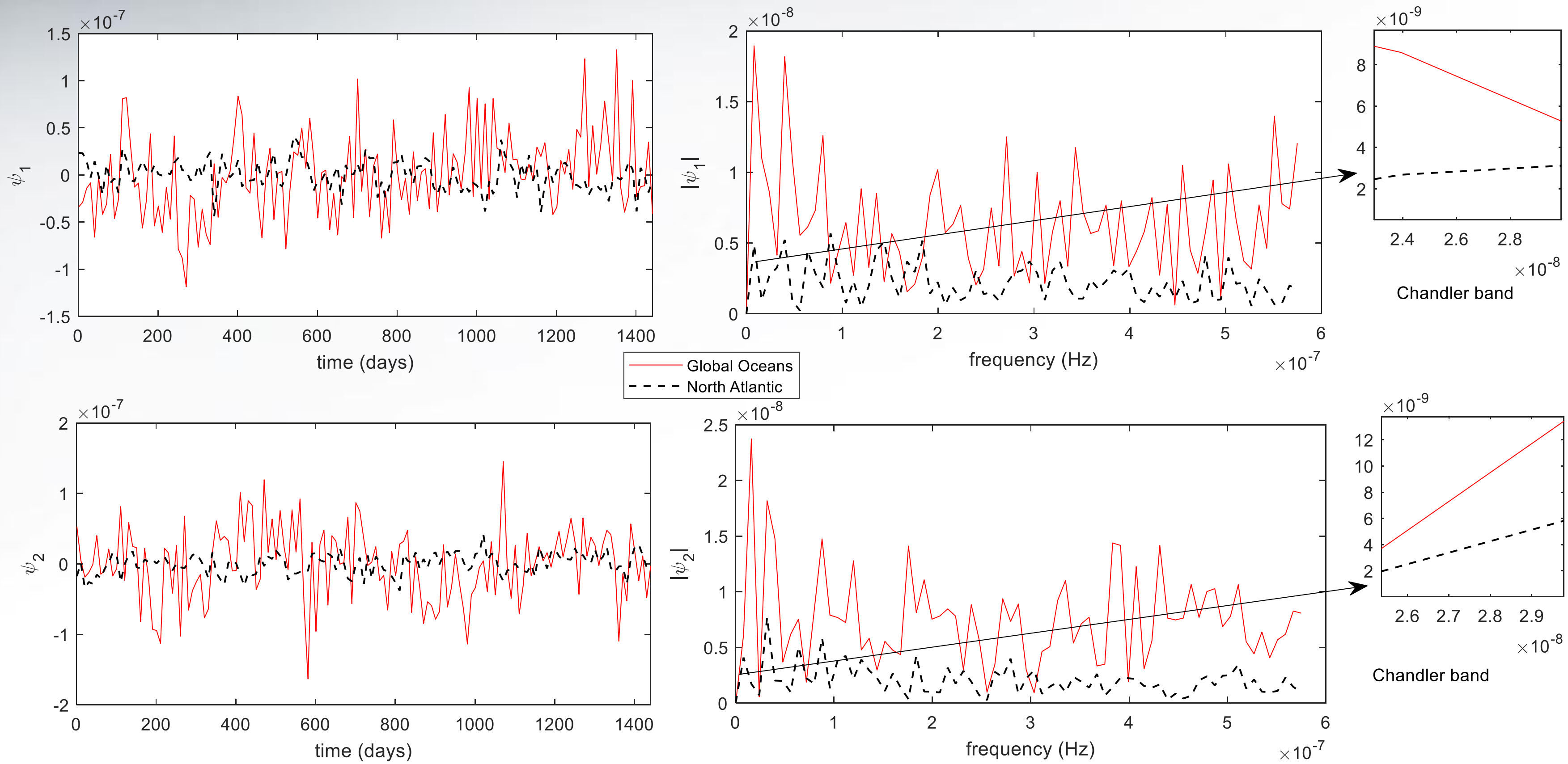
Comparison of Chandler wobble excitation functions using HYCOM & QG velocity fields



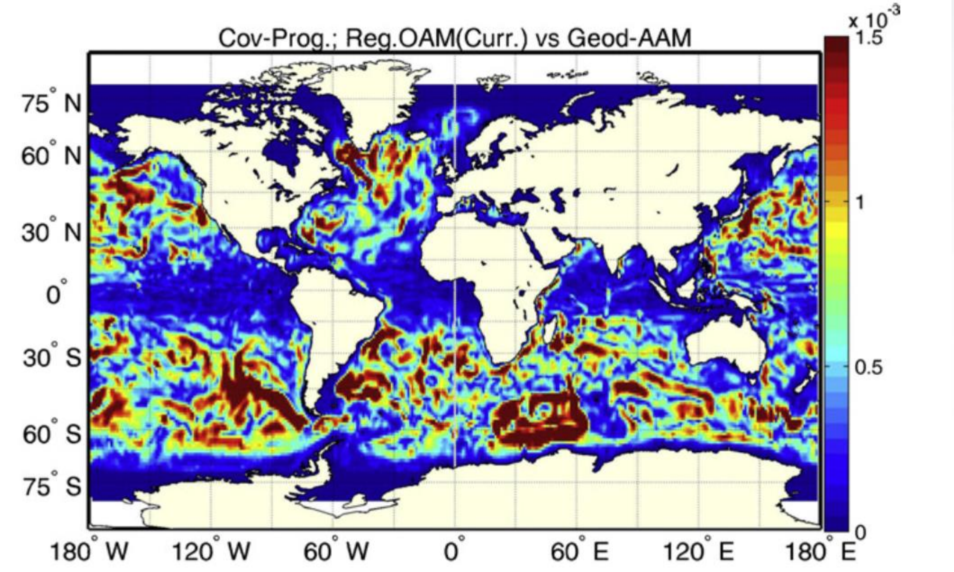
Comparison of the meanflow and RMS profiles in HYCOM & QG



Chandler wobble excitation functions: Global oceans vs. the North Atlantic (motion term)



North Atlantic is not the largest contributor in Chandler wobble excitation



Nastula et al. 2012

Excitation Process	Power, mas^2
Observed	1.26
Pacific Ocean	
χ_{uv}^{PO}	0.08(6.4%)
χ_{p}^{PO}	0.46(36.5%)
χ_{uv+p}^{PO}	0.28(22.2%)
Indian Ocean	
χ_{uv}^{IO}	0.18(14.3%)
χ_{p}^{IO}	0.18(14.3%)
χ_{uv+p}^{IO}	0.16(12.7%)
Atlantic Ocean	
χ_{uv}^{AO}	0.02(1.6%)
χ_{p}^{AO}	0.15(11.9%)
χ_{uv+p}^{AO}	0.09(7.1%)

Ma et al. 2009

(Naghibi et al., 2017)

Future work:

- Calculating Chandler wobble excitation over a longer period of time using HYCOM & QG outputs
- Comparing the predicted excitation with geodetic observation of the Chandler wobble after subtraction of mass terms estimated from geophysical GRACE satellite gravimetry data

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Thank you