# Meso and submeso-scale vertical velocity estimations in different dynamical regimes in preparation for the high resolution observations of the SWOT altimetry mission

A. PIETRI [1], X. CAPET [1], F. D'OVIDIO [1], J. LE SOMMER [2], J.M. MOLINES [2], A.M. DOGLIOLI [3], H. GIORDANI [4]

1 LOCEAN-IPSL, CNRS/IRD/UPMC, Paris, France
2 LGGE, Univ. Grenoble-Alpes / CNRS, Grenoble, France
3 Mediterranean Institute of Oceanography, Marseille, France
4 Météo-France, CNRM-GAME/GMGEC/NEMO, Toulouse, France

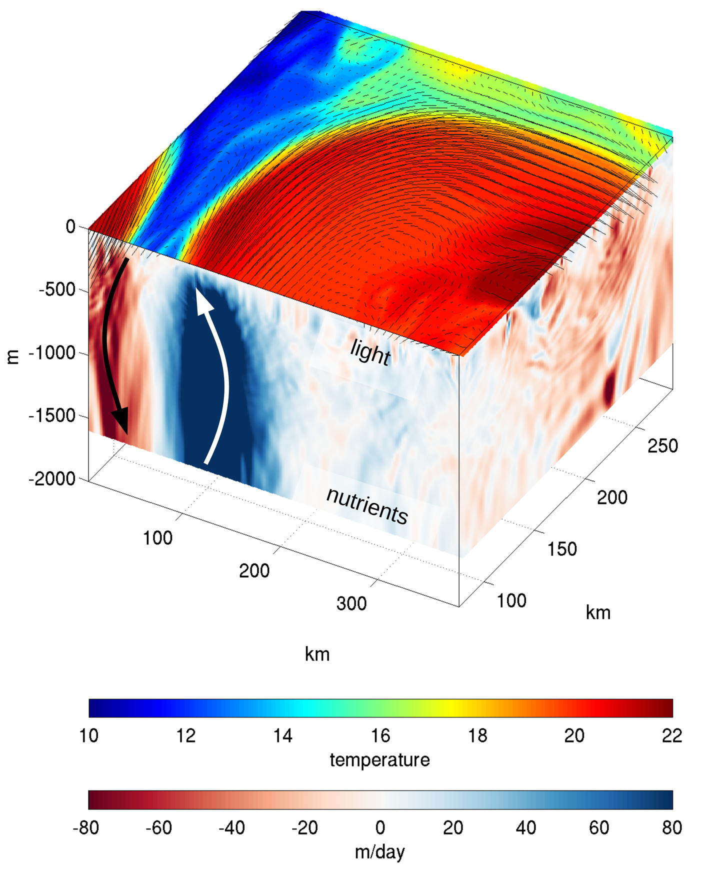
## 1. Introduction

Vertical exchanges in the ocean supply nutrients to the euphotic zone, subduct matter in the deep ocean and can be strong when driven by meso and submesoscale dynamics.

Vertical velocity (w) is driven by different sources: deformation of the main flow at different vertical and horizontal scales, surface forcing, Inertia-gravity waves, …

However w is difficult to observe because it's localized, has a small spatial scale, low intensity and a rapid variability. Thus, it is usually diagnosed from other data, most often using the Ω-equation.

<u>Here we compare and contrast the results from the Ω-equation (ω) in different flow regimes using different data sets.</u>

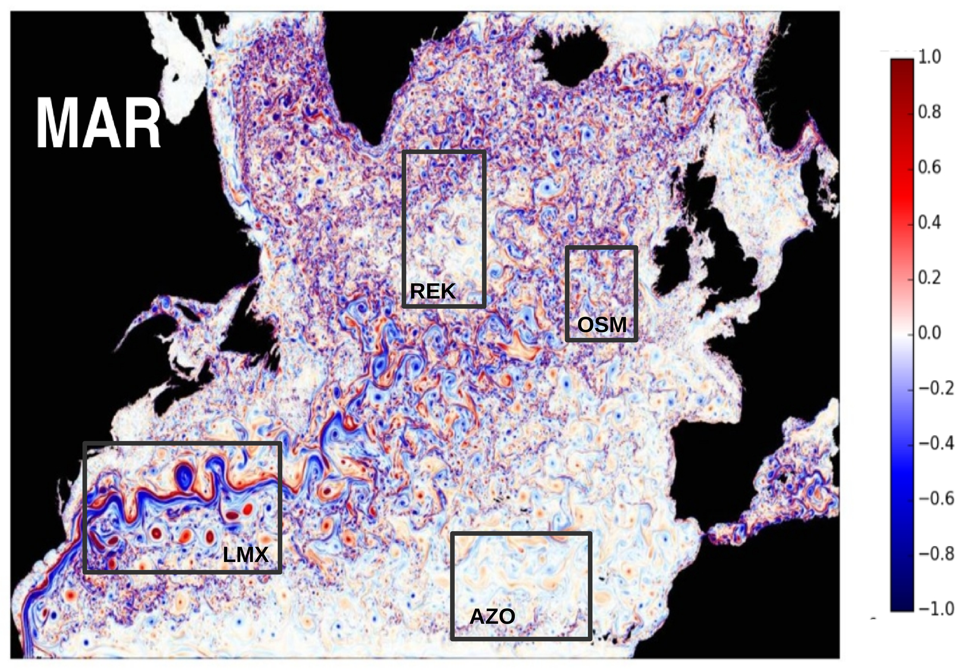



*surface temperature and vertical sections of vertical velocity in the Gulf Stream region of simulation NATL60*

## 2. numérical simulation: NATL60

The data from four contrasted regions in the NATL60 simulation is used to calculate ω and compare the results to $w_{model}$.

- numerical code : NEMO v3.5"
- horizontal grid : 1/60° (dx = 0.8-1.6 km )
- vertical grid : 300 levels (dz = 1m to 30 m)
- realistic boundary conditions and atmospheric forcing
- 4 series of 10 consecutive daily averaged outputs in March-June-September-December




*model surface vorticity in winter with the 4 regions of study highlighted*

## 2. The Omega Equation

$$f^2 \frac{\partial^2 w}{\partial z^2} + \nabla_h (N^2 . \nabla_h w) = \nabla . \boldsymbol{Q}$$

Different forcings can drive vertical velocity:

$$\boldsymbol{Q} = \boldsymbol{Q_{TW}} + \boldsymbol{Q_{DAG}} + \boldsymbol{Q_{FL}} + \boldsymbol{Q_{TD}}$$

**TW :« frontogenesis»**

Deformation of the flow

$$\begin{cases} Q_{twx} = \frac{g}{\rho}\left(\frac{\partial u}{\partial x}\frac{\partial \rho}{\partial x} + \frac{\partial v}{\partial x}\frac{\partial \rho}{\partial y}\right) \\ Q_{twy} = \frac{g}{\rho}\left(\frac{\partial v}{\partial y}\frac{\partial \rho}{\partial y} + \frac{\partial u}{\partial y}\frac{\partial \rho}{\partial x}\right) \end{cases}$$

**DAG : Deformation of the thermal wind imbalance**

$$\begin{cases} Q_{dagx} = f\left(\frac{\partial v}{\partial x}\frac{\partial u_{ag}}{\partial z} - \frac{\partial u}{\partial x}\frac{\partial v_{ag}}{\partial z}\right) \\ Q_{dagy} = f\left(\frac{\partial v}{\partial y}\frac{\partial u_{ag}}{\partial z} - \frac{\partial u}{\partial y}\frac{\partial v_{ag}}{\partial z}\right) \end{cases}$$

**FL : Turbulent fluxes of momentum and buoyancy**

Can be prescribed from atmospheric fluxes (wind, heat fluxes)

$$\begin{cases} Q_{dmx} = f\frac{\partial}{\partial z}\left(\frac{1}{\rho}\frac{\partial \tau_{yo_i}}{\partial o_i}\right) \\ Q_{dmy} = -f\frac{\partial}{\partial z}\left(\frac{1}{\rho}\frac{\partial \tau_{xo_i}}{\partial o_i}\right) \end{cases} \quad \begin{cases} Q_{thx} = -\frac{g}{\rho}\frac{\partial}{\partial x}\left(\frac{\partial F_{\rho o_i}}{\partial o_i}\right) \\ Q_{thy} = -\frac{g}{\rho}\frac{\partial}{\partial y}\left(\frac{\partial F_{\rho o_i}}{\partial o_i}\right) \end{cases}$$

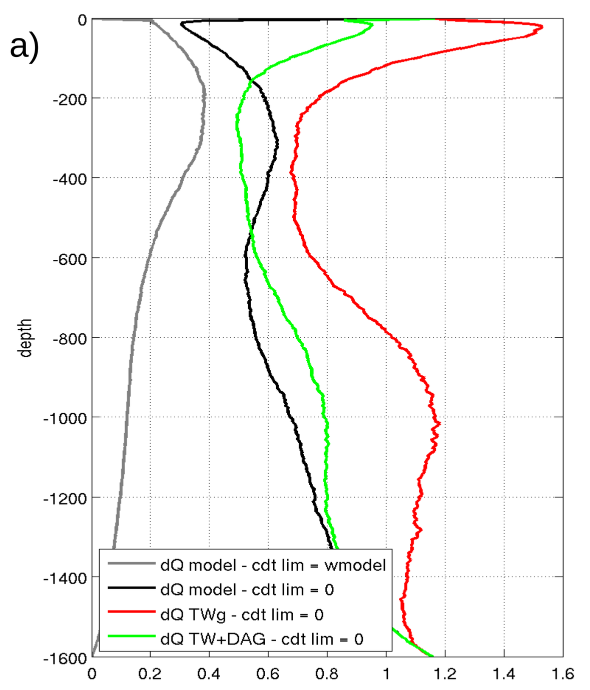
**TD : Trend of the thermal wind imbalance**

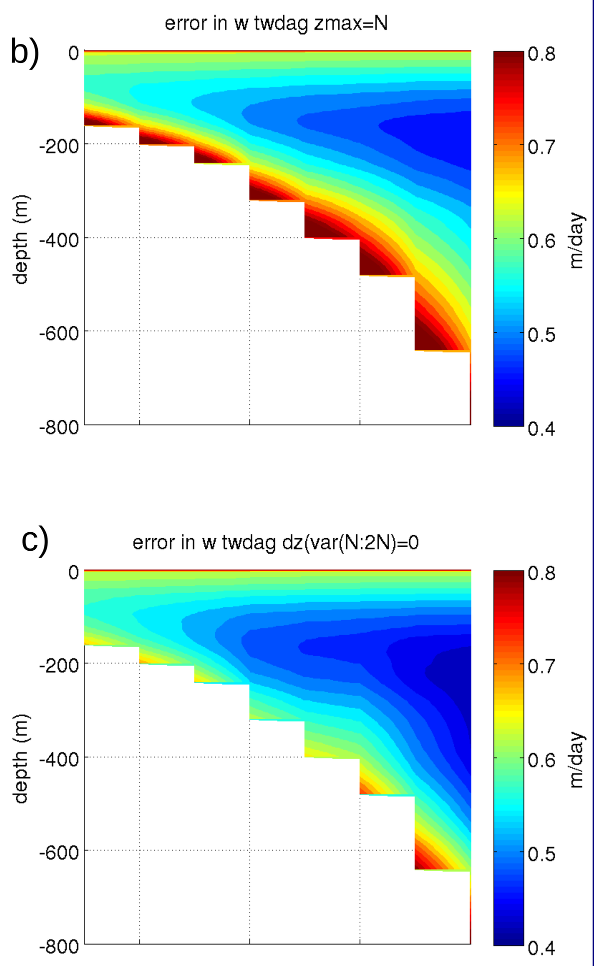
- Symmetric instability, inertial and sub inertial dynamics, …
- Can't be inferred from observations

$$\begin{cases} Q_{drx} = \frac{d}{dt}\left(f\frac{\partial v_{ag}}{\partial z}\right) \\ Q_{dry} = -\frac{d}{dt}\left(f\frac{\partial u_{ag}}{\partial z}\right) \end{cases}$$

## 4. Boundary conditions

The impact of the boundary conditions was studied by comparing different versions of the **Q** vector. In particular div(**Q**) and the boundary conditions were derived directly from $w_{model}$ to get an information on the accuracy of the solution.



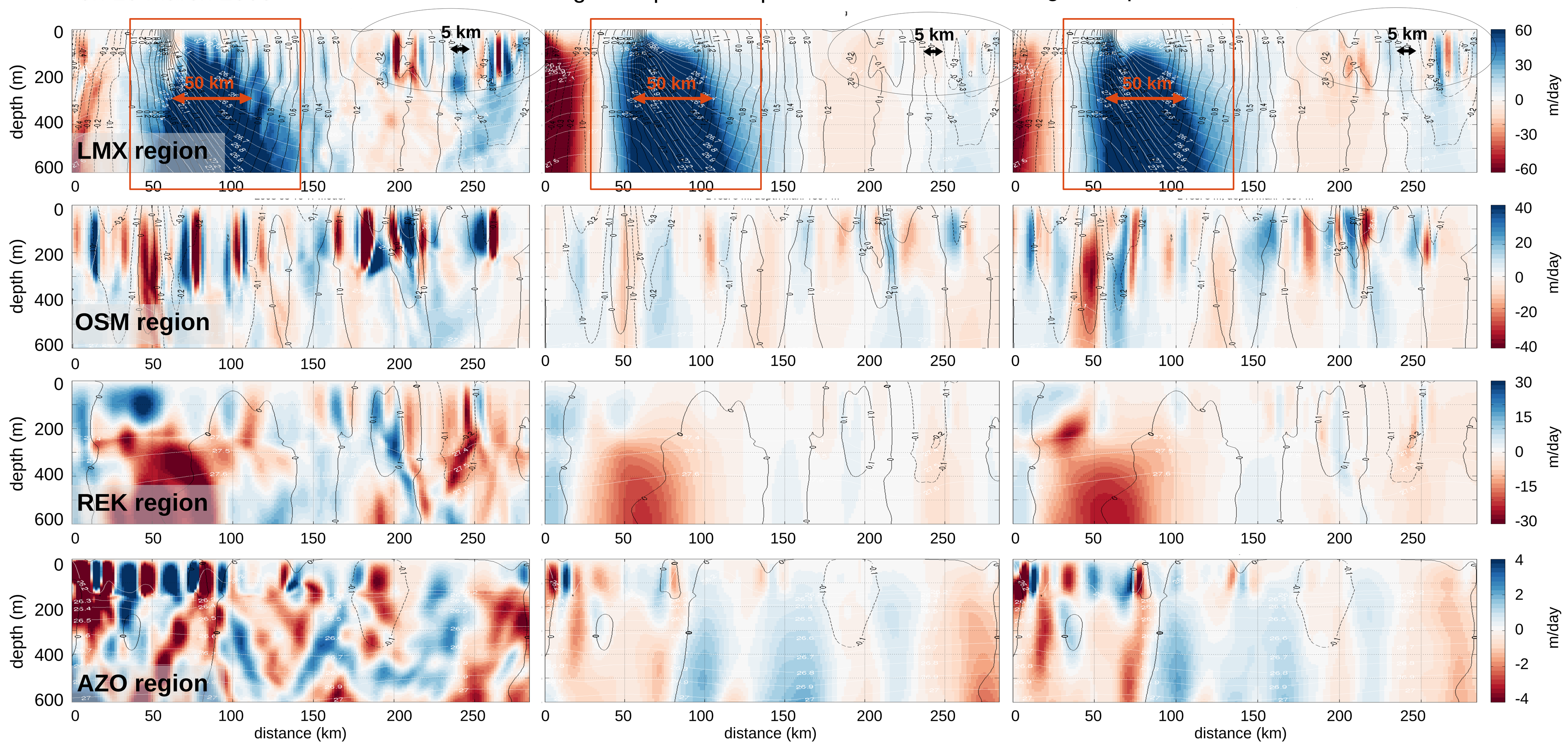

*a) Relative error in ω compared to $w_{model}$ for different **Q** vector formulations. b-c) Relative error in ω compared to $w_{model}$ for different water column depth (N). Boundary condition are b) 0 at z=N and c) 0 at z=2*N and dz(t,u,v)[N:2N]=0*

## 4. Vertical velocity

a) $\boldsymbol{w_{model}}$: Vertical velocity in the model on 10 March 2008

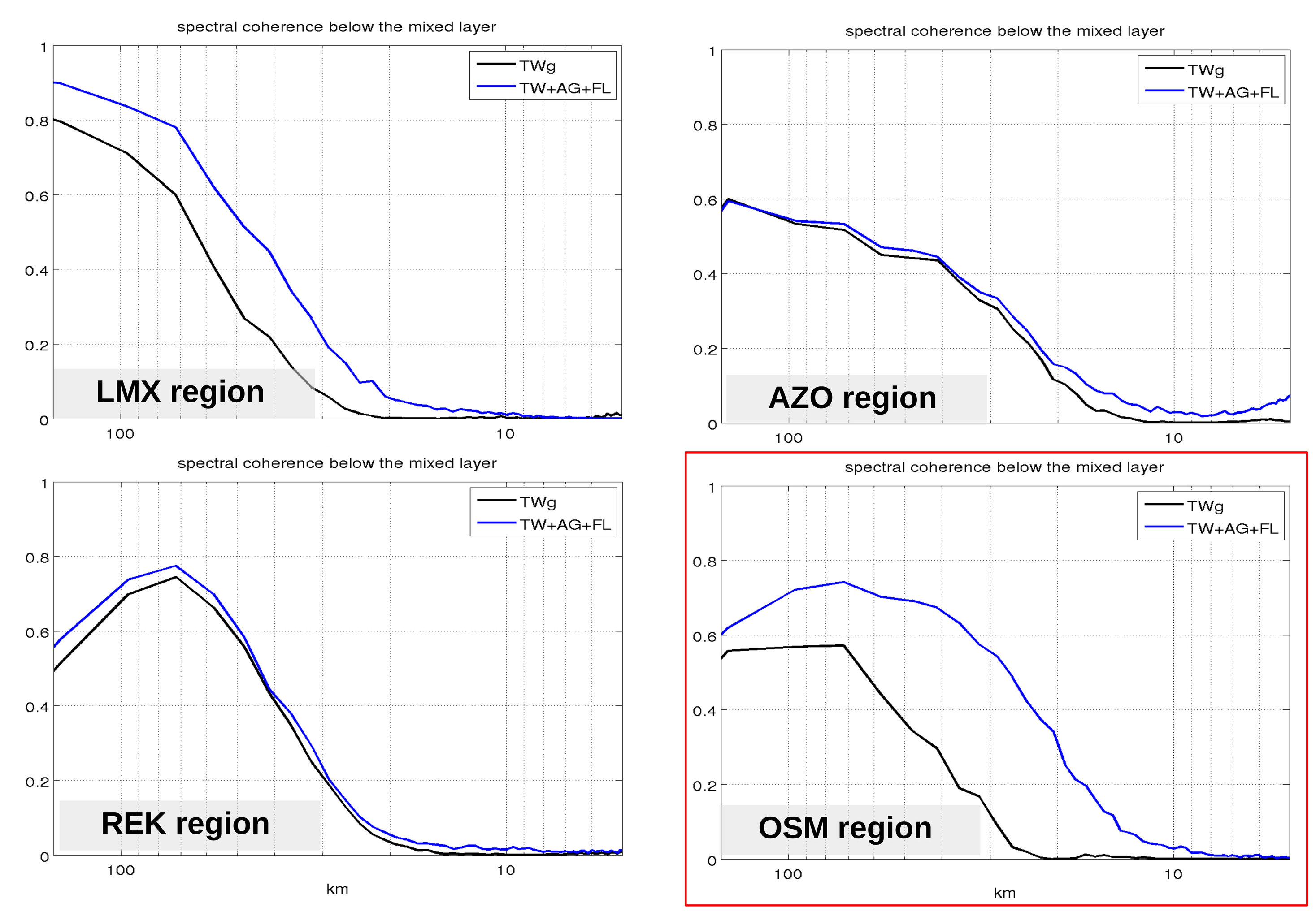
b) **TWg**: Vertical velocity from the quasi geostrophic Ω-equation

c) **TW + DAG + FL**: Ω-equation including the ageostrophic field and the windstress




*Vertical sections of (a) $w_{model}$ and (b and c) ω in the four regions for two different formulations of the **Q** vector.*

## 6. Dynamical regimes - regionality




*Spectral coherence between $w_{model}$ and ω below the mixed layer for the four regions in March*

The selected regions have very contrasted dynamics that affects the reconstruction of the vertical circulation by the Ω-equation.

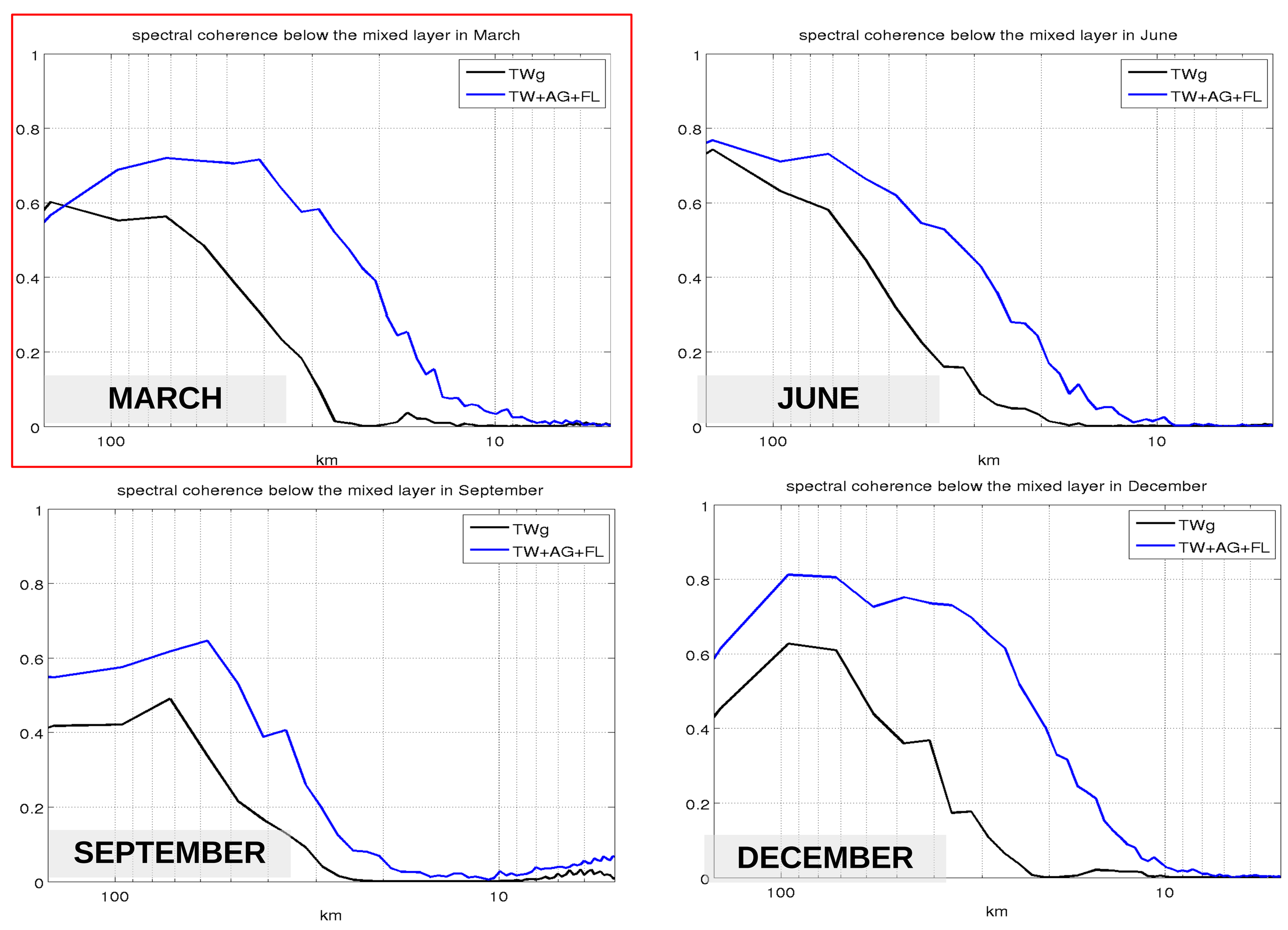
<u>LMX</u> : in this region energetic mesoscale is well represented, but the coherence decreases rapidly towards the small scales.

<u>AZO</u> : in general ω doesn't represent well the vertical circulation in this region, although w is generally weak everywhere.

<u>REK</u> : here, including higher order dynamics doesn't substantially improve the solution.

<u>OSM</u> : the region where the small scales are reproduced best by ω but only when the ageostrophic velocity is also included.

## 7. Dynamical regimes - seasonality




*Spectral coherence between $w_{model}$ and ω below the mixed layer in the OSM region*

## 7. Summary and ongoing work

→ The vertical velocity inferred from the Ω-equation <u>represents well the mesoscale energetic patterns</u>.

→ It doesn't give good results at submesoscale (below few tens of kilometers) in any dynamical regime.

→ the reconstruction from deformation has different skills depending on the region (and season)

→ improvement due to the inclusion of the others terms is also region (and season) dependent

**<u>SWOT</u>**

• ***Lower the resolution of the subsurface data***

→ how is the solution impacted by a reduced resolution in subsurface coupled with a high resolution surface information?

→ what kind of *in situ* information would be needed to resolve *w* depending on the regime?

• ***Q vertical variability***

→ how to propagate the information on the subsurface ?

→ can vertical modes of variability be identified ?