

Partition Between Barotropic And First Baroclinic Modes from Altimetric Velocities and Argo Float Mid-depth Displacements

C. Cabanes, T. Huck, A. Colin de Verdière

Laboratoire de Physique des océans, Brest



1. Introduction

- Currentmeters data have shown that the first baroclinic mode and the barotropic mode dominate the eddy kinetic energy [1]
 - SSH variability is well represented by the dynamic height variability in numerous regions at midlatitudes, the barotropic mode becoming more important at high-latitudes [2].
 - Recent observations suggest that strong correlation exists between 1000 m depth velocities deduced from Argo float displacements and surface geostrophic velocity anomalies from altimetry [3]
 - Such correlations are consistent with dominant barotropic mode and first baroclinic mode for SSH or the vertical structure of EKE variability.
- In this study, we first investigate the nature of the correlation between geostrophic surface velocity anomalies and the mid-depth velocity anomalies derived from Argo float displacements. We then used these two datasets to infer the partition between the barotropic mode and the first baroclinic mode.

2. Data

- Estimates of parking depth velocities (YOMAHA 07 dataset) 1997-2007
- Geostrophic surface velocity anomalies (AVISO)



- Data selection :
- pre-programmed parking depth at 1000 m and 1500 m
 - no time inversion/duplication in the sequence of fixes
 - baroclinicity error < velocities values

Geostrophic surface velocity anomalies (AVISO)

Interpolated at positions and times of the mid-depth velocity estimates

Subset of collocated velocity anomalies at the surface and at parking depth (85% at 1000m and 15% at 1500m)

3. Mean Flow and variability from Argo floats



The mean is computed by averaging all the data within R=500 km of the position of a velocity estimate, applying an elliptical Gaussian weight w function of the distance:

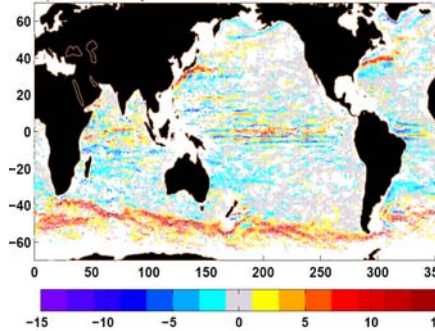
$$w(\Delta x, \Delta y) = \exp(-\Delta x^2/2\sigma_x^2 - \Delta y^2/2\sigma_y^2)$$

σ_x (σ_y) are defined to take into account the anisotropy of velocities :

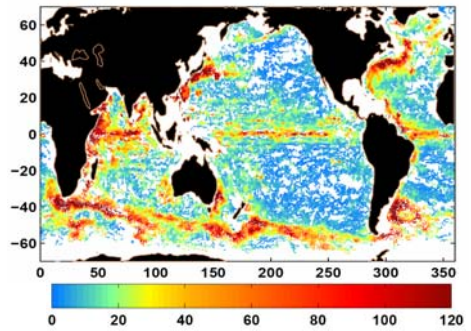
$$\sigma_x/\sigma_y = (\langle u^2 \rangle / \langle v^2 \rangle)^{1/2} \quad \text{and} \quad \pi\sigma_x\sigma_y = 15000 \text{ km}^2$$

σ_x (σ_y) \approx 70 (70) km at middle and high latitudes, away from boundary currents
100 (50) km within $7 - 8^\circ$ of the equator.

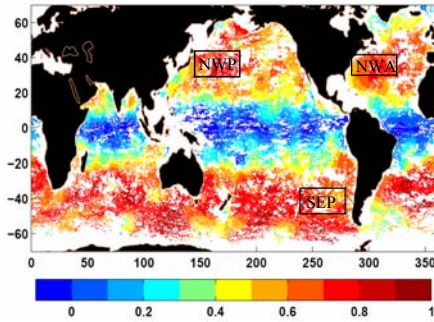
Mean Zonal Currents (cm/s) at 1000 m



Eddy Kinetic Energy (cm²/s²) at 1000 m



4. Correlation Between Surface and Mid-depth Velocity Anomalies



Correlation coefficient between the surface and the 1000 m depth meridional velocity anomalies

Correlation is computed at each observation location, the statistics taking into account all the points within 500 km at the same depth.

Global correlation (poleward 20°):
0.56(0.54) for meridional (zonal) component.

In which range of wavelengths (periods) the velocity anomalies at the surface best correlate with the velocity anomalies at 1000 m depth ?

Exp. Var.	NWA	Surface velocity field	
		No filter	300 km filter
at the surface	NWP	44 (54)	72(23)
	SEP	30 (69)	62(44)
	SEP	64 (36)	42(60)
Exp. Var.	NWA	43	7 (37)
at	NWP	48	7 (40)
1000m	SEP	40	28 (11)
			10 (30)

Variance explained (in %) at the surface and 1000 m by the spatially filtered or temporally filtered surface velocity anomalies in the 3 regions defined on the left. HP (LP) refers to high-pass (low-pass) filter.

High eddy kinetic energy areas (NWA, NWP):

The correlation is mainly related to large eddies with 300-400 km wavelength.

Lower eddy kinetic energy areas (SEP):

The correlation is largely due to structures with 200-300 km wavelength and period longer than 8 months.

5. Partition Between the Barotropic Mode and the First Baroclinic Mode

A) Velocity magnitude at 1000 m compared to the one at the surface

$$F_v^{1000}$$

obtained by minimizing $\sum (|v'(1000)| - R_v^{1000} |v'(0)|)^2$

B) First baroclinic mode magnitude at 1000 m compared to the one at the surface

$$F_1(1000)/F_1(0)$$

If the anomalous flow is the sum of a barotropic and a first baroclinic mode one can expect a linear relation between R^2 and $F_1(z)/F_1(0)$

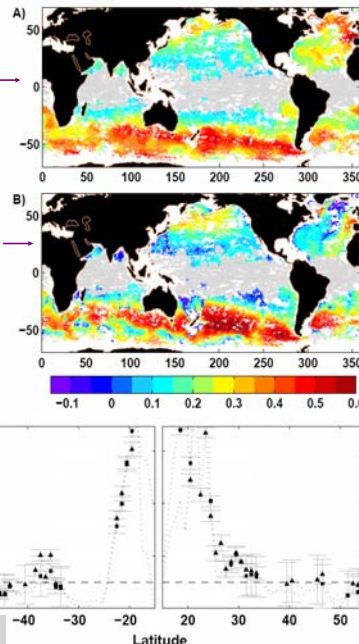
We checked if such a relation exist at a given latitude y :

$$R^2 = A(y) + B(y) \times \frac{F_1(z)}{F_1(0)} + \epsilon$$

C) First baroclinic mode to the barotropic mode contribution

$$B/A$$

for surface velocity anomalies.



- Clear dependence of B/A on latitude
- The first baroclinic mode dominates equatorward 30°
- The barotropic mode dominates in the ACC region.

6. Conclusion

- Nature of the correlation between geostrophic surface velocity anomalies derived from altimetry and the mid-depth velocity anomalies derived from Argo float displacements:

The correlation of surface anomalies with depth can be dependent on the wavenumber and period. In region of high EKE, there are evidences that the correlation is due to large eddies with wavelength 300-400 km, in accordance with a vertically coherent velocity structure observed for such anomalies [eg 5]. In areas of lower eddy kinetic energy such as SEP, the correlation is largely due to structures less than 300 km wavelength and period longer than 8 months.

- Fraction of u or v components in the first baroclinic mode versus the barotropic one, at the surface

The partition, valid for the part of the surface variability correlated with the one at mid-depth, is latitude dependent: the first baroclinic mode dominates equatorward 30° , while the barotropic mode is more important poleward. This is consistent with the results of [3]. Finally, one can expect that the increase of Argo dataset and further corrections on mid-depth velocities estimates will improve the determination of the partition between the barotropic and the first baroclinic modes.

7. Références

- Wunsch, C. (1997). The Vertical Partition of Oceanic Horizontal Kinetic Energy. J. Phys. Oceanogr., 27, 1770-1794.
- Guinchat, S., P.-Y. Le Traon, and G. Larnicol (2006). What can we learn from global altimetry/hydrography comparisons?, Geophys. Res. Lett., 33, L10604, doi:10.1029/2005GL025551.
- Willis, J. K., and L.-L. Fu (2006). Mid depth Circulation of the World Ocean: A First Look at the Argo Array, paper presented at the 15 years of Progress in Radar Altimetry Symposium, Venice, Italy, 13-15 March.
- Lebedev, K. V., H. Yoshinari, N. Maximenko, and P. Hacker (2007). Yomaha '07. Velocity data assessed from trajectories of argo floats at parking level and at the sea surface. Tech. Rep. No. 4(2), IPRC Technical Note No. 4(2), June 12.
- Swart, N. C., J. J. Ansong, and J. R. E. Lutjeharms (2008). Detailed characterization of a cold antarctic eddy. J. Geophys. Res., 113, C01009, doi:10.1029/2007JC004190.

CC is funded through a postdoctoral scholarship from CNES

