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

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## 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 form 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

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:

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

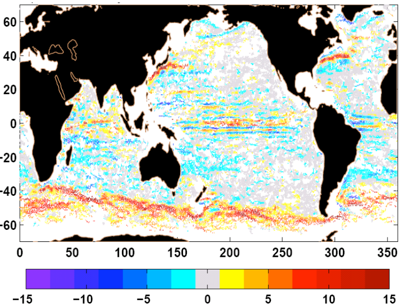
$\sigma x$ ($\sigma y$) are defined to take into account the anisotropy of velocities :

$\sigma_x/\sigma_y = (< u^2 > / < v^2 >)^{1/2}$ and $\pi \sigma_x \sigma_y = 15000$ km$^2$

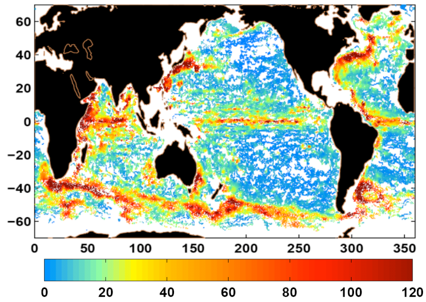
$\sigma_x$ ($\sigma_y$) ≈ 70 (70) km at middle and high latitudes, away from boundary currents

100 (50) km within $7-8°$ of the equator.

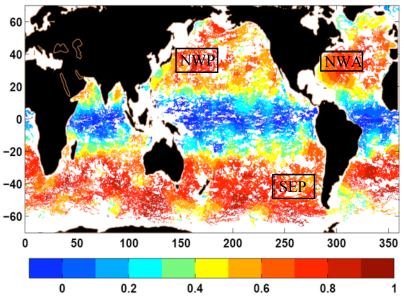
**Mean Zonal Currents (cm/s) at 1000 m**



**Eddy Kinetic Energy (cm$^2$/s$^2$) at 1000 m**



## 4. Correlation Between Surface and Mid-depth Velocity Anomalies




**Correlation coefficient between the surface and the 1000 m depth meridional velocitiy 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 ?**

| | | Surface velocity field | | |
|---|---|---|---|---|
| | | No filter | 300 km filter HP(LP) | 250 days filter HP(LP) |
| Exp. Var. at the surface | NWA | 100 | 44 (54) | 72(23) |
| | NWP | 100 | 30 (69) | 62(44) |
| | SEP | 100 | 64 (36) | 42(60) |
| Exp. Var. at 1000m | NWA | 43 | 7 (37) | 29 (14) |
| | NWP | 48 | 7 (40) | 32 (17) |
| | 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.

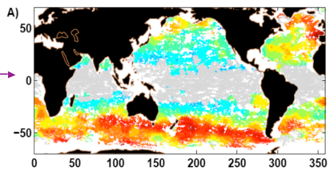
**Lower eddy kinetic energy areas (SEP)**
The correlation is largely due to structures with 200-300 km wavelength and period longer than 8 months.

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

**A) Velocity magnitude at 1000 m compared to the one at the surface** $R_v^{1000}$

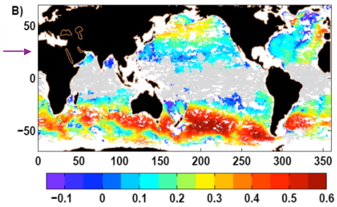
obtained by minimizing $\sum(|v'(1000)| - R_v^{1000}.|v'(0)|)^2$

A)



**B) First baroclinic mode magnitude at 1000 m compared to the one at the surface** $F_1(1000)/F_1(0)$

B)



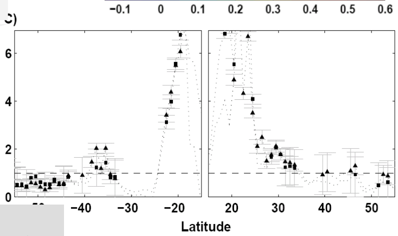
If the anomalous flow is the sum of a barotropic and a first baroclinic mode one can expect a linear relation between $R^z$ and $F_1(z)/F_1(0)$

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

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

**C) First baroclinic mode to the barotropic mode contribution** $\mathcal{B}/\mathcal{A}$ for surface velocity anomalies.

C)




- 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 form 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

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