Evidence of cyclonic recirculation off SW Iberia from Argo and Altimetric data

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1. β plume theory

- A large scale horizontal circulation may be produced by a disturbance of potential vorticity driven by a localized source or sink of mass (Fig.1).
- This dynamics can be described with linear vorticity balance equation:

$$\beta v = \frac{f_0 w^*}{H} + D \qquad (1)$$

β – Meridional gradient of planetary vorticity
v – Meridional velocity
f_0 – Coriolis frequency at a reference latitude
w^* - Cross isopycnal velocity
H – Layer thickness
D – Viscous dissipation of relative vorticity

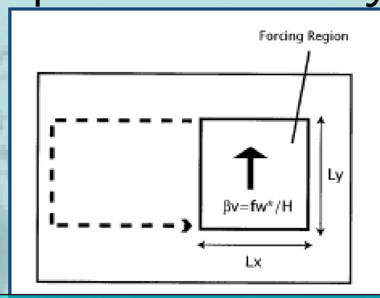


Fig. 1 – Schematic β –plume when water is leaving the layer [1]

- A small cross isopycnal transport is capable of forcing a horizontal circulation of much larger magnitude [2, 4].
- The circulation patterns induced by the local mass sink consist on bidirectional zonal flows: Eastward to the south of the sink and westward to the north of the sink [4].

GULF OF CADIZ

- Entrainment of Central Waters by the Mediterranean outflow causes a local mass sink that can generate a ***β* plume** type recirculation(Fig.2).
- Cyclonic recirculation may explain the existence of the Azores Current (the Eastward flow) and Azores Countercurrent (the Westward flow) (Fig.3)
- However, the simple balance scales with eq. (1) show that the zonal transports may be 2 orders of magnitude larger than that of the sink [2, 6], which means a too large transport for the AzC case.
- Recirculation flows may diminish when the forcing is near the frictional boundary layer (D large). [5]
- If in (1) topographic β is taken instead of planetary β, the vertical to horizontal transport ratio is decreased, and a more realistic scaling may be obtained for the GoC case [2]
- These balances are consistent only for linear steady-state ocean, and averaging for periods longer than the mesoscale is required to obtain these circulation structures.

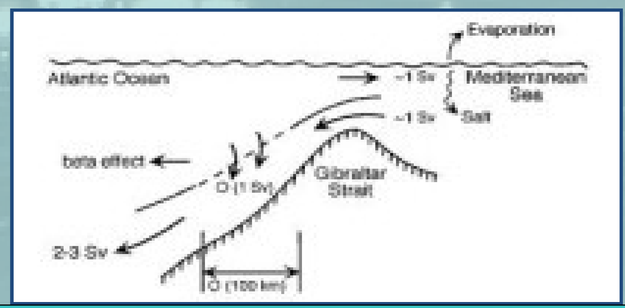


Fig. 2 – Schematic illustration of the interaction of the eastern N. Atlantic Ocean with the Mediterranean outflow in the Gulf of Cadiz [5]

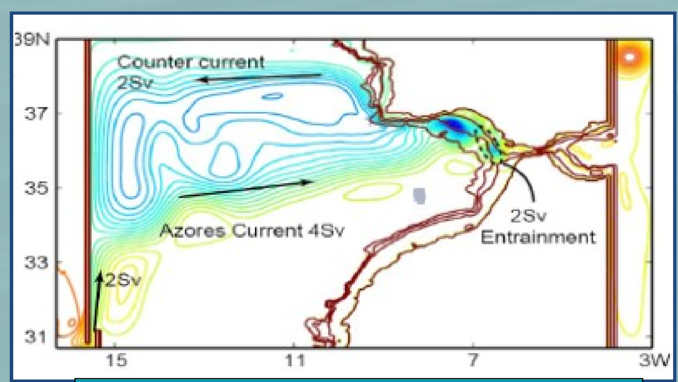


Fig. 3 - Topographic and eddy driven β –plume for the GoC [6]

<u>The main objective of this work is to find observational evidence of such time-mean recirculation</u>

3. Absolute dynamic topography

- In this work, absolute geostrophic surface velocities were calculated using Absolute Dynamic Topography (ADT) derived from altimetry and ARGO data [7]. For each ARGO profile an ADT estimate is obtained by referencing at the surface using altimetry data and a Mean Dynamic Topography (MDT) [see 7 for details on the calculation].
- All ADT estimastes were interpolated and geostrophic velocities were calculated with eq. (2).

$$fu = -g\frac{\partial \zeta}{\partial y} \qquad fv = g\frac{\partial \zeta}{\partial x} \qquad (2)$$

ζ – dynamic height

Fig. 4 shows the absolute geostrophic surface velocity vectors superimposed on the ADT map. One can see that the vectors leave the higher values of ADT to their right, as expected. The AzC can be seen between 33ºN and 35ºN (the eastward flow).

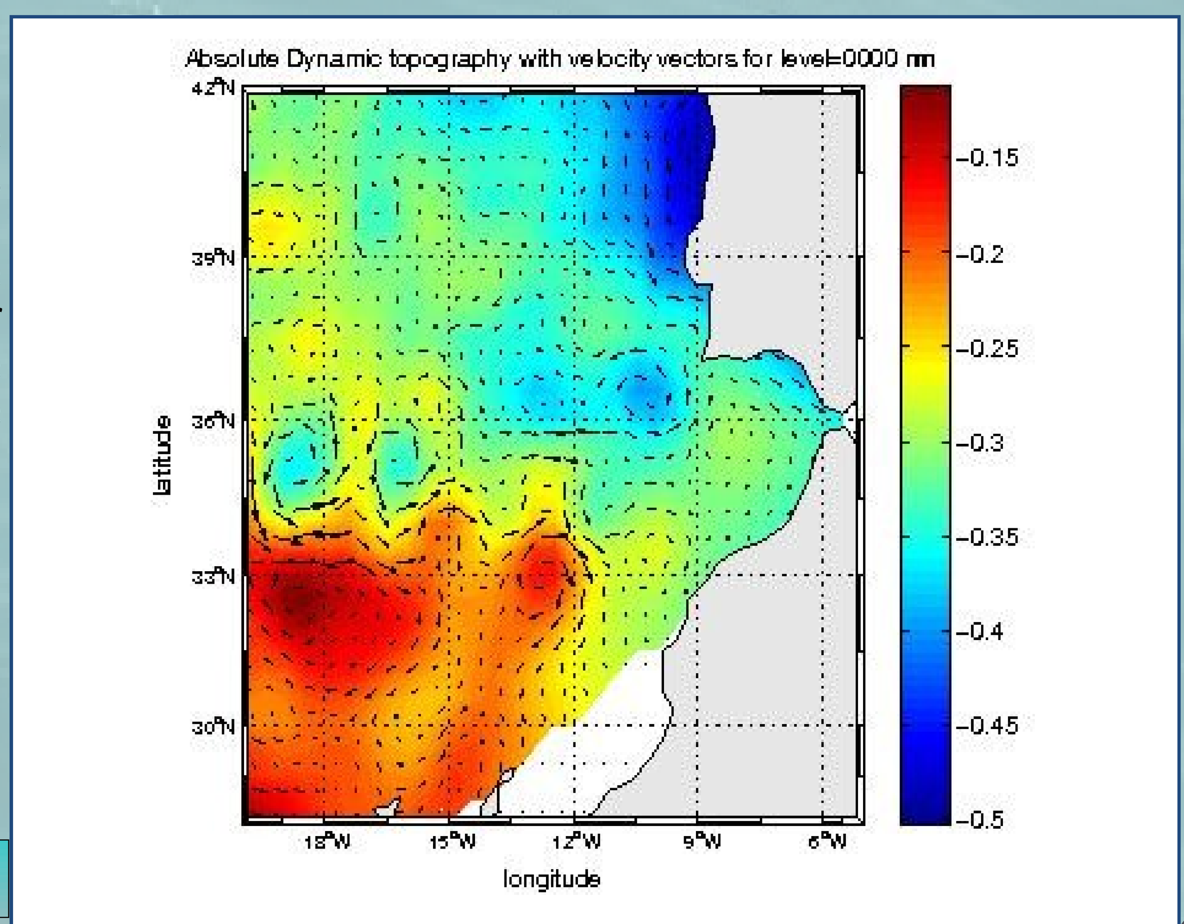
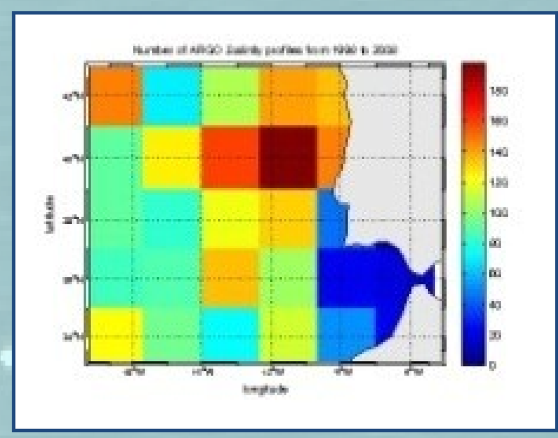


Fig. 4 – Absolute geostrophic surface velocity vectors plotted over an ADT map.

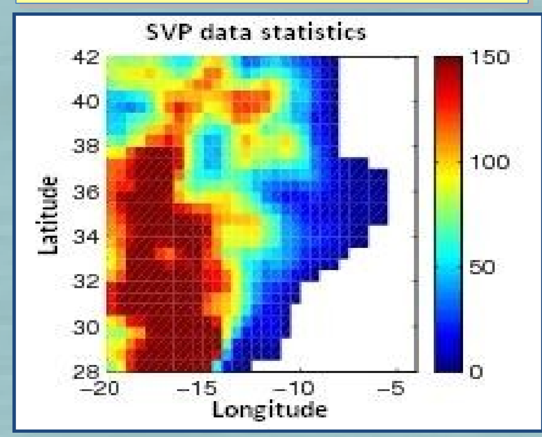
3. Absolute Surface Velocity

- In this work two different data sets were used to calculate absolute velocity fields, ARGO data combined with altimetry [7] and drifters data provided by the Surface Velocity Program [8].
- Fig. 5 shows the data coverage for the Gulf of Cadiz Region.

ARGO: 1998 - 2008



SVP: 1993 - 2005



Altimetry + ARGO: 1998 - 2008   **SVP : 1993 - 2005**

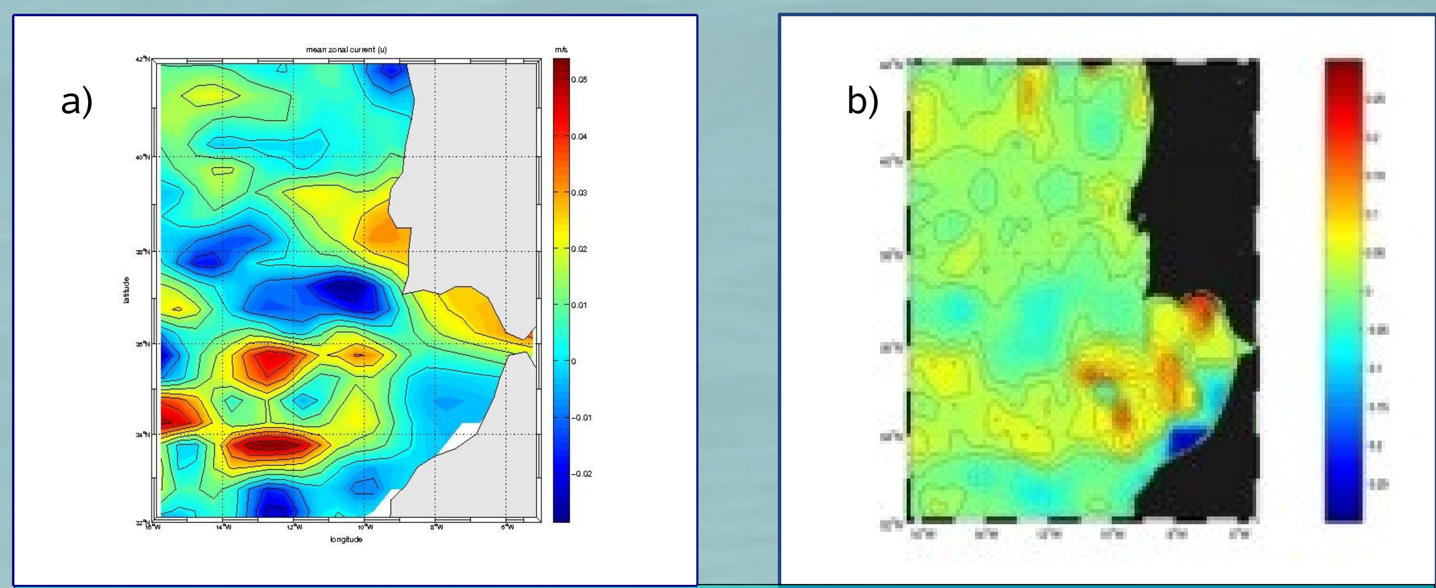


Fig. 6 – time-mean absolute surface velocity calculated with a) ADT; b) SVP drifter buoys

- The time-mean absolute surface velocity fields calculated with ADT from altimetry and ARGO, and the one calculated with SVP drifter data [8], show the Eastward flow (AzC) and the westward countercurrent to the north. This result is consistent with that predicted by topography and eddy driven β – plumes (Fig.6).

STREAM FUNCTION

Altimetry + ARGO: 1998 - 2008   **SVP : 1993 - 2005**

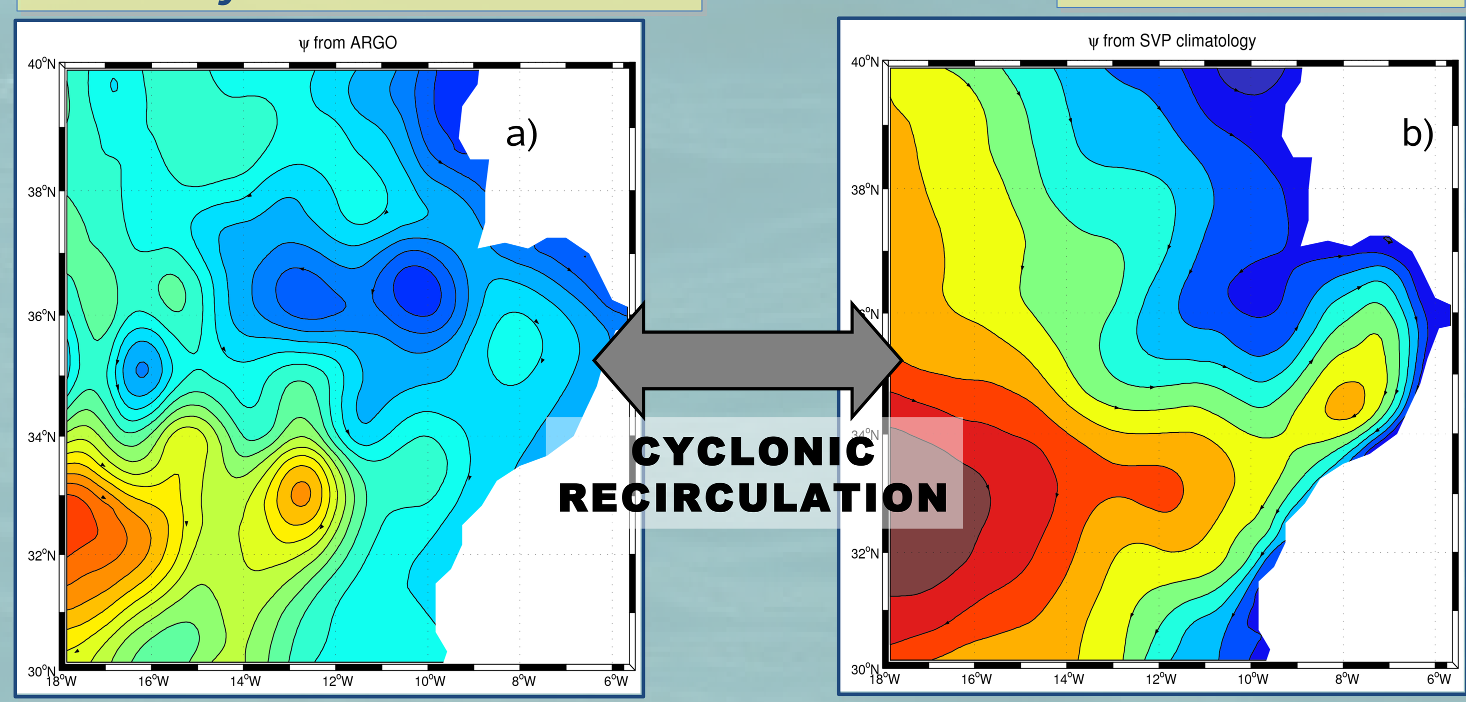


Fig. 7 – Stream function calculated for absolute surface velocities obtained from: a) Altimetry and ARGO data; b)SVP drifter buoys data

- The stream function was calculated for both surface velocity fields.
- In both cases, the flow enters the GoC from the southwest, circulates cyclonically and returns offshore in a west-northwest direction, generating a recirculation cell, as predicted by the β – plume theory (Fig.7).

5. Conclusions

- First observational evidence of a time-mean cyclonic recirculation cell resembling a β – plume, as predicted by several models, has been presented.
- Data from SVP drifter buoys and a product of Absolute Dynamic Topography (resulting from the merging of ARGO with Altimetry), were used to calculate time-mean absolute surface velocities, showing a cyclonic recirculation in the GoC, as predicted by models [3, 5, 1, 6].
- The increasing number of observations over the past 10 years (including ARGO data) was critical to reach such a result, since this cyclonic cell is only expected in the time-mean circulation. However, the data coverage of the study region is still low and needs to be complemented.

6. References

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[7]http://apdrc.soest.hawaii.edu (Atlantic – Pacific Data Research Center)
[8] www.aoml.noaa.gov/phod/dac/gpd_drifter.html (Global Drifter Program)

7. Acknowledgments

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