COHERENT VORTICES IN THE MEDITERRANEAN SEA

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Abstract

Some of the ideas and methods commonly used to study coherent structures in turbulent flows have been applied to analyse the role of coherent vortices in the Mediterranean Sea. Results have provided for the first time a general picture of the evolution of mesoscale eddies in the Mediterranean basins, and allowed analyzing in detail the relationship between their spatial structure and the transport and mixing of tracers, as well as the impact of ocean structures in the statistical properties of the Mediterranean circulation. A remarkable novel aspect is that the Mediterranean circulation is approached by extracting and isolating the dynamical role of the coherent structures.

Keywords : Mesoscale Phenomena, Remote Sensing, Turbulence, Circulation.

Coherent structures are recognized to be a key component to understand the dynamics of turbulent flows, and to have a great impact on the mixing properties of tracers. The quasi-bidimensional nature of the ocean flows together with the view, as seen in satellite images, of an ocean surface populated by mesoscale structures, lead to consider the two-dimensional and geostrophic turbulence theories as a paradigm for understanding the ocean dynamics.

Following these theories, the identification of vortices in two-dimensional geophysical flows has been proposed in terms of the Okubo - Weiss parameter W [1], defined as the square of the normal component of flow strain, plus the square of its shear component, minus the square of relative vorticity. We use W to identify a vortex (in fact the vortex core) as the simply connected region with W <- 0.2 σ (the spatial standard deviation of W), a useful threshold to establish the dominance of vorticity over strain.

Application of the method to altimeter sea surface anomaly maps [2] allows computing a census of vortex in the Mediterranean Sea. We have defined a coherent vortex as a vortex with amplitude (maximum of W inside the vortex) higher than 2 σ. Figure 1 shows the centers of coherent vortices identified in altimetric maps for a period of seven years. The different Mediterranean sub-basins do not have the same characteristics, and the detected structures concentrate mainly in areas where mesoscale eddies have been commonly observed by other means. The spatial distribution of most intense coherent vortices is correlated with the areas of high levels of eddy kinetic energy [3].

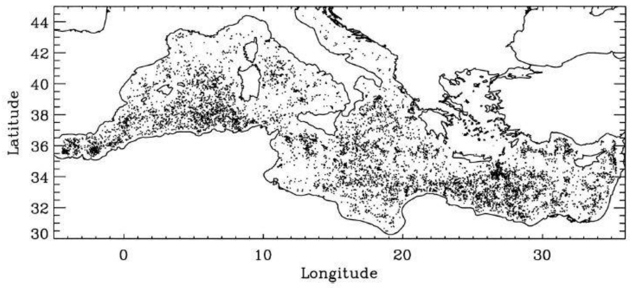

Fig. 1. Spatial distribution of the centers of observed intense vortices (a $>2\sigma_W$) for the period October 1992 - October 1999

An important outcome from 2D turbulence simulations is that coherent structures are responsible for the non-Gaussian character of the statistics on velocity fields [4]. Evidences on the non-Gaussianity of ocean velocity fields have been signaled from altimeter data, currentmeters and Lagrangian floats [5]. In the Mediterranean Sea probability density function (PDF) of velocity fields derived from Lagrangian buoys and from altimetric maps exhibit similar characteristics: a Gaussian core with tails separating from the Gaussian behaviour (Fig. 2). Using a field separation based on W we can determine the field associated to intense vortices and the contribution from the resulting background field. Fig. 2 shows that the non-Gaussian part of the velocity PDF is due to intense vortices that represent only 20 % of the total detected structures [6].

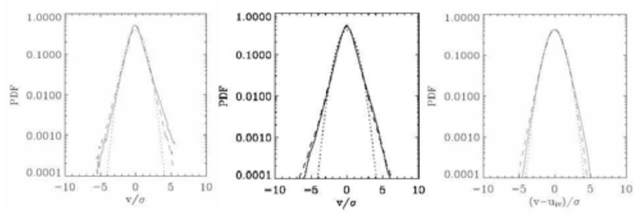

Fig. 2. Probability Density Functions of the Mediterranean surface velocity field obtained from Lagrangian drifters (left), from coherent vortices in altimetric maps (centre), and from the background altimettric velocity field (right)

These results suggest that intense vortices play a major role in the Mediterranean dynamics. To go deeper we have also performed an analysis of the vorticity field for the same dataset, but following a completely different technique for flow separation [7]. The flow is supposed to be separated in a non-coherent and a coherent part extracted by wavelet projection of the vorticity field. The velocity field associated with the coherent part, which is built from a relatively small number of wavelet coefficients, accounts for most of the enstrophy and energy of the original field.

This reinforces the idea that the small percentage of intense vortices dominates the dynamics in the Mediterranean Sea. Indeed, these structures are the main responsibles for the non-Gaussian velocity PDFs, which induce anomalous dispersion, and then classical constant eddy diffusivity approaches should be discarded in favor of more complex formulations. To account for the particle dispersion due to vortices, Lagrangian models may be formulated through a two-component stochastic process separating the dynamical contribution associated with the background non coherent induced field and the vortex-coherent induced dynamics.

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