Uniformly distributed vortex models: elliptic (Kida vortex), ellipsoidal vortices in deformation flows. Regular and chaotic dynamics

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Here we give a brief review of quasi-geostrophic dynamics of ellipsoidal vortex embedded in a deformation flow $\psi_0 = \frac{\gamma}{2}\left(x^2 + y^2\right) - exy - u_0 y + v_0 x$ in the approximation of the infinitely deep rotating ocean with a constant buoyancy frequency [1]. Deformation flows are flows incorporating shear, strain and rotational components. These flows are ubiquitous in the geophysical media, such as the ocean and atmosphere [2-4]. They appear near almost any salience, such as isolated coherent structures (vortices and jets), various fixed obstacles (submerged obstacles, continental boundaries). Fluid structures subject to such deformation flows may exhibit drastic changes in motion.

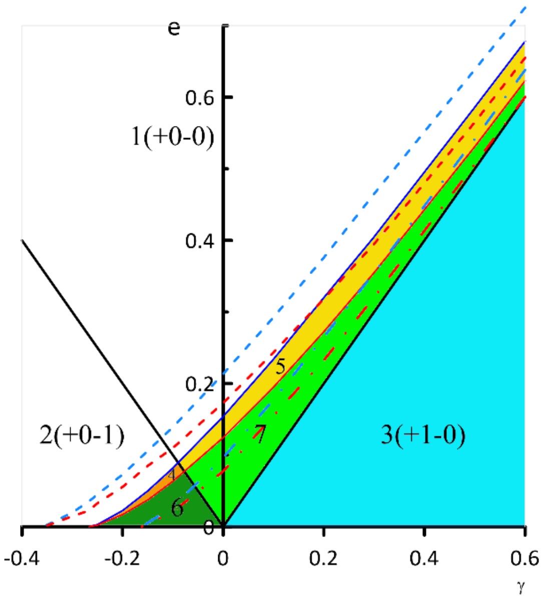

Fig. 1. Regimes of the ellipsoidal vortex motion on the plane (γ, e).

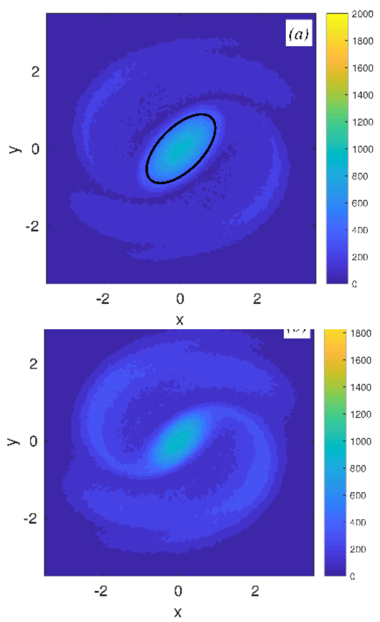

Fig. 2. Marker distributions after 40 characteristic time steps out of evenly distributed within the ellipsoid $6\cdot10^3$ markers for the case of a non-stationary vortex. (a) – the surface layer, (b) - the lower layer of the initial marker distribution. The vertical and horizontal turbulent diffusion are in action.

We consider the vortex with an ellipsoidal core with constant vorticity different from the background vorticity value. The core is shown to move along with the flow and to deform under the effect of it. Regimes of the core's behavior depend on the flow characteristics and the initial values of the vortex parameters (the shape and the orientation relative to the flow). These regimes are (i) rotation (along with the ellipsoid's axes ratio oscillation), (ii) oscillation about one of the two specific directions (along with the axes ratio oscillation), and (iii) infinite horizontal elongation of the core (see fig. 1).
It is shown, that zones of the water mass capturing can appear in the induced velocity field in the localized regimes (rotation and oscillation) of the core motion. The mechanisms of fluid particle trajectory chaotization are revealed; in particular, it is shown that owing to the double periodicity of the core motion, all the nonlinear resonances appear as pairs of two resonance islands with the same winding number. Also, we will consider the impact of diffusion on passive impurity advection (see fig. 2 and [5]).
In the case of the non-steady periodic deformation background flow, we will show the parametric resonance phenomena in the vortex core dynamics.
Finally, we analyze the possibility of the vortex core depth determination from its dynamic on the surface. If know the vortex semi axes oscillation amplitude and frequency, we can choose the appropriate phase portrait by varying the modeling vortex depth (see fig. 3 for typical phase portraits).

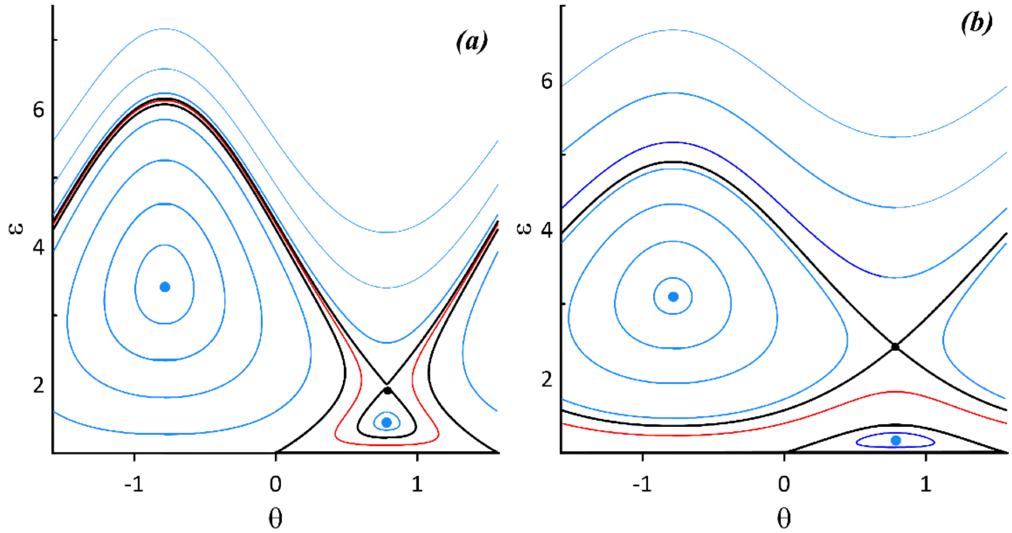

Fig. 3. Phase portraits of the ellipsoid vortex motion corresponding to Regimes: (**a**) 4 ($e = 0.02$ and $\gamma = -0.2$); and (**b**) 6 ($e = 0.01$ and $\gamma = -0.2$).

Références

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