VORTEX PAIR SCATTERING ON δ-SHAPED OBSTACLE

Ryzhov Evgeny[1], , Koshel Konstantin[1,2]
[1] *Pacific Oceanological Institute, Vladivostok, Russia*
[2] *Far Eastern Federal University, Vladivostok, Russia*

Abstract Using the quasi-geostrophic approximation [1], a model for a self-propagating vortex pair passing over an isolated δ-shaped obstacle on the f-plane is formulated. Without any background flow, the pair is scattered by the topography in an angle depending on the initial positions of the pair, the distance between the vortices and their strengths. However, the very dipole structure of the vortex pair undergoes insignificant changes during the passage. On the contrary, if there is an opposite-directed plane constant background flow, then the dynamics of the pair drastically alters. Now, the pair can be tore apart by the topography and the background flow, such that one vortex from the pair is being trapped by the topography, and the other vortex is being carried away by the background flow.

PAIR DYNAMICS WITHOUT A BACKGROUND FLOW

A self-propagating vortex pair (dipole) is a prominent vortex structure consisting of two opposite-strength vortices. Without any exterior perturbation, such a vortex pair propagates rectilineary and uniformly. In this paper, we investigate the passage of such a vortex pair over a topographic submerged obstacle. To this end, we employ the simplest model of vortical geophysical flows, namely, the model of geostrophic singular vortices [2]. Thus, the stream-function of the flow has a simple form in Cartesian coordinates $(x,\, y)$,

$$\psi = Uy + \mu \log\left(\frac{x^2 + (y+d)^2}{x^2 + (y-d)^2}\right) + \sigma \log\left(x^2 + y^2\right), \tag{1}$$

where ψ is the dimensionless geostrophic stream-function being proportional to the pressure, d is the initial distance between the pair's vortices, U is the dimensionless background flow velocity, μ is the dimensionless absolute value of the pair vortices' strengths, σ is the dimensionless topographic parameter of the closed recirculation zone, being generated by the submerged δ-shaped obstacle (further we will call this recirculation zone as the topographic vortex [3]).

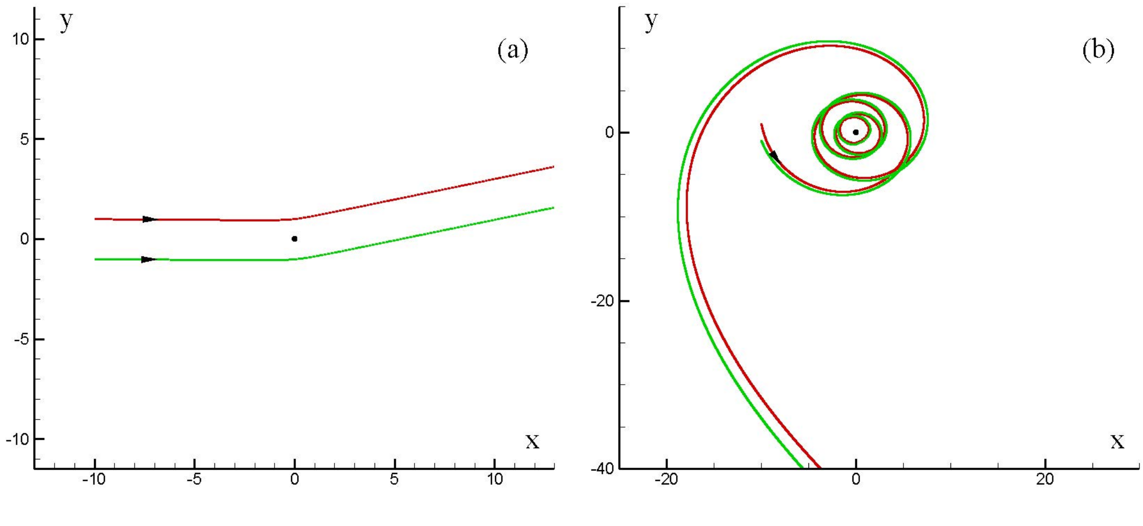

Figure 1. Vortex pair scattering: (a) weak scattering $\sigma = 10,\ \mu = 0.5$; (b) strong scattering $\sigma = 1,\ \mu = 0.5$.

Firstly, we consider the vortex dynamics without any background flow ($U = 0$). In this case, the submerged obstacle generates closed, extended to the infinity, stream-lines, which deviate the rectilinear and uniform propagation of the vortex pair. This deviation can be slight (see trajectories of the pair in fig. 1a) or very strong resulting in complete changing of the propagation direction of the vortex pair (see fig. 1b).

PAIR DYNAMICS DUE TO A CONSTANT BACKGROUND FLOW

Secondly, adding a constant background flow ($U = const$), the vortex dynamics alters drastically. Now, the vortex pair can be tore apart by the topography and background flow. The presence of the background flow results in the appearance of a separatrix, that encloses the topographic vortex region. So, the self-propagating vortex pair starts moving out of the topographic vortex closed region, and undergoes the influence of the topographic vortex only in its immediate vicinity.

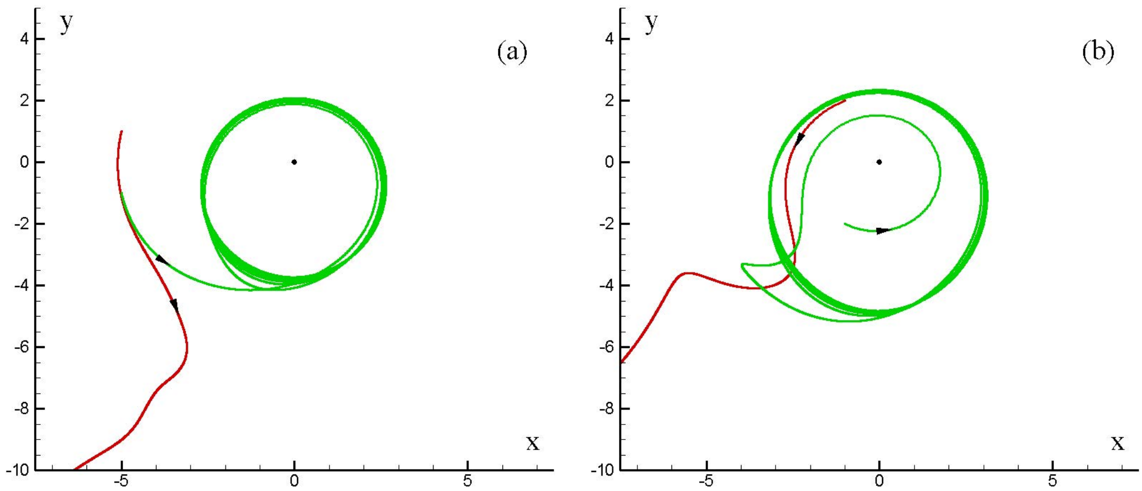

Figure 2. Vortex pair rupture: (a) $\sigma = 5,\ \mu = 1,\ W = -1,\ x = -5,\ y = 1$; (b) $\sigma = 5,\ \mu = 1,\ W = -1,\ x = -1,\ y = 2$.

So, if the the vortex pair manages to reach the separatrix, then, the vortex pair can be tore apart by the background flow (see fig. 2a). One vortex of the pair starts moving in closed trajectories about topographic vortex, while the other is being carried away by the background flow to the infinity. Figure 2b shows the rupture of the vortex pair, which starts moving within the topographic vortex. One can see that one vortex is being still carried away by the background flow, while the other, after a short time, is moving in closed regular trajectories.

References

[1] J. Pedlosky, *Geophysical Fluid Dynamics 2 ed.*, Stringer, New York (1987).
[2] V. M. Gryanik, M. V. Tevs, *Izv. Atm. Ocean. Phys.* **25**, 179–188 (1989).
[3] E. A. Ryzhov, K. V. Koshel, *Geophys. Astrophys. Fluid Dyn.* **105**, 536–551 (2011).