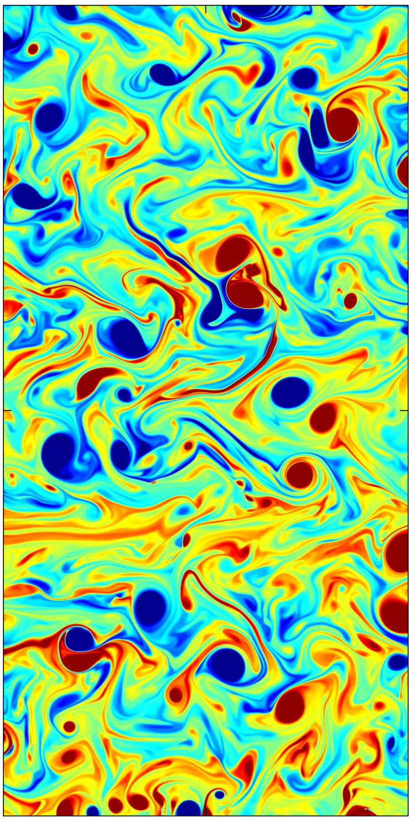
*Proposed PhD Research Project:*
# Isolated Coherent Vortices in Geostrophic Turbulence

## 1. Statement of the Problem



Mesoscale oceanic eddies play an important role in ocean dynamics by affecting isopycnal material transport, vertical stratification, large-scale currents, and air-sea interactions. Eddies occur virtually everywhere in the ocean, and their observational evidence comes from in-situ and satellite measurements (e.g., Chelton et al. 2011). The last decades have seen remarkable progress in understanding physical processes governing mesoscale eddies and their effects (e.g., review by McWilliams 2008). The theoretical framework for eddy dynamics is well established, and recent advances in observations and numerical models have allowed continued improvements in theoretical understanding of the properties, causes, and effects of the eddies. Many oceanic eddies behave like planetary waves, but many other eddies are better described as coherent isolated vortices, which are characterized by localized and concentrated vorticity anomalies. These vortices are relatively long-lived, and, during their lifetime, they transport huge amounts of water and various important properties, such as heat and chemical compounds.

Recently, as illustrated by the color Figure showing an instantaneous snapshot of the vorticity field (with intense red and blue anomalies corresponding to the cyclonic and anticyclonic vortices), high-resolution numerical simulations of baroclinic turbulence have captured, for the first time, dynamically consistent generation and consequent evolutions of ensembles of coherent isolated vortices, at an unprecedented level of detail and accuracy (Berloff et al. 2011).

The Project will focus on understanding the dynamical mechanisms that govern these enigmatic flow features.

## 2. Milestones of Analysis

The ambitious goal is to overhaul the existing theories of isolated coherent vortices (e.g., McWilliams 1986). The starting point will be statistical and dynamical analysis of the numerical model solutions, and this will require a fair amount of original scientific computation, as well as development of vortex detection and tracking algorithms. Then, we will proceed with taxonomy of the vortex population and systematic statistical description of the vortices's structural properties, trajectories, genesis and life cycles.

The phenomenological and statistical analyses will be followed by the broader research agenda:

- Dynamical analyses of individual-vortex models;
- Mechanisms of vortex generation and propagation;
- Material transport properties of vortices illuminated by Lagrangian and passive-tracer analyses;
- Mean-flow/vortex and vortex-vortex nonlinear interactions and feedbacks;
- Linear stability analysis of vortices;
- Radiation of planetary waves from unstable vortices;
- Rectification of vortex-induced flows.

The student will benefit from the interdisciplinary nature of the Project that combines Geophysical Fluid Dynamics, Applied Mathematics, and Numerical Modelling.


**References**

Berloff, P., S. Karabasov, J. Farrar, and I. Kamenkovich, 2011: On latency of multiple zonal jets in the oceans. *J. Fluid Mech.*, **686**, 534–567.

Chelton, D., M. Schlax, and R. Samelson, 2011: Global observations of nonlinear mesoscale eddies. *Progress in Oceanography*, **91**, 167–216.

McWilliams, J., 2008: The nature and consequences of oceanic eddies. In *Eddy-Resolving Ocean Modeling*, M. Hecht and H. Hasumi, eds., AGU Monograph, 131–147.

McWilliams, J., 1984: The emergence of isolated coherent vortices in turbulent flow. *J. Fluid Mech.*, **146**, 21–43.