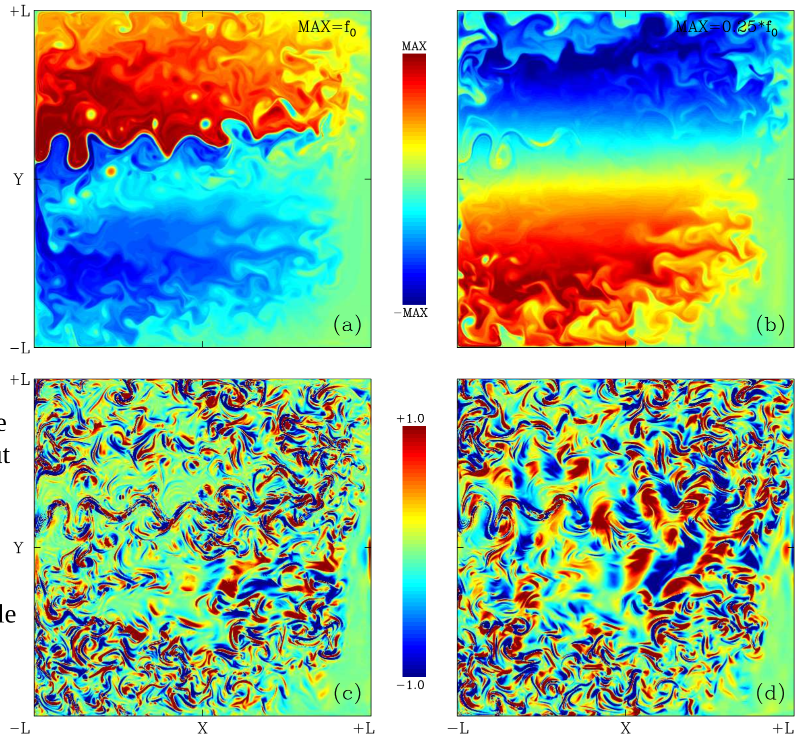
Proposed PhD Research Project:
Stochastic Parameterization of the Oceanic Eddy Backscatter

1. Statement of the Problem



The color Figure shows instantaneous snapshots of an idealized ocean circulation model: (a) upper-ocean and (b) deep-ocean fields of potential vorticity. This circulation is characterized by the giant subtropical and subpolar gyres, which are separated by the relatively narrow and fast eastward jet that meanders, radiates waves and sheds intense vortices. This jet is dynamically equivalent to the Gulfstream and Kuroshio extensions in the North Atlantic and Pacific. The jet extensions are very important for the climate and climate variability. For example, without the Gulfstream Great Britain would be fully covered by permanent glaciers, as this has happened in the past. The jet extension is maintained and controlled by the eddy backscatter process that translates small-scale nonlinear interactions (shown on the lower panels in terms of the instantaneous snapshots for the (c) upper and (d) deep oceans) into the strong jet with adjacent nonlinear recirculation zones and intrinsic variability over a broad range of scales (Berloff 2005; Berloff et al. 2007).

The goal of this Project is to figure out how to model the small-scale nonlinear interactions maintaining the eddy backscatter in terms of space and time correlated stochastic processes. This ambitious goal makes the Project a puzzle of fundamental fluid dynamics and stochastic processes, leading to new ways of thinking about turbulence. In perspective, accurate and efficient mathematical modelling of small-scale eddies is essential for improving predictive skills of the comprehensive climate models, but a great deal of physical understanding needs to be gained on the way.

2. Milestones of Analysis

On the one hand, the starting point will be comprehensive statistical and dynamical analysis of the numerical model solutions with various coarse-graining methods. We will construct time history of space-dependent nonlinear eddy forcing and look for its regressions on high-order stochastic processes, as well as for its correlations with the large-scale fields. On the other hand, we will project variability of the large-scale flow on the empirical orthogonal functions and their principal components and look for a simple set of nonlinear ODEs modelling the principal components and driven by additive or multiplicative stochastic noise.

These analyses will be complimented by the broader research agenda:

- Lagrangian analysis of potential-vorticity anomalies;
- Dynamical analysis of elementary stochastic forcings, represented by linear and nonlinear Green's functions;
- Extension of the above dynamical analysis to various background flows and distributed stochastic forcings;
- Search for local or nonlocal relationships between parameters of the stochastic processes and the large-scale fields.

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

References

Berloff, P., A. Hogg, and W. Dewar, 2007: The turbulent oscillator: A mechanism of low-frequency variability of the wind-driven ocean gyres. *J. Phys. Oceanogr.*, **37**, 2363–2386.

Berloff, P., 2005: Random-forcing model of the mesoscale oceanic eddies. *J. Fluid Mech.*, **529**, 71–95.