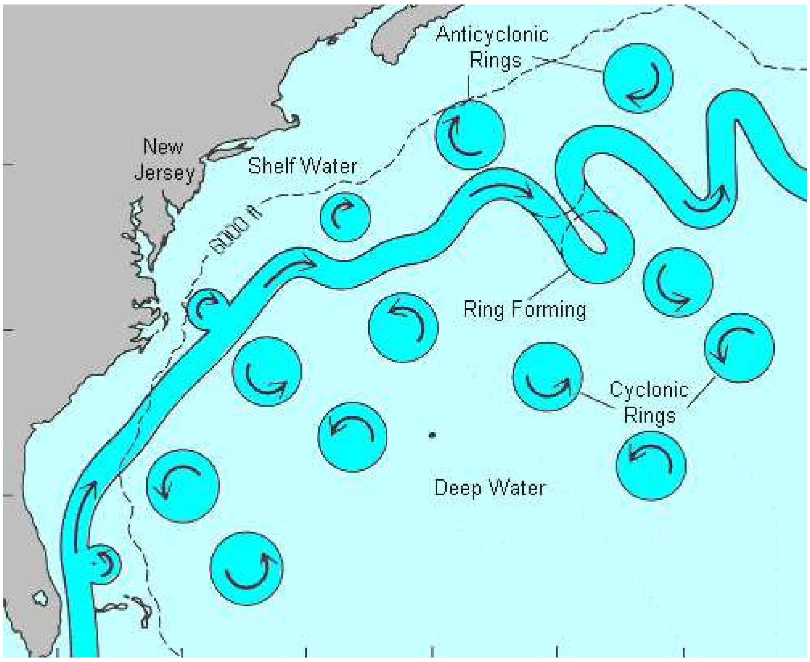
Proposed PhD Research Project:
Gulf Stream Dynamics with Primitive Equations

1. Statement of the Problem



The mighty Gulf Stream current (see its sketch on the Figure) originates in the Caribbean basin, then follows the eastern coastline of the United States, until it separates from the coast near the Cape Hatteras. After its separation, the Gulf Stream continues in the form of the north-eastward jet extension that carries relatively warm water across the North Atlantic towards Europe, and, thus, keeps European climate warm and mild.
The Gulf Stream can be viewed as giant, ribbon-like "river in the ocean" that meanders, sheds enormous vortices called the "rings", radiates complicated planetary waves and mixes up the North Atlantic waters.

Properties of the Gulf Stream flow system are heavily controlled by the Earth rotation and sphericity, as well as by the water density distribution across the ocean, by the coastline and bottom topography shapes. Because of all these factors, dynamical understanding of the Gulf Stream structure, spatio-temporal variability and other properties remains elusive, despite more than half-century of vigorous research on this challenging topic.

Nowadays, theoretical research on the Gulf Stream dynamics clusters around 2 main directions. On the one hand, the *primitive-equation* (i.e., with the minimal number of approximations made) oceanic general circulation models are configured and run in realistic set-ups and eddy-resolving regimes to provide some pioneering solutions. Unfortunately, these solutions are so expensive, that they can not be used for systematic studies of the underlying dynamical processes. On the other hand, most of the theoreticians who study the underlying processes confine their research to overidealized dynamical models (e.g., the classical quasigeostrophic model) that are good for representing some physical processes but are not good for some others. Thus, the present situation is extremely beneficial for upgrading the existing theories of the Gulf Stream dynamics with more advanced primitive-equation models, configured in spatially localized and geometrically idealized settings, with full control over the external forcing parameters.

The *goal of this Project* is to carry out ambitious supercomputations of the Gulf Stream evolution in geometrically idealized by dynamically rich mathematical approximations. *The Project is extremely challenging and intensive on the computational side.*

2. Milestones of Analysis

The Project will involve massively parallel simulations of the Gulf Stream with "light" and "heavy" types of primitive-equation models, for a sequence of increasing Reynolds numbers (hence, with increasing nonlinear eddy effects), and for various water density distributions. The codes of both models are freely available, but mastering them, configuring the models, carrying out all the computations, and analyzing the model solutions are all difficult tasks that will require genuine interest in scientific computations and computer modelling.

• The "light" model will be of shallow-water type with just a few constant-density layers;

• The "heavy" model will be with spatially fixed computational grid involving many vertical degrees of freedom;

• Dynamical analyses of the solutions will involve systematic upgrades of the massive theoretical knowledge about the Gulf Stream, accumulated over the last 50 years; these analyses will rely on various techniques that have to be adapted for the primitive equations.

References

Take a look at fascinating videos of the cutting-edge primitive-equation simulations of the Gulf Stream:
http://web.atmos.ucla.edu/˜gula/2/movies.php