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Numerical Simulation of Transient Boundary-Forced Radiation. Part I: The Linear Regime

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ABSTRACT

Increasing evidence suggests that the Gulf Stream system is the origin for much of the eddy variability observed in the northwestern Atlantic Ocean. However, the dynamical mechanisms by which eddy energy, once generated in the neighborhood of the Gulf Stream, penetrates into the midocean regions are not fully understood. Here we explore the proposition that radiation away from the Gulf Stream can be interpreted as an oscillatory response of the ocean gyre interior to the forcing associated with translation and temporal evolution of the Gulf Stream current and its meanders. Specifically, we propose as a possible mechanism responsible for pules of Rossby wave radiation the sudden growth to finite amplitude and successive amplitude pulsations of quasi-stationary or eastward-moving finite-amplitude meanders. To examine this mechanism in detail, we construct a model for radiation in which the quasi-geostrophic equivalent barotropic potential vorticity equation is forced to its northern boundary by assigned distributions of streamfunction and vorticity corresponding to 1) a stationary pulsating meander, 2) a slowly propagating meander, and 3) a combination of 1 and 2.

We use both analytical and numerical techniques to solve the linear boundary-forced initial value problem with and without lateral friction and with and without bottom topography. We focus not only on the steady forced response

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but also on the transient component of the interior Rossby radiation field. On the β-plane without topography, it is shown that radiation into the far field is only possible for meander pulsation below a critical frequency. Below this frequency, the transient far-field response is large and force basin modes are necessary, together with the forced equilibrium solution, to accommodate the prescribed initial state of the system. With the addition of viscosity to damp the transient basin modes, and for frequencies higher than the critical value, the response is trapped at the northern wall and no radiation can be supported in the far field.

The inclusion of a simple parabolic relief along the full channel does not modify the qualitative behavior of the interior field. The only effect of the parabolic relief is to modify the effective value of planetary β and the cross-channel structure of the westward-propagating Rossby modes. The above results are, however, profoundly altered with the addition of nonlinearity. In particular, new mechanisms are possible for the development of far-field radiation and for the appearance of nonlinear, coherent solutions, as will he shown in Part II of this paper.

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