Abstract View

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Numerical Simulation of Transient Boundary-Forced Radiation. Part II: The Modon Regime

Paola Malanotte-Rizzoli and Roberta E. Young

Department of Earth, Atmospheric and Planetary Sciences, Center for Meteorology and Physical Oceanography, Massachusetts Institute of Technology, Cambridge, Massachusetts

Dale B. Haidvogel

The Chesapeake Bay Institute, The Johns Hopkins University, Baltimore, Maryland

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ABSTRACT

In Part I of the present work we studied the transient Rossby wave radiation excited in the far field by a northern boundary forcing. We proposed as a possible mechanism responsible for transient pulses of Rossby waves the sudden growth to finite amplitude and successive amplitude pulsations of a stationary or eastward moving meander of an intense current like the Gulf Stream. In Part I the linear regime was thoroughly analyzed and the major findings were: 1) the transient part of the response initially excited by “switching on” the meander is the one responsible for the Rossby waves radiating and being clearly detectable in the far field; 2) the Rossby radiation is excited only when the meander pulsation frequency is below a critical value.

In this paper, we extend the results of Part I to the highly nonlinear regime addressing the problem of the production of nonlinear, coherent structures through the same boundary forcing mechanisms. The model used is the quasi-geostrophic, potential vorticity equation on a β-plane with or without topography, in a periodic channel forced by a northern boundary function. The forcing functions are designed to simulate (i) a stationary pulsating meander, (ii) a slowly propagating meander, (iii) a combination of both. This may constitute the simplest possible idealization of meander growth to finite amplitude, its successive steepening and bending with pinching off of eddies as frequently observed in the Gulf Stream system.

Using a boundary forcing idealizing a steady meander with a pulsating amplitude, we excite nonlinear vortices on the β-plane without topography. The related regime is called the “modon” regime as, at every pulsation cycle, two circulation patterns are produced, one cyclonic, the other anticyclonic. These vortices are part of a dipole pair and self-advect eastward or westward depending on their polarity (low-above-high or inverse). Through diagnostic tools

we show that these vortices are ‘reasonable’ modons, that is highly nonlinear, exact solutions of the equivalent barotropic model on the β-plane.

The second type of boundary forcing capitalizes upon a resonance mechanism which was previously studied analytically in the weakly nonlinear regime. In it, an interior vortex is resonantly excited by a meander with constant amplitude which propagates at one of the eigenspeeds of the free linear modes of the channel. This mechanism needs topography to be effective when using quasi-geostrophic dynamics. With parabolic relief all along the channel, a resonantly forced nonlinear eddy is excited in the interior which propagates eastward leaving the forcing wave trailing behind it. In the highly nonlinear limit, the excited vortex remains coherent against the effects of dispersion even when the northern boundary forcing is turned off. Through a process of Rossby-wave shedding, it adjusts itself to the free-modon solution of the potential vorticity equation with a parabolic topography, as shown by using modon diagnostics.

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