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Instability and Splitting of Mesoscale Rings using a Two-Layer Quasi-Geostrophic Model on an *f*-Plane

Motoyoshi Ikeda

Pacific Marine Environmental Laboratory, Environmental Research Laboratories, NOAA, Seattle, WA 98105

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ABSTRACT

Asymmetric instability of a circular Gaussian ring and evolution of a ring shape in a nonlinear case are studied using a two-layer quasi-geostrophic model on an *f* plane. Ring behavior is classified on an F-λ plane with other parameters fixed, where F is an internal rotational Froude number associated with a two-layer model, and λ is a ratio of the rotation speed in the lower layer to that in the upper layer. In the range concerned where $F < 4$ and $\lambda > 0$, the mode having an azimuthal wavenumber of 2 is the fastest growing, followed by the mode of the wavenumber 3. The ring is more unstable as F increases and as λ decreases, where larger F corresponds to smaller density difference or to a larger ring size. By numerical calculations, for which an initial perturbation of the wavenumber 2 is superimposed on a ring, ring behavior is classified into four groups from the most unstable to the most stable case: (i) a ring that splits into two small rings, (ii) a ring that rapidly becomes a slender ellipse and returns to a circle, (iii) a ring that slowly becomes an ellipse and returns to a circle, and (iv) a ring that approaches a circle from the beginning. For the groups (ii) and (iii), the ring is stabilized by nonlinear effects after the ring becomes a slender ellipse, although the ring is unstable during an infinitesimal perturbation.

Two connected rings are studied using numerical calculations. A weaker companion ring is absorbed into a stronger major ring when the distance between the two rings is identical to the radius of the ring. In contrast, when the distance is doubled, the companion separates from the major ring. The theory is applied to Gulf Stream rings.

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Headquarters: 45 Beacon Street Boston, MA 02108-3693
DC Office: 1120 G Street, NW, Suite 800 Washington DC, 20005-3826
amsinfo@ametsoc.org Phone: 617-227-2425 Fax: 617-742-8718
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