P3.6 MESOVORTICES, POLYGONAL FLOW PATTERNS, AND RAPID PRESSURE FALLS IN HURRICANE-LIKE VORTICES

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1. INTRODUCTION

Evidence exists that intensifying hurricanes, such as those which typically exhibit mesovortices within or near their eyewalls, generally contain thin annuli of enhanced vorticity in their eyewalls, and flow in the eye is often nearly irrotational. Emanuel (1997) provided theoretical evidence that the dynamics of the eyewall are frontogenetic and the local flow will tend towards a discontinuity. Using aircraft flight-level data, Kossin and Eastin (2001) found that during intensification, eyewall vorticity can become large within a thin annulus while vorticity near the eye center is nearly zero. An example of such a flow is shown in Fig. 1, which displays flight-level tangential wind and relative vorticity profiles observed by aircraft in Hurricane Guillermo (1997).

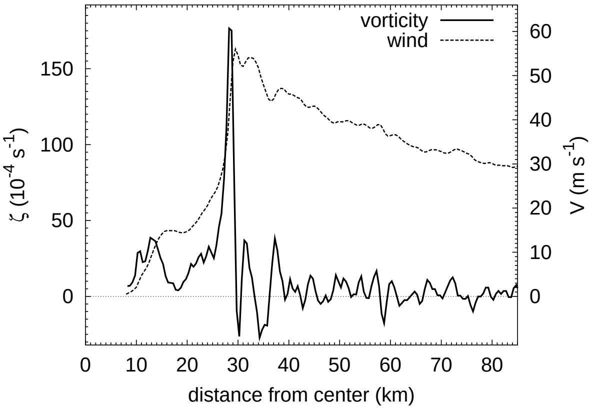

Figure 1: Flight-level profiles of vorticity and tangential wind observed in Hurricane Guillermo (1997).

The present work considers the unforced evolution of such thin annular rings of enhanced vorticity in a 2D barotropic framework, and demonstrates that a number of features that emerge bear strong resemblance to features observed in intensifying hurricanes. We find that under certain initial conditions, our numerical integrations produce mesovortices that are resistant to merger processes and can arrange themselves in persistent asymmetric configurations. Such resistance to merger has been well studied in the case of two corotating like-signed vortices (e.g., Moore and Saffman 1975; Saffman and Szeto 1980; Overman and Zabusky 1982; Griffiths and Hopfinger 1987; Melander et al. 1988; Carnevale et al. 1991a; Fine et al. 1991) and has more recently been considered in the case of n vortices which can emerge in electron plasma experiments and numerical simulations from unstable initial conditions, and subsequently arrange themselves into asymmetric equilibrium configurations (e.g., Fine et al. 1995; Jin and Dubin 1998; Schecter et al. 1999; Durkin and Fajans 2000). If the mesovortices eventually merge into a monopole at the vortex center, dramatic contraction of the radius of maximum wind (RMW) and subsequent central pressure falls are possible simply in terms of vorticity rearrangement in the complete absence of moist physical processes.

2. RESULTS

Numerical integrations are performed using a 2D barotropic pseudo-spectral model. In this model, vorticity evolution is described by

$$\frac{\partial \zeta}{\partial t} + \frac{\partial(\psi, \zeta)}{\partial(x, y)} = \nu \nabla^2 \zeta, \qquad \nabla^2 \psi = \zeta.$$

The model uses 512 × 512 collocation points on a 200 km × 200 km doubly cyclic Cartesian domain. The pressure field is diagnosed using the nonlinear balance equation

$$\frac{1}{\rho} \nabla^2 p = f \nabla^2 \psi + 2 \left[\frac{\partial^2 \psi}{\partial x^2} \frac{\partial^2 \psi}{\partial y^2} - \left(\frac{\partial^2 \psi}{\partial x \partial y} \right)^2 \right].$$

The model is initialized with a slightly perturbed axisymmetric basic state vorticity shown by the solid line in Fig. 2a. This unstable initial vortex quickly rolls up into a number of mesovortices that subsequently undergo rapid mergers but do not immediately merge to a monopole. Instead, 5 mesovortices are maintained for a number of hours.

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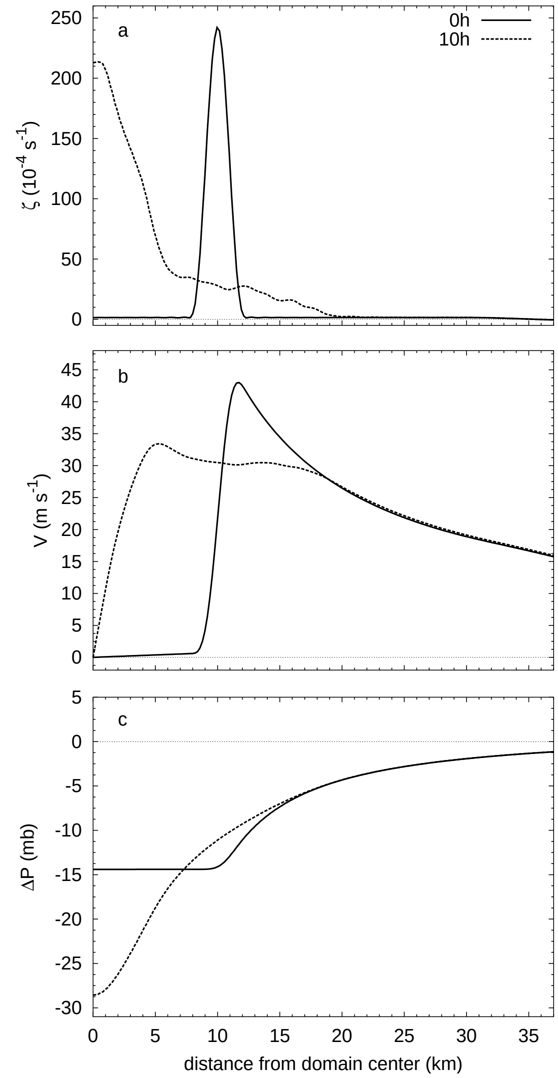

Figure 2: Azimuthal mean (a) vorticity, (b) tangential velocity, and (c) pressure perturbation at $t = 0$ (solid), and 10 h (dashed).

The interface between eye and eyewall reflectivity measured in hurricanes can consist of a number of straight line segments which give the eyes a polygonal appearance. The reflectivity is a measure of the shape of a mass of particles (raindrops) which are falling through a background flow at their relative terminal velocities. The flow associated with a persistent mesovortex configuration would result in a similar reflectivity field, as shown in Fig. 3. The straight line segments are separated by "kinks" in the tracer field and are especially evident inside the annular region containing the mesovortices, that is, near the eye/eyewall interface. Each kink is located slightly upwind of a mesovortex. Kinks that are sometimes evident in hurricane reflectivity fields are typically located slightly upwind of local maxima of reflectivity.

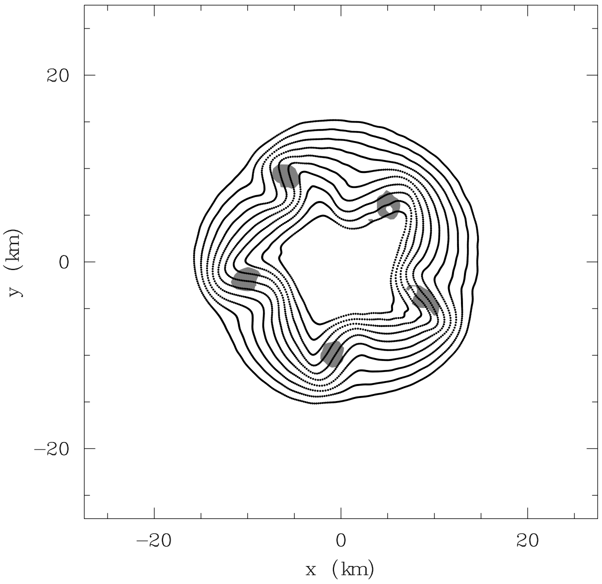

Figure 3: Convolution of initially concentric rings of passive tracers due to the presence of mesovortices in an eyewall. The mesovortices are identified by the small gray shaded areas.

If the mesovortices are not arranged in an equilibrium configuration, further mergers will occur, eventually forming a monopole. Such an end state is shown by the dashed lines in Fig. 2. At $t = 10$ h, the maximum average vorticity found near the domain center demonstrates the ability of the mesovortices to transport relatively unmixed vorticity from the initial annulus to the center of the final monopole. As high vorticity is transported inwards, the tangential winds inside $r \approx 10$ km increase considerably, the RMW decreases dramatically, and the central pressure perturbation doubles.

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3. REFERENCES

All references are found in

Kossin, J. P., and W. H. Schubert, 2001: Mesovortices, polygonal flow patterns, and rapid pressure falls in hurricane-like vortices. *J. Atmos. Sci.*, **58**, in press.

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