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IN WHAT SENSE IS THE HURRICANE EYE A “CONTAINMENT VESSEL”?

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1. INTRODUCTION

The exchange of air between the eye, eyewall, and surrounding environment of mature tropical cyclones is believed to be an important element in the understanding of the tropical cyclone intensity problem. The basis for this statement lies in the observations of Malkus (1958) and Willoughby (1998), both of whom investigate the structure, maintenance, and thermodynamics of mature hurricane eyes. Additional observations by LeeJoice (2000) and Eastin et al. (2003) support this view as well.

The current state of understanding implicates the following two ideas: (1) Mixing of moist boundary layer air from the eye into the eyewall represents an additional source of heat, and hence a boost in intensity (Schubert et al. 1999; Persing and Montgomery 2003). (2) Mixing of midlevel dry air from outside the rain area into the eyewall and/or eye may disrupt the thermodynamics that maintain the storm (Simpson and Riehl 1958; Emanuel 2003). As a first step in the current analysis, we employ the use of a high resolution simulation of vertically-sheared Hurricane Bonnie (1998). The simulation is carried out by Braun et al. (2003) using the PSU/NCAR MM5 (version 3.4). Horizontal grid spacing is 2 km on the innermost grid mesh.

2. APPROACH

Recent work by Prieto et al. (2001) furthers our understanding of tropical cyclone symmetrization processes in a 2D nondivergent barotropic model. A key element of their study is the computation of tracer particles, which showed mixing of air between the model eye, eyewall, and outside the vortex. Our method of analysis follows a similar approach by computing several thousand three-dimensional Lagrangian trajectories for air parcels seeded throughout the eye, eyewall, and surrounding regions of the vortex. The high number of trajectories is chosen in order to gather a “census” of the behavior and thermodynamic properties of air parcels in various regions of the mature system. Trajectories are computed (post model processing) 5 h forward in time using the three-dimensional model output (model output frequency is three minutes). Trajectories are seeded at every horizontal grid point within the eye, eyewall, and surrounding regions at various vertical levels throughout the troposphere; over 1000 trajectories are seeded at a single vertical model level.

3. RESULTS

Shown in Figure 1 are 10 sample trajectories viewed in the x-y horizontal plane. The trajectories are seeded in the boundary layer of the eye at a height of 453 m and 18-20 km from the storm center; the seed time is 15 h into the 2 km simulation. A radius-height view of these trajectories is shown in Figure 2. All of the trajectories shown are mixed into the eyewall (radius of maximum winds is approximately 40 km) and are carried upward in eyewall updrafts. Two of the trajectories, after reaching a height of 5-6 km in the eyewall updraft, are mixed back toward the storm center and come within 25 km of the center before being mixed back out into the eyewall updraft.

Figure 3 shows the percentage of trajectories seeded in the eye at a height of 453 m (a total of 857 trajectories) which reach the eyewall boundary during the 5 h trajectory calculation. Trajectories seeded as close as 6 km from the center are mixed out to the eyewall boundary within 5 h. Only 12 percent of these trajectories reach the eyewall; the “escape” percentage steadily increases with increasing seed radius.

The thermodynamic properties of the trajectories are being investigated as well. For the trajectories shown in Figs. 1 and 2, associated values of equivalent potential temperature [using Bolton’s (1980) formula] increase 5 K at low levels (initial values range between 368 and 370 K) before encountering the eyewall boundary (not shown).

Further details on trajectory behavior and associated thermodynamics will be given in the presentation. Ongoing work involves the analysis of trajectories seeded outside the eyewall. Results shown in Braun et al. (2003) suggest that despite the presence of environmen-

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*Corresponding author address: Thomas A. Cram, Department of Atmospheric Science, Colorado State University, Fort Collins, CO 80523; e-mail: tcram@atmos.colostate.edu tal shear on the system, the high voriticity core of the hurricane remains largely impervious to the entrainment of air parcels from outside the eyewall region.

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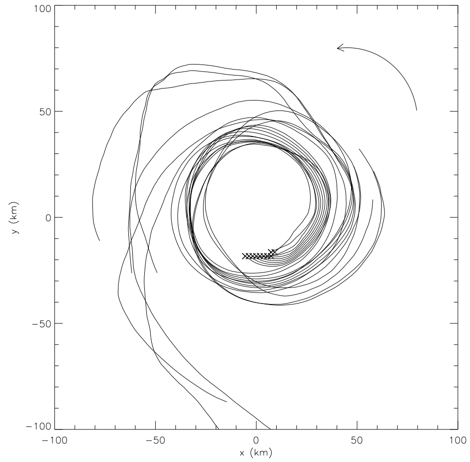

Figure 1: *Horizontal plan view of 10 sample trajectories seeded 18-20 km from the storm center and at a height of 453 m. Trajectory seed time is 15 h into the 2 km grid simulation and trajectories are calculated 5 h forward in time. Seed locations are marked by a '×'*

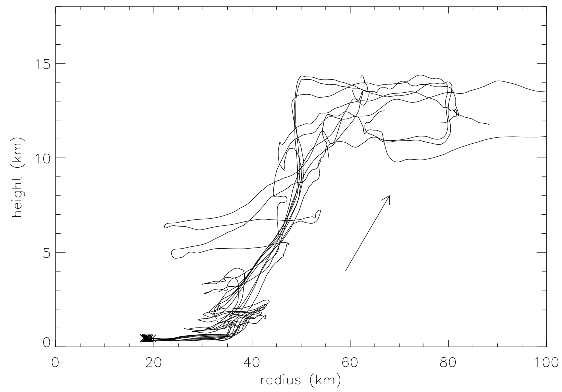

Figure 2: *The same trajectories shown in Fig. 1 viewed in a radius versus height perspective.*

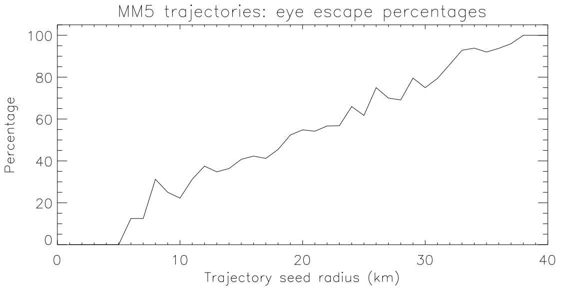

Figure 3: *Percentage of trajectories seeded at* $z = 453$ *m and inside a radius of 40 km which reach the eyewall boundary (*$r = 40$ *km). Percentages are plotted as a function of trajectory seed radius. Sample size is 857 trajectories.*