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TOPOGRAPHIC EFFECT ON A BAROTROPIC CYCLONE ENCOUNTERING A MOUNTAIN: LABORATORY EXPERIMENT AND NUMERICAL SIMULATION

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1. INTRODUCTION

The importance of topographic features on the evolution of tropical cyclones has been revealed in the literatures (e.g., Kuo et al. (2001); Lin et al. (1999)). In the present study, we do not dig into the complicated dynamics of tropical cyclones and their associated impacts from the topographic obstacles. Instead, we investigate the topographic effect of a barotropic vortex simply from the viewpoint of potential vorticity conservation under the framework of shallow water model. Several dimensionless parameters are defined to classify the flow dynamics qualitatively. From the experimental side, a stirred-induced vortex was generated in the vicinity of a scaled 3-D elliptic hill or in the vicinity of a north-south ridge in a rotating tank. From the numerical side, calculations based upon a modified shallow water model were performed to validate the experimental results. Close agreements were found between these two approaches, including the streamlines patterns and the vortex trajectory.

2. *THEORETICAL BACKGROUND*

2.1 Beta Similarity Laws For a Strong Cyclone Near Topography

Under the shallow water framework, we consider a strong cyclone motion ($Ro \approx O(1)$) in the vicinity of an isolated topography by assuming small variations of η and h_B , we can give an appropriate scaling on the cyclone motion so that the magnitudes of the non-dimensional variables are of order unity. Take the maximum tangential speed of the cyclone V_m as the reference velocity, $\zeta_m = V_m / R_m$ as the reference vorticity and ζ_m^{-1} as the reference time (the vortex turnaround time). In addition, we choose the maximum vortex depression η_v and the maximum topographic height h_M as the reference free-surface deviation and reference bottom topographic height, respectively, and thus we have two non-dimensional PV conservation forms

$$\frac{D}{Dt}\left(\left(\beta_0{}^*\right)_p y^* + \mu h_b{}^* - \gamma\mu^* + \zeta^*\left(1 + s_M^* h_b^* - s_v^* \eta^*\right)\right)_p = 0 \quad \text{(1a)}$$

$$\frac{D}{Dt}\left(\left(\beta_0{}^*\right)_m y^* + \mu h_b{}^* - \gamma\mu^* + \zeta^*\left(1 + s_M^* h_b^* + s_y^* - s_v^* \eta^*\right)\right)_m = 0 \quad \text{(1b)}$$

where Eqns (1a) and (1b) represents the non-dimensional PV conservation relationship, respectively. In these two equations, we have four important similarity parameters:

(a) the planetary beta parameter ,

$$\beta_0^* = \left(\frac{\beta_0 R_m^2}{V_m}\right)_p = \left(\frac{f_0 s_y R_m^2}{V_m D}\right)_m \quad (2)$$

(b) the topographic beta parameter and

$$\mu = \frac{f_0 s_M R_m a}{V_m D} \quad (3)$$

(c) the vortex beta parameter.

$$\gamma = \frac{f_0 s_v R_m^2}{V_m D} \quad (4)$$

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(d) the vortex size parameter

$$\lambda = a/R_m \ . \tag{5}$$

3. LABORATORY EXPERIMENT AND COMPUTATION

Laboratory experiments were performed in a rectangular glass water tank of horizontal dimensions 135 by 135 *cm* and 40 *cm* in depth mounted on a turntable (see Chu et al. 1998). See Chen (2001) for details on both the experimental apparatus and numerical calculations.

4. ILLUSTRATING EXAMPLE

Figure 1 illustrated an example of the results of streak photography of tracer particles (left column) and numerical streamlines (right column) for the vortex impinging the northern area of the 3-D hill. In the vicinity of the topography, a slight cyclonic deflection of the vortex path was observed both on the experimental and numerical results. Besides, when the vortex approached the topography, the translating speed of the vortex decreased and the vortex track deflected. After the vortex leaving the topography, both the translating speed and its direction were recovered to the previous state.

To explain the dynamics, both the slope effect and the size effect of the problem are very important. In this case, the planetary beta (which was mimic by a global sloping bottom) dominated the overall motion of the vortex; the local topographic effect originating from the 3-D elliptic hill was smaller than the background slope. Therefore, only a slight vortex path deflection was found in the results. Other experiments will be performed in our laboratory to investigate the general slope effect of the cyclone motion, for example, a vortex/ridge interaction.

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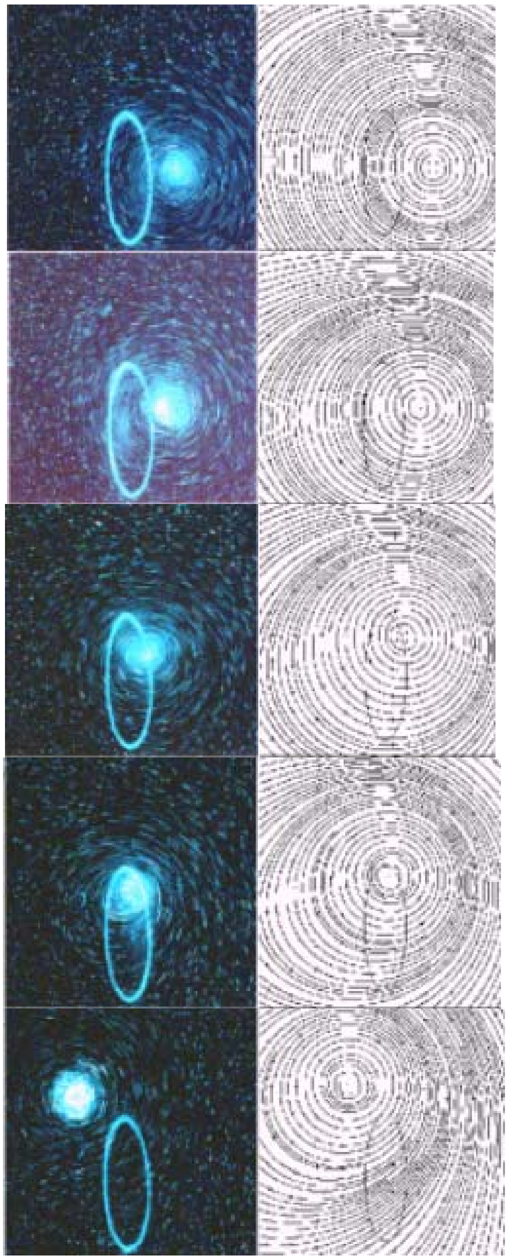

Figure 1 Vortex/topography interaction