P3.18

TRANSIENT WAKE FORMATION BY MOUNTAINS OF A BAROTROPIC CYCLONE ON A BETA-PLANE

Hung-Cheng Chen*, Chin-Chou Chu and Chien-Cheng Chang

Institute of Applied Mechanics, National Taiwan University, Taipei, TAIWAN, ROC

1. INTRODUCTION

Motivated by the observed mesoscale phenomena associated with the typhoons passing over the Central Mountain Range (CMR) of Taiwan Island, the underlying fluid dynamical aspects were investigated by numerical simulations of a barotropic cyclone interacting with a high mountain on a beta-plane. Using a modified shallow water model, a variety of flow features were revealed by monitoring the evolutions of the horizontal wind speed and the vertical vorticity during the vortex/mountain interaction. As the vortex approached to the southeastern side of the island by the planetary beta gyre, a pair of shedding vortices were formed on the lee side and was developed downstream of the mountain. Two strong hydraulic jumps emerged on the impinging of the main vortex to the wake vortices. After this impinging, the main vortex mixed with the shedding vortices and the whole vorticity patch was finally reorganized as a coherent vortex identity on the northwestern of the island. Applied to the flow features of a typhoon drifting past Taiwan, the simplified shallow water model captured many features of the observed phenomena such as upstream blocking, downstream sheltering, accelerated corner winds, and foehn and secondary vortex formation.

* *Corresponding author address*:
Hung-Cheng Chen,
National Taiwan University, Inst. of App. Mech., Taipei, 106 TAIWAN, ROC;
e-mail: d5543004@gauss.iam.ntu.edu.tw

2. NUMERICAL MODEL

A modified, dissipative shallow water model is proposed in this study and is written in non-dimensional flux form as:

$$\frac{\partial H}{\partial t} + \nabla \cdot \left(\vec{u} H\right) = 0 \qquad \text{(1a)}$$

$$\frac{\partial H\vec{u}}{\partial t} + \nabla \cdot \left(\vec{u} H \vec{u}\right) = -\left(Ro^{-1} + \beta_0 y\right)\vec{k} \times \left(H\vec{u}\right) \qquad \text{(1b)}$$

$$- Fr^{-2} H\nabla\left(H + h_B\right) + \hat{\nu}\nabla \cdot H\nabla\vec{u}$$

where Ro is the vortex Rossby number, β_0 is the beta number, Fr is the vortex Froude number and $\hat{\nu}$ is the non-dimensional kinematic viscosity coefficient. The dissipative momentum flux term was originally suggested by Schär and Smith (1993) on the simulation of hydraulic jump in the shallow water flow.

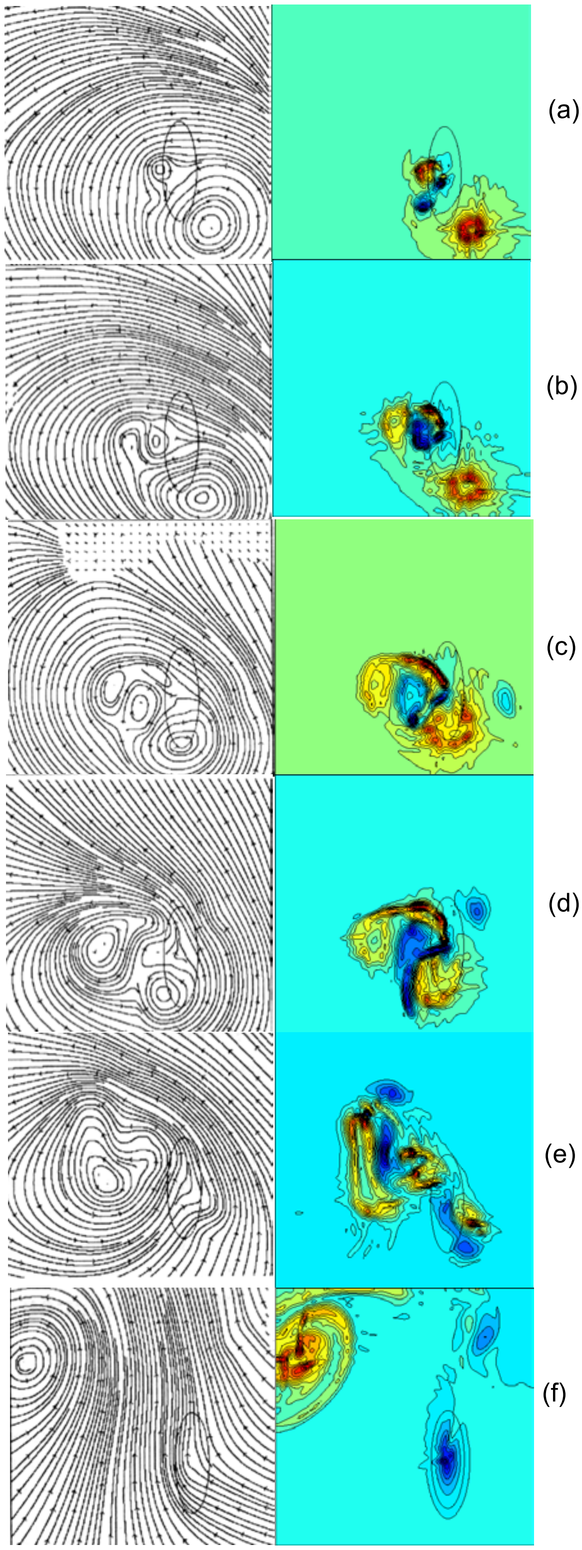
The numerical calculations were performed to numerically integrate (1a) and (1b) by a multidimensional positive-definite advection transport algorithm (MPDATA) which was proposed by Smolarkiewicz and Margolin (1998). In this study, we have also incorporated the MPDATA scheme by a Strang-splitting method and to implement the predictor-corrector concept for ensuring the time marching accuracy to second order under the influences of those forcing terms. On the treatment of boundary conditions, the relaxation boundary concept proposed by Davies (1983) are used.

3. PRELIMINARY RESULTS

Figure 1 illustrated an example of the results of the computational streamlines and vertical vorticity for an event of a typhoon-like vortex encountering an ideal 3-D elliptic mountain on a beta-plane. In this study, we observed the associated flow phenomena, especially on the transient behaviors of the vortex, in the vicinity of a very high and steep mountain. In this case, the ratio of the mountain height to the layer depth is 0.95; therefore, the flow will be accelerated from sub-critical into supercritical flow.

In figure 1, the vortex approached to the hill by the beta-effect and impinged on the southeastern side of the hill associated with a lee vortex (a). By a local topographic beta, the main vortex moved along the hill clockwisely and induced shedding eddies in the lee (b-c). From (c) to (d), the main vortex impinged into the area of shedding vortices and then encountered a series of chaotic, vorticity mixing from the shedding vortices with alternative sign. After that, in (f), an coherent vortex was reorganized behind the mountain in a surprising way. Besides, two lee-side hydraulic jumps were also found in (d) when the main vortex impinged into the lee vorticity patches.

Figure 1 Vortex/high mountain interaction



Reference:

Schär and Smith, 1993: Shallow-water flow past isolated topography. Part I: Vorticity production and wake formation. J. Atmos. Sci. 50, 1373-1400

Smolarkiewicz, P. K. & Margolin, L. G., 1998: MPDATA: A finite-difference solver for geophysical flows. J. Comput. Phys. 140, 459-480.

Kuo, H.-C., R. T. Williams, Jen-Her Chen, and Yi-Liang Chen, 2001: Topographic effects on barotropic vortex motion: no mean flow. *J. Atmos. Sci.*, **58**, 1310-1327

Lin, Y. L., Han, J. and Hamilton, D. W., 1999: Orographic influence on a drifting cyclone. *J. Atmos. Sci.*, **56**, 534-562

Chen, H. C., 2001: Interaction of a barotropic cyclone with topography: laboratory experiment and numerical simulation. Ph.D Thesis, National Taiwan University.