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A Study of Finite Amplitude Barotropic Instability

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ABSTRACT

We report cases with a series of disturbances tilted upshear along the shear zone during the Mei-Yu season. The scale involved is much smaller than the local Rossby radius of deformation; we hypothesize the relevance of barotropic instability, and have explored the nonlinear evolution of barotropic instability. The small and finite amplitude theories are reviewed; their relevance to the observations are briefly discussed. Eigenvalues of ideal three and four region models are calculated analytically. A new Fourier Chebyshev nondivergent barotropic model is constructed. With the initial value problem approach, our experiments on barotropic instability with a vorticity strip either have hyperbolic tangent or Bickerly jet type of wind profiles. We studied the time evolution of the shear layers in terms of the formation of fundamental eddies and successive pairing or merging of eddies. The mutual intensification of counter-propagating Rossby waves (vorticity gradient waves) across the vorticity strip, breakdown of the vorticity strip, local concentration of vorticity and vortex mergering processes were simulated. While the barotropic instability is an efficient way to concentrate vorticity in a small region, the later vortex merging can enlarge the vortex sizes but not the intensity of the resultant vortex. We propose that the concentration and the merging of vortices can create a favorable localized environment within the shear zone for the moist baroclinic processes to operate.

As far as the intensity, shape and evolution of the individual vortices are concerned, they are very sensitive to initial background noise (1/100 of mean vorticity). In other words, there is no predictability in the nonlinear evolution. However, the maximum growth rate and the dominant wavelength of vortex can be predicted from the linear analysis. The Bickerly jet possesses higher growth rate than the hyperbolic tangent case on the f plane. We document chaotic behavior of sudden breakup of shear zone and associated vortex merging after a couple of regular cycles of wave-mean flow interaction with shear zone maintained. In the thirty-day integration, the vortices on the β plane become disorganized and scattered while they still remain well organized on the f plane.

(Key words: Barotropic instability, Vortex merging, Counter-propagating, Rossby waves)

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