Article ID: 1006-8775(2006) 02-0089-04

THE MESOSCALE WAVES AND THE FORMATION OF POLYGONAL EYE WALL IN TYPHOONS

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Abstract: Mesoscale waves in typhoons were diagnosed by using a simulated typhoon data in this paper. Through analyzing the structure of the waves in typhoons, we found that the waves possess the mixed features of gravity inertial waves and vortex Rossby waves. On the one hand, positive geopotential height perturbation is corresponding to negative vorticity perturbation and anticyclonic circulation. At the same time, negative geopotential height perturbation is corresponding to positive vorticity perturbation and cyclonic circulation. The maximum perturbation occurs near the radius of the maximum wind in the typhoon. On the other hand, the mesoscale waves possess the features of strong convergence and divergence and ageostrophic wind. Finally, the authors presented a concept model to explain a linkage mechanism between the mesoscale waves and the formation of polygonal eye wall in the typhoon.

Key words: typhoon; gravity–inertial-waves; vortex-Rossby-waves

CLC number: P444 **Document code:** A

1 INTRODUCTION

Research into the asymmetric structure inside the typhoon has become one of the heated topics in recent years and mesoscale waves in the typhoon are regarded as one of the important causes for the formation of the structure[1-4]. In the meantime, it also has important effect on the movement and intensity of the typhoon. The spiral rain-bands and polygonal eye wall in the typhoon are important features of the asymmetric structure. There are mainly two explanations for their formation. One is the theory of gravity inertial waves[1, 2] and the other is the theory of vortex Rossby wave[3 – 5, 7 - 8]. In this work, through using high-resolution MM5 model output data of Hurricane Andrew by Liu[6] and Wu's method[9] to separate mesoscale waves inside the typhoon, the structural and transportation characteristics and the nature of the mesoscale waves were studied and discussed. A possible explanation for the formation of the polygonal eye wall was also presented in the last part of this work.

2 COMPONENTS OF ASYMMETRIC WAVES AND STRUCTURE OF THE MESOSCALE WAVES

Fig.1 gives the asymmetric geopotential height field at 850 hPa and perturbance of geopotential height with wavenumber at 1 and 2 and their superposition. It shows that the asymmetric component with wavenumber 1 is dominant in typhoons, which takes up most of the total asymmetric quantity. The amplitude of the wave component is smaller for wavenumber 2. It is then seen that the superposition of geopotential height fields with wavenumber 1 and 2 (Fig.1d) can basically reflect the whole asymmetric geopotential height field. Similar conclusions can be drawn from the computations of diversity, vorticity and vertical velocity field. It is therefore known that primary mesoscale waves inside typhoons are basically of low wavenumber.

Received date: 2006-01-23; **revised date:** 2007-05-17

Foundation item: Natural Science Foundation of China (40575022); Key National Foundation Research Project (2004CB418301)

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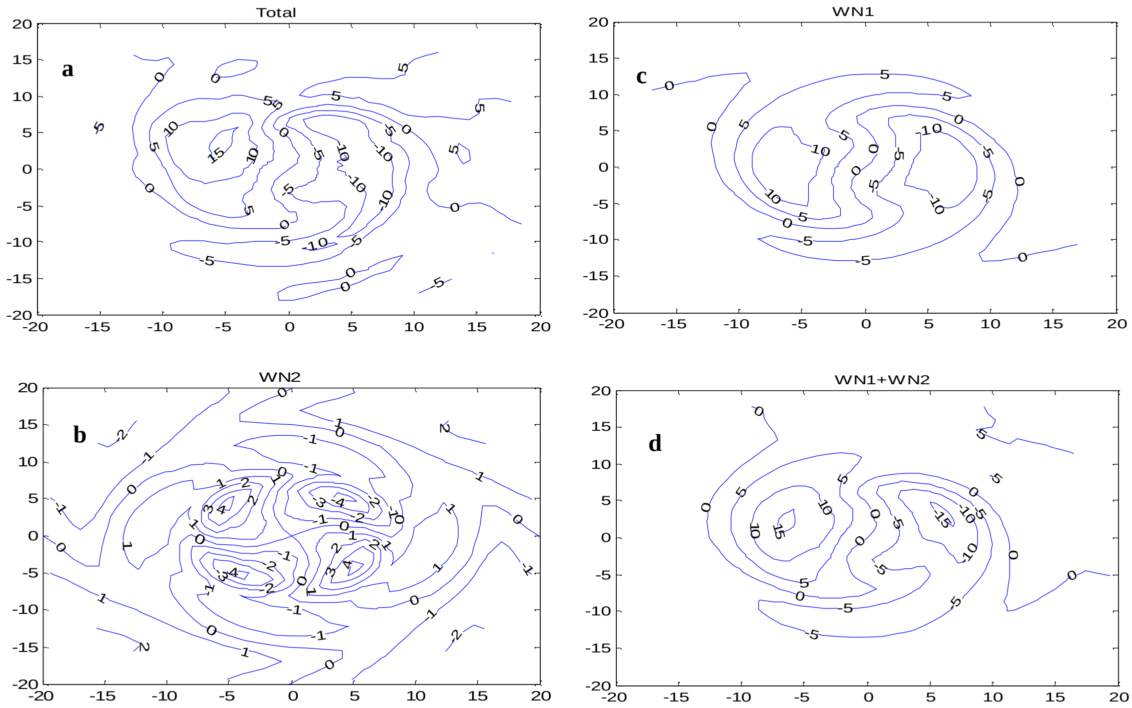

Fig.1 Asymmetric geopotential height at 850 hPa for the whole field (a), wavenumber 1 (b) and wavenumber 2 (c) and wavenumber 1 and 2 (d). Unit for geopotential height meter: m^2/s^2; *x* and *y* are the gridpoints and mesh interval is 6 km.

Fig.2 shows the perturbations of geopotential height, relative vorticity and diversity, general vertical velocity and wind field perturbation. It is known from the figure that large fluctuations of typhoon mesoscale waves mainly appear within 100 km from the hurricane center, with the largest amplitude near the radius of maximum wind speed. The center of perturbation high (low) pressure of the geopotential height field has a phase consistent with that of the vorticity perturbation. In the flow field, it corresponds to an anticyclonic

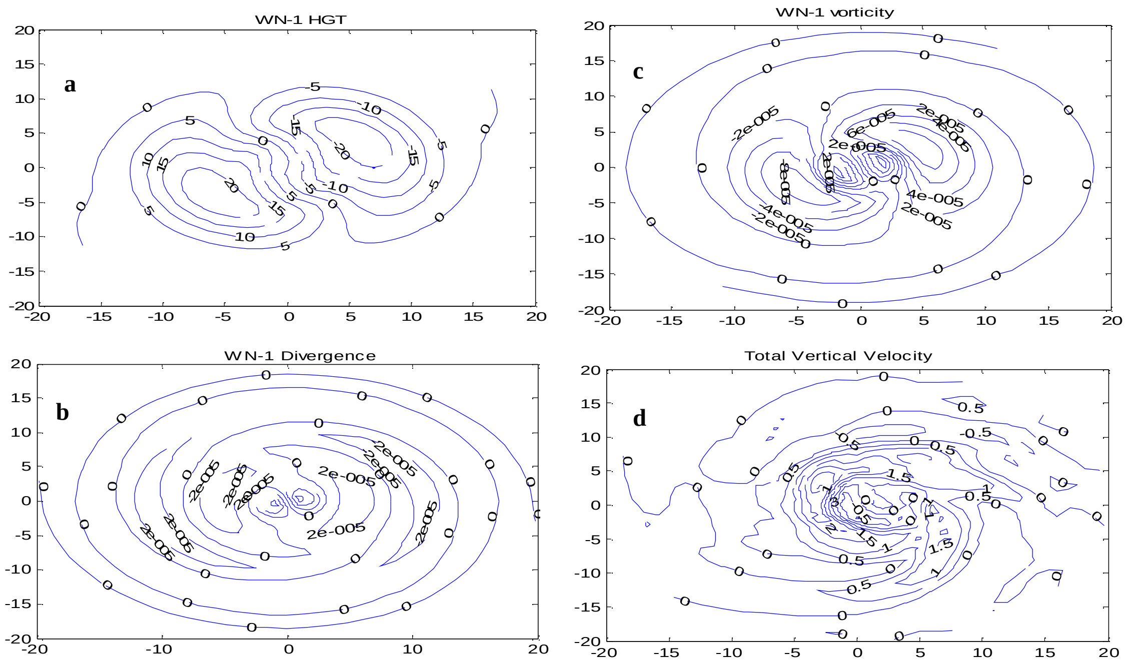

Fig.2 The geopotential height (a), vorticity (b), divergence (c), general vertical motion (d) for wavenumber 1 at 850 hPa. Unit: m^2/s^2 for geopotential height; /s for vorticity and divergence; m/s for vertical velocity.

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(cyclonic) circulation. The ascending motion is relatively strong (weak) when it is between the front of the disturbing low (high) and the rear of the disturbing high (low). All of the features disclose important characteristics of the vortex Rossby wave.

In the meantime, in the inner side of the eye wall, perturbation centers of positive (negative) geopotential height are corresponding to those of positive (negative) vorticity. The amplitude of vorticity perturbation is in the same order of magnitude with diversity perturbation and the wave is of strong convergence and divergence. The ageostrophic motion of the perturbation wind field is quite significant, with large traversing-contour component and ageostrophic extent. These characteristics are typical of gravity inertial waves.

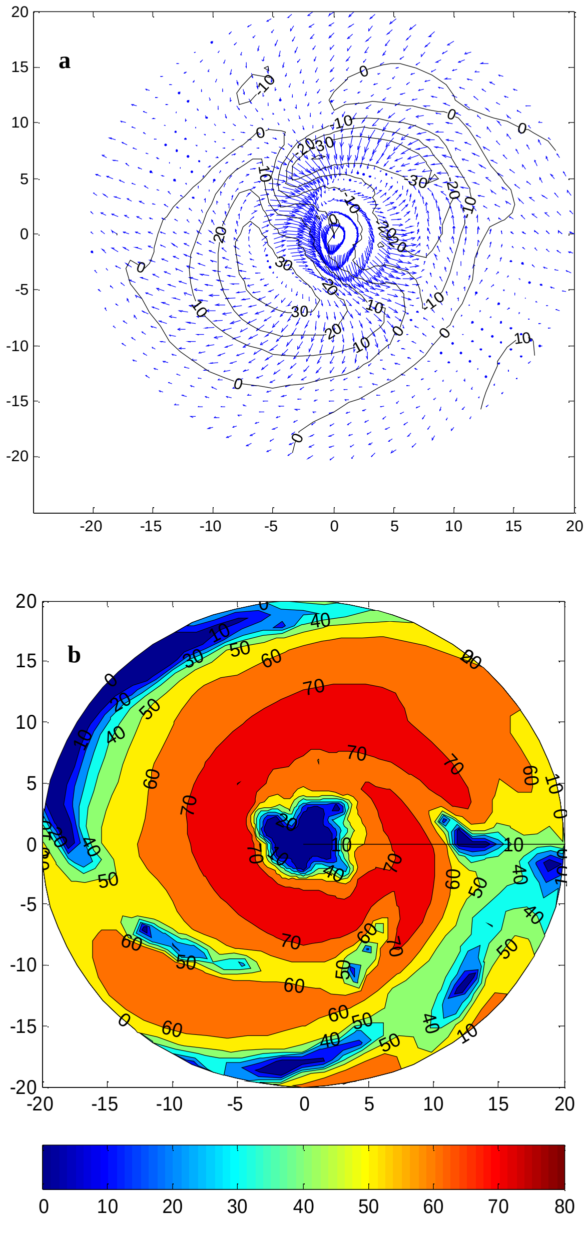

Fig.3 Asymmetric wind field and geopotential height field (a) for wavenumber 1 at 850 hPa and its simulated radar echo (b). Unit: Unit: m^2/s^2 for geopotential height; dBz for radar echo.

As cyclonic flow fields superimpose with anticyclonic flow fields in the front of the perturbation low and the rear of the perturbation high, contours of geopotential height are densely distributed and wind speed is large, an area of intense inflow will form. When the two types of circulation superimpose each other, contours of geopotential height are densely distributed and airflows flow out in divergence, an area of intense outflow will form. The clockwise, spiral outward expansion of vorticity and divergence are an indication that the wave is transporting both tangentially and outwardly.

3 MESOSCALE WAVES AND THE FORMATION OF POLYGONAL EYE WALLS

The formation of a polygonal eye wall in typhoons eventually explains why precipitable particles distribute unevenly within the eye wall — it is closely associated with the transportation of mesoscale waves.

First of all, the transportation of mesoscale waves in typhoons will cause uneven distribution of ascending motion in the tangential direction inside the eye wall to result in inhomogeneous distribution of convection and precipitable particles. The wave is characteristic of vortex Rossby wave near the eye wall, with ascending motion relatively strong in the front of the low and rear of the high but relatively weak in the front of the high and rear of the low. The ascending motion is directly related with convection so that convection is strong and the density of precipitable particles is large in areas with intense ascending motion while being weak and small in areas with weak ascending motion.

Secondly, horizontal airflows can change the spatial distribution of precipitable particles by exerting advection effect on them. Generally, the precipitable particles will advect to the lee side of the airflow.

Thirdly, the transportation of mesoscale waves in typhoons will cause uneven distribution of horizontal airflows in the radial direction within the eye wall. The advection causes uneven distribution of precipitable particles in the radial direction. It is known from the allocation between asymmetric wind field and geopotential height for perturbation with 1 wavenumber (Fig.1) that it shows strong divergence and convergence of the gravity inertia wave and anticyclonic circulation of the high and cyclonic circulation of the low superpose each other to form areas of strong inflow and outflow. The transportation of such waves will cause uneven distribution of the radial airflow so that there are both inflow and outflow in the radial direction inside the eye wall. Through advection, precipitable particles can change their

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distribution inside the eye wall. In the inflow area, the radial inflow causes the particles to transport to the eye, making the eye wall indent towards the cyclone center in the radar echo. In the outflow area, the radial outflow causes the particles to transport outward in the radial direction from the eye wall, which protrudes outwards in the radar echo. Likewise, waves with higher number of wavenumber also form inflow and outflow areas of their own and change the shape of the eye wall by different degree, though with the inflow and outflow at different intensity.

For analyses of other aspects, refer to the Chinese edition of the journal.

4 CONCLUSIONS

In summary, the following conclusions can be drawn:.

(1) The mesoscale wave found inside the typhoon is characteristic of both the vortex Rossby wave and gravity inertial wave.

(2) The transportation of in-typhoon mesoscale waves is one of the important causes for the formation of the polygonal eye wall. The transportation causes uneven distribution of the convection inside the eye wall on the one hand and results in uneven distribution of inflow and outflow around the eye wall on the other. The combined effect is the uneven distribution of precipitable particles inside the eye wall, which are reflected as polygonal structure in the radar echo and satellite imagery.

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