6B5 Dynamics of Northwest Pacific Tropical Disturbances

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1. INTRODUCTION

The summer monsoon in the tropical Northwest Pacific has a climatological mean trough, or depression, in the lower troposphere that has a scale of several thou- sand km in both the zonal and meridional directions. On the equatorial side of this depression is an elongated belt of westerlies which meets easterlies from the central and eastern Pacific in the southeast part of the depression, resulting in a confluence region in the vicinity of 140E-160E. The general feature of westerlies meeting easterlies at 850 hPa somewhere near the monsoon trough region is always present in both the synoptic and the intraseasonal time scales (e.g., Fig. 1 in Sobel and Bretherton 1999). The tropical wave-type disturbances east and west of this confluence region are observed to behave differently (Chang and Miller 1977). To the east, synoptic-scale waves are observed to propagate toward the west in the equatorial latitudes of 5N-15N, with a period of around 4--5 days. These waves tend to be vertically tilted and exhibit relatively loose coupling with convection. To the west, a substantial amount of synoptic scale variability in the tropics is associated with deep disturbances that exhibit tight coupling with convection. During the active phase the disturbances tend to travel west/northwestward. The growth of a new disturbance is often observed to the southeast of the previous disturbance. Chang et al. (1996) and Sobel and Bretherton (1999) presented examples of northwestward propagating series of synoptic-scale tropical depressions, with the observed period of approximately 8 days and a spatial scale of about 2500-3000 km.

The interactions between monsoon circulations and tropical disturbances in Northwest Pacific, where the low-level mean flow is westerly in the west and easterly in the east, are studied in Kuo et al. (2001). Their barotropic model results suggest that the scale contraction by the confluent background flow, the nonlinear dynamics, the β-effect, and the large-scale convergence are important for the energy and enstrophy accumulation near the region where the zonal flow reverses.

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The largest accumulation occurs when the emanating zonal wavelength is around 2000 km. This is due to the fact that longer Rossby waves experience less scale contraction and nonlinear effects while shorter Rossby waves cannot hold a coherent structure against dispersive effects. The intensified disturbance may disperse energy upstream, leading to a series of trailing anticyclonic and cyclonic cells along the northwestward propagation path. When an opposing current is present, the energy dispersion leads to the formation of new disturbance in the confluence zone by the vortex axisymmetrization dynamics.The results suggest the possibility that the nonlinear processes in an opposing mean zonal flow can lead to vortex development from tropical waves without disturbance-scale diabatic heating.

The nonlinear interaction of the wave with the confluent background flow on the β-plane, which lead to a change of spatial scales, is important for the nonlinear energy accumulation. In this work, we study the temporal aspect of the nonlinear wave accumulation dynamics. We consider the interaction of the waves in the easterly with the low-frequency variation of the large-scale flow. The interactions may generate active and inactive periods of tropical disturbance formation in the Northwest Pacific.

2. RESULTS AND DISCUSSIONS

We perform calculations with a nondivergent barotropic model on a double periodic domain. The detail of the model can be found in Kuo et al. (2001). Figure 1 shows Hovmoller diagram of kinetic energy for the experiment with the wave period of 5 days. The amplitude of the wave is modulated with a period of 15 days and the large-scale flow is varied with a period of 30 days. The contours are with unit of 0.1 m^2s^{-2}. It is clearly that there is a low-frequency alternation of active and inactive accumulations near critical longitude (grid 120). This alternation of active and inactive energy accumulation varies according to the frequencies of large-scale flow and the incoming waves. Our idea is that an intensification of the disturbance when the large-scale flow is in-phase with the incoming waves from east. Namely, when the strong confluence and convergence phase of the large-scale flow is phase-locked with the cyclonic phase of incoming waves, intensification is likely to occur. On the other hand, if the frequency or the phase associated with the large-scale flow is quite different from that of the incoming waves, there may be alternating periods of intensification and weakening, resulting in active and inactive periods for the successive formation of tropical disturbances. In addition, the enhancement of the vorticity field may speed up the process of axisymmetrization and result in a shorter period for the formation of a coherent vortex, while the weakening of the vorticity field may slow down or interrupt the process. As a result, the interaction of different frequencies in the waves and the large-scale flow, plus the axisymmetrization dynamics, may modify the time and spatial scales of the successive formation of tropical disturbances. In addition, these process may also be affect by the energy dispersion processes. Thus, the interaction of the nonlinear dynamical processes with different frequencies may lead to an alternation of active and inactive periods of tropical disturbance formation in the Northwest Pacific.

REFERENCE

Chang, C.-P., J. Chen., P. A. Harr and L. E. Carr, 1996: Nothwestward-propagating wave patterns over the tropical western North Pacific during summer. *Mon. Wea. Rev.*, **124**, 2245-2266.

Kuo, H.-C., J. Chen, R. T. Williams, and C.-P. Chang, 2001: Rossby waves in zonally opposing mean flow: Behavior in Northwest Pacific summer monsoon. J. Atmos. Sci., **58**, 1035-1050.

Sobel, A. H., and C. S. Bretherton, 1999: Development of synoptic-scale disturbances over the summertime tropical northwest Pacific. J. Atmos. Sci., **56**, 3106-3127.

Chang, C.-P., and C. R. Miller, III, 1977: comparison of easterly waves in the tropical Pacific during two contrasting periods of sea-surface temperature anomalies. J. Atmos. Sci., **34**, 615-628.

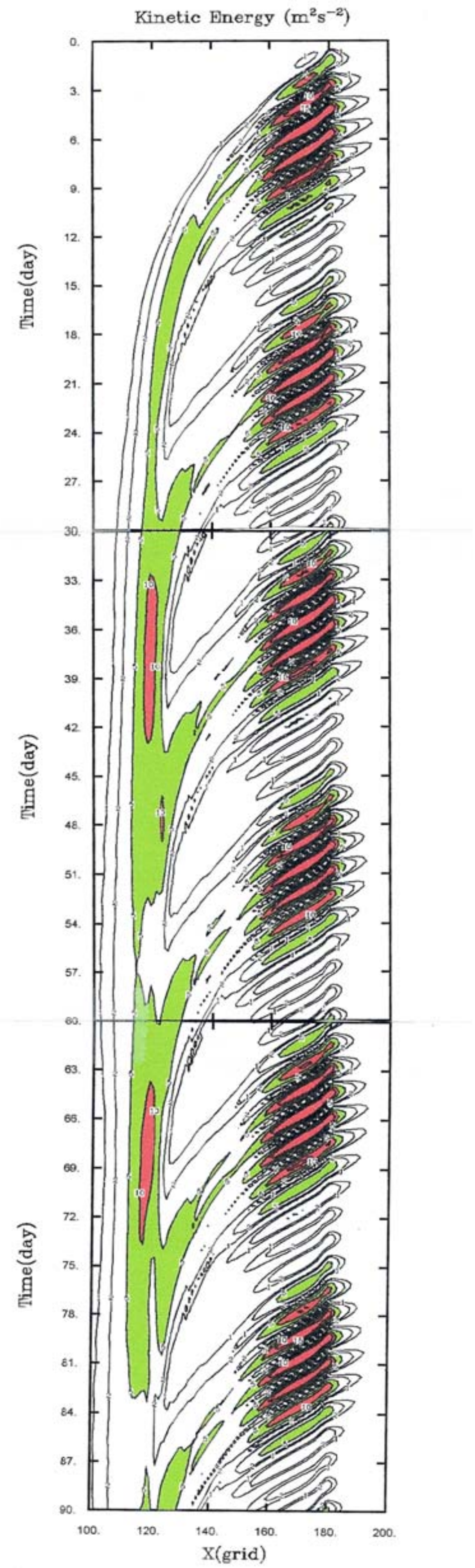

Fig.1. Hovmoller diagram of kinetic energy for the nonlinear wave accumulation experiment. The contours are with unit of 0.1 m^2s^{-2}. The period of the incoming wave is 5 days and the amplitude of the waves is modulated with a period of 15 days. The convergence and confluence effect of the large-scale flow is varied with a period of 30 days. The critical longitude is near grid 120.