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PRELIMINARY STUDY ON STRUCTURE OF WINTERTIME TYPHOON NANMADOL IN 2004

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Abstract: Using NCEP/NCAR reanalysis, the structure of a wintertime typhoon named Nanmadol that landed on Taiwan 4 December, 2004 has been examined in this paper. It is found that Nanmadol looks similar in structure and time evolution to summer typhoons; the central part of it is warm and humid, and the convergence is observed in the lower troposphere while there is divergence in the upper troposphere. The differences between wintertime and summertime typhoons are found. The southwest stream flow in the lower troposphere and cyclonic disturbance in the upper troposphere seem significantly weaker in Nanmadol than in summertime typhoons. The EOF analysis performed for sea level pressure (SLP) of Nanmadol shows that about 90% of the total variance of temporal changes in typhoon circulation can be explained by two leading EOF modes of EOF1 and EOF2. EOF1 shows the structure and intensity variations of Nanmadol while EOF2 shows the changes in environmental SLP distributions that influences the moving direction of Nanmadol.

Key words: typhoon; wintertime; nature; structure

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1 INTRODUCTION

As shown in research and statistical results [1 – 6], Typhoon Nanmadol (No.0428), which made landfall on Taiwan Dec. 4, 2004, is the storm moving on land at the latest time of year in China since 1949. Summer is a season when typhoons are the most active while winter sees few cyclonegenesis and fewer landfalls in China. It is then important to study typhoons making landfall in winter. Previous study focuses on typhoons in summer with few on those in autumn or winter. Statistical characteristics, track change and relationships between the cold air movement and the cyclonegenesis and evolution of typhoons have been the main topics [1 – 10]. In this work, efforts are mainly on the structural features of Nanmadol, a west Pacific typhoon that formed in early winter and made landfall, and its evolution, for its similarities to and differences from wintertime typhoons, so that future study can be done with better basis.

2 STRUCTURAL CHARACTERISTICS OF THE TYPHOON

The reanalysis data of NCEP/NCAR is used to study the circulation structure and thermodynamic structure of Nanmadol and Imbudo (No.0307), a summertime typhoon. It is shown in comparison and analysis that Nanmadol's warm and humid structure is well defined and there is low-level convergence in association with high-level divergence, though with heights lower than the summertime counterpart to which complete cyclonic circulation reaches. In fact, it is poorly seen at levels higher than 200 hPa and low-level convergence and high-level divergence are weaker than normal. In the case of Nanmadol, the southeasterly and southwesterly converge with the northeasterly, with the easterly playing a major role. For Imbudo, however, the westerly is dominant among the converging flow and an intense southwesterly jet stream appears. The low-level southwesterly

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converging flow is poorly defined for Nanmadol and transports water vapor just moderately.

3 USE OF EOF METHOD IN ANALYZING THE STRUCTURE OF TYPHOON STRUCTURE

The center of typhoon is set at that of the gridpoints and 22 time levels of the SLP field going through the whole course of life cycle are taken to constitute original temporal series for EOF decomposition of the anomalous field of SLP over the whole process of Nanmadol. The contribution is nearly 90% from the accumulated variance of the first two eigenvectors (referred to as EOF1 and EOF2), which pass the significance test [11] and are good indicators of the variation of typhoon's spatial structure. EOF1 (Fig.1a) gives a structure in which the middle has higher values than the part surrounding it, i.e. the center is the eye. It shows a basic pattern of large pressure gradient at the periphery of the typhoon, which is a typical distribution of the pressure field during the mature phase of typhoon. Its corresponding first temporal coefficient series does well in depicting a main process of pressure field variation for the life cycle of typhoon, i.e. the change in intensity. EOF2 (Fig.1b) shows that the eye is located at a symbol of the designated typhoon, with the enclosed circle and the part to its west being positive and that to its north negative. From the evolution of the second temporal series, it is known that pressure falls over the continent southwest of the typhoon but rises northeast of it, which is just the distribution of pressure field during the westward movement of the typhoon, i.e. the change in movement.

Temporal coefficients of EOF1 and EOF2 and the distribution of coefficients of their correlation with the fields of surface temperature anomaly, humidity and 500-hPa vorticity are respectively determined (Fig.2). The results show that there is substantial change in these fields with the variation of life cycle intensity and track of the typhoon. The typhoon intensifies over the ocean where SST is relatively warm and moves in this direction. The variation of the 500-hPa vorticity field agrees with that of pressure and the variation of ambient field around the typhoon is shown during the movement. During the variation of typhoon intensity, a main area of positive correlation of the relative humidity field is over the ocean to the east of the typhoon. Humidity is decreasing as the typhoon evolves, which is unfavorable for the supply of water vapor from the southeast. During the movement of the typhoon, a main area of humidity correlation is to the

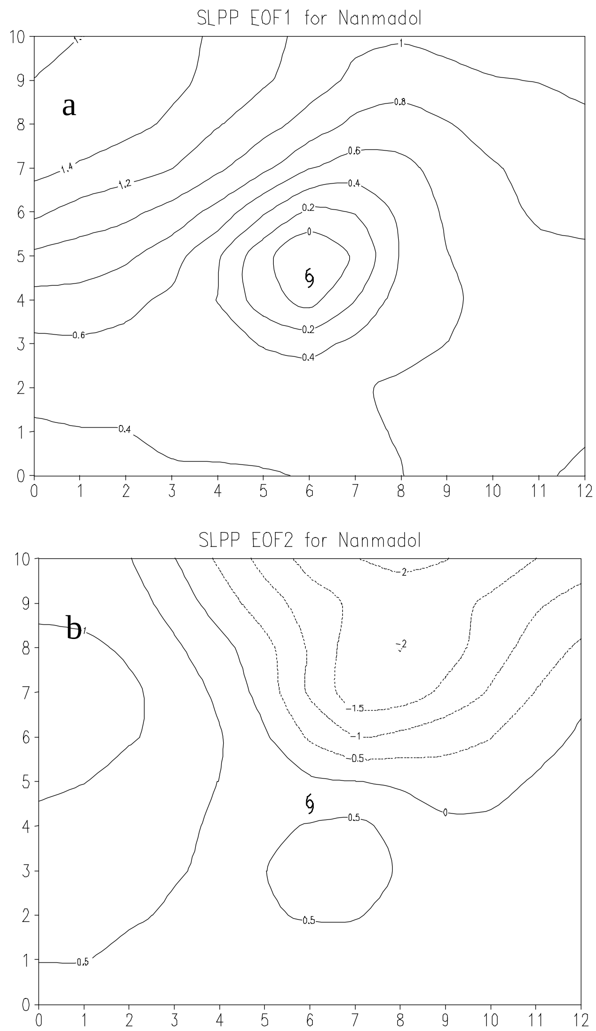


Fig.1 The modes of EOF-analyzed sea level pressure anomalies with Typhoon Nanmandol. (a) and (b) are for EOF1 and EOF2, respectively (unit: ×0.1).

distant west of it, suggesting that the condition of water vapor there be favorable to the formation and development of local convection. When the typhoon weakens and dissipates, however, relative humidity gets smaller to the west of the storm, reflecting the strengthening of dry and cold continental air during the ending phase of the typhoon.

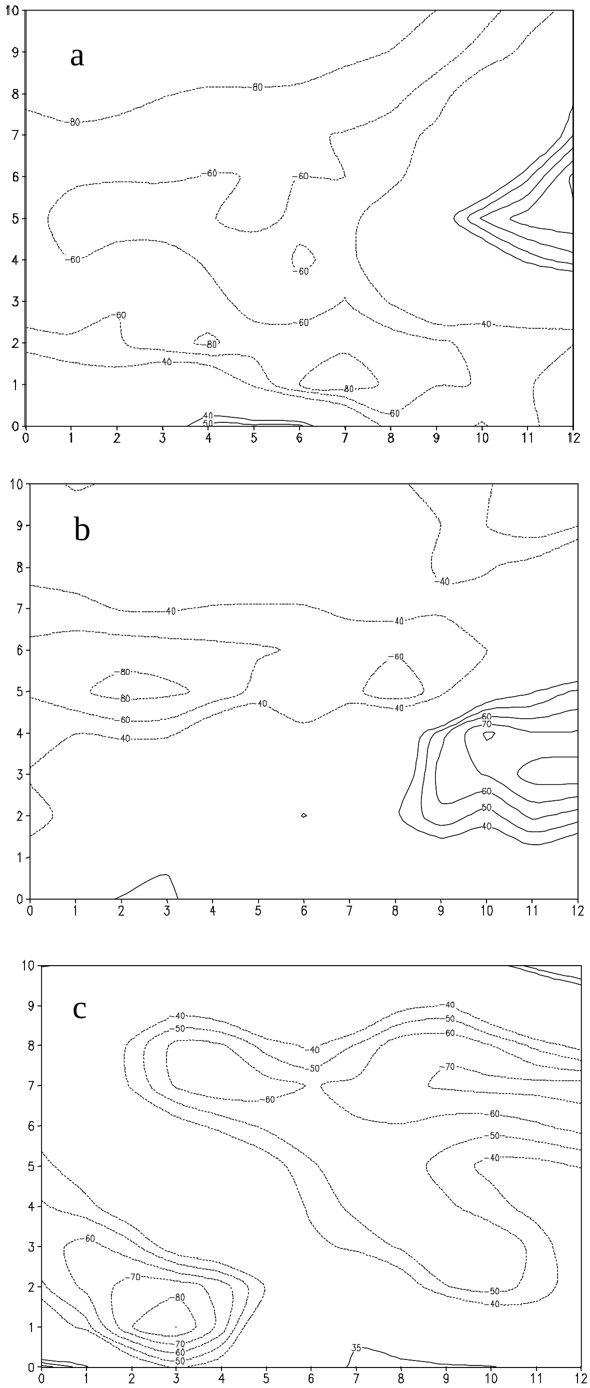
For analyses of other aspects, refer to the Chinese edition of the journal.

4 CONCLUSIONS AND DISCUSSIONS

As shown in the results of the analysis here, the wintertime typhoon Nanmandol is characteristic of the following:

(1) Like summertime typhoons, it has well-defined warm and humid core and dynamic and thermodynamic structure of low-level convergence versus high-level divergence. The warm core is destroyed and weakened to dissipation when cold air intrudes into it as the typhoon turns to head for the north to get close to the continent.

(2) The low levels of the typhoon are dominated by the convergence of the northeasterly with the southeasterly and southwesterly. What is different is that Nanmandol does not have a well-defined southwesterly in low-level converging flows and brings



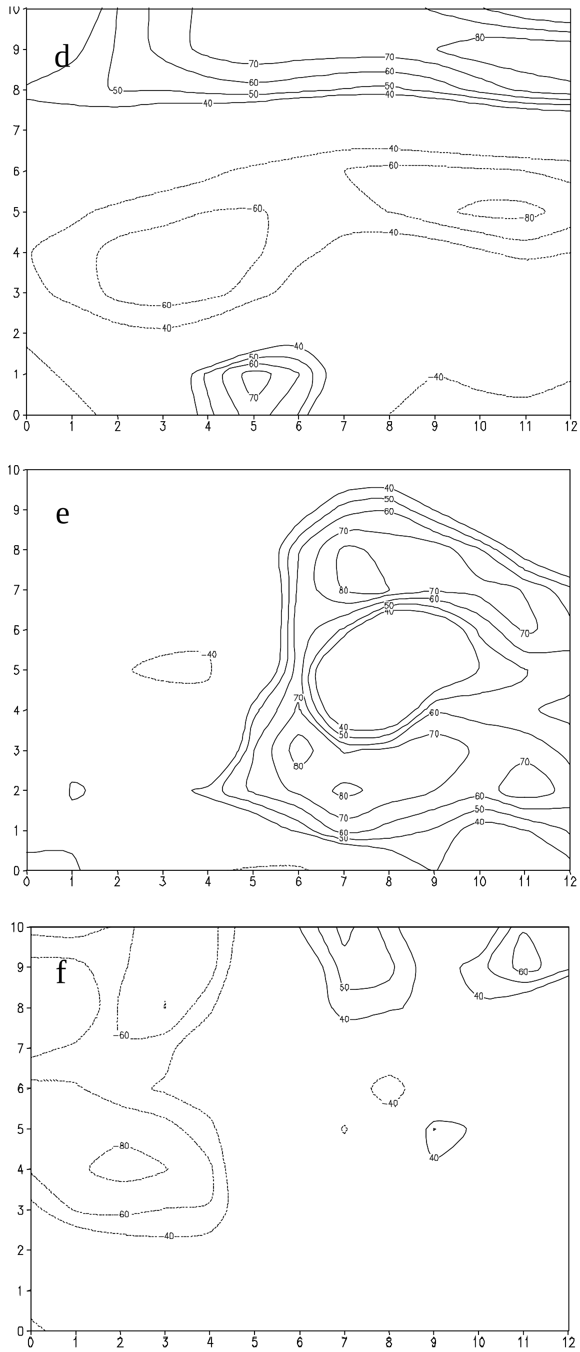


Fig.2 The distribution of the correlation between the first and second temporal coefficients between surface temperature anomaly (a, b), 500-hPa vorticity (c, d) and relative humidity at sea level (e, f). Unit: ×0.01.

about relatively few water vapor. The cyclonic circulation does not reach as high as its summertime counterpart and exerts weaker disturbance to the atmosphere.

(3) As shown in the EOF analysis, the variation of the pressure field structure of the typhoon is mainly shown by the first two eigenvectors of EOF, one being

an "intensity mode" and the other a "movement mode". The two eigenvectors are well correlated with the variation of temperature, vorticity and humidity, reflecting the changes associated with the internal dynamic structure and movement of the typhoon during the generation and development.

It must be noted that Typhoon Nanmandol is studied in terms of general thermodynamic and dynamic structure with the reanalysis data of NCEP/NCAR. As the resolution is relatively low, the fitting of the intensity of typhoon center is also relatively weak, resulting in unsatisfactory analysis of the actual typhoon, and fitting of pressure especially, at the center. At present, results have been desirable with the study of the variation of intensity, track and structure of typhoons using the latest observations like the Doppler and high-resolution TRMM satellite data [12 - 14] and these latest means and methods of measurement can be used to conduct intensive research on the nature and movement of wintertime typhoons.

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