Vol.14 No.1 **JOURNAL OF TROPICAL METEOROLOGY** June 2008

Article ID: 1006-8775(2008) 01-0049-04

NUMERICAL SIMULATION AND MESOSCALE ANALYSIS OF A TORRENTIAL RAIN CAUSED BY TYPHOON

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Abstract: A heavy storm rainfall caused by Typhoon Aere (No.0418) when landing at Fujian has been successfully simulated by using AREM model. The simulation result is scale-separated by spatial band-pass filtering, which reveals the mesoscale low pressure and convergence line that has direct impact on this rainfall process. The physical characteristics of the two mesoscale systems and their relation with rainfall are also analyzed. Study shows that there exists a well corresponding relationship between the storm rainfall and mesoscale divergence and strong updraft arising from the convergence, which is caused by the interactions between the mesoscale systems and topographic features, and is directly responsible for the rainfall.

Key words: AREM model; typhoon rainfall; numerical simulation; mesoscale analysis

CLC number: P426.62 **Document code:** A

1 INTRODUCTION

Being one of the countries that are most frequently affected by typhoons in the world, China is exposed to torrential rain and floods caused by the landfall of typhoons that seriously threaten its economy, people's livelihood and property [1]. With the ongoing perfection of numerical prediction models and data condition, the forecast of typhoon track has been much improved, making it possible to make accurate forecast of landfall while leaving the forecast of typhoon intensity and associated torrential rain largely unsolved. Due to the effect of multiple factors like circulation patterns and terrain, the intensity and area of torrential rain centers are marked by strong local and irregular distribution [2]. As shown in a number of precipitation observations, the intense precipitation brought about by typhoon landfall is significantly inhomogeneous and mesoscale [3], making it difficult to forecast torrential rain and undertake mitigation efforts. On the basis of successful numerical simulation, the method of scale separation will be used here to identify the mesoscale systems corresponding to centers of intense precipitation and study the relationships between the fields of physical quantities and their relationships with intense precipitation, in the hope that the results can provide the analysis and forecast of landfall-related torrential rains with better methods, means and basis.

2 NUMERICAL SIMULATION SCHEMES AND ANALYSIS OF RESULTS

In this study, an improved limited-domain h-coordinated numerical model for torrential rains (AREM[5]) is used to conduct numerical simulation of the typhoon-related torrential rain of interest. Then, model-output high-resolution data are used to have mesoscale analysis.

2.1 *Schemes of numerical simulation*

The AREM is a model in the h-coordinates with the Arakawa mesh in the horizontal direction. The domain for computation here is 100.0°E – 130.0°E, 15.0°N – 40.0°N, with 181×151 regional gridpoints at a horizontal interval of 12 km. There are 32 vertical layers from the surface to the level of 10 hPa in unequal interval. Technical schemes include a non-local boundary scheme, explicit grid-scale precipitation scheme, improved convection adjustment scheme of Betts-Miller [7, 8] and two-step shape-preserving advection scheme (TSPAS[9]). The initial model values are the NCEP reanalysis data at a resolution of 1°, with a 24-h integration, 90-s steps

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Received date: 2007-01-16; **revised date:** 2008-03-10

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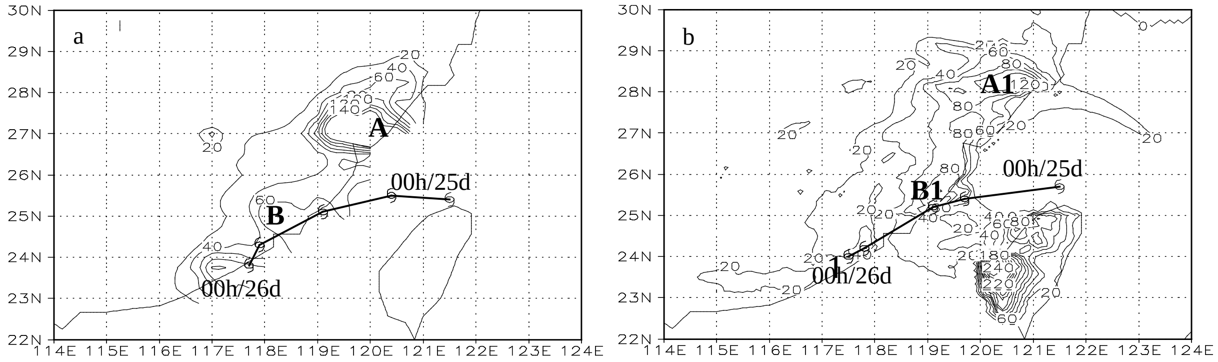

Fig.1 The observed and simulated precipitation (unit: mm) (a) and simulated track (b) of Typhoon Aere for the time between 00:00 Aug. 25 and 00:00 Aug.26, 2004.

and yield results once every hour.

2.2 *Analysis of the simulations*

Fig.1a gives the rainfall measured at automatic weather stations for the time 00:00 Aug. 25 – 00:00 Aug. 26 and observed typhoon track at 6-h intervals. It is known from comparisons of Fig.1a with Fig.1b that the model performs well in simulating a main area of precipitation along the coast of Zhejiang and Fujian provinces. Except for the main rainfall area and slightly lighter intensity of C1, all others have similar distribution with the observation. Besides, the model is also successful in reproducing a spiral rain zone over the East China Sea and intense rain over the mountains on the western coast of Taiwan, which agree with a spiral typhoon cloud system as captured on cloud imagery by Fengyun-2 weather satellite (figure omitted). The simulated position of the eye for 00:00 Aug. 26 is about 50 km to the northwest of the observed one.

3 SCALE SEPARATION AND MESOSCALE FILTER ANALYSIS

Both the observed and simulated amount of precipitation shows clearly that the typhoon-related torrential rain is of significant mesoscale. An improved version of the Barnes filter is used to conduct scale separation of the model output to see more clearly the mesoscale systems immediately causing the rain by studying their fields of physical quantities and their roles in intense precipitation.

Fig.2 gives the curves of response function of the filter, in which R1 and R2 indicate the response curves of two low-pass filters and RB shows those of the band-pass filter. It is known from the figure that the wavelength of the maximum response is at 400 km for the band-pass filter. A mesoscale wave with a 200-km horizontal scale can be separated from the band-pass filter.

Fig.3 gives the hourly curves of rainfall at the centers of precipitation A1, B1 and C1. Following the distribution as shown in the figure, 05:00 and 11:00 are used in the analysis of mesoscale systems responsible for the intense rain, using the scale separation.

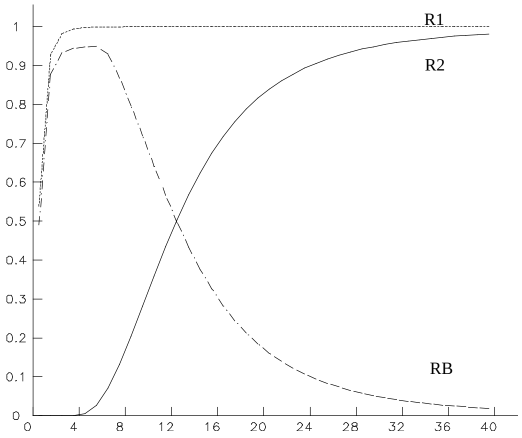

Fig.2 Response curves of the band-pass filter with the wavelength l (unit: 10^2 km).

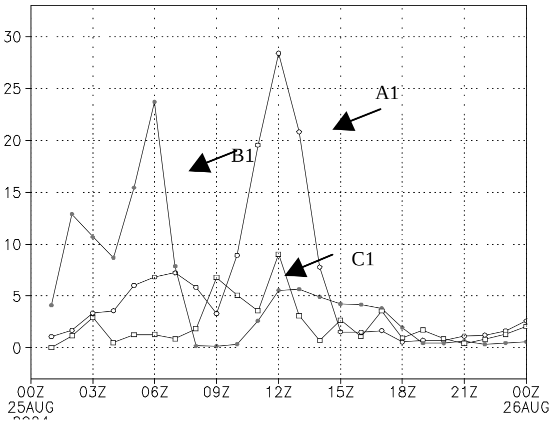

Fig.3 Curves of hourly rainfall at the simulated centers of precipitation.

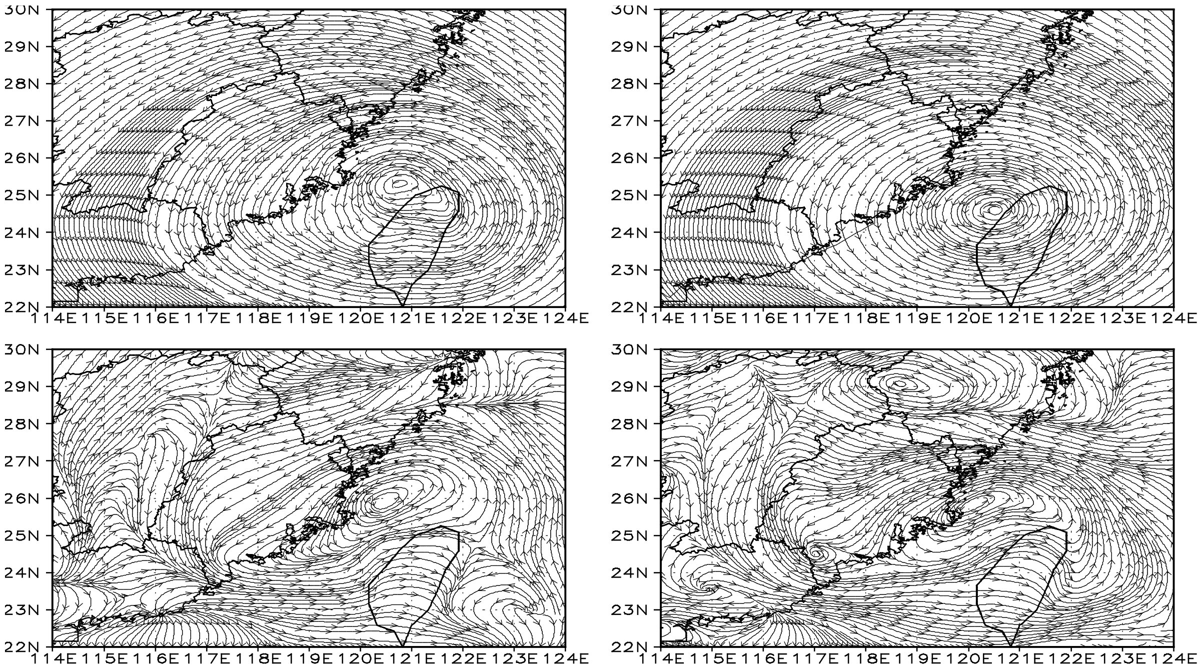

Fig.4 700-hPa flow field before and after the filtering on Aug.25. a. Before filtering at 05:00; b. after low-pass filtering at 05:00; c. after the band-pass filtering at 05:00; d. After the band-pass filtering at 11:00.

Fig.4 gives the 700-hPa flow field before and after the filtering. It is known from the curve RB that the band-pass flow field after scale separation (Fig.3c & 3d) is a mesoscale system at a horizontal scale of 200 km, indicating a much weakened typhoon circulation, which is at the synoptic scale.

4 FIELD OF PHYSICAL QUANTITIES OF MESOSCALE SYSTEM

With the method of scale separation. the previous section has revealed two mesoscale systems, convergence line and low pressure circulation, which have immediate effect on the typhoon-related torrential rain. To better understand the relationships between the two systems and intense precipitation, main characteristics of physical quantities need to be studied. It is shown that strong updraft motion appears over the windward slope about 100 km west of the low circulation center instead of the center of mesoscale low circulation, showing that a zone of intense rain on the coast south of 26.5°N is a result of the interactions between the typhoon circulation, mesoscale low circulation and local terrain. Work remains to be done to learn more about its mechanism in detail.

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

5 RESULTS AND DISCUSSIONS

(1) The AREM works well in simulating and predicting the process of a torrential rain caused by Typhoon Aere (No.0418), in both the moving track and distribution, laying a solid foundation for more study.

(2) With the use of band-pass filter technique, a mesoscale system with a 200-km horizontal scale is clearly separated from the model-output high-resolution data, showing that the mesoscale converging line and low pressure have good corresponding links with the two centers of precipitation in both spatial and temporal evolution and are immediately responsible for this torrential rain.

(3) Further study on the field of physical quantities has shown that the rain is of significant mesoscale, which shows well in both temporal / spatial scales, fields of upper and lower levels, and the allocation of vertical velocity and divergence. The allocation of upper and lower divergence fields is a good indicator of torrential rains. The interactions between the mesoscale system and terrain have formed intense uplifting and convergence to cause strong condensation of water vapor transported due to the typhoon circulation, resulting in the generation and development of the typhoon-related mesoscale torrential rain.

This work does not have any intensive study and discussion of the interactions between mesoscale systems and typhoon circulation. The generation of torrential rain is resulted from the interactions between multiple dynamic factors and physical processes. The next task is to derive a diagnostic equation that involves mechanisms of interactions between systems of different scales for more quantitative diagnostic analysis of main factors responsible for the generation and development of mesoscale systems and interactions between systems of different scales.

REFERENCES:

[1] LI Jiang-nan, WANG An-yu, YANG Zhao-li, et al. Advancement in the study of typhoon rainstorm [J]. J. Trop. Meteor., 2003, 19(suppl.): 152-159.

[2] CAI Ze-yi, YU Ru-cong. A numerical simulation of an extraordinary storm rainfall caused by a landing typhoon with LASG mesoscale model [J]. Scientia Atmospherica Sinica, 1997, 21(4): 459-471.

[3] LI Jiang-nan, MENG Wei-guang, YAN Jing-hua, et al. Mesoscale characteristics and causes of tropical storm Fitow (0114) heavy rain [J]. J. Trop. Meteor., 2005, 21(1): 24-32.

[4] XU Yuan-tai, DING Yi-hui. Objective analysis of meteorological fields and mesoscale filter [J]. Chinese Journal of Atmospheric Sciences, 1988, 12(3): 274-282.

[5] YU Ru-cong, XU You-ping. AREM and its simulations on the daily rainfall in summer in 2003 [J]. Acta Meteorologica Sinica, 2004, 62(6): 715-723.

[6] YU Ru-cong. Properties of the Spatial Finite-Difference Scheme Based on the E-Grid [J]. Chinese J. Atmos. Sci., 1994, 18(2): 152-162.

[7] BETTS A K. A new convective adjustment scheme I – Observation and theoretical basis [J]. Quart. J. Roy. Meteor. Soc., 1986, 112(473): 677-691.

[8] BETTS A K, MILLER M J. A new convective adjustment scheme, Part II: Single column tests using GATE wave, BOMEX, ATEX and arctic air- mass data sets [J]. Quart. J. Roy. Meteor. Soc., 1986, 112(473): 693-709.

[9] YU Rucong. A two-step shape – preserving advection scheme [J]. Adv. Atmos. Sci., 1994, 11(4): 479-490.

Citation: ZHAO L G, ZHOU Y and LI Y Y et al.. Numerical simulation and mesoscale analysis of a torrential rain caused by typhoon. *J. Trop. Meteor.*, 2008, 14(1): 49-52.