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THE FORMATION AND DEVELOPMENT OF A MESOSCALE CONVECTIVE SYSTEM WITH HEAVY RAINFALL ALONG SOUTH CHINA COASTAL AREA

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Abstract: Observational analysis shows that a Mesoscale Convective System (MCS) occurred on May 13 – 14 2004 along the coastal area in South China. The MCS initiated among the southwesterly flows within a west-east orientation low-level shear line. Associated with the system, in its subsequent development stages, no distinct vortex circulation developed in low-level. Instead, a cyclonic flow disturbance was observed in the mid-troposphere. How the convection starts to develop and evolve into a MCS? With observational analysis and numerical simulation, the problem has been studied. The high-resolution MM5 simulation shows that topographic convergence along the coastal line and the nearby mountains in western South China plays an important role to initiate the MCS convection. Once the convection occurs, due to the condensation heating, a cooperative interaction between the preexisting mid-level disturbance and convection is created, which may greatly affect the MCS development during periods when the system continues moving eastward. Compared to some typical MCS that happen in Southern China, which are usually accompanied with upward development of cyclonic vorticity, the development and evolution of the investigated MCS shows distinguishing features. In this article, the physical mechanisms responsible for the intensification of mid-level disturbance are discussed, and a viewpoint to interpret the effects of mid-level disturbance on the MCS organizational development is proposed.

Key words: topographic convergence; mid-level disturbance; mesoscale convective system (MCS); numerical simulation

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1 INTRODUCTION

Mesoscale convective systems, or MCSs, involve intense convective precipitation on the meso-b and meso-a scales. Different from ordinary convective cells, MCS is more organized, covers larger horizontal scale and lasts longer, being able to trigger new convective development during the evolution of its organization. Much work has been done abroad in this aspect and many achievements accomplished [1 – 3].

South China is one of the areas that are subject to frequent MCS activity in the country and often experiences torrential rain and intense convection weather. In addition to some kinds of interactions with the westerly system, its evolution is also closely associated with warm, humid and unstable circulation condition found in the atmosphere of the region. As shown in studies, some of the rain-causing MCSs are usually accompanied with the development of vortexes at low levels, which over time tend to result in repeated appearance of convective cloud clusters that evolve into MCSs [4, 5].

It is also found in observation that some of the MCSs in South China are not necessarily in the company of well-defined vortex systems; southerly warm and humid flow, if consistent throughout low levels, can be hot bed for MCSs. One of such representative case is the MCS that formed on the coast of western South China on May 13 – 14, 2004. It formed in a warm and humid southerly flow south of a low-level shear and developed when the flow got stronger while a low-level vortex was not significant. It is also known from the initial location from which convection began to develop and the distribution of

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precipitation that, low-level convergence, especially a mesoscale convergence that results from complicated coastal terrain in the area, may have a large role in the initialization and development of the convection. Furthermore, the organization and development of the MCS during the eastward movement may be related to the strengthening and development of a 500-hPa disturbance in the flow field.

On the basis of observational analysis of the evolution of MCS, this paper aims to apply MM5, a mesoscale numerical model, to simulate the process for probes into the effect of various physical process on its evolution and understand, through diagnostic study of the simulated results, the roles of factors like middle-level disturbances in the generation, organization and development of the MCS.

2 EVOLUTION OF CONVECTIVE SYSTEMS AND OBSERVED FEATURES OF THE ENVIRONMENTAL FIELD

Fig.1 gives the cloud imagery from satellites and corresponding radar echoes of the MCS forming over the coast of western South China in its initial and mature phases of evolution. Maintaining for nearly 10 hours from initial development to final dissipation, it brings abundant precipitation to the area and Pearl River Delta region.

Fig.2 gives the distribution of accumulated rainfall over 24 hours from 00:00 May 13 to 00:00 May 14 as recorded by a network of automatic weather stations (AWS) in Guangdong province. The convection and precipitation began in the coastal areas due to special local terrain. Fig.3 gives the distribution of the local terrain (as indicated by a box in Fig.2) and evolution of precipitation measured by the AWS network.

It is known from large-scale environmental field that the convective system develops from a southerly warm and humid flow, which is consistent south of the shear at low levels. The vortex circulation is not significant where the convection takes place. The mid-level disturbance is more significantly shown in the

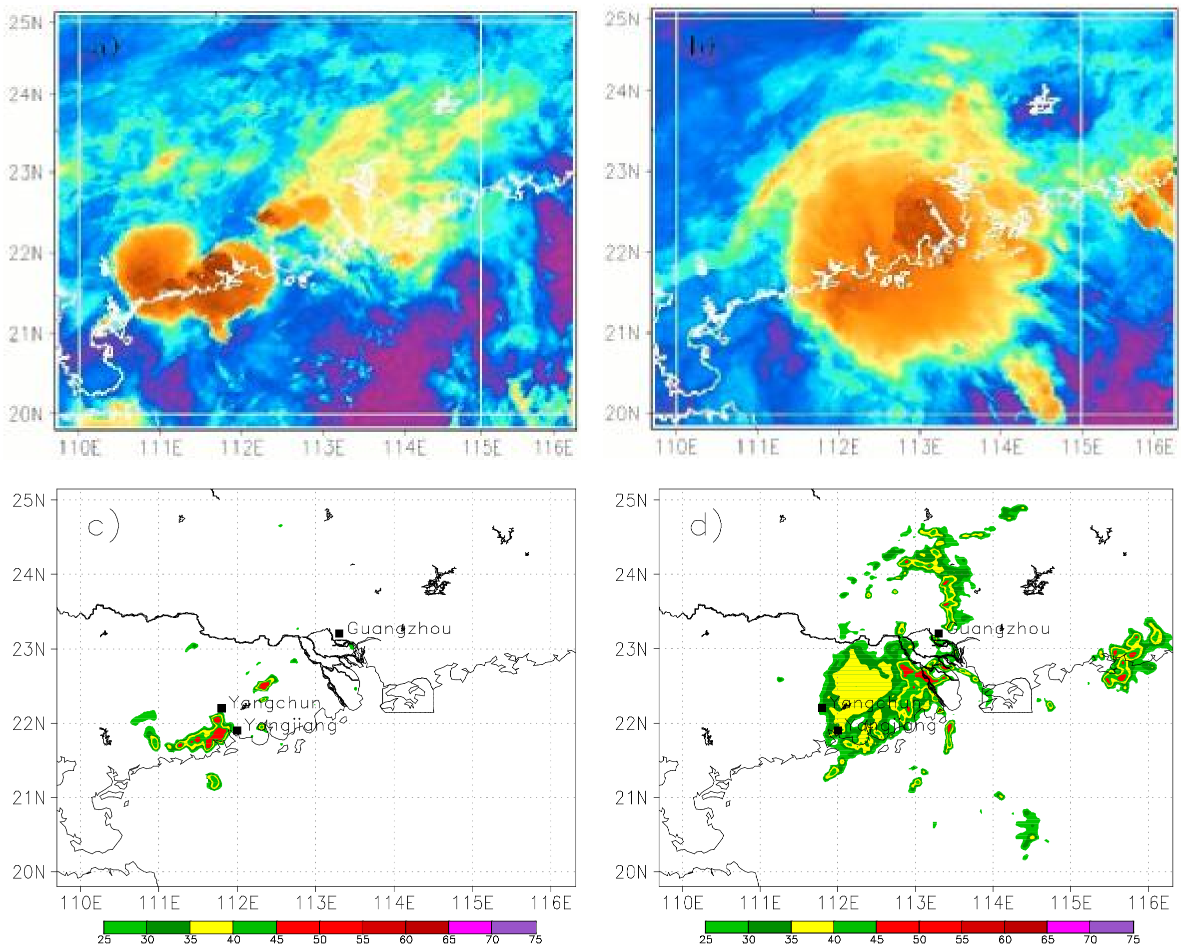

Fig.1 Satellite cloud imagery (a, 13:58; b, 20:53) and radar echoes (c, 14:00 Guangzhou; d, 21:00 Guangzhou) of a MCS for the initial and mature phase of the evolution May 13, 2004.

flow field than in the geopotential field, which agrees with previous experience of observation. The variation of the geopotential field during the torrential rain is more of a result brought about by the rain, which is lagging in time. By contrast, the variation of a precedent flow field is more capable of predicting the forthcoming of a heavy rain [9]. Disturbances in the precedent flow field, therefore, deserve more attention in the forecast, for its strengthening could play some role in the subsequent organization and development of convective systems.

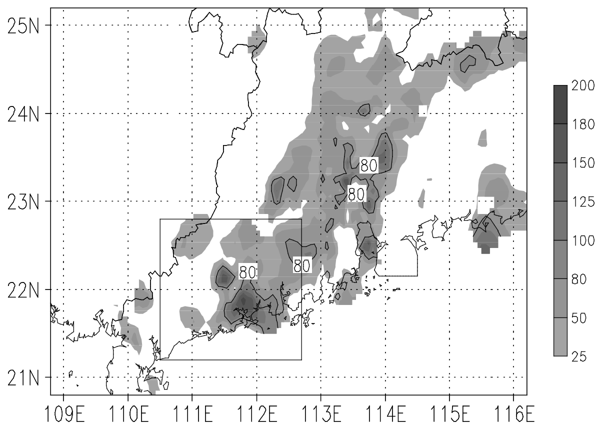

Fig.2 24-h accumulated rainfall from 00:00 May 13 to 00:00 May 14, 2004. Unit: mm

3 NUMERICAL SIMULATION

3.1 *Design of simulation experiment*

The MM5 of NCAR/PSU is used in a numerical simulation experiment. Nested in four meshes, the model has gridpoint intervals of 36 km (D01), 12 km (D02), 4 km (D03) and 1.33 km (D04); D03 covers most of South China while D04 is located on the coast of western South China. Two-way nesting is adopted for the two outer meshes and two inner meshes. The model top is set at 100 hPa with 37 σ layers in unequal vertical interval. The time of simulation starts at 00:00 May 13 and ends at 12:00 May 14, 2004. The following physical processes are included in the control; The cumulus convection parameterization scheme of Betts-Miller is used for the domains of 36 and 12 km while no such schemes are considered for the domains of 4 km and 1.33 km; All of the four domains include the mixed-phase micro-physical process of Reisner; The high-resolution Blackadar scheme is used for the boundary layer; And a scheme for cloud radiation is used, too. For model background and boundary layer condition, the 1.25° × 1.25° gridpoint data from Japan Meteorological Agency are used. For the first 12 hours, four-dimensional assimilation is performed, once every 6 hours for upper levels and every 3 hours for surface, of satellite, aircraft and ship measurements as well as conventional sounding and surface observation.

3.2 *Simulations*

The MCS in question does not develop significantly until after 12:00 May 13. As shown in the simulations for the time at the resolution of 36 km, the model is successful in simulating the circulation patterns at 850 hPa and 500 hPa, which are similar with the results of analysis. South China is also to the south of a shear with low trough at the level of 850 hPa, consistent southwesterly prevails at the middle and lower levels and 500-hPa disturbance is developing over the coast of western South China (figure omitted).

On the basis of that, simulations with different model resolutions have successfully reproduced the precipitation processes of the MCS, though the simulation with high resolution is closer to reality than that with low resolution, as shown in the amount and distribution of precipitation. Besides, with the evolution of time, the model precipitation also has some similar characteristics with the observation.

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

4 CONCLUSIONS

On the basis of analyzing the observation, this work is successful in applying MM5 to simulate a MCS that takes place May 13 – 14, 2004, and studying the impacts of topographic convergence and mid-level disturbance on the formation and development of MCS.

(1) The MCS of interest forms over an area of complicated terrain in the western coast of South China, which is subject to consistent warm and humid southerly flow at low levels. Though the vortex circulation is not significant, there is a cyclonic disturbance in the 500-hPa flow field corresponding to the MCS.

(2) With the increase of model resolution, MM5 is able to simulate precipitation caused by complicated terrain and convection that develops in MCS. The initialization and evolution of convection are linked to topographic convergence while the organization and development of MCS are related with the strengthening of mid-level disturbance.

(3) Strengthening with the development of disturbance, mid-level disturbance is often accompanied by the development of a low-level vortex system, which shows significantly in the vortex field and corresponds to the warm sector. Similar to mechanisms by which MCV develops at middle

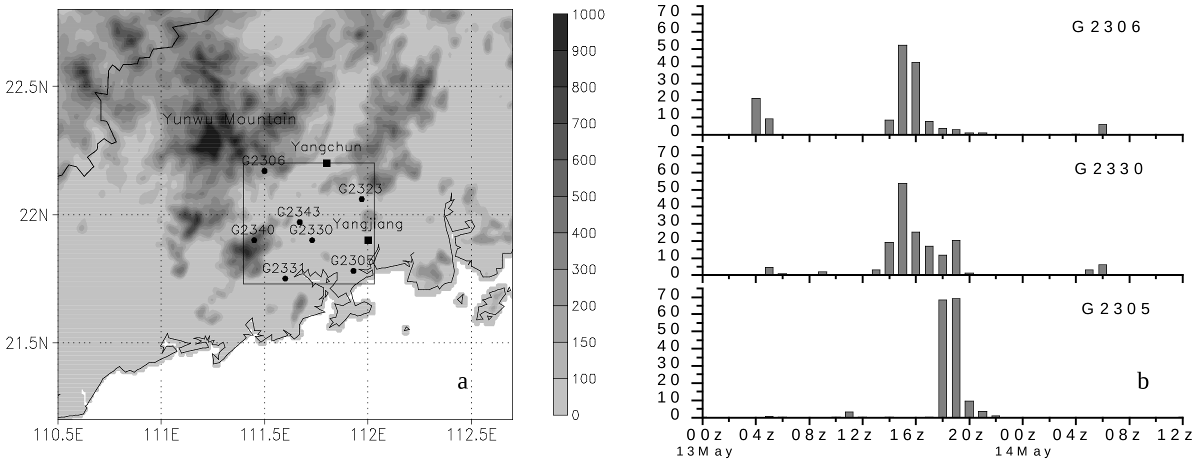

Fig.3 Distribution of coastal terrain in western South China (a) and evolution of precipitation (b). The unit is mm for (b).

latitudes, mid-level disturbance is closely associated with the latent heating by condensation during convection development.

(4) The organization and development of MCSs are associated with positive feedbacks formed between mid-level disturbance and convection. A mid-level initial disturbance existing earlier is very important for convection, which forms an efficient heating zone within the disturbance area right from the beginning of the development and helps in reducing the Rossby deformation radius of L_R locally. It is then favorable for the flow field to take cyclonic response accordingly so as to sustain the convection until MCS is generated in consequence.

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