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THE INFLUENCE OF SOUTH CHINA SEA SUMMER MONSOON ON THE RAINSTORM ASSOCIATED WITH THE LANDFALLING STRONG TROPICAL STORM BILIS (0604)

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Abstract: Bilis (0604) is a strong tropical storm that sustained over land for a long time, bringing torrential rain. With conventional observation data, radar data and infrared satellite imagery, Mesoscale Convective Systems (MCSs) are found to form and develop successively, which cause torrential rain. Then numerical simulation is conducted using MM5 to simulate a 66-h post-landfall process. The simulated distribution and intensity of precipitation match the observation well. With the simulated result, the characteristics and process of MCS development are analyzed with the finding that the convergence of the tropical depression and South China Sea (SCS) summer monsoon over The south of China causes the formation of a mesoscale vortex, mesoscale convergence center and mesoscale convergence line, which are favorable to the development and sustaining of the MCSs. A sensitivity experiment indicates that the SCS summer monsoon transports unstable energy and water vapor continuously, which is of vital importance to rainstorms.

Key words: Bilis; MM5; SCS Summer Monsoon; MCS

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1 INTRODUCTION

Changes in the intensity and precipitation are very complicated during the landfall of tropical cyclones. The generation of landfall-induced torrential rain is subjected to several factors, such as the tropical cyclones's intensity, track, environmental fields and terrain, and much work has been done on them [1-10].

Being a severe tropical storm that sustained long after landfall and brought about exceptionally heavy rain, Bilis covered an extensive area, produced large amount of precipitation and lasted unusually long duration. It keeps the longest ever record of staying alive after landfall (for up to 120 h). Over a wide variety of features from intensity change, eccentric structure, post-landfall sustaining and movement to interactions with the SCS summer monsoon, Bilis is a unique tropical cyclone that has great potential value in research. It is then necessary to probe deeply into its associated processes of torrential rain from the possible role of the SCS summer monsoon in inducing the rain.

2 BRIEF INTRODUCTION TO BILIS AND ASSOCIATED PRECIPITATION

Beginning its life cycle over the western waters of

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western Pacific July 9, 2006, Bilis intensified to a severe tropical storm on July 11, made its first landfall in the island of Taiwan on July 13 and the second one in northern Fujian on July 14. Afterwards, it moved to the northwest before turning to the southwest by west and weakening to a tropical storm in southwestern Jiangxi on July 15. Then, Bilis headed westward slowly and maintained a low-pressure circulation until July 18, during which it passed through southern Hunan, northern Guangxi and eastern Yunnan.

The landfall of Bilis in Fujian caused severe precipitation in the coastal area of the province and southern Zhejiang. The raining area shifted to Guangdong where heavy to exceptionally heavy rain was recorded in the eastern part. In the meantime, part of southern Hunan and northern Guangdong also witnessed very heavy rain. When it weakened to a tropical storm on July 15, heavy rain appeared over most of Guangdong, southern Guangxi, Jiangxi and Hunan with unusually heavy rain over some areas. Process rainfall generally ranged from 50 mm to 200 mm in these areas. From July 13 to 18, precipitation amounted to 200 mm to 400 mm in eastern Zhejiang, eastern Fujian, eastern Guangdong, southern Jiangxi and Hunan. Rain centers mainly appeared in the coastal areas of Fujian and Guangdong with the amount generally more than 200 mm. Another rainfall center is over southern Hunan with the total more than 300 mm.

3 MESOSCALE CONVECTIVE SYSTEMS

With conventional surface observations, 30-min interval satellite imagery from the Chinese Fengyun-2C and 6-min interval radar measurements from Guangzhou, Meizhou and Huizhou, convective cloud clusters are studied for the rain duration. From a table (omitted) that gives the characteristics of some main convective cloud clusters within the duration of heavy rain, it is known that MCSs are mainly active in the south of China. Did they have something to do with the summer monsoon in the South China Sea when Bilis was at its full strength? Why were there so many MCSs with this severe tropical storm? Spatially-and-temporally contiguous, high-resolution numerical simulations have to be used instead to have thorough and comprehensive understanding of the mesoscale convective systems accompanied with this heavy rain process, due to the limitation of conventional observations and NCEP reanalysis data.

4 DESIGN OF NUMERICAL EXPERIMENTS AND VERIFICATION OF RESULTS

The non-hydrostatic mesoscale model MM5 is used for a domain of 14.70°N – 36.31 °N, 99.88°E – 132.12 °E, which covers the region for this process of torrential rain. Horizontally, there are 241 × 181 gridpoints and the grid interval is taken at 15 km. Vertically, the model is made up of 29 layers at unequal intervals. For the parameterization of model physics, Betts-Miller’s scheme for cumulus convection and Reisner’s Type I explicit scheme for cloud physics are used. To take into account the role of shallow convection, Blackadar’s high-resolution boundary layer scheme is used for the computation of the boundary layer and the CCM2 scheme is used for radiation.

Fig.1 gives the comparisons between simulated and observed total rainfall for 06:00 July 14 – 00:00 July 17. Only the over-land distribution is presented here.

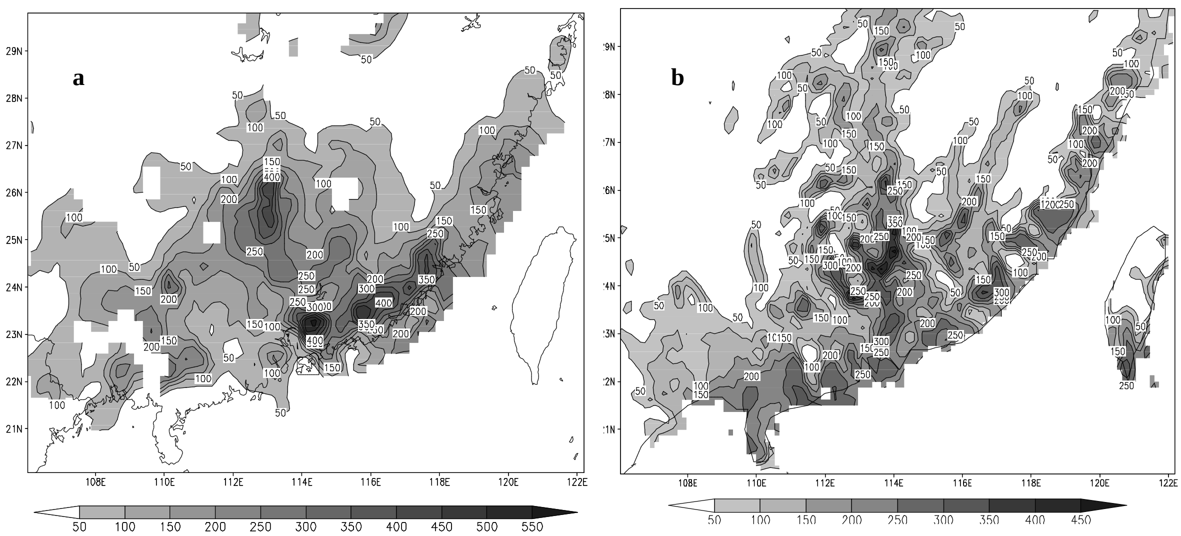

Fig.1 Total rainfall for a 66-h duration between 06:00 July 14 and 00:00 July 17. a. observations; b. model simulations. Unit: mm

5 IMPACTS OF SCS SUMMER MONSOON ON THE TORRENTIAL RAIN

As shown in large amount of work [11-13], severe precipitation is closely linked with the anomalous variation of the general circulation in tropical low-latitudes, in which the south of China sits. In 2006, the summer monsoon broke out in the fourth pentad of May over the South China Sea and kept intensifying from July 6 to 13, acquiring the maximum on July 13 before weakening afterwards; the monsoon remained active from July 14 to 17. As shown on the 850-hPa map (Fig.2), a southwest lower-level jet stream was strong and prevailed with intensity above 16 m/s from 06:00 July 14 to 00:00 July; it began to strengthen with the onset of the torrential rain and shifted much northward. The jet stream was mainly from the southwest and covered a swath of 3 – 6 latitudes from north to south and about 3 longitudes from east to west, which was typically on the synoptic scale with a mesoscale low-level jet embedded.

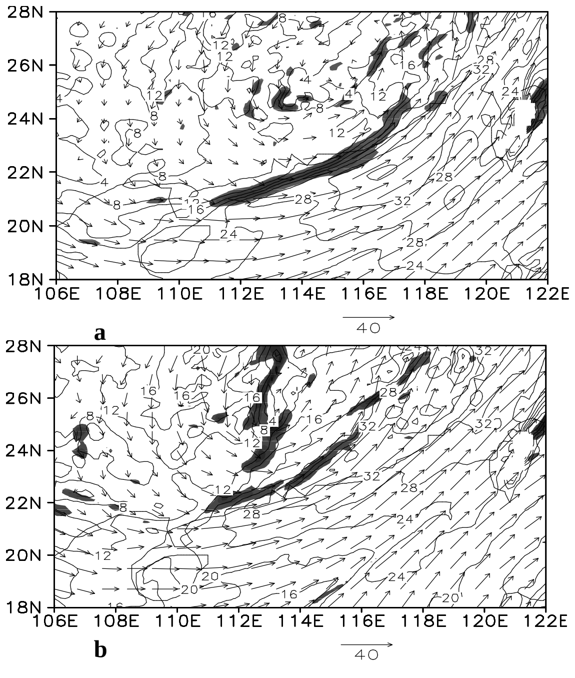

Fig.2 The 850-hPa wind field (by isolines and wind vectors) and vorticity (by shades for the area where it >2×10^{-4} s^{-1}) simulated for 06:00 July 15 (a) and 00:00 July 16 (b).

From a process of monsoonal cloud surge interacting with the spiral cloud band for July 5 – 15 (figure omitted), it is known that while Bilis and its subsequent tropical depression moved towards the west, large amount of monsoonal clouds were surging towards the northeast from the South China Sea and Bay of Bengal to encounter the storm, whose converging action helps strengthen the ascending motion. Examined in terms of the model-simulated surface flow field (Fig.3), the northern flow from Bilis met with the SCS summer monsoon over the south of China, which was the region over which multiple mesoscale eddies, converging centers and mesoscale convergence lines developed so as to be environmentally favorable for the formation and sustaining of mesoscale convective systems.

See the Chinese edition of the journal for more details.

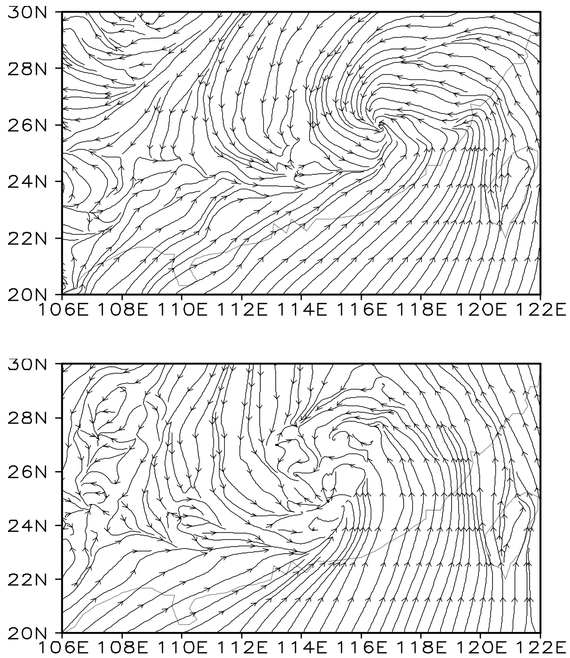

Fig.3 Simulated surface flow field for 15:00 July14 (upper panel) and 12:00 July 15 (lower panel).

6 SUMMARIES

With a mesoscale model, this study has successfully simulated a process of torrential rain over Guangdong, Fujian, Guangxi and Hunan that lasted 66 hours from July 14 to 17, 2006 after Bilis made landfall. By a sensitivity test (Fig.4), the role of the SCS summer monsoon in the rain induced by Bilis has been studied quantitatively.

(1) After the landfall of Bilis, mesoscale convective cloud clusters kept forming and evolving. This study has analyzed the convection cloud clusters by using conventional surface observations, infrared satellite imagery and radar data.

(2) The low-pressure circulation of Bilis met with the SCS summer monsoon over the south of China to enable the development of multiple mesoscale eddies, converging centers and mesoscale convergence lines, which made the environment favorable for the

formation and sustaining of mesoscale convective systems. As shown in the sensitivity test, the monsoon supplied the area of torrential rain, via warm and humid airflows, with unstable energy and water vapor. It is illustrated that the monsoon played a very important role in the generation of hard rain.

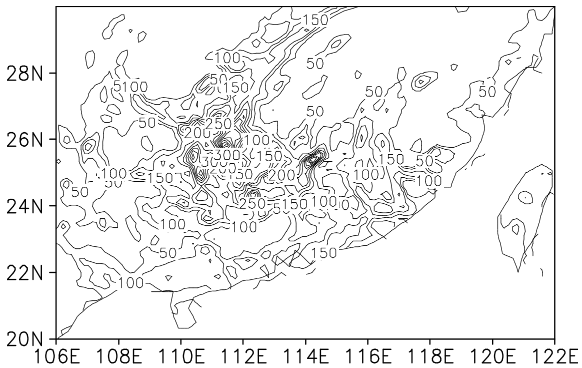

Fig.4 Simulated total rainfall for 06:00 July 14 – 00:00 July 17. Unit: mm

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