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DIAGNOSTIC INVESTIGATION OF SIMULATION BIAS WITH THE GRAPES- MESO MODEL FOR A TORRENTIAL RAIN CASE

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Abstract: In this paper, the numerical simulation bias of the non-hydrostatic version GRAPES-Meso (Mesoscale of the Global and Regional Assimilation and Prediction System) at the resolution of 0.18º for a torrential rain case, which happened in May 31st to June 1st 2005 over Hunan province, are diagnosed and investigated by using the radiosondes, intensive surface observation, and the operational global analysis data, and the sensitivity experimental results as well. It is shown in the result that the GRAPES-Meso could reproduce quite well the main features of large-scale circulation and the distribution of the accumulated 24h precipitation and the key locations of the torrential rainfall are captured reasonably well by the model. However, bias exist in the simulation of the mesoscale features of the torrential rain and details of the relevant systems, for example, the simulated rainfall that is too earlier in model integration and remarkable underprediction of the peak value of rainfall rates over the heaviest rainfall region, the weakness of the upper jet simulation and the overprediction of the south-west wind in the lower troposphere etc. The investigation reveals that the sources of the simulation bias are different. The erroneous model rainfall in the earlier integration stage over the heaviest rainfall region is induced by the model initial condition bias of the wind field at about 925hPa over the torrential rainfall region, where the bias grow rapidly and spread upward to about 600hPa level within the few hours into the integration and result in abnormal convergence of the wind and moisture, and thus the unreal rainfall over that region. The large bias on the simulated rainfall intensity over the heaviest rainfall region might be imputed to the following combined factors of (1) the simulation bias on the strength and detailed structures of the upper-level jet core which bring about significant underpredictions of the dynamic conditions (including upper-level divergence and the upward motion) for heavy rainfall due to unfavorable mesoscale vertical coupling between the strong upper-level divergence and lower-level convergence; and (2) the inefficient coupling of the cumulous parameterization scheme and the explicit moisture in the integration, which causes the failure of the explicit moisture scheme in generating grid-scale rainfall in a certain extent through inadequate convective adjustment and feedback to the grid-scale. In addition, the interaction of the combined two factors could form a negative feedback to the rainfall intensity simulation, and eventually lead to the obvious underprediction of the rainfall rate.

Key words: GRAPES-Meso; torrential rainfall simulation; bias diagnosis

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1 INTRODUCTION

It is shown in studies that reasonable simulation of large-scale circulation background of precipitation and overall distribution of precipitation do not necessarily mean that the simulated structure of mesoscale systems and torrential rains and their evolution are also reasonable and consistent with the observation. To obtain a credible result of mesoscale simulation, careful verification of the simulated result of the precipitation, especially the verification and analysis of its evolution with time, are essential[1, 2]. Starting from a typical case of torrential rain, this work verifies the detailed features, especially those evolving with time, of the simulated precipitation on the meso-α scale and

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simulated torrential rain on the meso-β scale, with the aid of a mesoscale numerical model “GRAPES-Meso”, and quantitatively studies model bias arising from the simulated environmental field of the torrential rain. On the basis of it, dynamic diagnosis and numerical sensitivity experiments are used to analyze the possible causes for the generation of the bias to offer useful clues and ideas for the development and improvement of mesoscale model systems and operational application.

2 NUMERICAL SIMULATION AND VERIFICATION

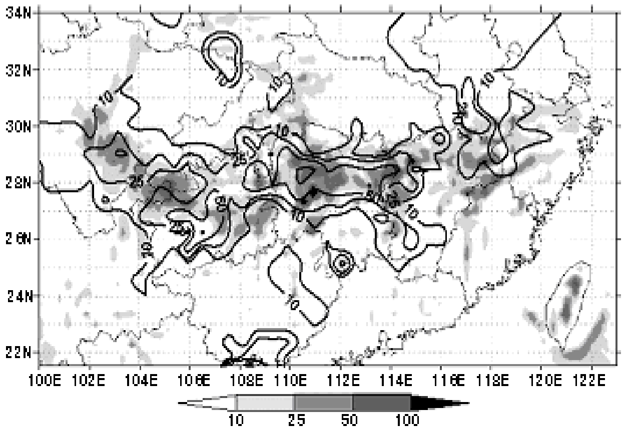

Fig.1a 24-h rainfall simulated by Grapes-Meso for the period 00:00 May 31 – 00:00 June 1, 2005 and the comparison with observation. The shaded area is the simulation and the thick, solid line is the 24-h observation that is displayed intensively.

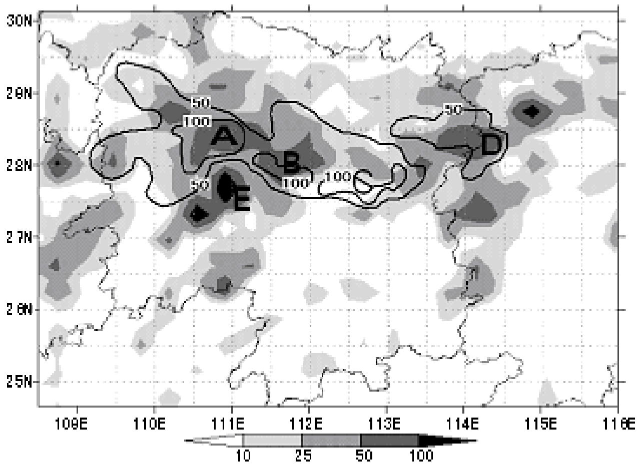

Fig.1b 24-h rainfall simulated for Hunan province over the same period as Fig.1a and the comparison with observation. The bold, solid lines are the contours of for observed rainfall of 50 mm and 100 mm and main areas of torrential rain are denoted with A, B, C and D. The shaded areas are where simulated precipitation occurs.

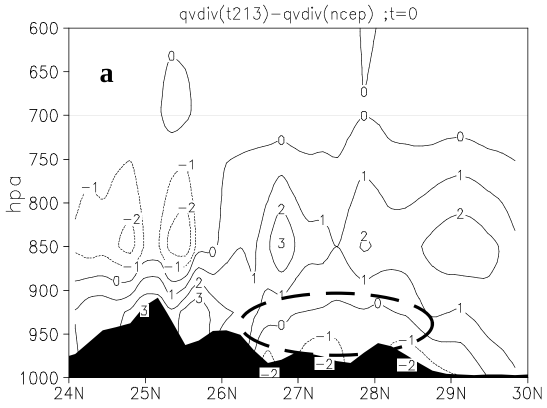

Fig.2a Cross section of diversity bias (112 °E) between Test TCTL and Test TNEW1 for water vapor flux at the initial integration time (units: $10^{-7}\cdot g\cdot hPa^{-1}\cdot cm^{-2}\cdot s^{-1}$).

2.1 Simulation of large-scale circulation

Generally, the model has reasonable simulation of the pattern and evolution of large-scale circulation and especially close to reality for the level of 500 hPa and its variation. There are, however, bias in some of the details, like the evolution of the core of an upper-level jet stream and intensity of the shear for a low-level 850-hPa vortex. Such simulation bias, though maybe unimportant from the large-scale viewpoint, will possibly have significant effect on detailed simulation and prediction of precipitation.

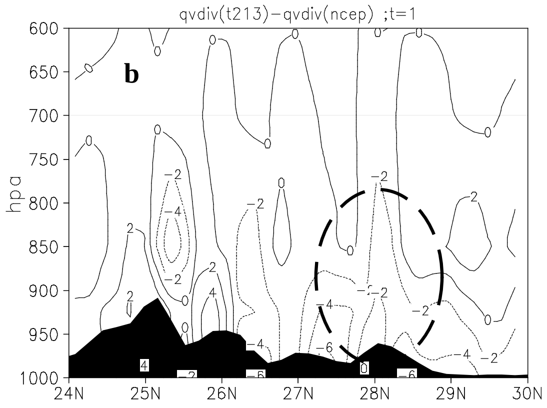

Fig.2b Same as Fig.2a but for one hour of integration tine.

2.2 Simulation of overall distribution of precipitation and mesoscale features of torrential rains

Though it produces the shape and alignment of 24-h accumulated rainfall that agree well with the observation, GRAPES-Meso has some bias in simulating the covering area of the rain, location of the rain center and rain rate in the simulation of the torrential rain and exceptionally heavy rain (Fig.1a & 1b). In addition, there are two obvious bias in the simulation of precipitation evolution with time: the

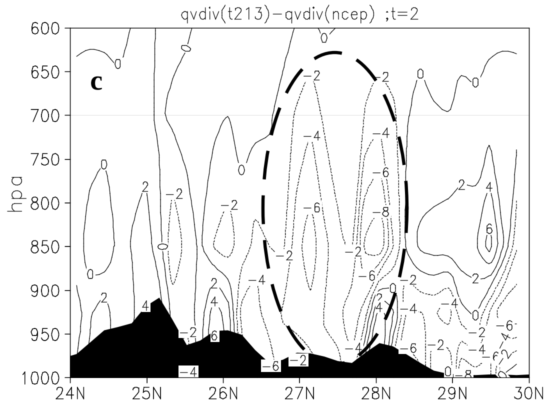

Fig.2c Same as Fig.2a but for two hours of integration time.

simulated rain appears earlier than the observation and lasts without pause, with insignificant and weak peaks.

3 PRELIMINARY DIAGNOSTIC DETERMINATION AND STUDY OF THE SIMULATION BIAS

As shown in various studies, bias in the initial field and incorrect description of the physics are the main reasons for the simulation bias[3 – 10].

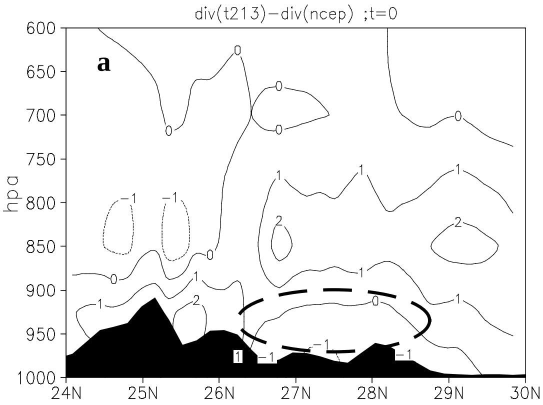

Fig.3a Cross section of diversity bias (112 °E) between Test TCTL and Test TNEW1 for wind at the initial integration time (units: $10^{-7}\cdot g\cdot hPa^{-1}\cdot cm^{-2}\cdot s^{-1}$).

3.1 Sensitivity of simulated results to the initial field

A sensitivity experiment for the initial field, TNEW1, is designed and compared with the original experiment (taken as the control TCTL). The only difference between them is that the initial field uses the NCEP analysis data rather than the T213 analysis. It is discovered that the earlier appearance of the torrential rain core in TCTL is much associated with the information input to the model.

3.2 Diagnostic determination of the initial bias

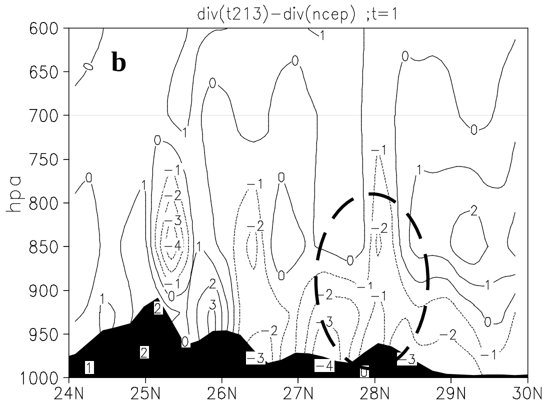

Fig.3b Same as Fig.3a but for one hour of integration tine.

Further study has shown that the rainfall bias simulated for the core of the torrential rain in both experiments agree with the bias area of diversity for water vapor flux. The convergence bias of water vapor flux is in the shallow air layer near 925 hPa of the lower troposphere at the initial time but keeps growing, intensifying and transporting upward in the first few hours of integration (Fig.2a, 2b, 2c). Significant corresponding relationships are found between the bias of water vapor convergence and precipitation. More diagnosis of individual terms shows that the bias of weak low-level wind field convergence in the initial phase of integration are growing substantially in the first few hours and transporting upward rapidly (Fig.3a, 3b, 3c), evolving with time in a way similar to that of the bias of water-vapor flux divergence. It is shown that the bias of wind field convergence and their growth with time in TCTL are the main reasons for the presence of bias in water vapor flux and their rapid growth.

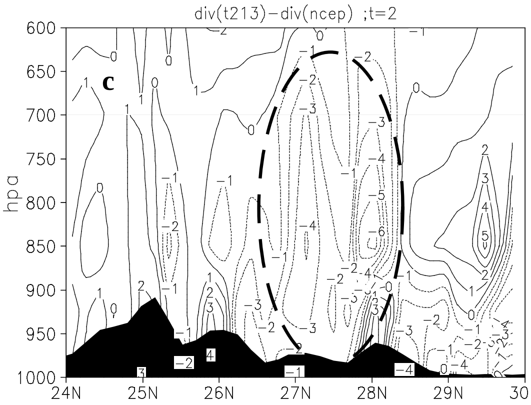

Fig.3c Same as Fig.3a but for two hours of integration tine.

3.3 Discussions of weak simulated precipitation peaks

As shown in the analysis and diagnosis, the much weaker simulation of rain rates by GRAPES-Meso may be caused by the following two factors. First, the bias in the fine core structure of the upper-level jet stream, which result in chain reaction by having weak simulated upper-level divergence over the area of the torrential rain and inhibiting the intense development of the vertical motion there. Second, the sub-grid scale and grid scale are not coordinated as desired and when the convective parameterization scheme starts the environmental condition of temperature and humidity needed for condensation and rain formation on the grid scale of the model will be affected. The two factors will also interact with each other to have negative feedback to the precipitation.

To improve and upgrade the capabilities of mesoscale models to simulate and predict quantitative precipitation, it is very important to describe model physics realistically and coordinate various physical schemes.

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

4 CONCLUSIONS AND DISCUSSIONS

With mesoscale numerical experiments of a typical torrential rain and detailed analysis and diagnostic study of the simulation bias, this work draws the following conclusions:

(1) Viewing from the synoptic process, the model can be used as a useful numerical product that provides good reference and guidance for short-term prediction of precipitation.

(2) Compared with the observation, the bias of simulation for the torrential rain are earlier appearance of precipitation, much weaker precipitation peaks, larger low-level wind speed and smaller wind speed of upper-level jet stream core.

(3) The earlier appearance of precipitation is mainly resulted from the bias of initial values rather than the model itself.

(4) Adjustment of convection and feedback from the fields of temperature and humidity on the grid scale are not sufficient enough to affect the conditions needed for condensation and rain to occur and thus hinder the role of the explicit precipitation scheme.

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