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NUMERICAL STUDY ON THE EFFECT OF RAINWATER EVAPORATION ON SEVERE CONVECTIVE WEATHER UNDER DIFFERENT BOUNDARY LAYER PARAMETERIZATION SCHEMES

Tang Jie, Liu Xiaoli
Nanjing University of Information Science and Technology, Key Laboratory of aerosol and cloud precipitation in China Meteorological Administration, Nanjing, Jiangsu 210044
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Abstract Three boundary layer parameterization schemes (MRF,UW,YSU) in mesoscale numerical model (WRF) are used to simulate a severe convective weather in Zhejiang on November 9, 2009 without considering the rainwater evaporation term and considering the rainwater evaporation term. The numerical simulation results of macroscopic and microscopic physical mechanisms of strong convection were compared. The results show that without considering the evaporation of rainwater, the rainbands simulated by the three boundary layer schemes are narrower, hourly precipitation is smaller, convective monomer moves slower, and the precipitation overlap area is more. The simulated radar reflectivity intensity is significantly reduced and the echo band is narrower. Whether rain evaporation is considered or not, the YSU scheme simulates the strongest precipitation and radar reflectivity, MRF scheme is close to it and the UW scheme is the weakest. By analyzing the macro conditions of convection development, it can be seen that under the condition of considering the rainwater evaporation, high and low altitude divergence configuration simulated by the three boundary layer schemes is better, the water vapor transport is more abundant, updraft and downdraft are stronger, providing more favorable conditions for the occurrence and development of strong convection. Whether rain evaporation is considered or not, the water vapor conditions and high and low altitude divergence configuration simulated by the YSU scheme are better, results simulated by MRF scheme is similar to YSU scheme. The convection generation condition simulated by the UW scheme is the weakest of the three schemes. Under the condition of considering the rainwater evaporation, more hydrogel particles simulated by three boundary layer schemes, and stronger updraft, which is more conducive to development of convection. Whether rain evaporation is considered or not, the MRF and YSU schemes can simulate more rain, mainly because the vertical movement of the airflow is stronger, and more cloud water becomes cold cloud water under the strong ascending airflow, and more cold water frozen with graupel to form graupel, graupel melts to produce more rain. The UW scheme have poor macroscopic conditions, and the updraft is weaker. Cold cloud water is less, and cold cloud water and graupel are less frozen, resulting in less rainwater content

Keywords: mesoscale numerical model, boundary layer parameterization scheme

1. Introduction

The boundary layer scheme is an important part of the study of physical parameterization schemes in numerical models(Morrison et al. 2008;Aksoy et al. 2006;Deng et al. 2006). The selection of boundary layer parameterization schemes in the model has a significant impact on the simulation results of strong convection processes(Jankov et al. 2004;Nielsengammon et al.2010). Many scholars have successively made relevant researches to show that under the same circumstances, the ability of the boundary layer scheme to predict precipitation is not the same(Zhang et al. 2013;Zhou et al. 2013). Introducing a reasonable boundary layer parameterization scheme can effectively improve the ability of numerical models to simulate strong convective weather(Wang et al. 2010;Cai et al. 2007).

In recent years, research on cloud microphysical structures has become an important means of understanding the process of strong convection(Doswell et al. 1987).The phase change of water is an important part of the study of cloud microphysical structure. The phase change of water in strong convection process, especially the evaporation process, melting process and latent heat change caused by sublimation process are the main causes of vertical airflow field change(Li et al. 2013). Many scholars use numerical models to explore this, and believe that the latent heat change caused by evaporation process is the main influence factor of vertical flow field and convective cloud system characteristics change in cloud(Yang et al. 2009). Through analysis, it is found that precipitation occurs due to evaporation, which causes the amount of supercooled water in the cloud to decrease(Wang et al. 2002). Discuss the relationship between microphysical processes such as rainwater evaporation process and latent heat, and find that the rainwater evaporation process is the main cause of the downdraft(Fernández-González et al. 2016), the low-level sinking airflow is mainly generated by the melting process and the evaporation process(Liu et al. 2010),and the evaporation process and the melting process in the convective system increase the instability of the convective system(Braun et al. 2010).

Based on this, this paper uses three different boundary layer parameterization schemes (MRF, UW, YSU) to simulate a strong convective weather process in Zhejiang, and discusses the impact of rainwater evaporation on this case from macroscopic and microscopic perspectives.

2. Observations and model

a. Observations

On November 9, 2009, there was strong convective weather in Zhejiang Province. At 08:00 (UTC), south trough is located in the south of China at 500 hPa, and the temperature trough after the height trough, will continue to move eastward and deepen,and affect the Zhejiang area. At 700 hPa, low-level jet stream in the south of the Yangtze River valley transport warm and humid air, accompanied by strong convergence of water vapor at the front. At 850 hPa, the shear line above the Yangtze River vally promotes air convergence and elevation.And the temperature ridge is located in the coastal area,under the southwesterly airflow, warm air is transported to the north. The cold air on the ground is transported southward under the guidance of the northwest airflow.This high and low altitude configuration is very conducive to the development of strong convective weather in Zhejiang.(Fu et al. 2016).

b. Introduction of simulation scheme

In this paper, WRF v3.4 mesoscale model is used for numerical simulation. The initial field and the lateral boundary field are provided by using the NECP global reanalysis data (1×1) every 6 hours. The longitude and latitude of the simulation center for the severe convection weather process is 29.6。N ,119.8。E. The integration time of the model is 00:00 (UTC) on November 9, 2009, the integral time is 12 hours, the step length is 36s; the two nesting of the model is used. The grid spacing is 6 km, 2 km, the second grid number is 262×280, the output time is 30mins and 10 mins, the model is divided into 27 layers in the vertical direction, and the top pressure is 100hPa. The topographic data are the global 5 m and 2m topographic data of U.S. Geological Survey. The region of this simulation is shown in figure 1. With the exception of the boundary layer parameterization schemes (MRF, UW, YSU), the other parameter schemes of the two regions are designed with the same scheme (Table 1).Under the conditions of different boundary layer parameterization schemes, the rainwater evaporation s are turned on and off respectively, and then numerical simulations are carried out for this case.

Table 1 Schemes selected in this study

Microphysical scheme	MY
Land surface process scheme	Noah
Near-surface layer scheme	MYJ Monin-Obukhov
Long wave radiation scheme	RRTM
Shortwave radiation scheme	Dudhia
Cumulus convection parameterization scheme	Kain-Fritsch(new Eta)

3. Results

a. Surface precipitation analysis

Figure 2 shows the 12-hour cumulative precipitation simulated by the three boundary layer parameterization schemes without considering the rainwater evaporation term (top) and considering the rainwater evaporation term (bottom).In any case, the simulated cumulative precipitation is higher than the actual measurement. Under considering rainwater evaporation, the cumulative precipitation simulated by UW scheme is the closest to the actual situation. Moreover, it can be seen that without considering the rainwater evaporation term, local cumulative precipitation is significantly increased simulated by the three boundary layer parameterization schemes at the junction of Anhui and Anhui, and the rain belt is narrow. The