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Original scientific paper

Different effects of latent heat in planetary boundary layer and cloud microphysical processes on Typhoon Sarika (2016)

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Three simulation experiments were conducted on Typhoon (TC) "Sarika" (2016) using the WRF model, different effects of the latent heat in planetary boundary layer and cloud microphysical process on the TC were investigated. The control experiment well simulated the changes in TC track and intensity. The latent heat in planetary boundary layer or cloud microphysics process can affect the TC track and moving speed. Latent heat affects the TC strength by affecting the TC structure. Compared with the CTL experiment, both the NBL experiment and the NMP experiment show weakening in dynamics and thermodynamics characteristics of TC. Without the effect of latent heat, the TC cannot develop upwards and thus weakens in its intensity and reduces in precipitation; this weakening effect appears to be more obvious in the case of closing the latent heat in planetary boundary layer.

The latent heat in planetary boundary layer mainly influences the generation and development of TC during the beginning stage, whereas the latent heat in cloud microphysical process is conducive to the strengthen and maintenance of TC in the mature stage. The latent heat energy of the cloud microphysical process in the TC core region is an order of magnitude larger than the surface enthalpy. But the latent heat release of cloud microphysical processes is not the most critical factor for TC enhancement, while the energy transfer of boundary layer processes is more important.

Keywords: typhoon, latent heat, planetary boundary layer, cloud microphysical processes

1. Introduction

Both planetary boundary layer and cloud microphysical processes are important physical factors affecting the occurrence and development of TC. Many scholars have proposed different parameterization schemes regarding these two important physical processes. However, planetary boundary layer and cloud microphysics scheme are two significant uncertainties in numerical forecasting, more studies are required to investigate their adaptability.

The latent heat in both planetary boundary layer and cloud microphysics processes plays an important role on the TC, where the latent heat in planetary boundary layer is vertically delivered to the upper level via surface fluxes and thus provides energy for the TC. Liu et al. (2017) pointed out that both surface fluxes and vertical mixing exert important effects on the prediction accuracy of TC intensity. But according to the study by Braun and Tao (2010), TC intensity mainly depends on the surface fluxes rather than vertical mixing. Ming and Zhang (2016) found that the intensity of simulated TC is highly sensitive to the ratio of TC enthalpy to momentum, which exceeds the effect of either variate alone on TC intensity. Meanwhile, some others have discussed the effect of turbulent diffusion coefficient in planetary boundary layer on TC intensity (Smith and Thomsen, 2010; Rotunno and Bryan, 2012; Zhang et al., 2017). Coupled-Ocean-Atmosphere-Wave-Sediment Transport (COAWST) modeling system has a better performance simulating the path and intensity of the typhoon (Warner et al., 2010). With the study of the model on the interaction among coastal storm dynamic, the boundary layer, and sea temperature, the thermodynamic state of the sea surface, and the development of tropical and extratropical cyclones, the impact of air-sea interaction on TCs is further revealed (Zambon et al., 2014a, 2014b; Zambon, 2014).

The prediction of TC intensity greatly depends on the selection of cloud microphysics schemes (Khain et al., 2016). The latent heat in cloud microphysical processes, which is mainly released by the phase transformation of various moisture variables (Li et al., 2013a), provides energy for the TC. Li et al. (2013b) suggested that the amount of released latent heat has little effect on TC track but greatly affect TC intensity, structure and precipitation; the latent heat and the feedback effect of convection together have significant impact on TC intensity. Wang (2009) proposed that the distribution and change of condensation heating in outer spiral rainbands can affect TC intensity and structure. Non-adiabatic heating leads to enhanced (weakened) TC through affecting the outer rainbands and the inner core structure (Li et al., 2014). Chan and Chan (2016) also believed that the release of latent heat in the outer rainbands of eyewall can increase TC intensity.

Many previous studies have explored the sensitivity of TC intensity to the planetary boundary layer parameterization schemes or cloud microphysics parameterization schemes (Li and Pu, 2008; Liu et al., 2017; Ricchi et al., 2017;

Ming et al., 2012; Kim et al., 2017), or separately discussed the effect of the latent heat in cloud microphysical process on TC intensity (Li et al., 2013b; Liu et al., 2017). Cloud microphysics schemes have less influence on the TC path than the intensity. When warm rain physics was used, the simulated TC intensity increased (Tao et al., 2011). The release of latent heat inside the eye wall above the cloud base of the TC was balanced by the strong cooling trend of the vertical advection above the cloud base. The microphysical parameterization affected the thermal structure of the surface layer (Williams, 2019). By contrast, few studies have investigated the relative effect of the latent heat in planetary boundary layer and cloud microphysical processes. Which is more important for TC, latent heat in planetary boundary layer or latent heat in cloud microphysical processes? How are they different in the effects on TC intensity? This is exactly the research focus of the present paper.

2. TC Sarika (2016)

Tropical storm "Salika" generated over the sea east to the Philippines at 12:00 on 13 October 2016, strengthened into a typhoon at 21:00 on the 14^{th}, then strengthened into a strong typhoon at 06:00 on the 15^{th}, and further strengthened into a super typhoon at 15:00, the largest wind speed nearby the center was 52 m/s. It landed on the eastern coast of Luzon, Philippines around 18:20. The maximum wind speed near the center was 55 m/s when it landed. After landing, it weakened into a typhoon. After entering the South China Sea at 01:00 on the 16^{th}, it was gradually approaching the eastern coast of Hainan Island directed by subtropical high airflow. It further strengthened into a strong typhoon at 9:00 on the 17^{th}, and landed in Hele Town, Wanning at 1:50 on the 18^{th}. The maximum wind speed was 45 m/s and the minimum air pressure was 950 hPa near the center. Then it crossed Hainan Island through Qiongzhong, Quzhou and weakened into a strong tropical storm at 12:00 on the 18^{th}. At 06:10 on the 19^{th}, it landed again on the coast of Xingdong, Fangchenggang, Guangxi Zhuang Autonomous Region. The maximum wind speed near the center was 25 m/s. Considering that "Sarika" brought severe impact on China and the Philippines, TC Committee decided to remove the name of "Sarika" at the 49^{th} TC Committee meeting in February 2017.

3. Experimental design

The Weather Research and Forecasting (WRF V3.8.1) model was selected for the simulation control experiment (CTL). The CTL experiment had 33 uneven vertical levels and three domains of 195 × 168, 301 × 256 and 304 × 265 grid points, with resolutions of 27, 9 and 3 km, respectively. NOAH land surface scheme, GFS planetary boundary layer scheme, WSM6 cloud microphysics scheme (Hong and Lim, 2006), RRTM long-wave radiation scheme, Dudhia short-wave radiation scheme and Tiedtke cumulus parameterization scheme were chosen, but there is no cumulus parameterization scheme in domain 3. The 1° × 1° NCEP/NCAR reanalyze FNL data was used as the initial and boundary condition. The model ran from 00:00 on October 16 to 00:00 on October 19 of 2016.

The sea temperature used here is NCEP/NCAR reanalysis FNL data. The distribution initial field of the sea temperature (Fig. 1) shows that when Sarika entered the South China Sea, the sea temperature over the South China Sea was above 26 °C, with the maximum reached 30 °C. The typhoon path was located in a high sea temperature area. The coupling of wind stress and sea temperature has an important impact on the boundary layer (Chelton et al., 2001, 2007; O'Neill et al., 2003, 2005, 2010). The sea-atmosphere coupling model has a better simulation of tropical cyclones. Tropical cyclone paths and intensities are highly sensitive to initial conditions. Different, boundary layer schemes, sea temperature, surface roughness, and coupling methods all affect cyclones (Ricchi et al., 2016, 2017, 2019). The sea temperature field in the coupled model has an important impact on the dynamics of the boundary layer, especially the impact of the SST field on the generation of wind wave, currents, and storm surges (Warner et al., 2010; Olabarrieta et al., 2012). The sea temperature sensitivity test shows that when the sea temperature decreases, the low-intensity surface radiation has a certain effect on delaying and weakening the development of the typhoon. While the temperature increases, the high-intensity surface radiation will weaken the features of the high-intensity vortex (Miglietta et al., 2011). The study of Cassola et al (2016) showed that using real-time small-scale SST fields made a significant improvement in severe precipitation prediction over the Mediterranean region.

In order to explore the relative effect of latent heat in the planetary boundary layer and cloud microphysics, two sensitivity experiments were designed, where the first was to close the latent heat flux in the planetary boundary layer parameterization scheme (*i.e.*, the NBL experiment), but the friction of the boundary

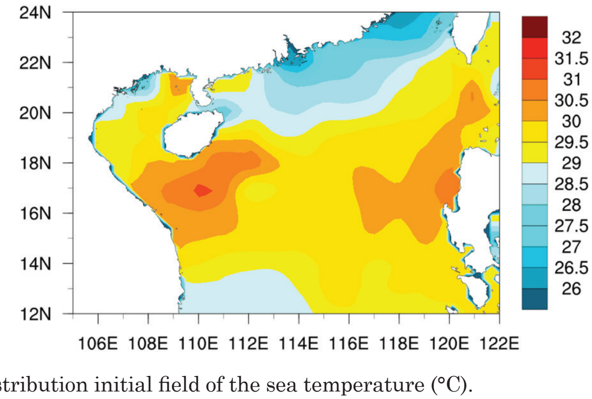

Figure 1. The distribution initial field of the sea temperature (°C).

layer was not excluded. The second was to close the latent heat release in the cloud microphysics parameterization scheme (*i.e.*, the NMP experiment); other settings were consistent with CTL.

4. Results

4.1. Track

The TC center is identified as the minimum sea level pressure (MSLP) in the first layer. As time changes, the position of the minimum sea level pressure changes and the TC center moves as well. The TC track simulated by the CTL experiment was consistent with the actual situation (Fig. 2). The close of either latent heat in planetary boundary layer or latent heat in cloud microphysics scheme exerted an impact on the TC track. Before 00 o'clock on the 17th, the

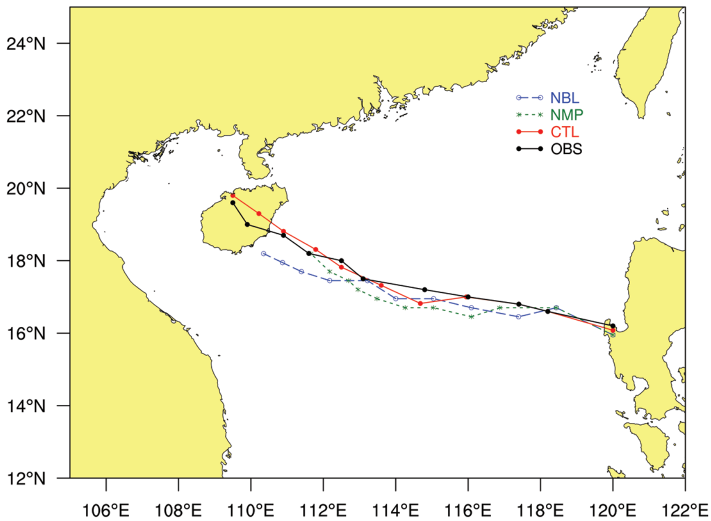

Figure 2. TC track.

moving speed along the simulated tracks by NBL and NMP experiments was consistent with that of the CTL experiment; after that, the moving speed slowed down and the TC center lagged behind the CTL experiment. The speed in NMP experiment was slower than that in NBL experiment, and the TC track was also more southward than the CTL experiment.

4.2. Intensity

The MSLP simulated by the CTL experiment was similar to the actual situation (Fig. 3). Furthermore, the CTL experiment successfully simulated the char-

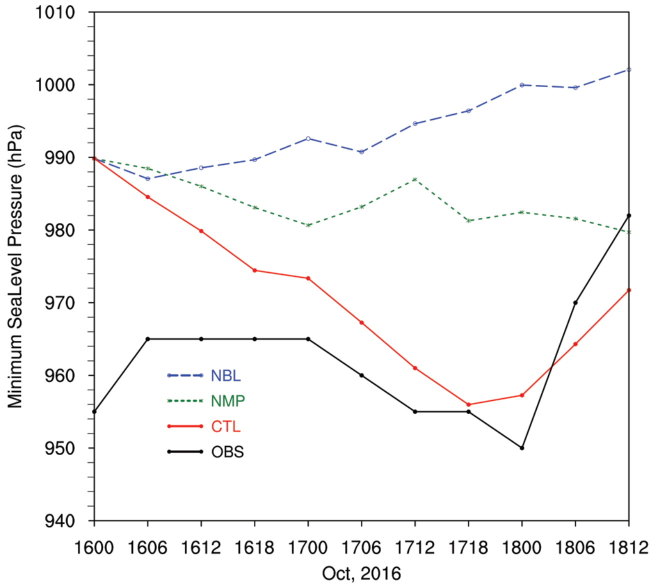

Figure 3. TC intensity.

acteristics that the TC first strengthened and then weakened. However, NBL and NMP experiments failed to simulate the changing characteristics of TC intensity. In particular, the NBL experiment completely failed to simulate the process of TC strengthening, where the minimum sea-level pressure was continuously increasing. The minimum sea-level pressure in the NMP experiment was lower than that in the NBL experiment and the TC continued to strengthen before 00:00 on the 17^{th}; after that, the TC first weakened and then began to strengthen after 12 o'clock on the 17^{th}. This demonstrates that the strengthening of TC is mainly supplied by the energy from the planetary boundary layer before landing while intensity maintenance in the mature phase is closely associated with the cloud microphysical latent heat process. The weakening of TC is mainly affected by the underlying surface and completed via the planetary boundary layer process.

4.3. Precipitation

According to the 72-hour accumulated precipitation, the CTL experiment simulated the torrential rain center in Hainan Island (Fig. 4a), according to the observation of Qionghai meteorological station at the torrential rain center, accumulative precipitation reached 649.7 mm from 16:00 on October 17 to 16:00 on October 18 of 2016. The NMP experiment simulated false precipitation center and region (Fig. 4c); the precipitation in the NBL experiment was characterized

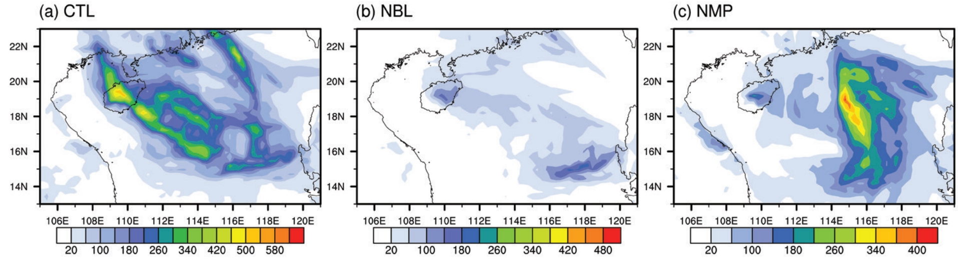

Fig. 4. Accumulated precipitation from 00:00 on October 16 to 00:00 on October 19 (Unit: mm).

by lower amount and smaller distribution area (Fig. 4b). With reduced latent heat, TC precipitation was significantly decreased; the reduction of the latent heat in planetary boundary layer exerted greater impact on precipitation than the reduction of the latent heat in cloud microphysics scheme.

4.4. Evolution of circulation and structure

In the intensifying phase before TC landing (from 18:00 on October 17 to 00:00 on October 18), the TC circulation simulated by the CTL experiment (Figs. 5a, 5d) was significantly stronger than that by the NBL experiment (Figs. 5b, 5e) and the NMP experiment (Figs. 5c, 5f) at both the lower level of 850 hPa and the middle-upper level of 500 hPa. Nevertheless, at the level of 850 hPa, the TC circulation simulated by the NMP experiment (Fig. 5c) was significantly stronger than the NBL experiment (Fig. 5b); at the level of 500 hPa, the TC circulation simulated by the NBL experiment (Fig. 6) was significantly stronger than the NMP experiment (Fig. 5f). Similar characteristics were also showed in terms of the tangential wind (Fig. 6). According to the comparison of the NBL and NMP experiments, under the influence of the latent heat in cloud microphysical processes alone (Fig. 6b), the flow field of tangential wind developed to higher altitude with weak intensity at the lower level; under the influence of the latent heat in planetary boundary layer processes alone (Fig. 6c), the flow field of tangential wind was strong at the lower level without vigorous development to high altitude. This suggests that the latent heat in planetary boundary layer mainly affects the TC circulation at the lower level, while the latent heat in cloud microphysical processes mainly plays a role in the middle and upper levels.

All the three experiments have simulated the warm core structure of TC (Fig. 7). Among them, the maximum of the positive temperature deviation in the CTL experiment reached 5.5 °C, at a height of 6 km, and that in the NBL experiment was 2.2 °C, at a height of 5–6 km, mainly concentrated in the lower layer, while that the NMP experiment reached up to 4.5 °C, at a height of 5–6 km, greater than that in the NBL experiment, which indicated that the latent heat of the boundary layer had a greater weakening impact on the warm core than that in the cloud microphysics.

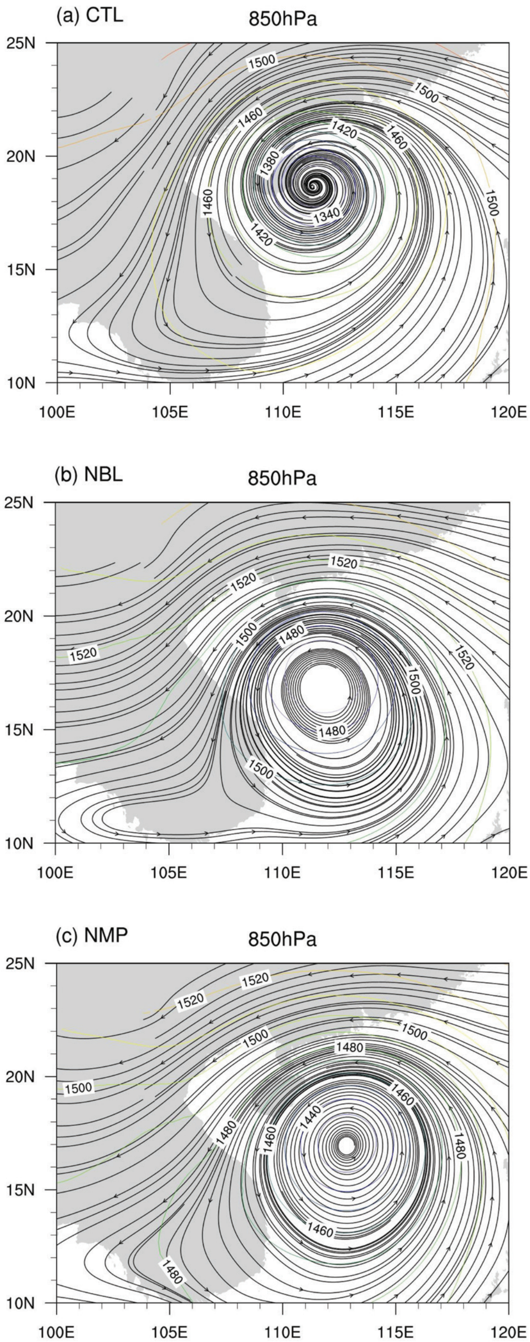

Figure 5. Circulation field and height field of TC in the intensifying phase (Unit: gpm).

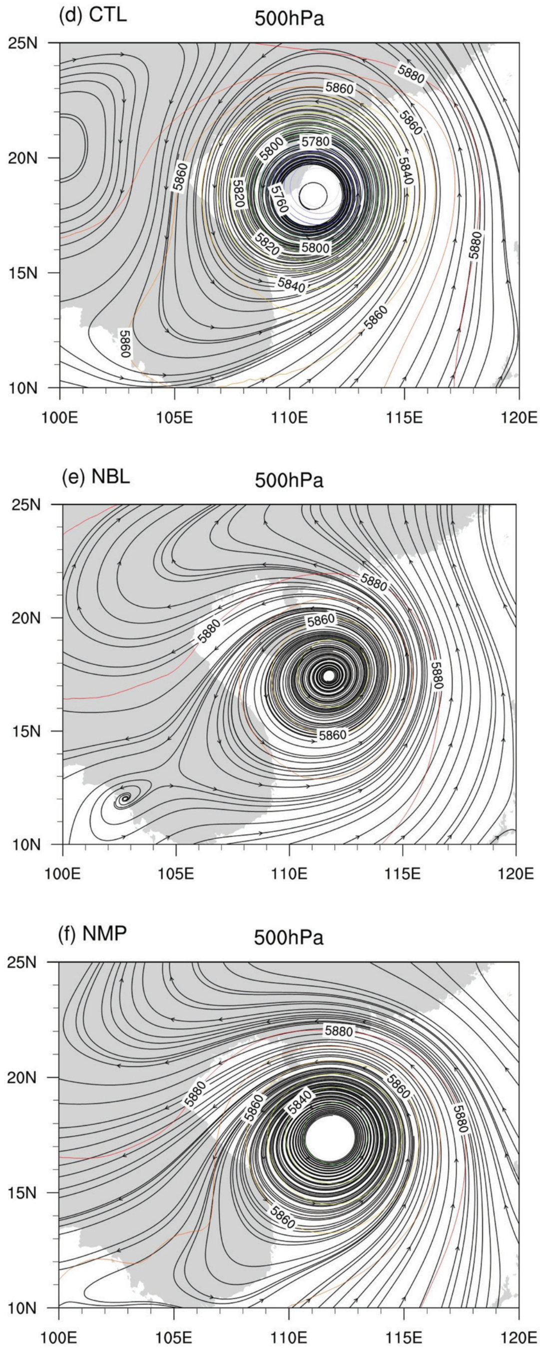

Figure 5. Continued.

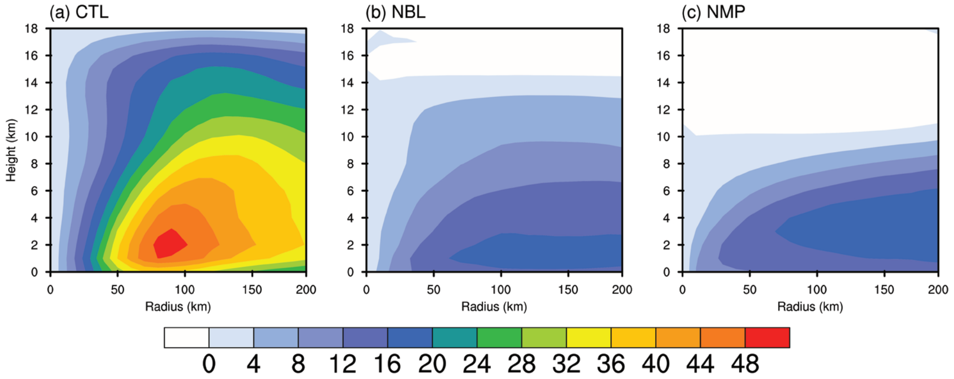

Figure 6. Azimuth average tangential wind of TC in the intensifying phase (Unit: m/s).

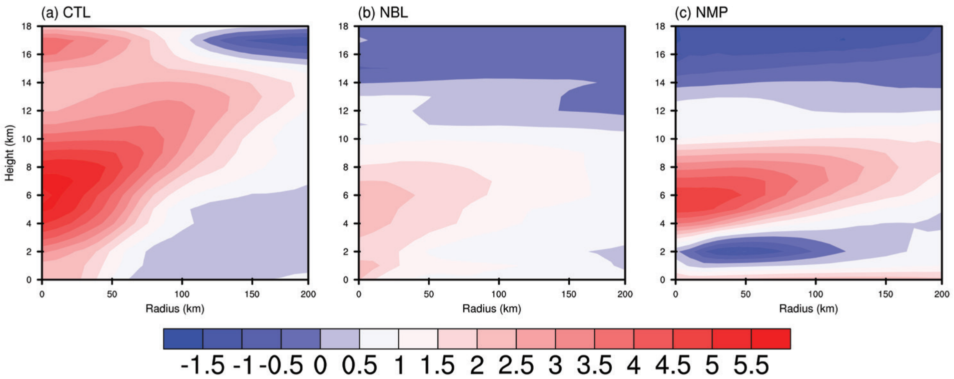

Figure 7. Azimuth average temperature deviation of TC in the intensifying phase (Unit: °C).

According to Hart (2003), the thermal wind parameters at the upper and lower levels of the troposphere were intended to characterize the core heating and cooling structure. When the values of these two parameters are both greater than 0 during TC, it is indicated that the up and down layers of the TC are all warm-cored. For the calculation, the lower layer of the troposphere is 900 ~ 600 hPa and the upper layer is 600 ~ 300 hPa:

$$\left.\frac{\partial(\Delta Z)}{\partial \ln p}\right|_{900\,\text{hPa}}^{600\,\text{hPa}} = -\left|V_T^L\right| \tag{1}$$

$$\left.\frac{\partial(\Delta Z)}{\partial \ln p}\right|_{600\,\text{hPa}}^{300\,\text{hPa}} = -\left|V_T^U\right| \tag{2}$$

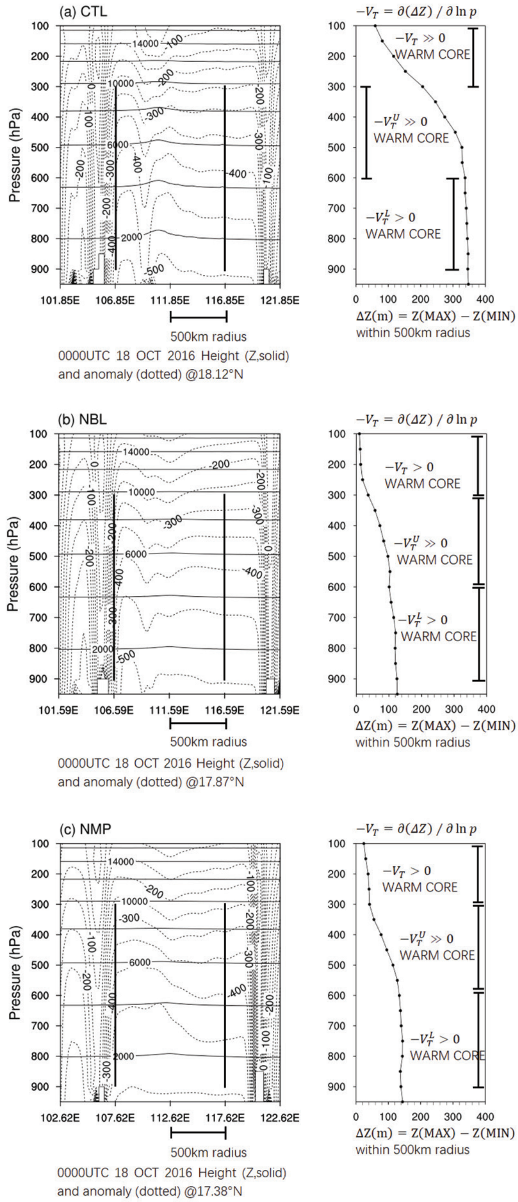

Figure 8. Derivation of parameters $-V_T^L$ [Eq. (1)] and $-V_T^U$ [Eq. (2)] for TC exhibiting tropospheric warm core structure. (*left*) Longitudinal cross section of height (Z, m; solid contour every 2,000 m) and anomaly from zonal mean (*dotted*, m). Two vertical lines indicate the 500-km radius. (*right*) Height difference (ΔZ) within this radius. Cyclone phase is derived from thermal wind [$\partial(\Delta Z)/\partial \ln p$] in two layers. $-V_T^L$ is calculated using a linear-regression fit of ΔZ between 900 and 600 hPa; $-V_T^U$ is calculated between 600 and 300 hPa.

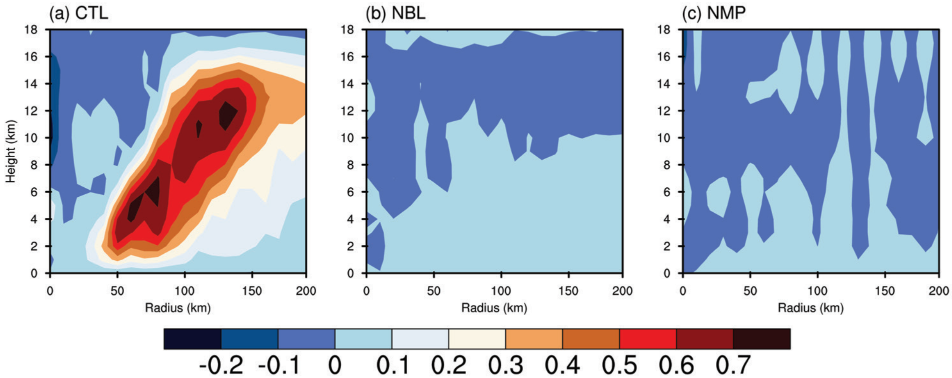

Figure 9. Azimuth average vertical velocity of TC in the intensifying phase (Unit: m/s).

The TC height perturbation ($\Delta Z = Z_{MAX} - Z_{MIN}$) is evaluated within a radius of 200 km (Fig. 8). For the left side of the TC center landed on the land and the friction effect, the radius of the warm core reduced compared to the right side (Fig. 8). ΔZ increased with the vertical height, that is, $-V_T^L > 0$ and $-V_T^U > 0$. All three simulated TCs had a warm-heart structure. The warm-heart structure was weaker in the lower troposphere and stronger in the upper layer. Warm-heart structure in cloud microphysics was weaker turning off the latent heating in the boundary layer than that in the cloud microphysics.

The latent heat also has significant impacts on vertical velocity (Fig. 9). The upward vertical velocity in the CTL experiment stretches along the cloud wall to the top of the troposphere, at the maximum of 0.7 m/s. The vertical velocity in the NBL experiment reaches the maximum of 0.05 m/s, and the upward vertical velocity, reached only the height of about 8km, implying that the height for convective activities of TC was simulated by the NBL scheme to be low. The upward vertical velocity in the NMP experiment can reach the upper troposphere, facilitating the upward transport of the latent heat of the boundary layer.

The high temperature in the CTL experiment is mainly concentrated in the mid-layer of 5–8 km (Fig. 10), and reaches the maximum of over 6 °C at the maturity stage with time change, emerging in the mature stage of TC, and the temperature deviation decreases after TC landing. In the NBL experiment, the maximum positive temperature deviation occurs at a height of 8–10 km at 24–30 hours, and the warm core region locates high for the absence of the latent heat of the boundary layer. The maximum positive temperature deviation simulated in the NMP experiment locates lower than that of the NBL experiment, at a height of 6–8 km, and the positive temperature deviation of 5 °C appears at 42–52 hours. The warm core zone in both the NBL and NMP experiments move to the lower layers over time, and TC can hardly develop upward. The positive

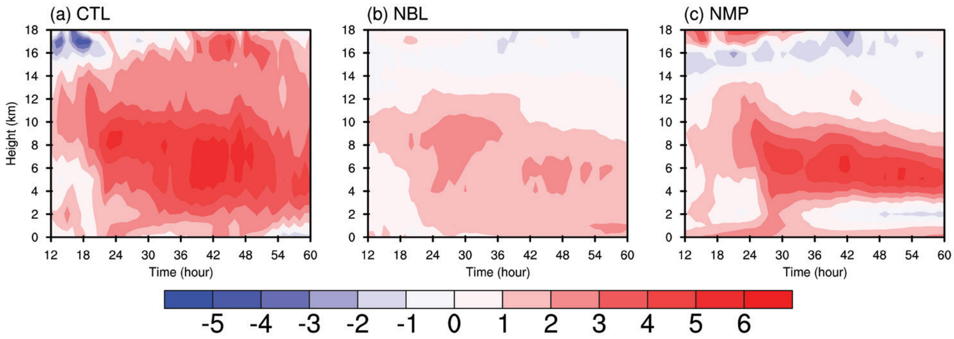

Figure 10. Evolution of temperature deviation (°C) at the TC eye (The radius of TC eye is 50 km) from t=12 to 60 hr.

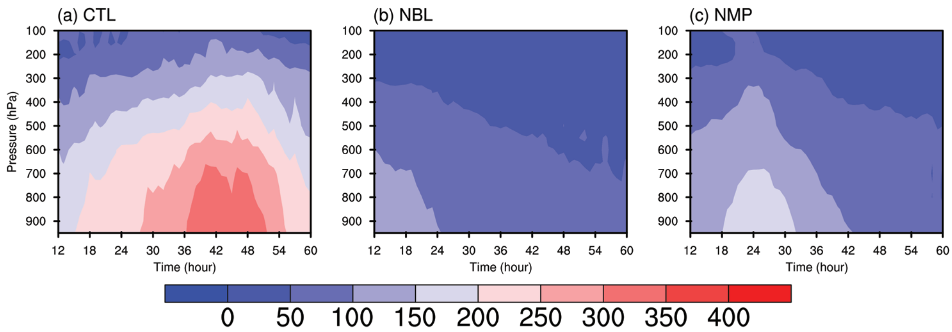

Figure 11. Evolution of azimuth average ΔZ (m) from t=12 to 60 hrs at the TC core region.

temperature deviation produced in the NBL experiment is lower than that in the NMP experiment, the position of the warm core zone higher than that of the NMP experiment, indicating that the latent heat in the boundary layer has greater impacts on the development of the warm core structure of TC than that in the cloud microphysics.

It can be seen from the temporal variation of the average disturbance height ΔZ over the area 200 km away from the TC center that the simulated TC in three tests all developed into a warm-hearted structure (Fig. 11), ΔZ reached the maximum in CTL test, NBL test, and NMP test in 36–48 hours, 12–24 hours, and 18–30 hours, respectively. It is smaller in NBL test than in NMP test. The temporal variation of disturbation height was consistent with that of TC intensity (Fig. 3).

The tangential wind in the CTL experiment was small at the initial development stage (Fig. 12) and grows with the TC developing and then reaches the maximum before the TC landing and then decreases. The maximum tangential wind in the NBL experiment occurs within the radius of 110–170 km from TC

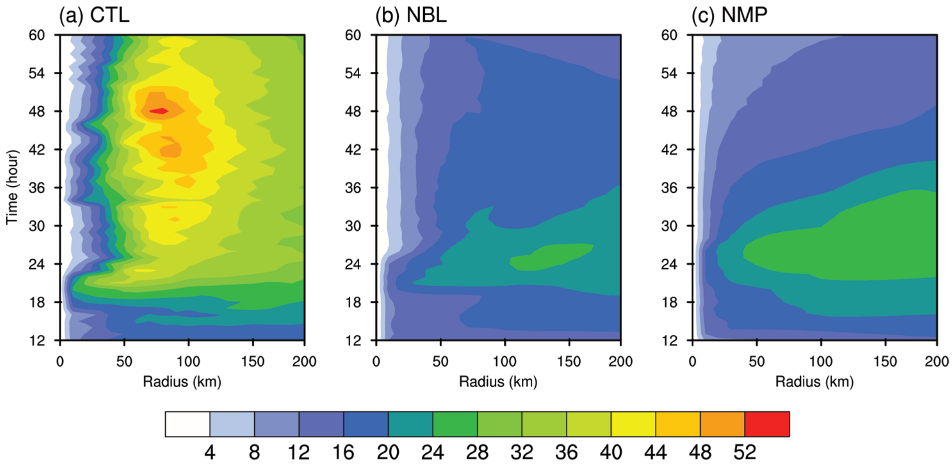

Figure 12. Evolution of azimuth average tangential wind (m/s) at a height of 1 km from *t*=12 to 60 hrs.

center at 23–27 hours, and then decreases, while that in the NMP experiment emerges within the radius of 70–180 km from TC center at 23–30 hours, and then reduces. Without the latent heat, the strength of TC can't last for a long time. The latent heat of the boundary layer has a greater effect on the weakening of the tangential wind than that of the cloud microphysics.

The divergence simulated in the CTL experiment is largely concentrated in the TC eye zone (Fig. 13), and shows convergence movement in the cloud wall. At the TC maturity stage, the radial wind convergence reaches the maximum at

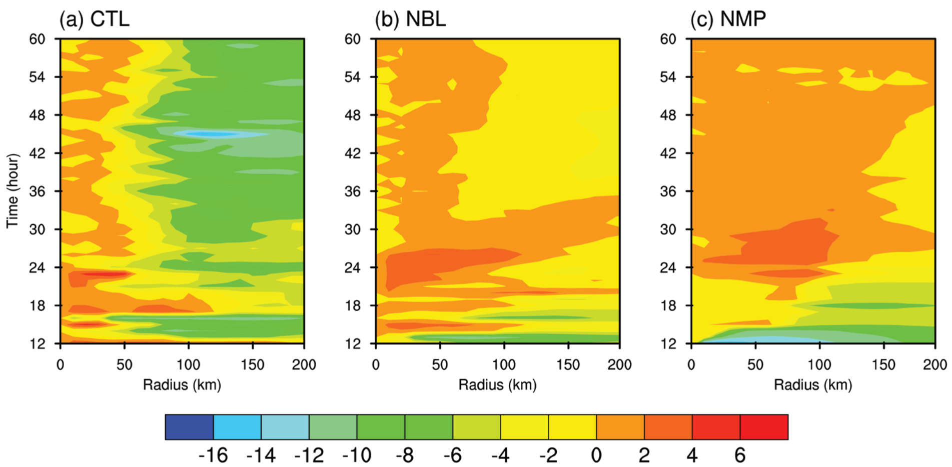

Fig. 13. Evolution of azimuth average radial wind (m/s) at a height of 1 km from t=12 to 60 hr.

about 45 hours. The maximum convergence simulated in the NBL experiment occurs at the initial 13–14 hours and then diminishes steadily. The divergent area in the TC center increases continuously, and the divergence reaches the maximum at 25–26 hours, not propitious for the development of TC to the upper level. The initial radial wind in the NMP experiment reaches –14 m/s, with greater convergence than that in the NBP experiment, but the convergence shows a short duration and divergence appears almost in the following 24 hours.

Based on the comparison of TC structure of the three experiments, it's known that both the lack of boundary layer and the latent heat in cloud microphysics have a marked impact on the structure of TC, depriving TC to develop deep convection, the value of each quantity is much smaller than the CTL experiment, and the reduction of the NBL experiment is greater than that of the NMP experiment, which also indicates that the latent heat in the boundary layer has greater impacts on the TC structure than that in the cloud microphysics.

The role of boundary layer friction in tropical cyclogenesis and intensification has also been studied extensively, and thus the boundary layer parameterization plays a crucial role in organizing deep convection in the inner core of the nascent vortex and thus, directly affects the timing of cyclogenesis (Kilroy et al., 2017). The appearance of the TC eye is a process in which vortexes tend to stabilize (Schubert and Hack, 2017). Asymmetric forcing may lead to increased vortex intensity (Nolan and Stern, 2007). High sea temperature and low vertical shear are important conditions for the formation of TC eyes and have an important effect on the formation of the warm heart of TC (Vigh and Schubert, 2009). Through re-calculation of the Sawyer-Eliassen equation, it was found that thermal and environmental conditions were more important for the rapid enhancement of tropical cyclones than dynamic conditions (Pendergrass and Willoughby, 2009). The warm heart usually appeared at 4–8 km. The variation of the warm heart height does not necessarily indicate the change of the storm intensity (Stern and Nolan, 2012).

4.5. Evolution of energy and intensity

The latent heat energy of the cloud microphysical process (Fig. 14b) in the TC core region is an order of magnitude larger than the surface enthalpy (Fig. 14c), and the surface enthalpy energy is an order of magnitude larger than the TC kinetic energy (Fig. 14a). However, the variations of the surface enthalpy, TC kinetic energy and TC intensity are greatly consistent. From 48 to 60 hours, the large amount of latent heat released during cloud microphysics did not strengthen TC. Therefore, the latent heat release of cloud microphysical processes is not the most critical factor for TC enhancement, while the energy transfer of boundary layer processes is more important. The NMP experiment shows also that the latent heat in planetary boundary layer mainly influences the generation and development of TC during the beginning stage (Fig. 3), whereas

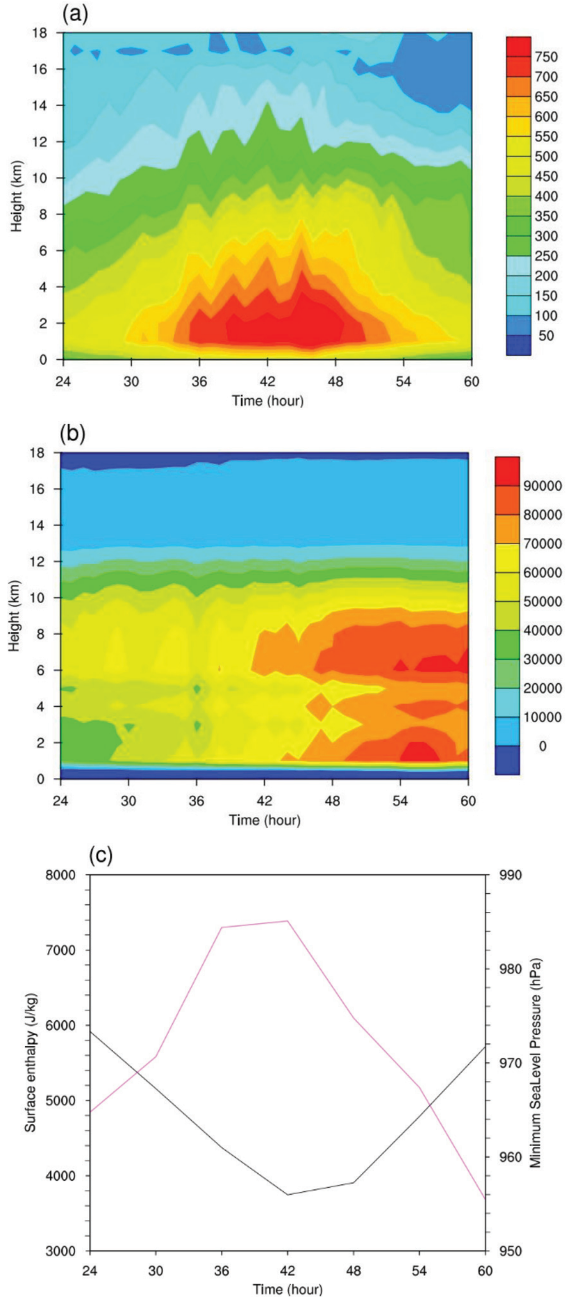

Figure 14. Evolution of (*a*) azimuth average kinetic energy (J/kg), (*b*) azimuth average latent heat (J/kg) and (*c*) surface enthalpy (J/kg, red line) and MSLP (hPa, black line) from t=24 to 60 hrs of the CTL at the TC core region (the radius is 200 km).

the NBL experiment shows the latent heat in cloud microphysical process is conducive to the strengthen and maintenance of TC in the mature stage.

Comparing Fig. 14 and Fig. 2, the TC kinetic energy reached the maximum before landing, and the latent heat could reach the maximum after landing. It shows that the strong TC landing brought strong rainfall over Hainan Island. The strengthening of the typhoon before landing was provided with energy mainly from the boundary layer. The maintenance of the typhoon maturing stage is closely related to the latent heat process of the cloud microphysics. The weakening of the typhoon is mainly affected by the underlying surface through a boundary layer process. Without the energy transport from the sea surface, TC is significantly weakened.

5. Conclusions

In this paper, based on the WRF model, three simulation experiments were conducted for TC "Sarika" (2016) using planetary boundary layer parameterization GFS scheme and cloud microphysics parameterization WSM6 scheme. Through the sensitivity experiments by closing the latent heat in planetary boundary layer and latent heat in cloud microphysics scheme separately, the different effects of the latent heat in planetary boundary layer and cloud microphysical processes were discussed in detail, which came to the following conclusions:

The CTL experiment well simulated the changes in TC track and intensity. The latent heat in both planetary boundary layer and cloud microphysical processes had significant effect on the TC track, movement speed and intensity. When the latent heat in planetary boundary layer and cloud microphysics scheme was closed, the TC track was changed with reduced moving speed and significantly weakened TC intensity; compared with closing the latent heat in cloud microphysics, closing the latent heat in planetary boundary layer exerts greater impact on TC intensity.

Without the effect of latent heat, precipitation decreased and TC circulation at the lower and middle levels were significantly weakened. Furthermore, such changes became even more obvious upon closing the latent heat in planetary boundary layer.

Latent heat affects the TC strength by affecting the TC structure. Compared with the CTL experiment, both the NBL experiment and the NMP experiment show weakening in dynamics and thermodynamics characteristics of TC, and the former has greater weakening than the latter, and also a greater height than the latter as well. The TC eye structure formed in the NBL experiment is clearer than the NMP experiment. However, the TC strength simulated by the NBL experiment is weaker than that by the NMP experiment.

Closing either the latent heat in planetary boundary layer or the latent heat in cloud microphysics scheme disabled the TC circulation to develop upwards. According to the comparison of the NBL and NMP experiments, under the influence of the latent heat in cloud microphysical processes alone, the cyclonic circulation of TC developed to higher altitude with weak intensity at the lower level; under the influence of the latent heat in planetary boundary layer processes alone, the cyclonic circulation of TC was strong at the lower level without vigorous development to high altitude. This suggests that the latent heat in planetary boundary layer mainly affects the generation and development of TC circulation at lower level, while the latent heat in cloud microphysical processes plays a major role at middle and upper levels. Before landing, the intensifying of TC is mainly supplied by the energy from the planetary boundary layer, while intensity maintenance in the mature phase is closely associated with the cloud microphysical latent heat processes. The latent heat release of cloud microphysical processes is not the most critical factor for TC enhancement, while the energy transfer of boundary layer processes is more important.

Of course, there are many factors affecting TC, and the sensitivity of TC to different microphysical schemes and different boundary layer schemes are also different. Different boundary layer schemes have little influence on TC track, but have a significant influence on the strength and structure of TC (Ding et al., 2018). There is still a lot to do in the future. Such as the implementation of marine aerosols (Rizza et al., 2018). The use of high-resolution SST strongly triggers the evolution of these TCs. Therefore, the use of coupled atmosphere-ocean-spray-wave models could be more performing and mature numerical means for sensitivity studies. Furthermore, given the intensity of the phenomenon studied, and with a view to climatic change, schemes for the simulation of extreme waves and complex vertical mixing systems could be implemented (Barbariol et al., 2017), especially in areas highly complex and anthropized coastal areas (Bonaldo et al., 2019). In addition, by implementing satellite analysis and comparison for each modeling sector such as waves and SST.

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SAŽETAK

Različiti utjecaji latentne topline u planetarnom graničnom sloju i mikrofizičkih procesa u oblacima na tajfun Sarika (2016)

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Kako bi se ispitali različiti utjecaji latentne topline u planetarnom graničnom sloju i mikrofizičkih procesa u oblacima, WRF modelom su provedena tri eksperimenta za tajfun (TC) “Sarika” (2016). Kontrolnim eksperimentom dobro su simulirane promjene intenziteta i putanja TC-a. Latentna toplina u planetarnom graničnom sloju te mikrofizički procesi u oblacima mogu utjecati na putanju TC i na brzinu njegovog gibanja. Latentna toplina utječe na jačinu TC-a putem promjene strukture TC-a. U usporedbi s CTL eksperimentom i NBL i NMP eksperiment ukazuju na slabljenje dinamike i termodinamičkih svojstava TC-a. Bez utjecaja latentne topline TC se ne može vertikalno razvijati i stoga mu intenzitet slabi, a količina oborine se reducira; to slabljenje je očitije u slučaju kada je latentna toplina ograničena na planetarni granični sloj.

Latentna toplina u planetarnom graničnom sloju uglavnom utječe na stvaranje i razvoj TC-a u početnoj fazi, dok latentna toplina vezana za mikrofizičke procese u oblaku pogoduje jačanju i održavanju njegove zrele faze. Latentna toplina mikrofizičkih procesa u oblakcima u jezgri TC-a je za red veličine veća od prizemne entalpije. Međutim, oslobađanje latentne topline pri mikrofizičkim procesima u oblacima nije najvažnije za jačanje TC-a, već je za njegovo jačanje važniji transfer energije u procesima planetarnog graničnog sloja..

Ključne riječi: tajfun, latentna toplina, planetarni granični sloj, mikrofizički procesi u oblaku

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