Simulation and Mechanisms of Diurnal Variation and Nocturnal Peak of Warm Season Precipitation over Sichuan Basin, China

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Introduction

Sichuan Basin (SB) is one of the main precipitation centers in China in the warm season (Zhu et al. 2017). Warm season precipitation exhibits prominent diurnal cycles, with a minimum during the day, and a maximum around mid-night local time (Yu et al. 2007). Past studies have mainly attributed the mid-night peak of SB to the mountain-basin solenoidal circulations which suppress daytime and promote nighttime precipitation.

In this study, forecasts covering three summer months of 2013 at a 4-km convection-permitting resolution are used to investigate the primary mechanisms of the precipitation diurnal cycles over SB. The forecasts reproduce well the observed spatial and temporal distributions and diurnal cycles, including the precipitation peak near midnight (0100-0200 LST). Prominent diurnal changes in the boundary layer moisture fluxes into the SB are found to play more important roles in modulating the precipitation diurnal cycles in SB, and the changes in moisture fluxes are for the most part due to inertial oscillations of boundary layer southwesterly low-level jet (LLJ).

Precipitation Spatial Distributions

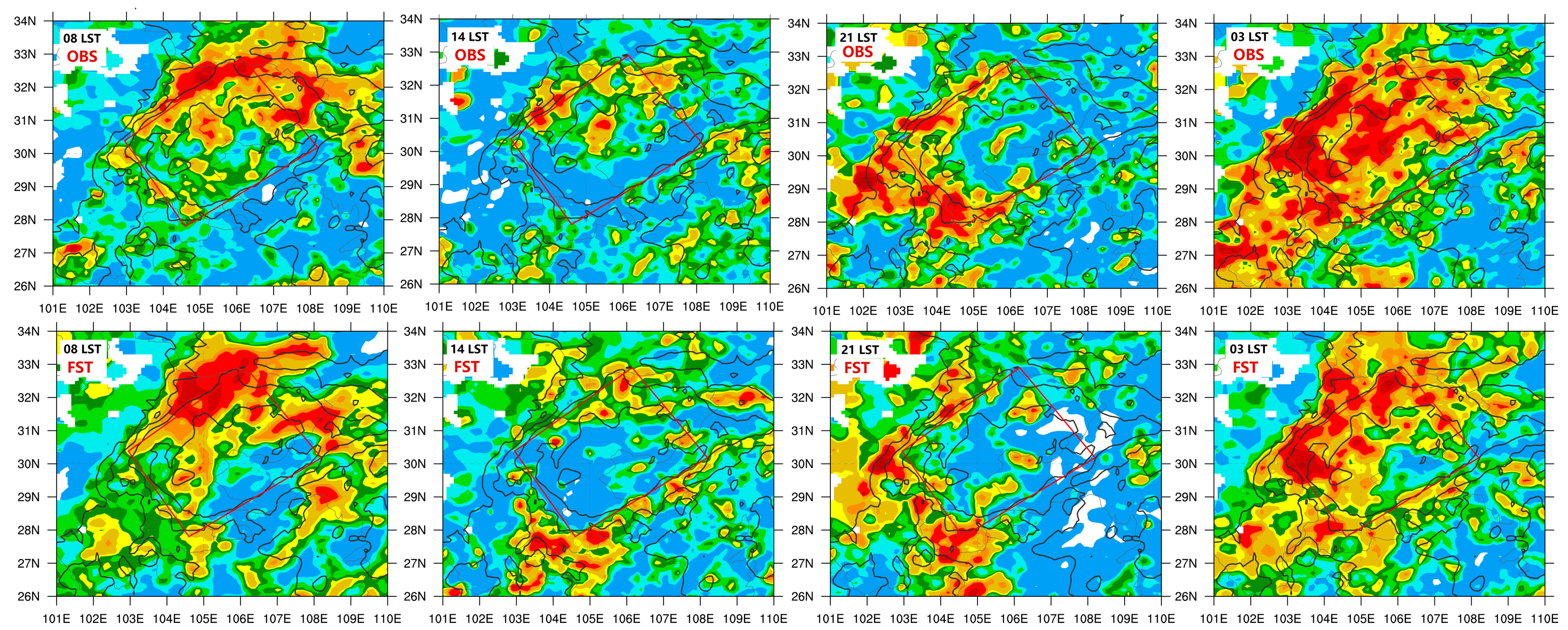

Figure 1. The spatial distributions of the observed and model predicted hourly precipitation over the Sichuan Basin. averaged over June-August of 2013. According to hourly diurnal variation of precipitation, precipitation peaks at 03 LST.

Diurnal Variations

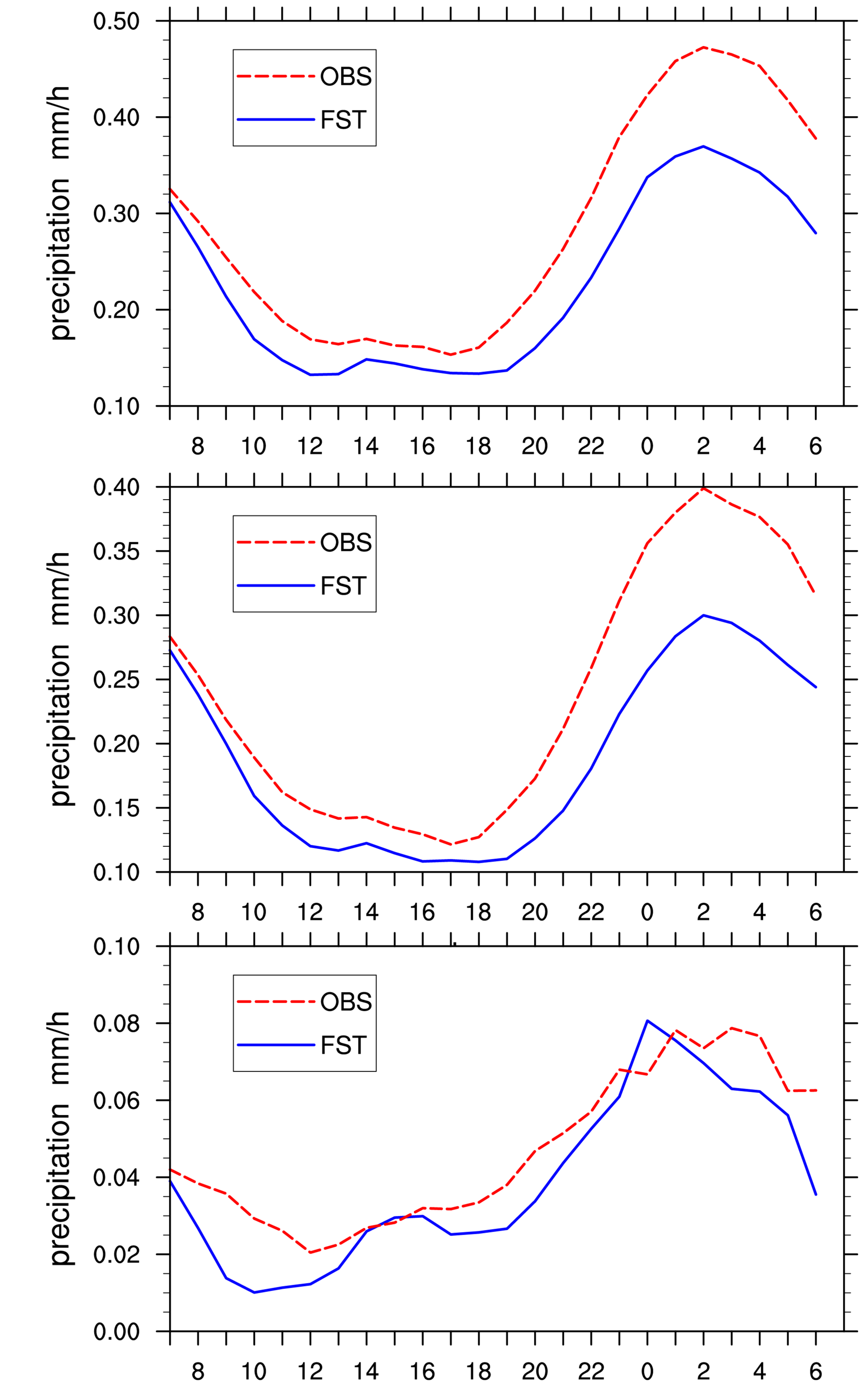

Figure 2. Observed (OBS) and forecast (FST) diurnal precipitation in the budget area (see Fig. 1), for (a) total precipitation, (b) stratiform precipitation, (c) convective precipitation.

Cross Sections of Total Winds

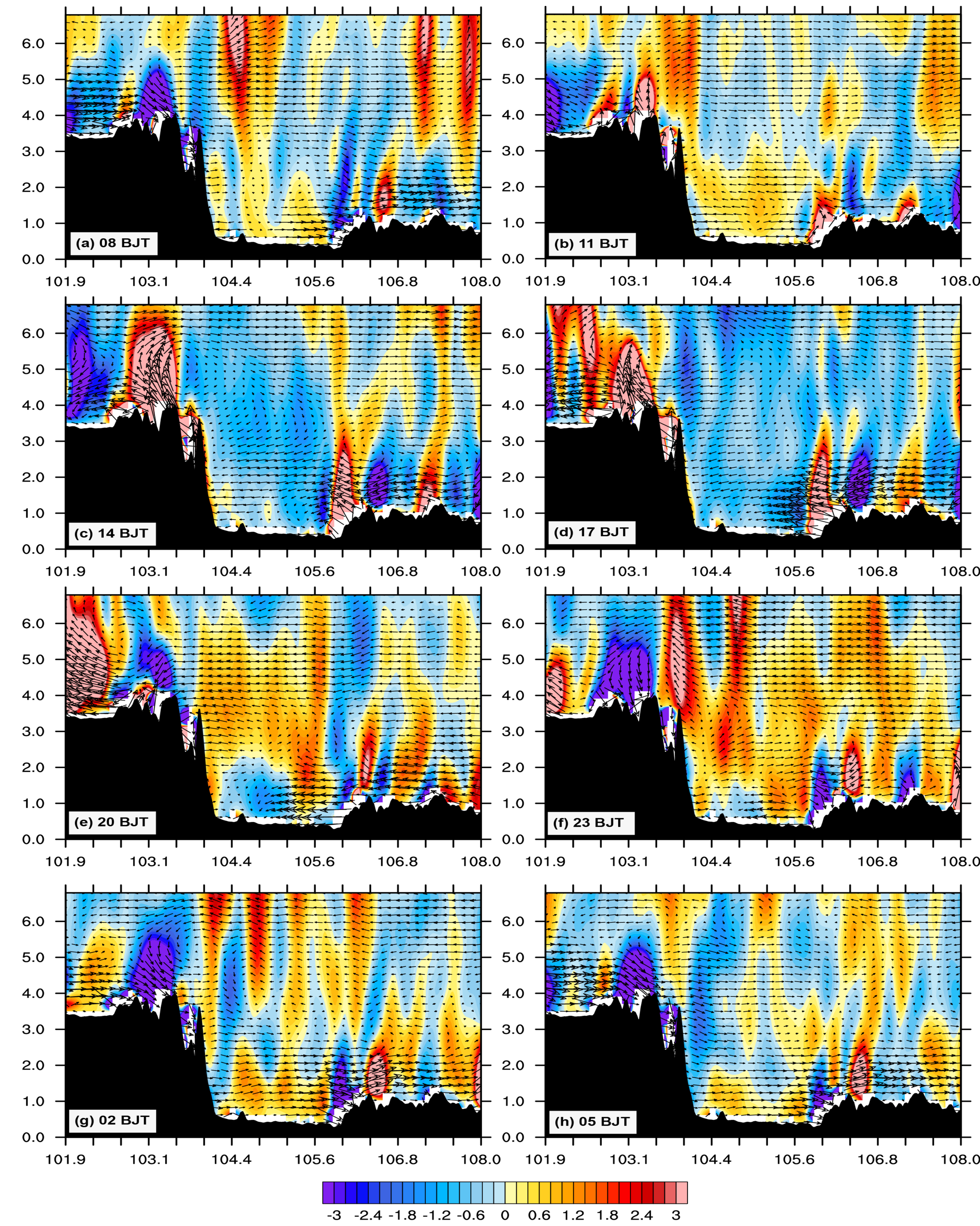

Figure 3. Cross-sections along the prevailing wind (see Fig. 7), from 0800 BJT to 0500 BJT, every three hours. The vertical wind speed is amplified by 100 times for the vector plots. Time average is performed over June through August of 2013.

Wind Purterbation

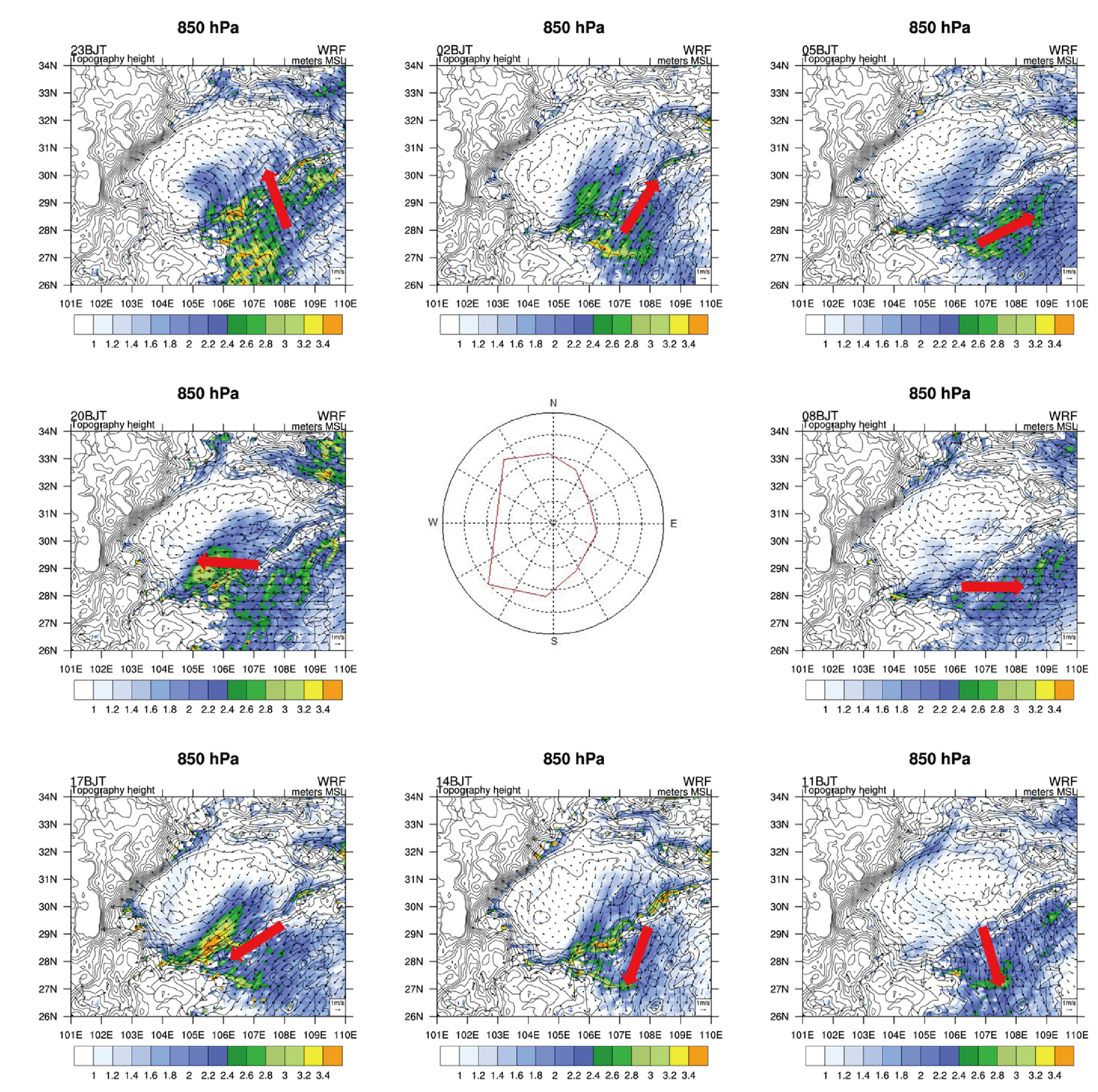

Figure 4. The wind perturbations (vectors and wind speed) from daily mean at 850

The wind perturbations show clockwise rotation throughout the 24 hours of day, due to boundary layer inertial oscillations. The direction of the perturbation winds southeast of SB modulates rainfall over SB. Southeasterly perturbation winds at night correspond to the stronger total flow and more moist air into SB, creating precipitation peak. On the contrary, northeasterly perturbation winds decrease total flow, pull air out of the basin, leading to precipitation minimum during the day.

Concept Map

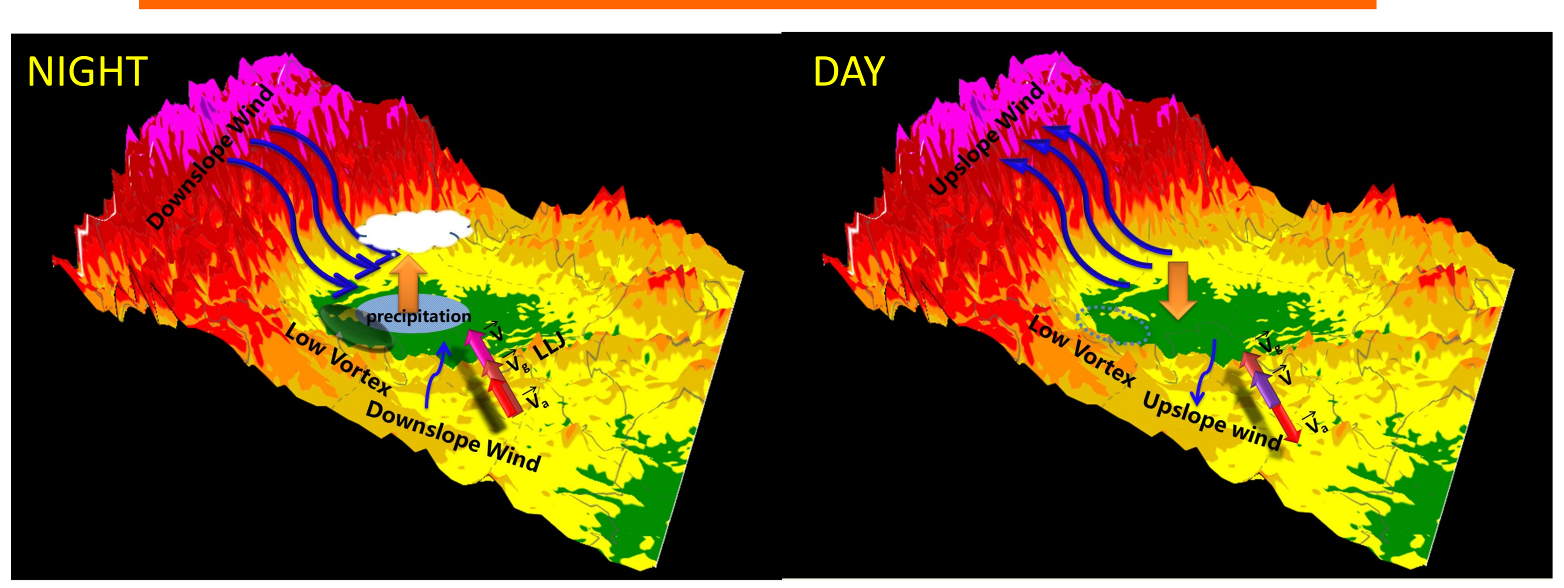

Figure 8. Concept model illustrating the proposed mechanisms of precipitation diurnal cycle over Sichuan Basin

Diurnal ageostrophic perturbation winds strengthen the prevailing south-southeasterly flows and bring extra moisture into SB at night, enhancing moisture flux convergence in SB and producing nocturnal precipitation maximum. At the mean time, cold downslope drainage flows developing along the slopes of plateaus on the west and southwest sides of the Basin enhance the low-level convergence also in the SB. The drainage flows are however very shallow and cold, and play secondary role in enhancing night-time precipitation. During the day, upslope flows and negative perturbation winds out of the basin on the southeast side of Basin act to "pull" low-level air of the basin, which together with the descending compensating flow over the Basin act to suppress precipitation during the day.

Moisture Fluxes through 4 Faces of Budget Box

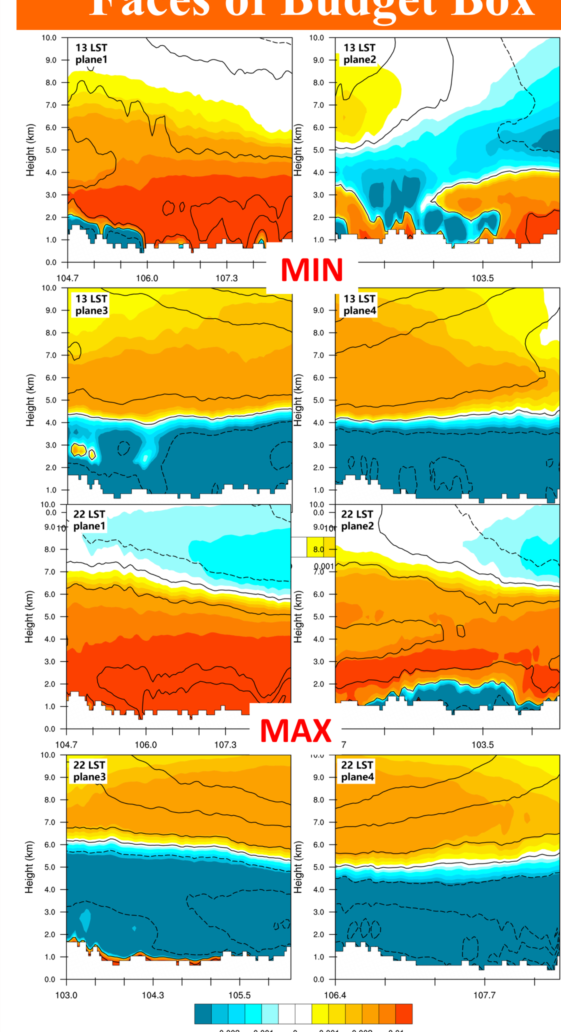

Figure 5. The moisture flux of the four plane around the SB (the box is marked in the prevailing wind at 850 hPa).

Diurnal Variation of Moisture Flux

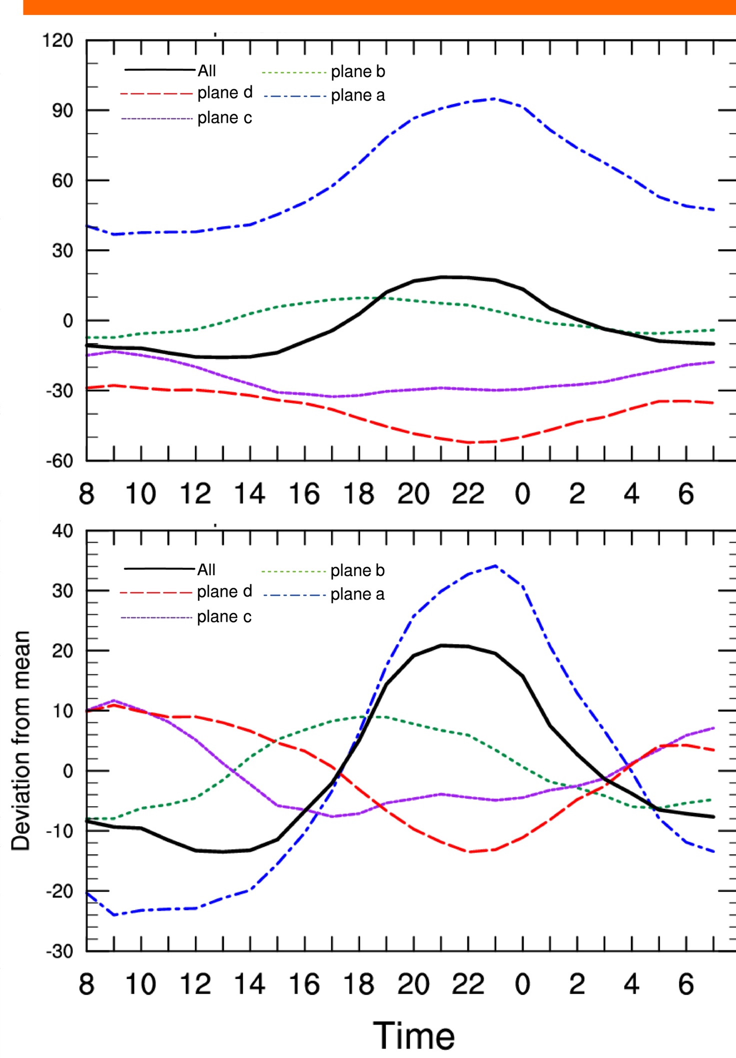

Figure 6. Moisture fluxes and moisture flux diurnal variations through four faces of the budget box. Solid black line is the total result of the box in Figure 5. The red, purple, green and blue lines are for planes a, b, c, and d (see in Fig. 7) respectively, while the black line is for the total.

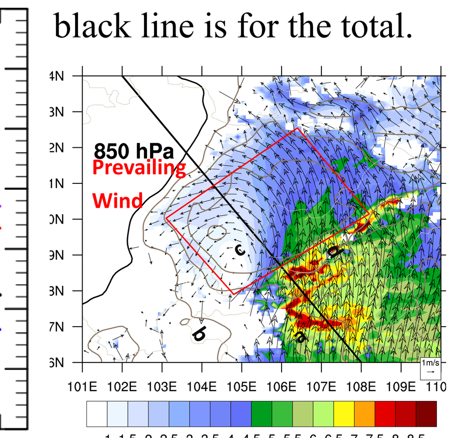

Figure 7. prevealing wind at 850hPa

Summary

This study finds that apart from the solenoidal effects, prominent diurnal inertial oscillations of boundary layer southwesterly low-level jet (LLJ) into the basin appear to play at least as important roles in modulating the diurnal cycles of precipitation on SB. When the perturbation winds associated with the inertial oscillations turn towards the basin at midnight, the enhanced LLJ advect much more moist air into the basin and also enhance flow convergence within the basin, forcing strong precipitation. In the afternoon, the perturbation winds act to 'pull' air out of the basin. A basin-wide moisture budget analysis reveals that the moisture flux from the southeast side of the basin dominates over the net moisture flux into the basin, suggesting the crucial role of the enhanced nocturnal LLJ in the formation of nocturnal precipitation. In addition, the LLJ is located at the right side of a mesoscale vortex over the SB and helps increase the vortex intensity and favor more.

Main References:

Zhu, K., M. Xue, B. Zhou, K. Zhao, Z. Sun, P. Fu, Y. Zheng, X. Zhang, and Q. Meng, 2017: Evaluation of Real-time Convection-Permitting Precipitation Forecasts in China During the 2013-14 Summer Season. J. Geophy. Res., Accepted.

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