The Response of Precipitation to Initial Soil Moisture over the Tibetan Plateau: Respective Effects of Boundary Layer Vertical Heat and Vapor Diffusions

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1. Background

Genesis and propagation of summer precipitation over the Tibetan Plateau are commonly accompanied by a meso-α-scale boundary layer vortex—the Tibetan Plateau vortex (TPV). Although responses of TPV and its precipitation to surface diabatic heating/soil moisture anomaly have been noted, how this response works in detail in the boundary layer (BL) is still unclear.

The evolution of heat and moisture structures in the BL, which is strongly affected by vertical diffusion process, can distinctly influence the consensus about the impact mechanism of soil moisture on precipitation. So far, the impacts of BL vertical diffusion are complex and still controversial. One crucial issue is that in current BL scheme, vertical diffusion for heat (K_h) and vapor (K_q) are not strictly distinguished (Mellor and Yamada 1974; Nakanishi and Niino 2006; Hong et al. 2006). However, observation and large eddy simulation results showed that there are obvious differences between K_h and K_q, and there are also different results on which is larger or smaller for K_h and K_q (Laubach et al. 2000; De Roode 2007).

We motivate to discuss the respective effects of K_h and K_q in the response of precipitation to soil moisture anomaly. The issues we concerned are: (1) how do dry or wet land surface over the TP affect the precipitation intensity? (2) What are the respective effects of K_h and K_q?

2. Case description

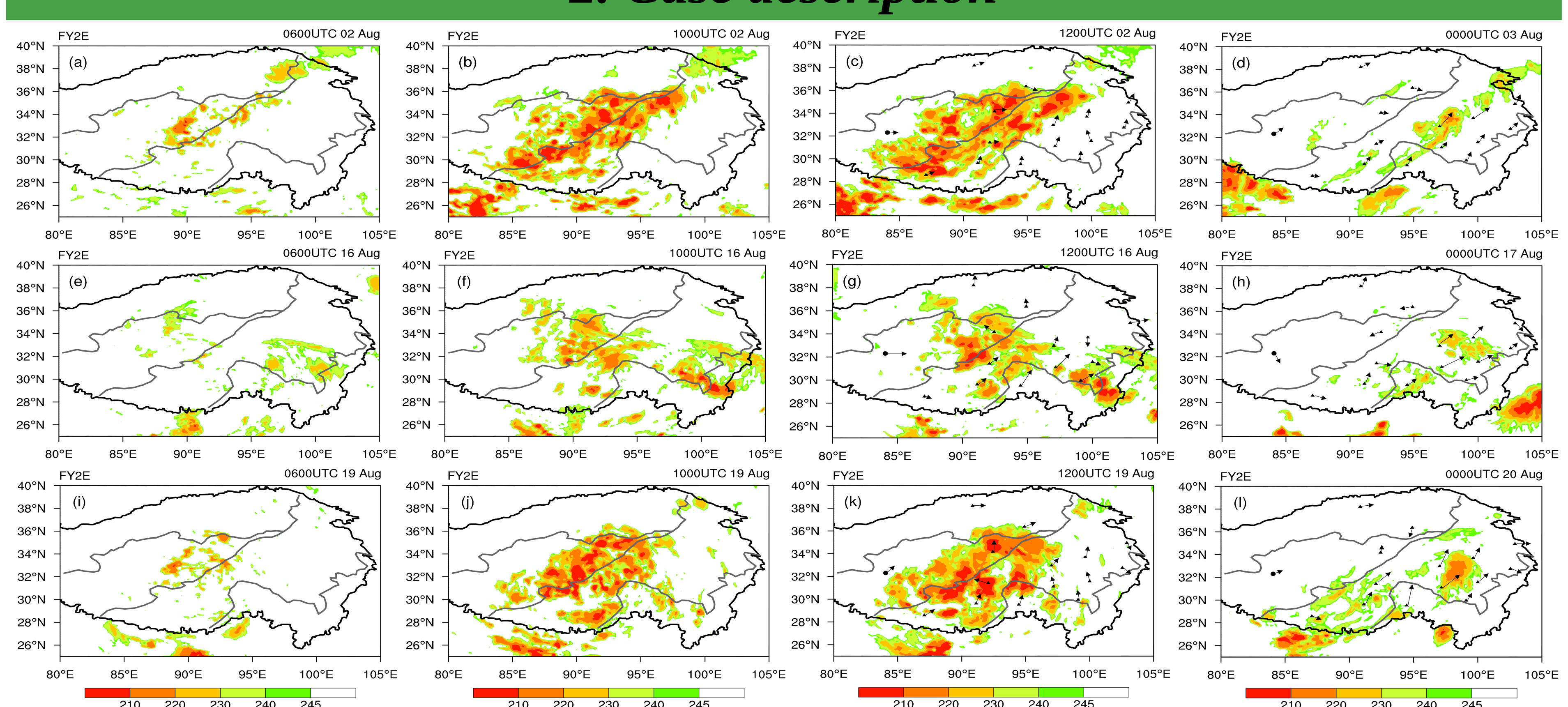


Figure 1. The observed cloud-top brightness temperature (unit: K) for three precipitation cases

3. Comparison of precipitation intensity

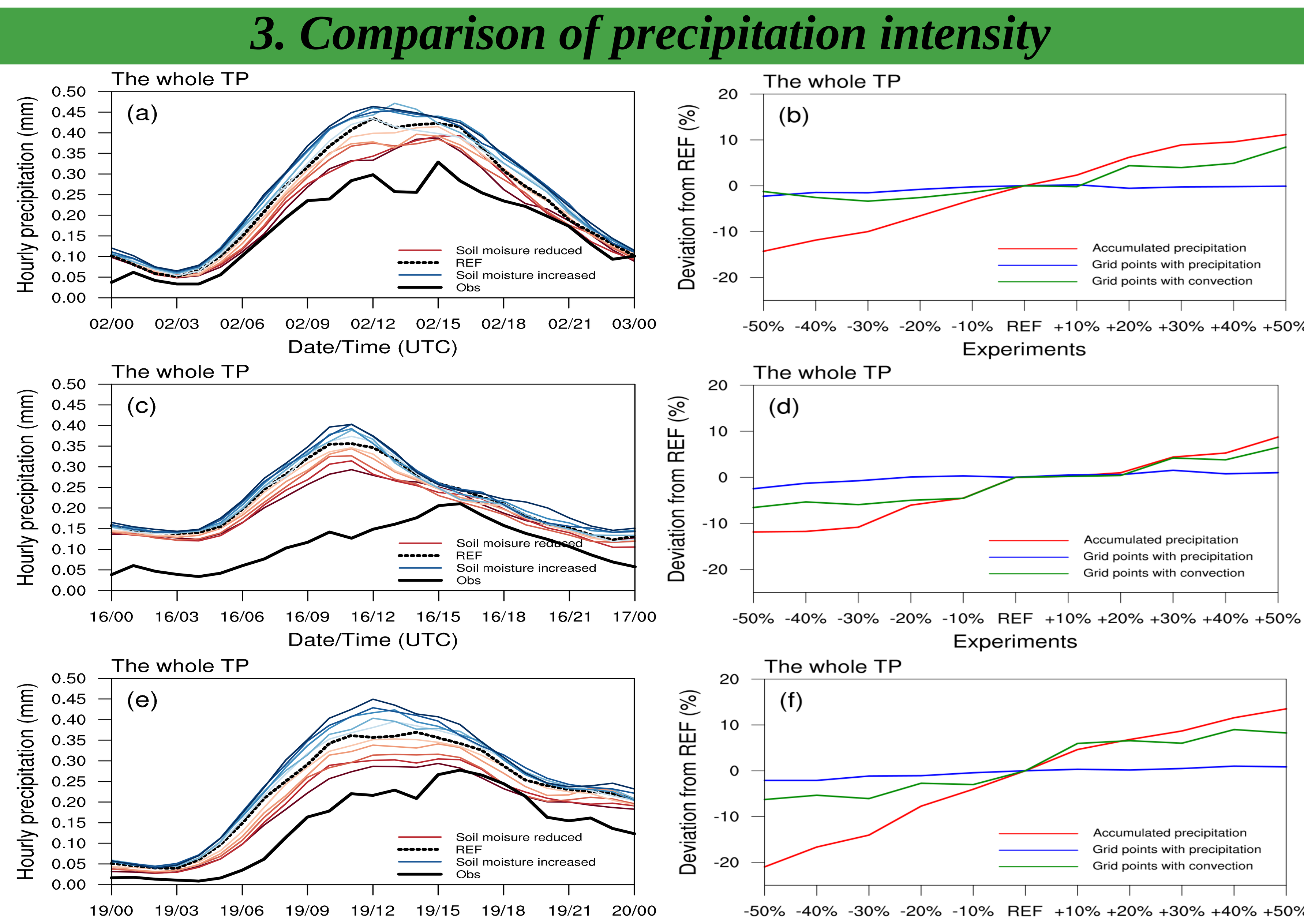


Figure 2. Comparison of time-series of precipitation and convection over the TP.

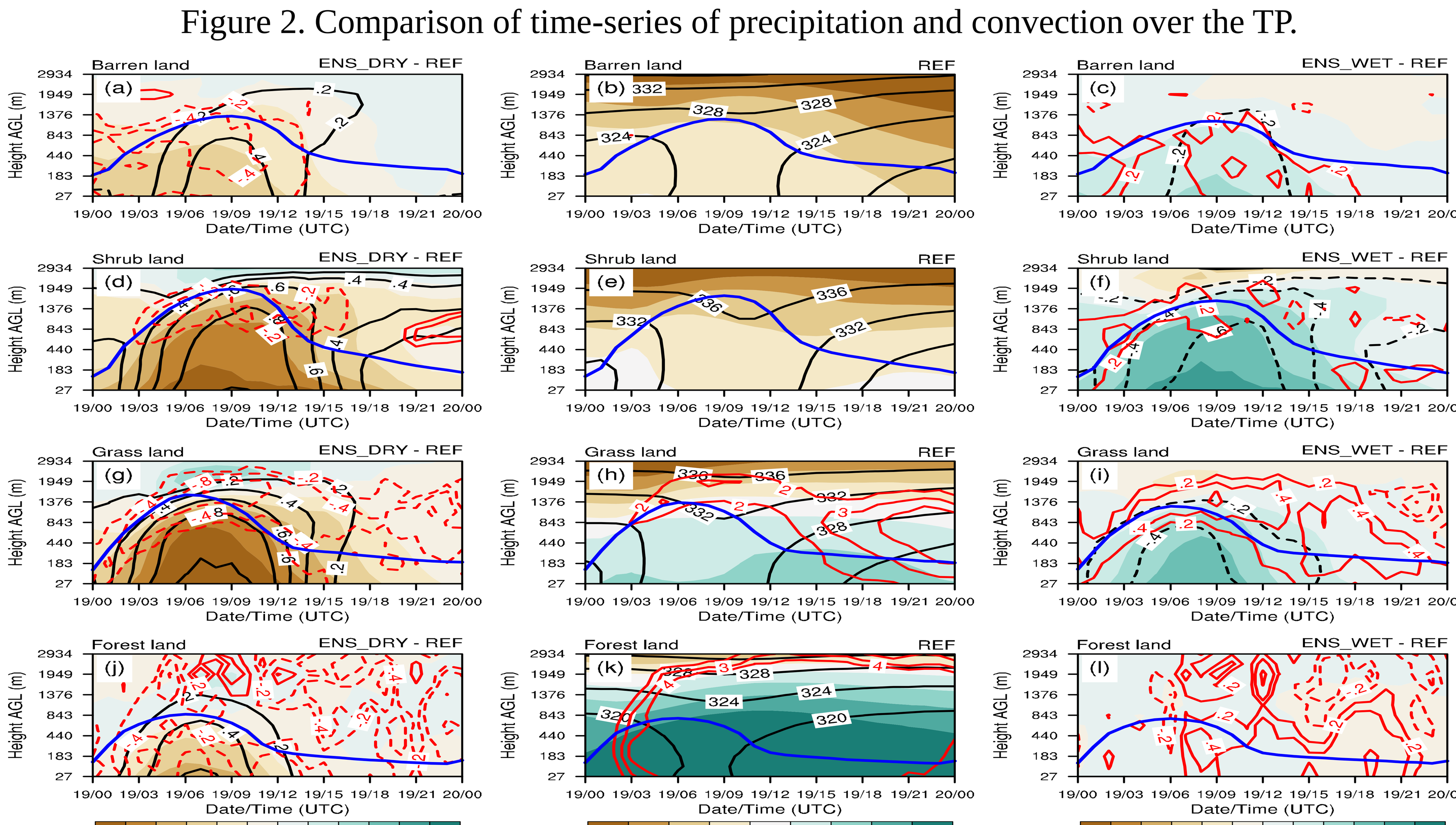
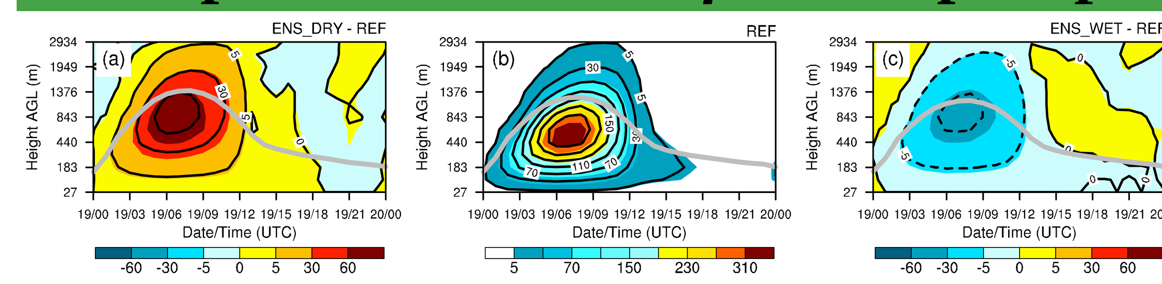


Figure 3. Time *vs.* height cross-section of BL structures

Wetter land surface benefits to more convections and precipitation by increasing water vapor in the BL and encouraging air saturation near the top of the BL.

4. Impact mechanism of SM on precipitation in view of K_h and K_q

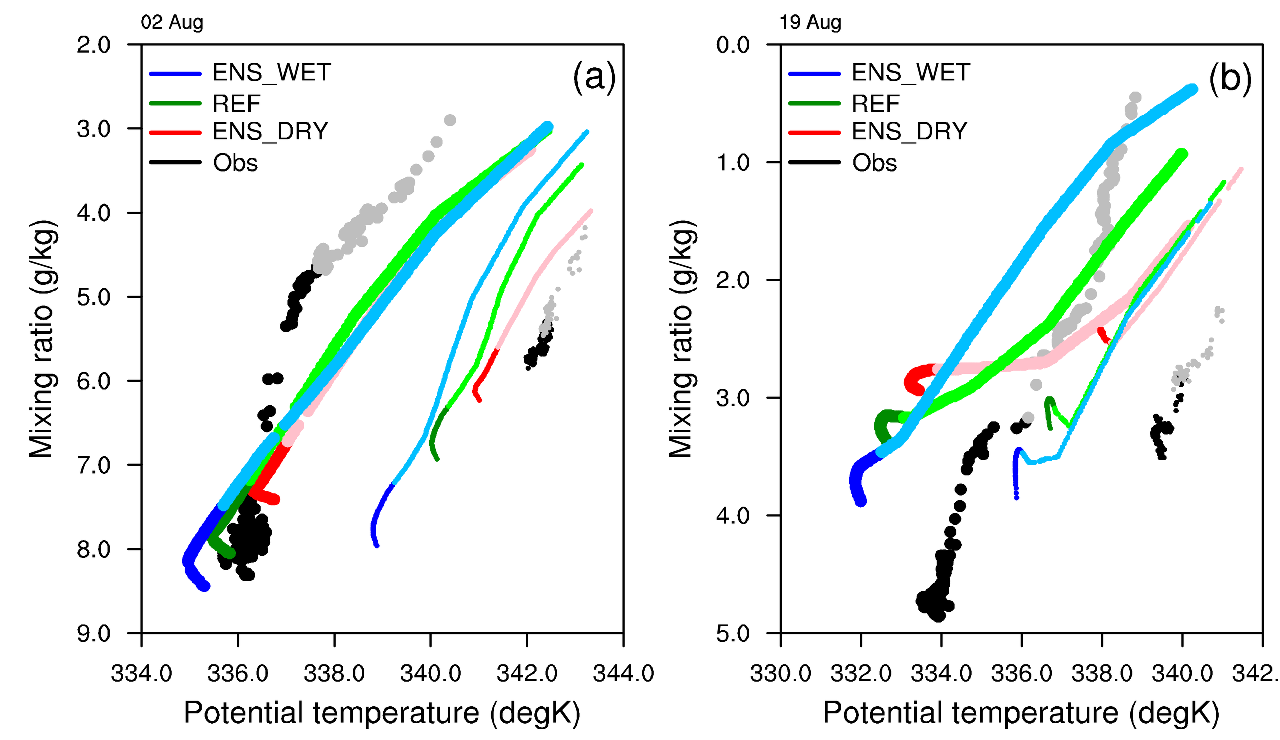


$$\left(\frac{\partial \theta}{\partial t}\right)_{diffusion} = \frac{\partial}{\partial z}\left(K_h \cdot \frac{\partial \theta}{\partial z}\right) - \frac{\partial}{\partial z}(K_h \cdot \gamma_\theta)$$

$$\left(\frac{\partial q}{\partial t}\right)_{diffusion} = \frac{\partial}{\partial z}\left(K_q \cdot \frac{\partial q}{\partial z}\right) - \frac{\partial}{\partial z}(K_q \cdot \gamma_q)$$

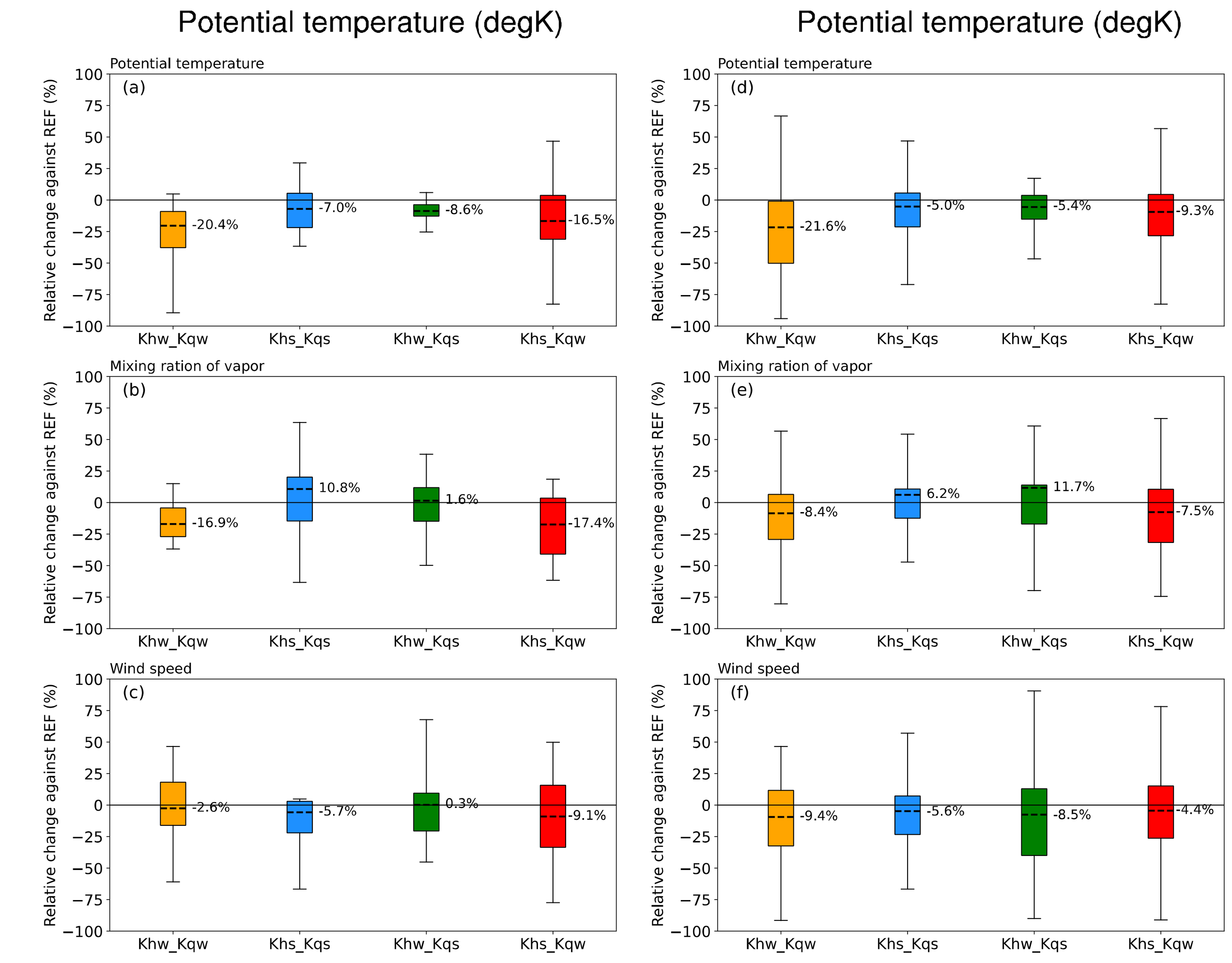
Figure 4. Time *vs.* height cross-section of K_h and K_q

5. Respective effects of K_h and K_q



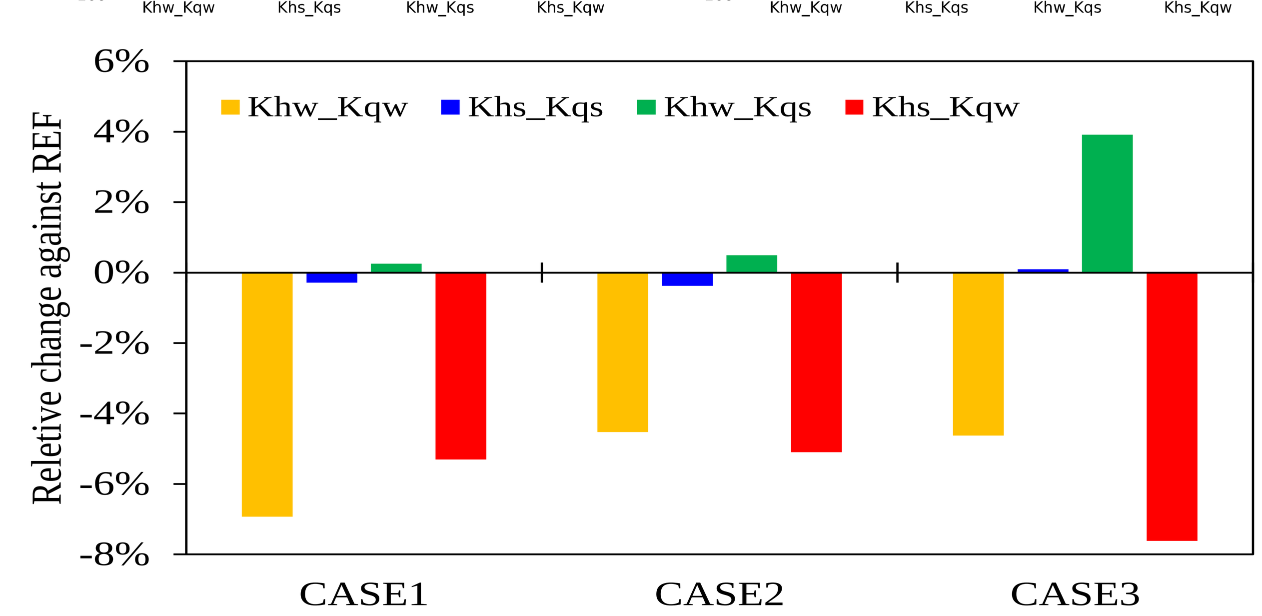
A distinct simulation bias is that, from 0600 to 1200 UTC, simulations well capture the observed increase of θ, but obviously underestimate the observed decrease of q_v, regardless of dry or wet land.

Figure 5. Comparison of mixing line (θ *vs.* q_v at different height) between *sim.* and *obs.*



Compared to REF, the mean simulation bias of heat and moisture could be reduced by 20.4% and 16.5% in Khw_Kqw experiment and 16.9% and 17.4% in Khs_Kqw experiment; the other two experiments, however, have weaker and even worse influence.

Figure 6. Relative change of heat, moisture and wind in BL in sensitivity simulations of *K* against REF.



The K_h and K_q have competitive impacts on precipitation intensity, and precipitation simulation will be improved under specific configuration of K_h and K_q.

Figure 7. Relative change of precipitation in sensitivity simulations of *K* against REF

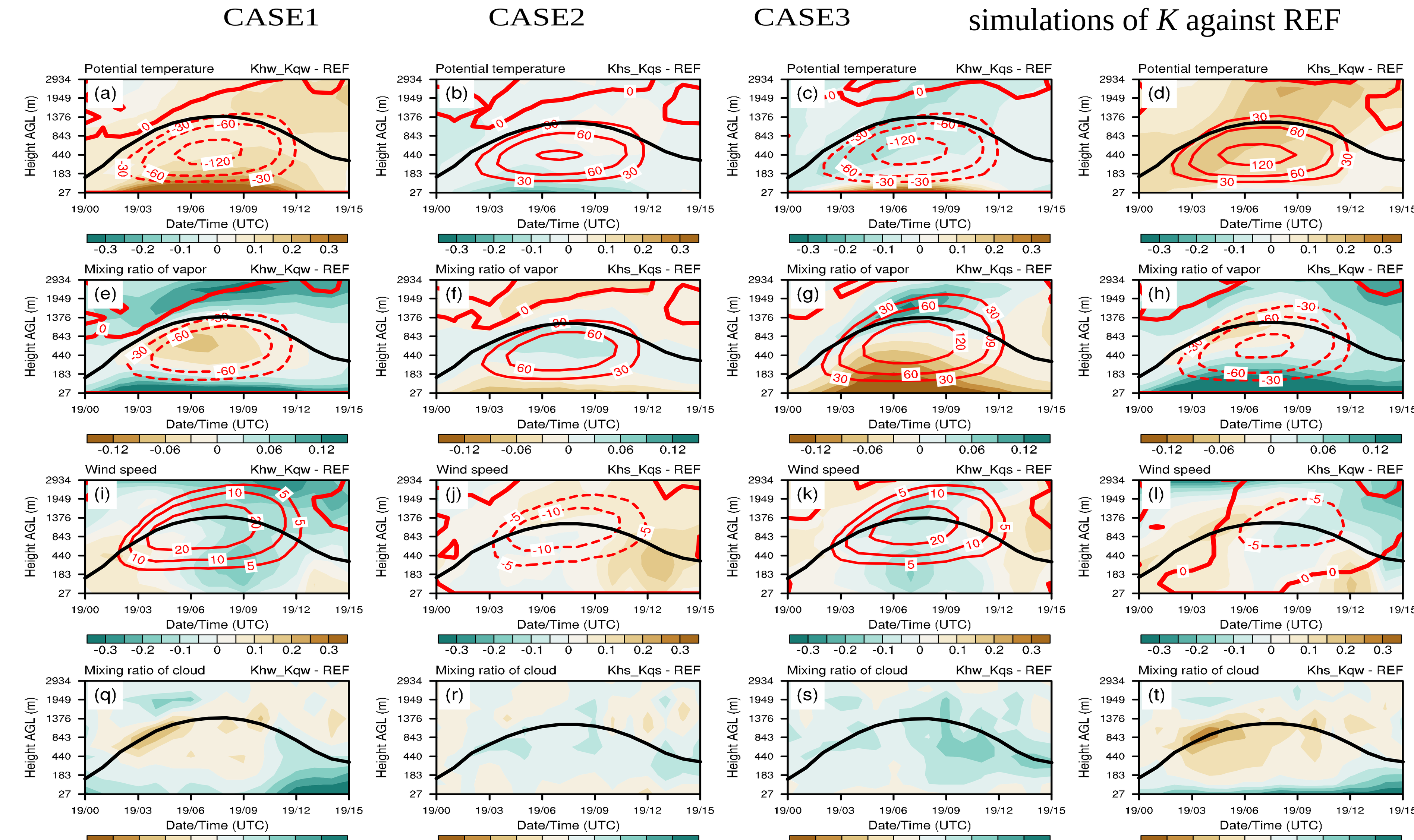


Figure 8. Time *vs.* height cross-section of BL structures between sensitivity runs of *K* and REF

6. Concluding remarks

- **Wetter land surface produces weaker K_h and K_q, which is conducive to the net gain of water vapor in the BL and encourage air saturation near the top of the BL, leading to more convection and precipitation..**
- **The simulation of heat and moisture in the boundary layer could be improved by perturbing the relative intensity of K_h and K_q .**
- **The K_h and K_q have competitive impacts on precipitation intensity by influencing the relative importance of water vapor and atmospheric stability conditions in the BL. Adjusting the relative intensity of K_h and K_q would deactivate the competitive effects. Stronger K_h but weaker K_q would alleviate the overestimated precipitation by inhibiting vertical transport of moisture to the top of boundary layer and attenuating convective instability in the boundary layer.**

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