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Land–Sea Contrast in the Diurnal Variation of Precipitation from Landfalling Tropical Cyclones

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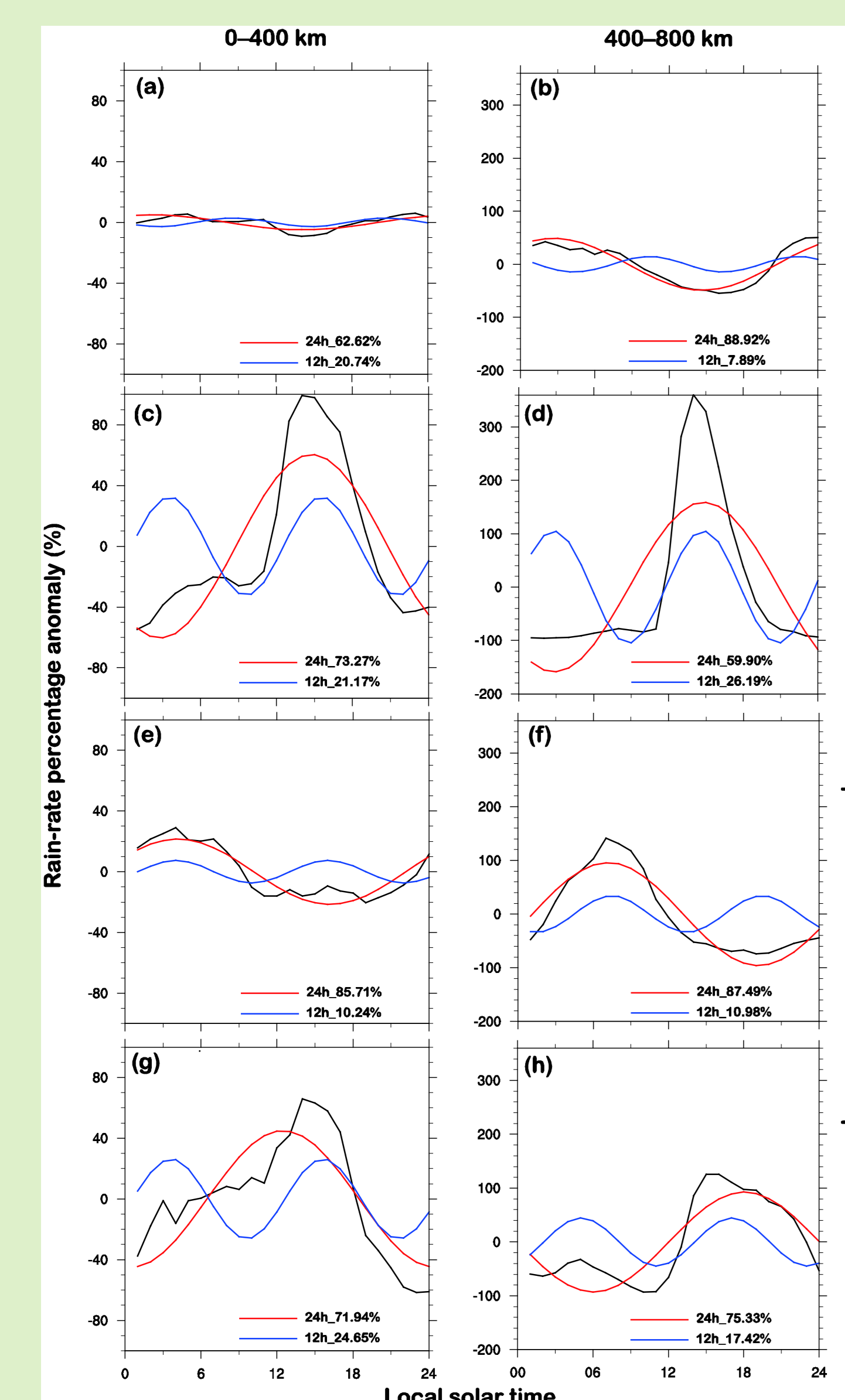
1. Background

- Recent composite analysis of landfalling tropical cyclones (TCs) suggests a rain rate peak in the early morning, however, there is some disagreement among the observational studies.
- The diurnal cycle is one potentially predictable and important component of TC precipitation variability.
- We investigate the differences in the diurnal variations of precipitation over land and sea within the primary circulation region of a landfalling TC, and the underlying mechanism.

2. Experimental setup of idealized cases

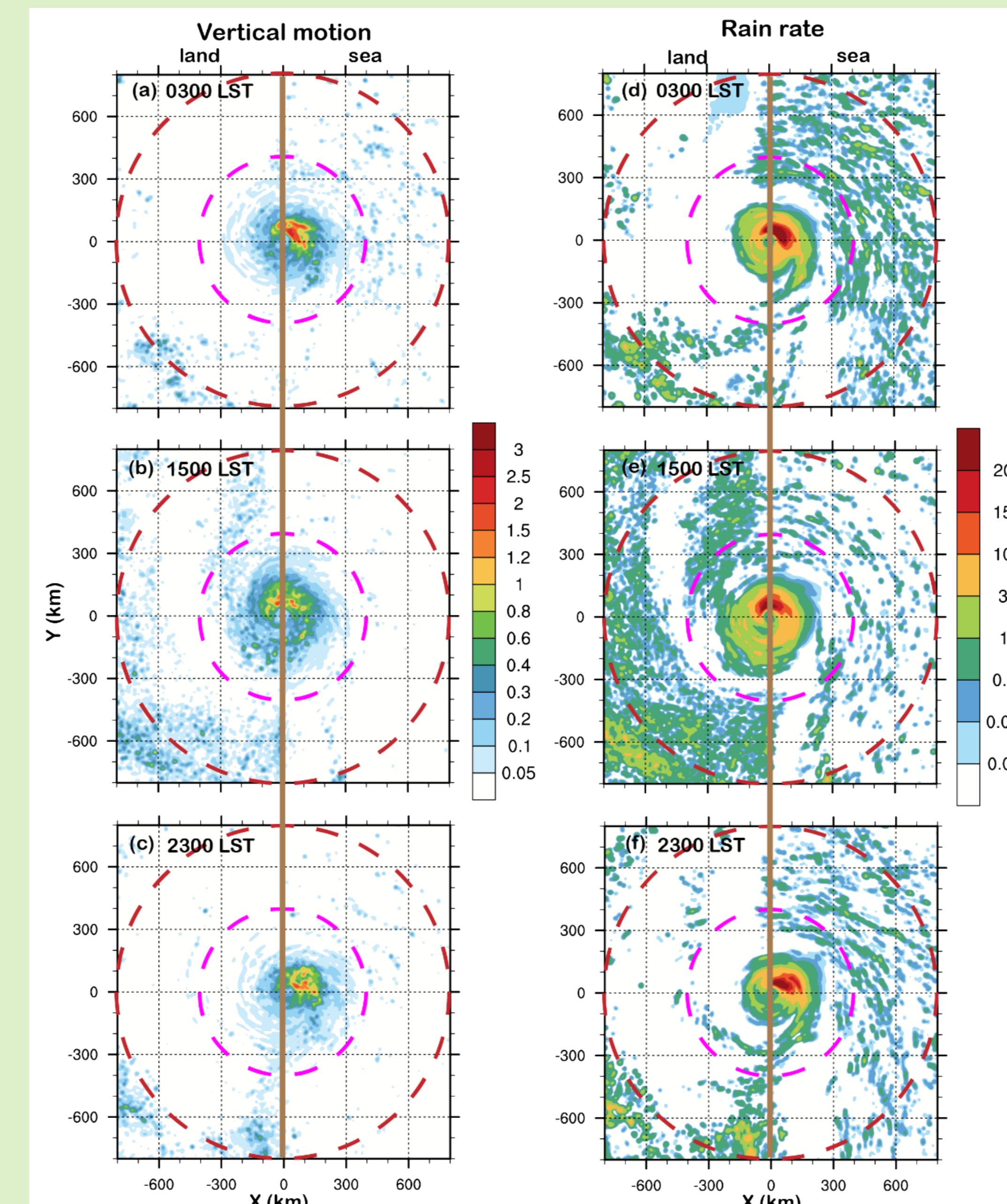
- OCEAN:** ocean-only, SST=301 K, fixed
 - LAND:** land-only, surface temperature varied
 - SHORE:** a north–south oriented straight coastline at the center
- CM1 model
 - grid space of 4 km
 - RRTM-G radiation
 - WSM6 microphysics
 - YSU boundary layer
 - f plane at 20° N

3. Land–Sea Contrast in the Diurnal Variation of Precipitation

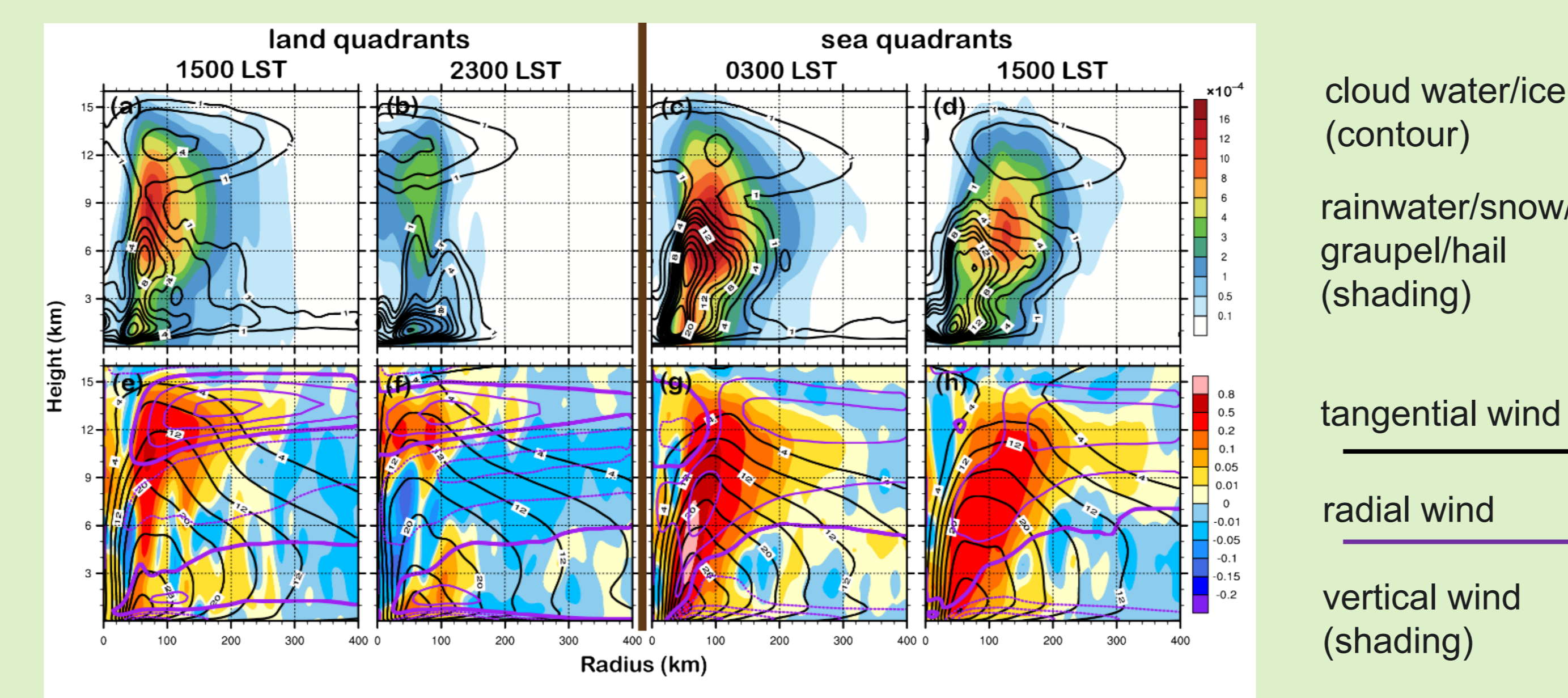


- OCEAN:** Maximum precipitation occurs around early morning or midnight in both the TC primary circulation and outer region
- LAND:** Maximum precipitation occurs during the early afternoon
- SHORE_ocean-part:** The timing of precipitation was essentially the same as in OCEAN experiment
- SHORE_land-part:** The amplitude of the 24-hr harmonic was only a little smaller than in LAND, and the timing in the outer region had a small lag

Snapshots of column maximum vertical motion and rain rate at key times

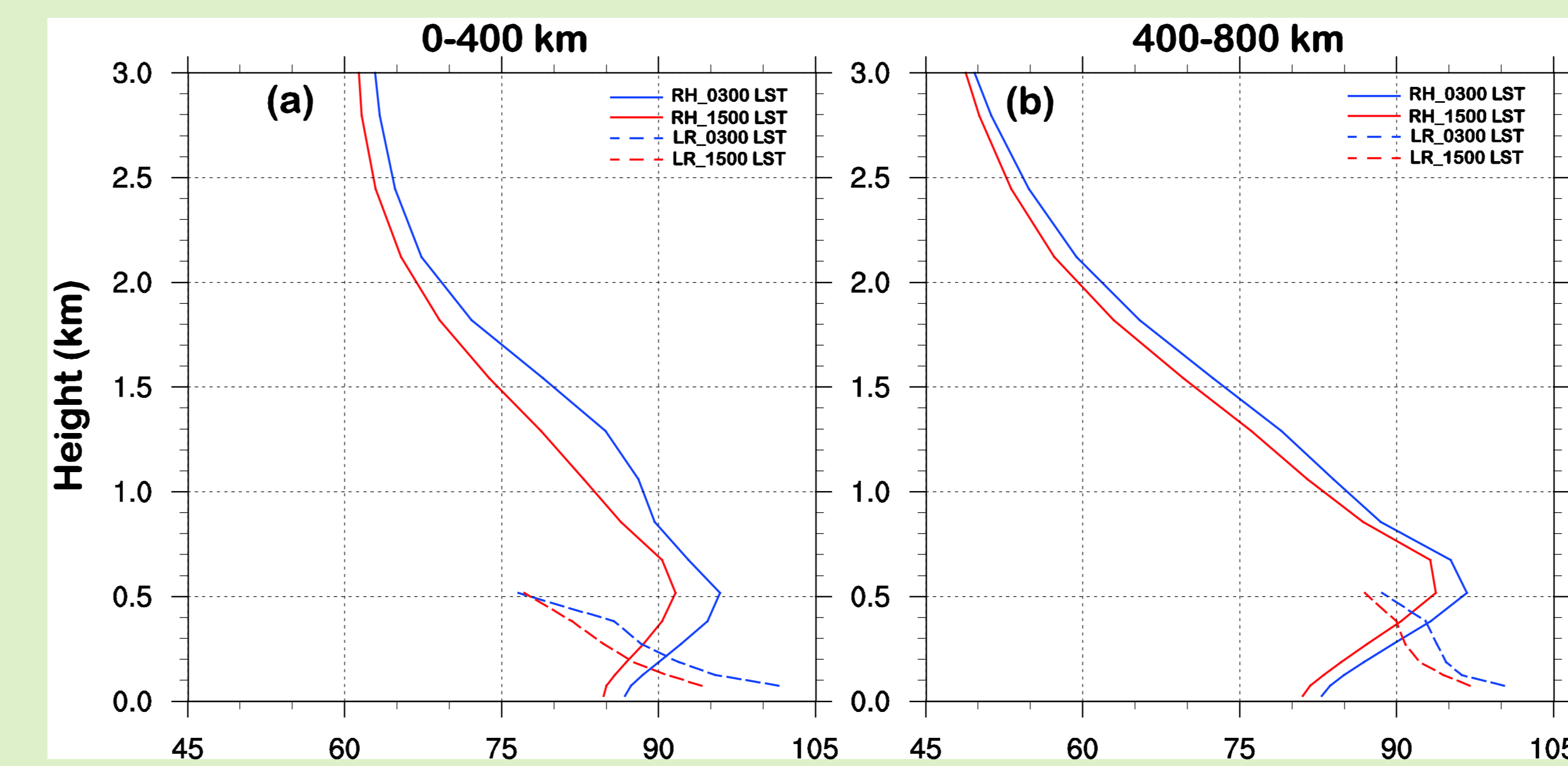


Vertical structures of the TC at key times



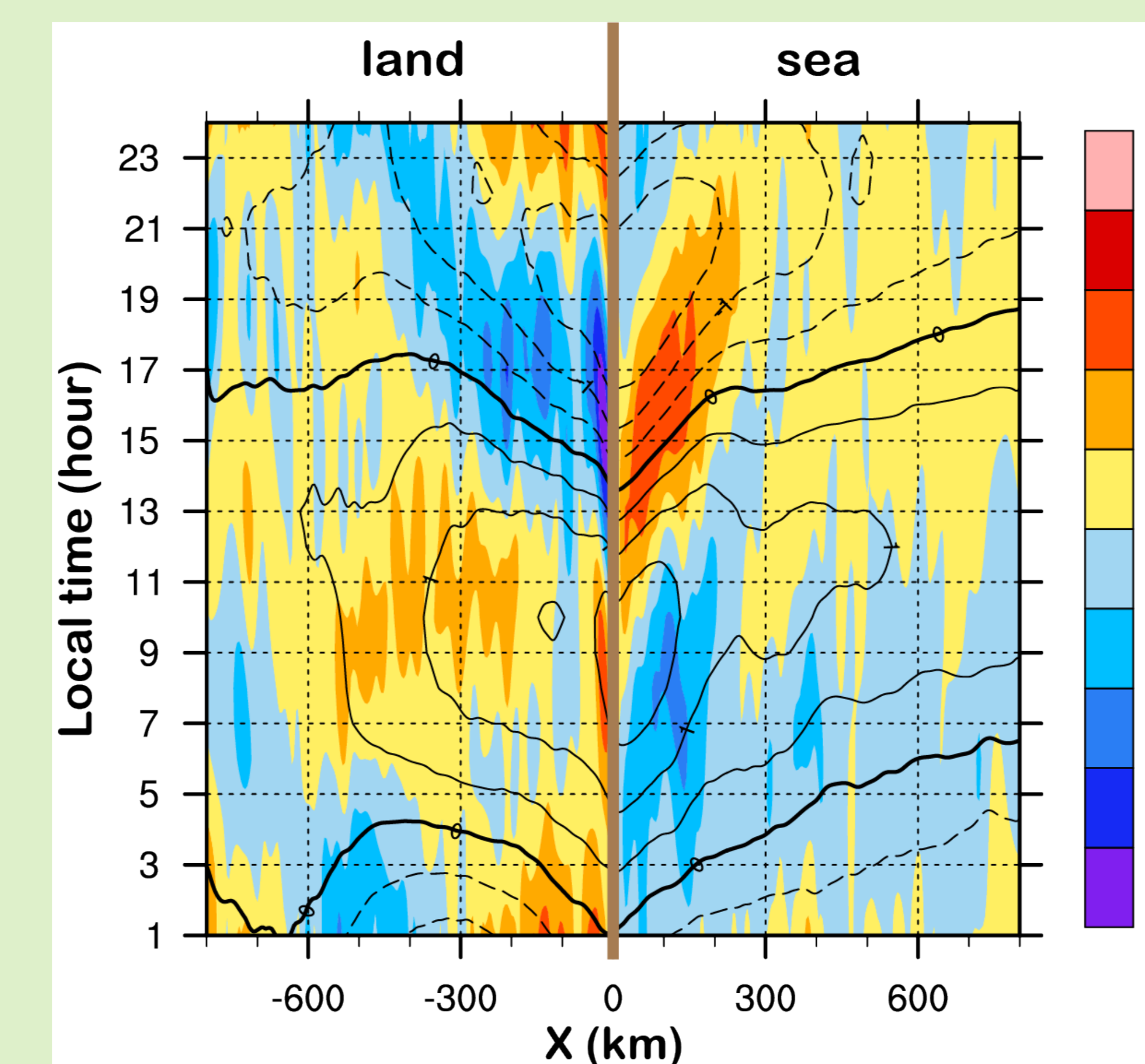
- The cloud and rainwater mixing ratio were greater over land at 1500 LST. We attribute this to the stronger updraft of the eyewall and low-level upward motion outside the eyewall at 1500 LST compared with 2300 LST.

Averaged relative humidity (solid; %) and lapse rate (dashed; 0.1K/km) over ocean quadrants of SHORE



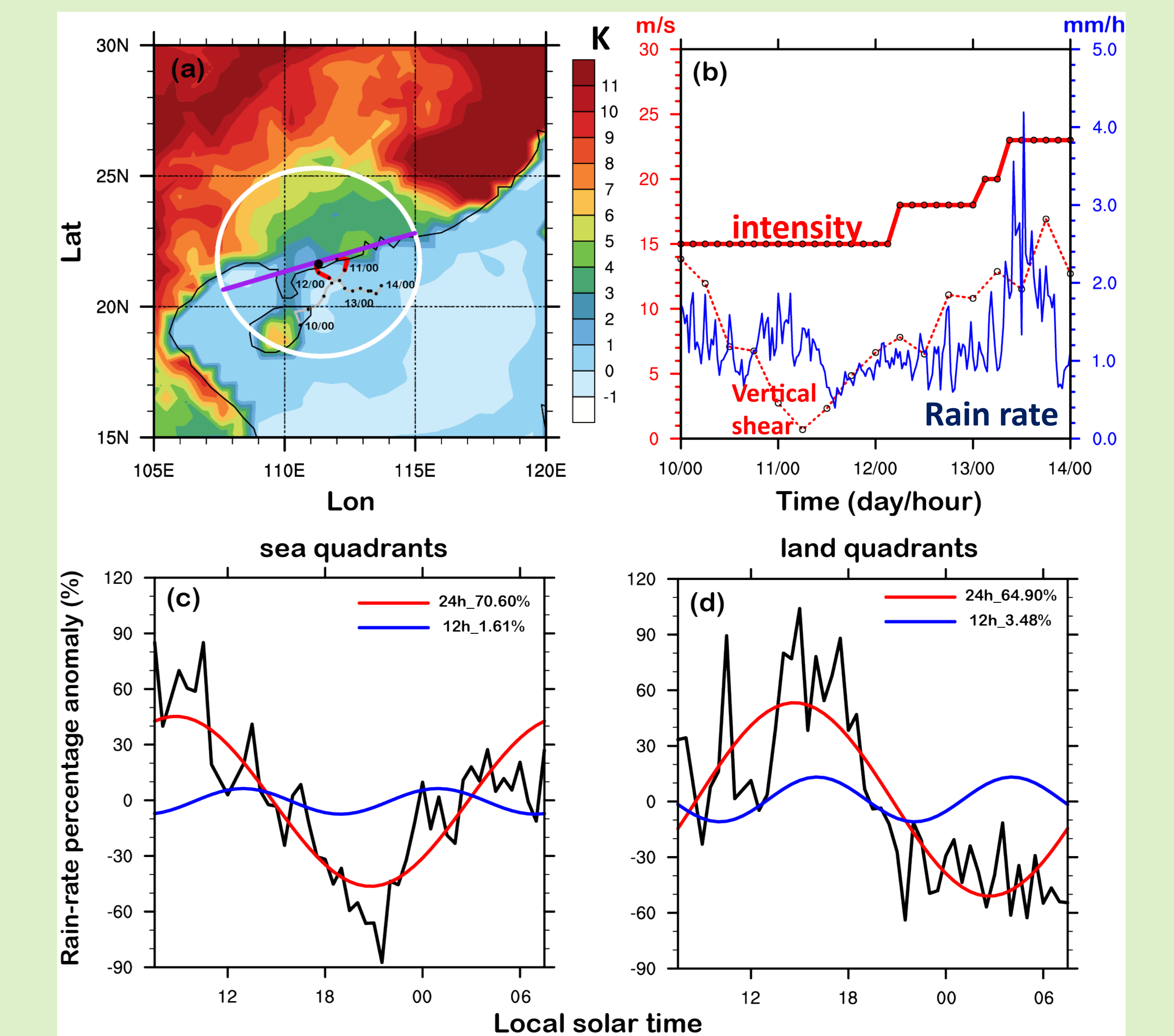
- Higher relative humidity and instability at night over the sea due to net radiative cooling are beneficial to convection and maximum precipitation.

Average divergence anomaly (shading), east–west wind anomaly (contour) under 1 km (400 km < R < 800 km)



- Outside of the TC's primary circulation, the direct effect of land surface heating acts on the diurnal variation of precipitation over land. The indirect effect generated by the land–sea surface temperature contrast also acts on the diurnal variation of precipitation, both over the land and sea by the low-level convergence associated with the land–sea breeze.

4. Verification Using Observed TC Bebinca (2018)



- The SST nearby remained nearly constant 303 K, while the maximum diurnal variation of land surface temperature is greater than 7 K.
- The maximum precipitation within a radius of 400 km over the sea (land) occurred at 9 (15) LST in the morning (afternoon).
- These results from Bebinca are essentially consistent with those from the idealized SHORE experiment.

5. Concluding Remarks

- For a TC stalling at the shoreline the peak rainfall over land lags that over sea by 8–12 hr.
- Over sea the nighttime radiative cooling results in an early morning peak of rainfall.
- Over land the highest surface temperature and maximum buoyancy in the afternoon lead to peak rainfall at this time.

References:

Tang, X. et al. 2019: Land–sea contrast in the diurnal variation of precipitation from landfalling tropical cyclones. *JGR: Atmos*, 124(22), 12010–12021.