Water Budget and Intensity Change of Tropical Cyclones over the Western North Pacific

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Abstract

This study examines four water budget components associated with western North Pacific tropical cyclones (TCs) of different intensity change categories. The results show that surface evaporation and total precipitable water (TPW) in the outer environment play important roles in storm rapid intensification. The roles of surface evaporation and TPW in storm RI are related to the enhanced convective available potential energy by moistening and warming the boundary layer. The largest amount of column-integrated moisture flux convergence (MFC) associated with weakening TCs, which results in the heaviest precipitation, is because their strongest mean intensity promotes moisture transport. The results agree with the notion that TC intensity change results from a competition between surface moisture and heat fluxes and low-entropy downdrafts into the boundary layer.

Introduction

- TC intensity prediction still lags track prediction.
- Difficulties in rapid intensification prediction are mainly due to our limited understanding of its associated complex physical processes.
- The moisture in the storm environment is still a poorly understood factor affecting storm intensity and the conclusions are not consistent.
- No studies have compared the roles of water budget components in rapid intensification of WNP TCs .

Data and methodology

- Study period: 2001-2009
- JTWC TC best-track; TRMM 3B42 V7 precipitation (P)
- NCEP FNL; IFREMER3 evaporation (E); TMI TPW
- Water budget equation: $\frac{\partial \mathrm{TPW}}{\partial \mathrm{t}} = E + MFC - P$

Definition of intensity change categories

Category	Definition	No. of sample	Mean initial intensity (kt)
Rapidly intensifying (RI)	ΔV24 ≥ 30 kt	441	59.6
Slowly intensifying (SI)	10 kt ≤ ΔV24 < 30 kt	1362	51.6
Neutral (N)	–10 kt < ΔV24 < 10 kt	1311	53.4
Weakening (W)	ΔV24 ≤ –10 kt	1197	85.9

Results

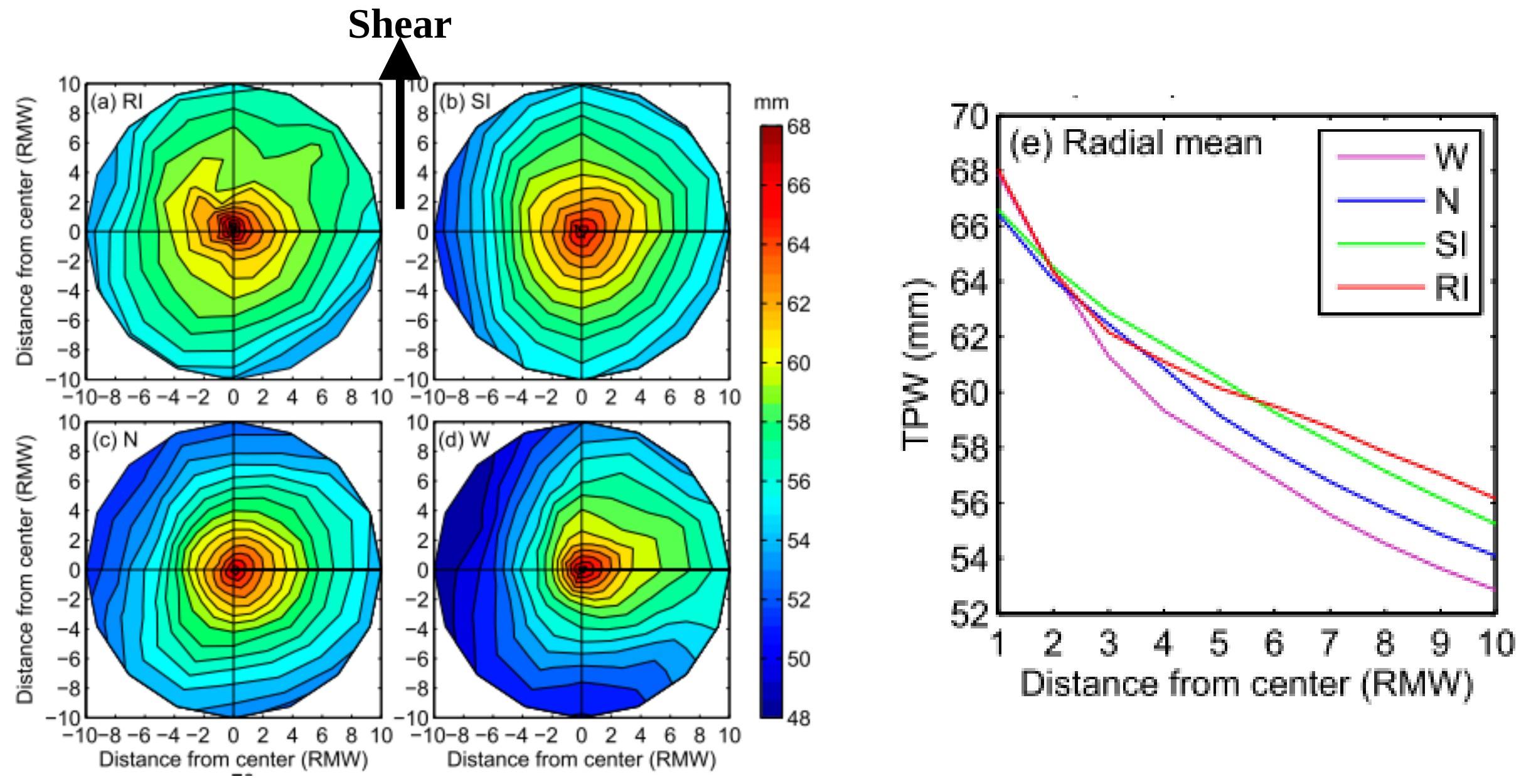

Figure 1. Composite shear-relative distribution of TPW (mm) associated with TCs in the (a) RI, (b) SI, (c) N, and (d) W categories, and (e) radial means for the four categories.

TPW in the outer environment (beyond 6 RMW): **RI > non-RI storms**
TPW in the inner environment (within 5 RMW): comparable

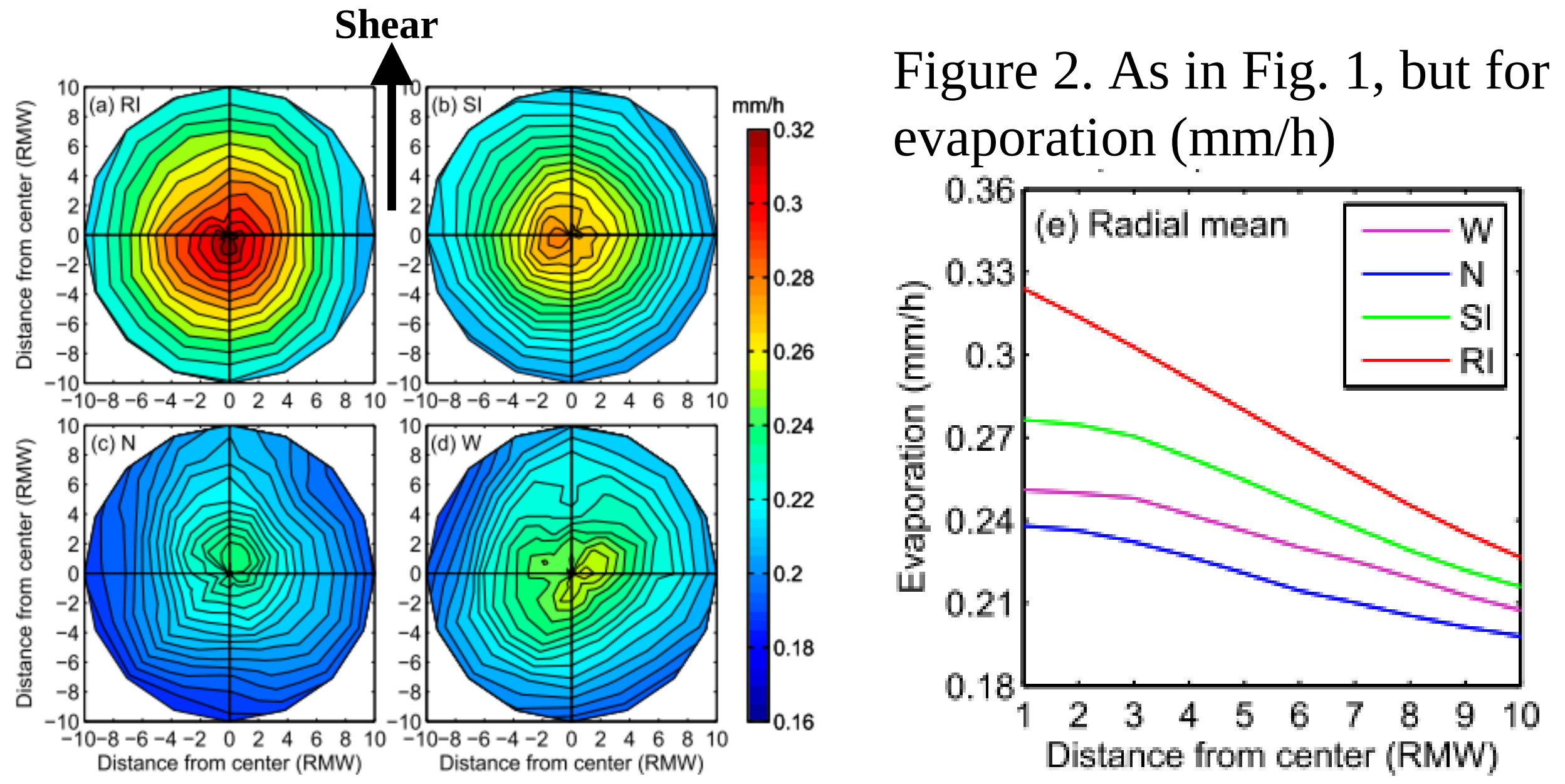

Figure 2. As in Fig. 1, but for surface evaporation (mm/h)

RI storms: **much higher** surface evaporation and **more symmetric** pattern

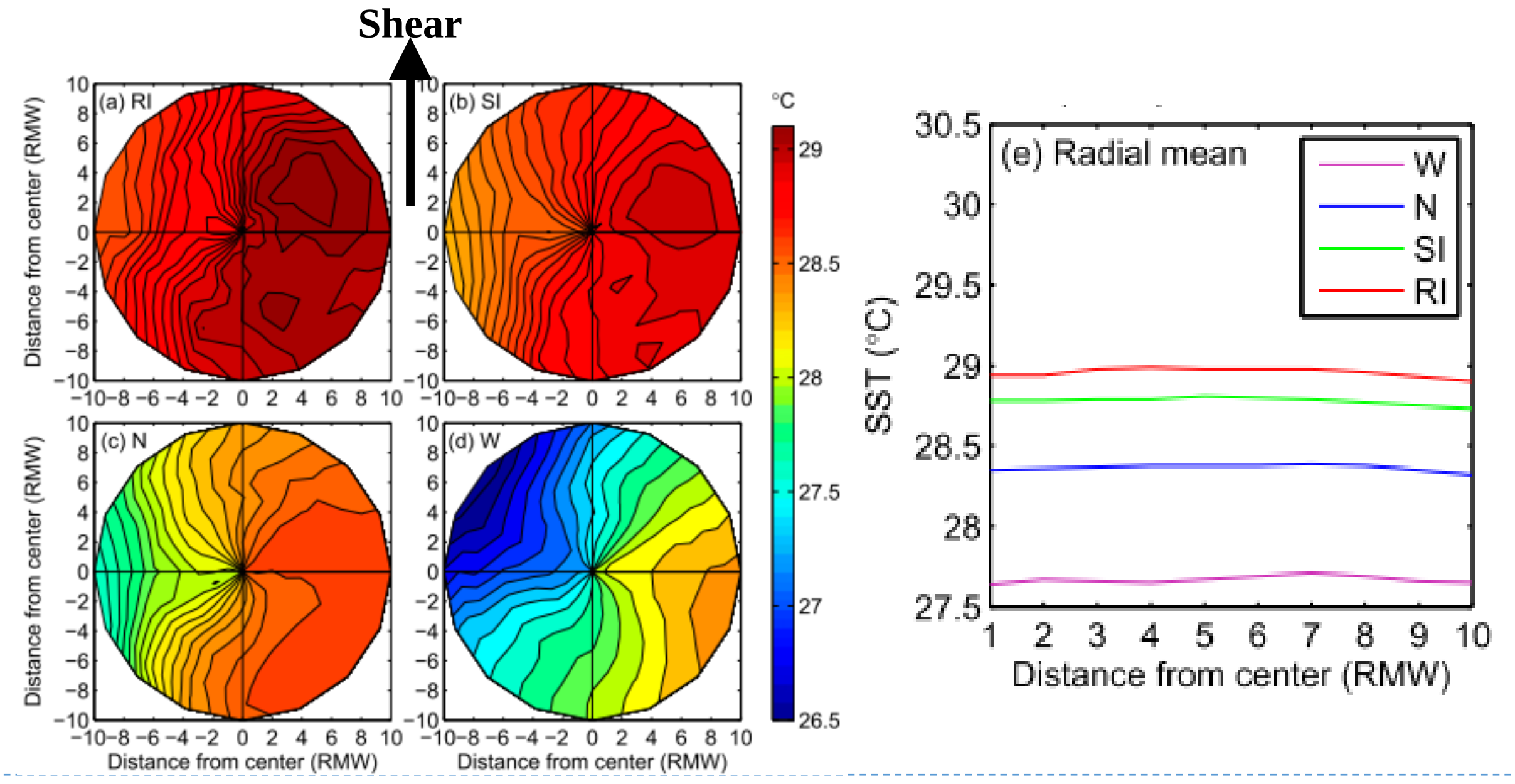

Figure 3. As in Fig. 1, but for SST (℃)

RI storms **do not** have the **highest initial intensity** but have the **highest SST**.
W storms: **lowest SST** but **higher surface evaporation than N storms** because of their **high initial intensity**

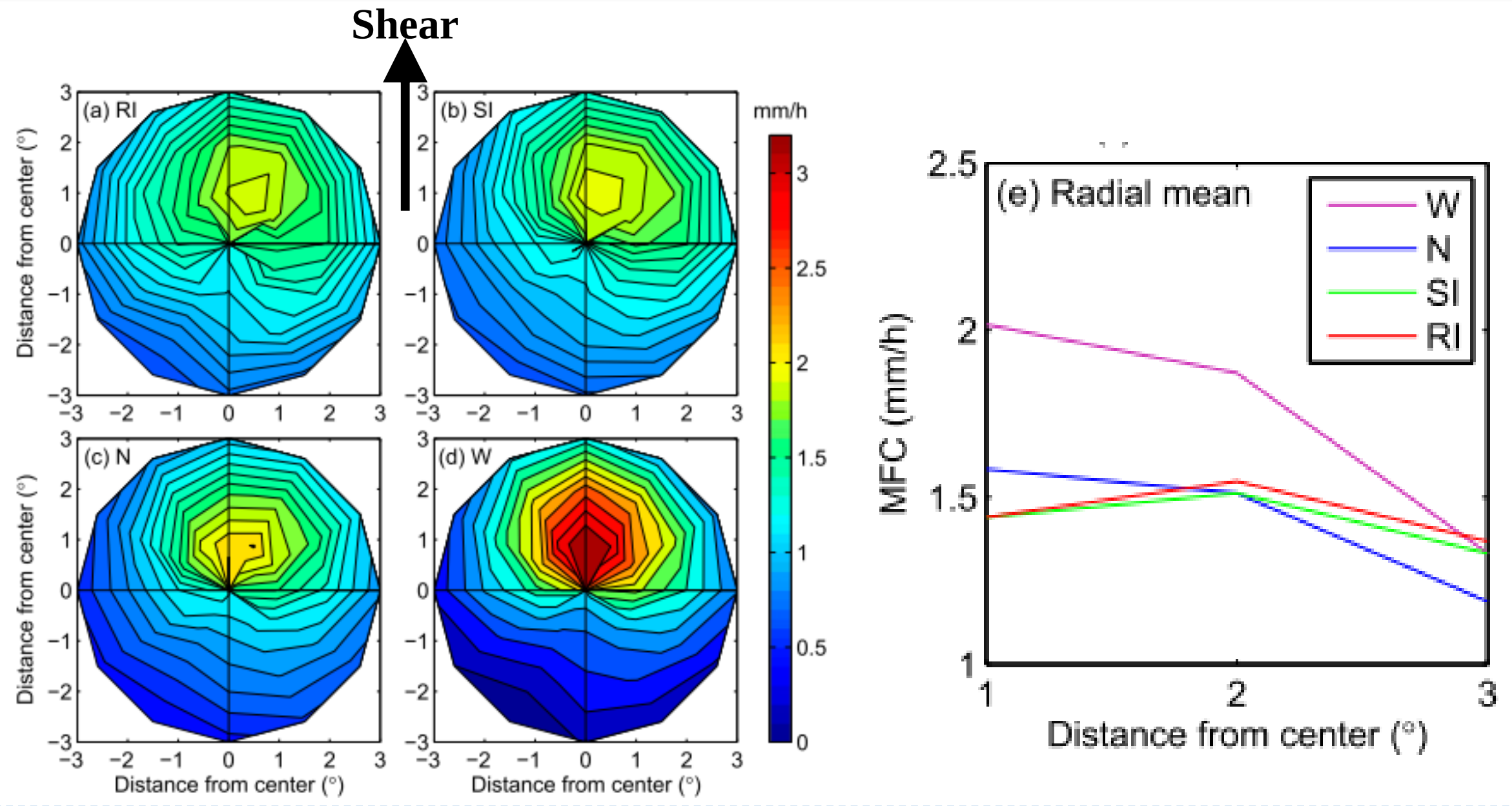

Figure 4. As in Fig. 1, but for MFC (mm/h)

Maximum: **downshear** direction
W storms: **strongest** MFC due to their highest initial intensity
RI storms: **weakest** MFC

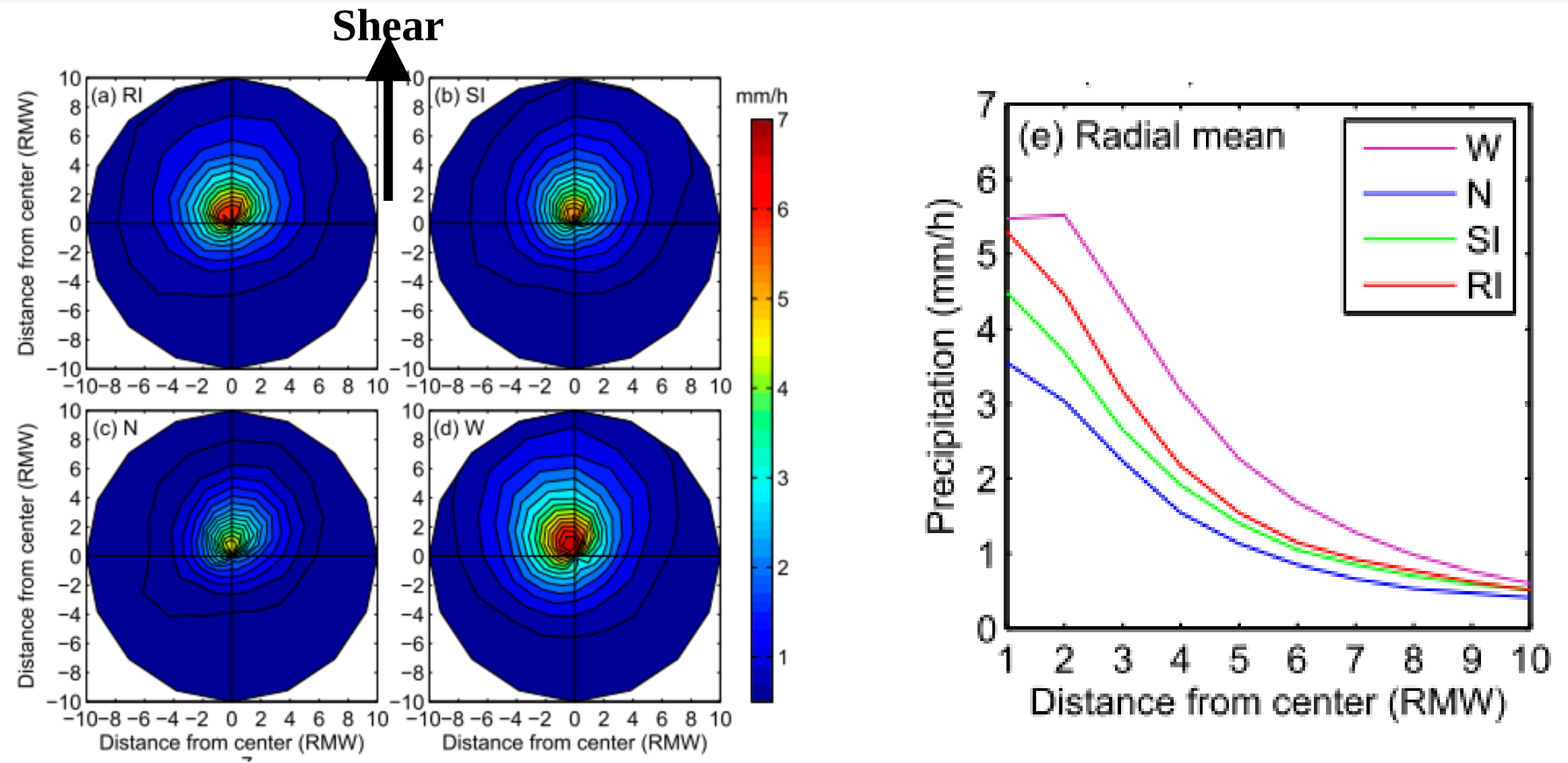

Figure 5. As in Fig. 1, but for precipitation (mm/h)

Maximum: **downshear left** quadrant, W>RI>SI>N
The **cyclonic displacement** of the maximum precipitation relative to the maximum column-integrated MFC is due to **advection of hydrometeors by TC tangential winds**.

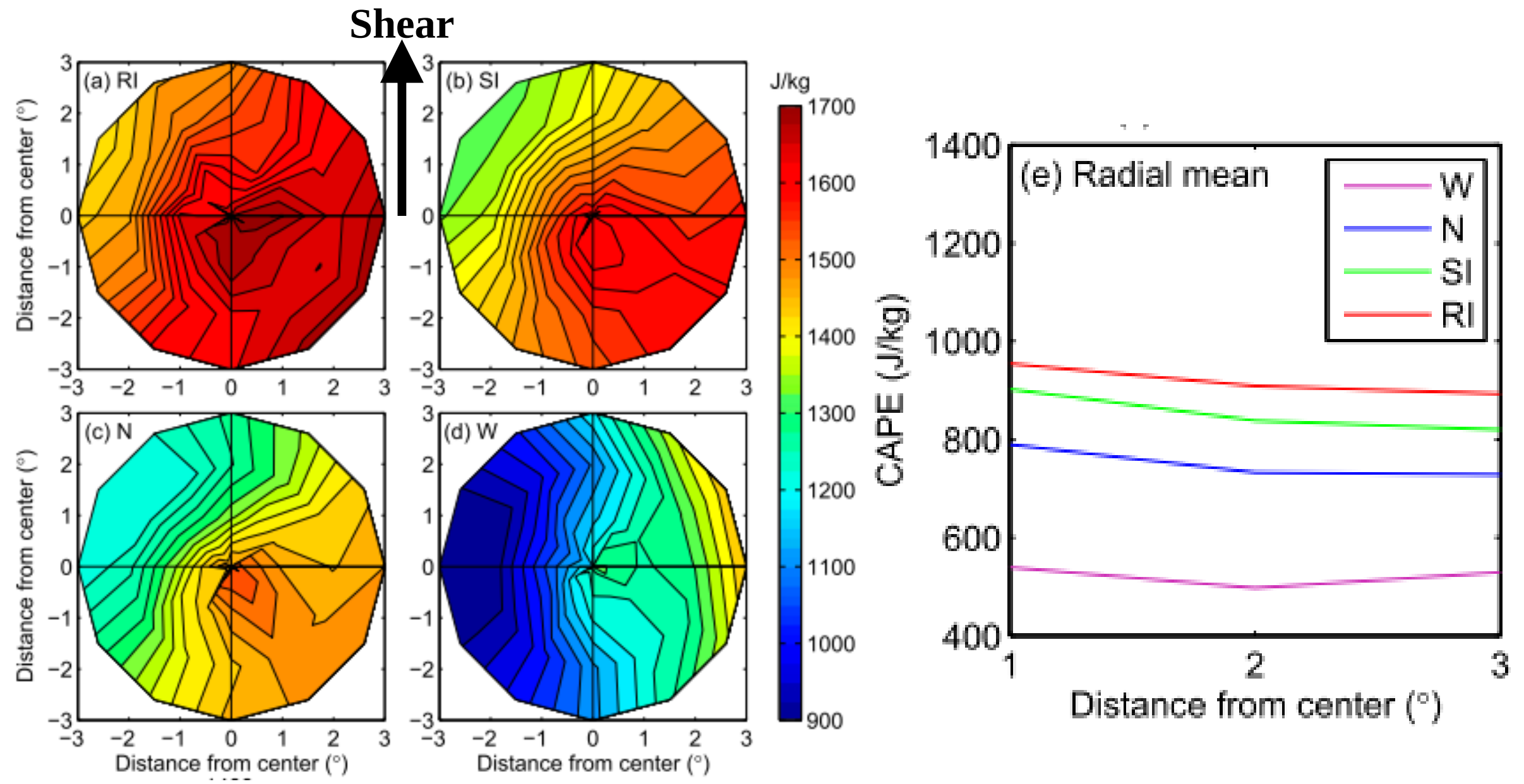

Figure 6. As in Fig. 4, but for CAPE (J/kg)

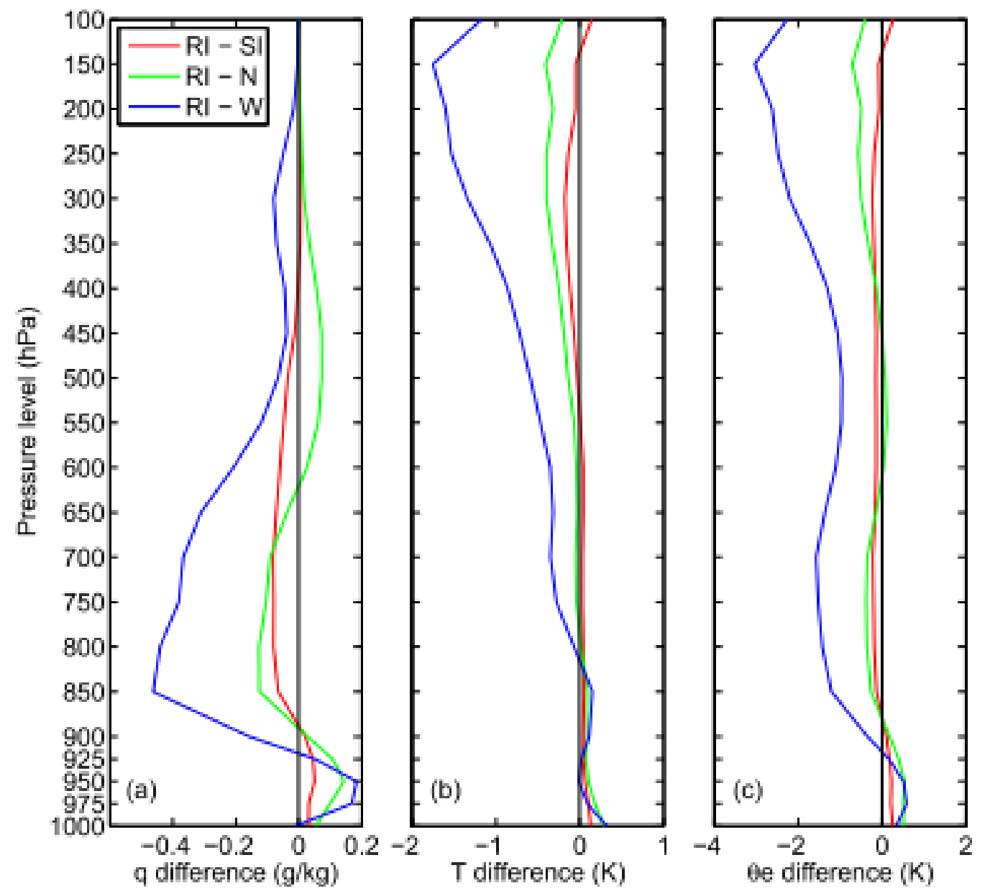

Figure 7. Vertical profiles of differences in (a) specific humidity (g/kg), (b) temperature (K), and (c) equivalent potential temperature (K) between RI and SI categories (red), between RI and N categories (green), and between RI and W categories (blue) averaged within 300 km of the storm center.

CAPE: RI>SI>N>W
In the **boundary layer**, RI storms are associated with **higher temperature** and **specific humidity** due to **more moisture and heat exchange** (Fig. 2), resulting in **higher** θ_e.

Summary

- Surface evaporation and TPW in the outer environment play crucial roles in storm rapid intensification.
- The roles of surface evaporation and TPW in storm RI are related to the enhanced CAPE by moistening and warming the boundary layer.
- Strong downdrafts and evaporative cooling associated with increased precipitation could reduce TC intensity by bringing low θ_e air from the middle troposphere down to the boundary layer.

Reference: Gao, S., S. Zhai, B. Chen, and T. Li, 2017: Water budget and intensity change of tropical cyclones over the western North Pacific, *Mon. Wea. Rev.*, **145**, 3009-3023.