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A Comparison Study between Rapidly-Intensifying and Slowly-Intensifying Tropical Cyclones: Observational Analyses and Model Simulations

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Abstract

This study investigates tropical cyclones (TCs) over the western North Pacific during the period of 2012–2024. Based on the 24-h change in maximum sustained wind speed, TC cases were classified into rapid intensification (RI) and slow intensification (SI) groups. Ice water path (IWP) and rain water path (RWP) derived from the GPM SSMIS precipitation profile retrieval products, together with global infrared brightness temperature (T_B) data, were utilized to examine the evolution of the inner-core microphysical structures before and after intensification. Composite analyses indicate that both RI and SI cases exhibited asymmetric structures influenced by vertical wind shear before intensification, with high IWP, high RWP, and low T_B regions primarily concentrated within the downshear quadrants. However, following the onset of intensification, the regions of high IWP and high RWP in the RI cases gradually expanded from the downshear side into the upshear side, causing the inner-core thermodynamic structure to become more axisymmetric. In contrast, the high-value regions in the SI cases remained confined to the downshear semicircle throughout the intensification period. Axisymmetricity analysis further indicates that the RI cases possessed higher axisymmetricity at all stages of evolution, and the difference between the two groups increased with time.

In addition, WRF model simulations were conducted for the rapidly intensifying case, TC Surigae (2021), and the slowly intensifying case, TC Bailu (2019), in particular. WRF simulations indicate that during rapid intensification, the latent heating, high-IWP, and high-RWP regions of Surigae gradually expanded into the upshear side, forming a deep heating structure surrounding the TC center. In contrast, the latent heating and precipitation structures of Bailu remained confined to the downshear region. Further analyses of precipitation types and water vapor transport indicate that, at RI onset, both deep convection and stratiform precipitation increased significantly in the upshear side of Surigae. Strong upward motion associated with deep convection, together with horizontal moisture advection, continuously transported low-level water vapor into the middle and upper troposphere. This process progressively moistened the upshear region and favored the development of convection, thereby establishing a more axisymmetric latent heating structure and contributing to the RI of Surigae. In contrast, the SI case of Bailu exhibited weaker horizontal and vertical water vapor transport, causing the upshear region to remain relatively dry and unfavorable for the development of convection and latent heating; thus contributing to the SI of Bailu.

Keywords: Tropical Cyclone (TC); Rapid Intensification (RI); Slow Intensification (SI); Ice Water Path (IWP); Rain Water Path (RWP)