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Department of Atmospheric Sciences Ph.D. Dissertation Announcement

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SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY

The Role of Boundary Layer Dynamics in Tropical Cyclone Intensification

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Abstract:

This study examines the role of boundary layer dynamics in tropical cyclone (TC) intensification. The hypothesis is that although surface friction has a negative effect on TC intensification by the frictional dissipation (dissipation effect), it contributes positively to TC intensification by modifying the strength and radial location of eyewall updrafts/convection and also enhancing eyewall contraction (indirect effect). To test the hypothesis and isolate the direct dissipation effect and indirect effect, three models with different complexities are used to conduct idealized experiments with varying surface drag coefficient and TC vortex structure. Results from a simplified dynamical framework, which includes three layers: a multi-level boundary layer model below, a shallow-water-equation model as the middle layer, and an upper layer, are discussed first. In this framework the mass sink in the middle layer is parameterized by a mass-flux at the top of the boundary layer to mimic eyewall heating such that the indirect effect of boundary layer dynamics on TC intensification can be evaluated. Namely, the frictional boundary layer in response to gradient wind distribution above the boundary layer controls the strength and radial location of eyewall convection, which in turn contributes to eyewall contraction and intensification of the gradient wind. Results show that through the indirect effect of surface friction, TCs with larger surface drag coefficient, smaller radius of gale wind (RGW), and higher intensity display faster eyewall contraction and more rapid intensification, and that the fastest intensification occurs for TCs with the initial radius of maximum wind (RMW) at around 80 km.

Results from full-physics model simulations using the Tropical Cyclone Model version 4 (TCM4) are discussed with the focus on the relative importance and the combined direct dissipation and indirect effect of boundary layer dynamics due to the presence of surface friction on TC intensification. Results show that the intensification rate of a TC during the primary intensification stage is insensitive to surface drag coefficient, suggesting that the positive contribution due to the indirect effect of surface friction to TC intensification is almost offset by the negative contribution resulting from the direct dissipation effect of surface friction. However, greater surface friction can significantly shorten the initial spin-up stage (the onset of the primary intensification stage) through faster moistening of the inner core of the TC vortex but would lead to a weaker storm in the mature stage. The results thus strongly suggest that the boundary layer dynamics contributes significantly to the onset of the primary intensification while has important but dual opposite effects on the subsequent intensification rate during the primary intensification stage. Results from further sensitivity experiments demonstrate that the TC vortex initially with a smaller RMW or a smaller RGW has shorter initial spin-up stage and intensifies more rapidly during the primary intensification stage through the indirect effect of the boundary layer dynamics discussed in the simplified framework.