Ph.D. Defense Announcement
Alexander DesRosiers
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Defense
CIRA Commons or Teams

Post Defense Meeting
ATS Main Conference Room (209 ATS)

Committee:
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From Surface to Tropopause: On the Vertical Structure of the Tropical Cyclone Vortex

The internal vortex structure of a tropical cyclone (TC) influences intensity change. Beneficial structural characteristics that allow TCs to capitalize on favorable environmental conditions are an important determinant as to whether a TC will undergo rapid intensification (RI) or not. Accurately forecasting RI is a significant challenge and past work identified characteristics of radial and azimuthal structure of the tangential winds which favor RI, but vertical structure has received less attention. This dissertation aims to define vertical structure in a consistent manner to improve our understanding of how it influences intensity change in observed and modeled TCs, as well as discern when strong winds are more likely to reach the surface with potential for greater impacts.

Part 1 investigates the height of the vortex (HOV) in observed TCs and its potential relationships with intensity and intensification rate. As a TC intensifies, the tangential wind field expands vertically and increases in magnitude. Past work supports the notion that vortex height is important throughout the TC lifecycle. The Tropical Cyclone Radar Archive of Doppler Analyses with Recentering (TC-RADAR) dataset provides kinematic analyses for calculation of HOV in observed TCs. Analyses are azimuthally-averaged with tangential wind values taken along the radius of maximum winds (RMW). A threshold-based technique is used to determine the HOV. A fixed-threshold HOV strongly correlates with current TC intensity. A dynamic HOV (DHOV) metric quantifies vertical decay of the tangential wind normalized to its maximum at lower levels with reduced intensity dependence. DHOV exhibits a statistically significant relationship with TC intensity change with taller vortices favoring intensification. A tall vortex is always present in observed cases meeting a pressure-based RI definition in the following 24-hr period, suggesting DHOV may be useful to intensity prediction.

In Part 2, numerical modeling simulations are utilized to discern mechanisms responsible for the observed relationships in Part 1. Vertical wind shear (VWS) can tilt the TC vortex by misaligning the low- and mid-level circulation centers which prevents intensification until realignment occurs. Both observed and simulated TCs with small vortex tilt magnitudes possess DHOV values consistent with those observed prior to RI. In aligned TC intensification, DHOV and intensity have a

mutually increasing relationship, indicating the metric provides useful information about vertical structure in both tilted and aligned TCs. Vertical vortex growth during RI is sensitive to internal processes which strengthen the TC warm core in the upper-levels of the troposphere. Comparison of a TC simulated in the presence of a concentrated upper-level jet of VWS to a control simulation in quiescent flow indicates that disruption of intensification in the upper levels limits vortex height and intensity without appreciable low- to mid-level tilt.

Part 3 focuses on decay of the TC wind field as it encounters friction near the surface in the planetary boundary layer (PBL). Surface winds are important to operational TC intensity estimation, but direct observations within the PBL are rare. Forecasters use reduction factors formulated with wind ratios (WRs) from winds observed by aircraft in the free troposphere and surface winds. WRs help reduce stronger winds aloft to their expected weaker values at the surface. Asymmetries in the TC wind field such as those induced by storm motion can limit the accuracy of static existing WR values employed in operations. A large training dataset of horizontally co-located wind measurements at flight level and the surface is constructed to train a neural network (NN) to predict WRs. A custom loss function ensures the model prioritizes accurate prediction of the strongest wind observations which are uncommon. The NN can leverage relevant physical relationships from the observational data and predict a surface wind field in real-time for forecasters with greater accuracy than the current operational method, especially in high winds.