Ph.D. Defense Announcement
Ting-Yu Cha
Tuesday, November 8, at 3:00 p.m. MT

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Ph.D. Defense

November 8, 2022
3:00 p.m. MT

Defense
ATS Large Classroom (101 ATS) or Teams

Post Defense Meeting
ATS Main Conference Room (209 ATS)

Committee:
Michael Bell (Adviser)
Russ Schumacher
Kristen Rasmussen
Wen-Chau Lee (NCAR)
Steven Reising (Electrical and Computer Engineering)

Investigation of the dynamics of tropical cyclone precipitation structure using radar observations and numerical modeling

Precipitation from tropical cyclones (TCs) produces significant damage and causes fatalities worldwide. Forecast skill of the structure of precipitation in a TC remains challenging, due in part to limited fundamental understanding of the underlying complex dynamics and limitations in our observational capability. This dissertation seeks to improve our understanding of the underlying dynamics of TC precipitation structure by using and improving radar retrieval techniques and numerical modeling.

In Part 1, the vortex dynamics of TC polygonal eyewall structure during rapid intensification (RI) of Hurricane Michael (2018) are examined from ground-based single-Doppler radar analysis. Although the organization of polygonal precipitation asymmetries has been theorized to be related to vortex Rossby wave (VRW) dynamics, prior studies have had observational limitations that prevent a detailed description of the phenomena. Here, we present the first observational evidence of the evolving wind field of a polygonal eyewall during RI to Category 5 intensity by deducing the axisymmetric and asymmetric winds at 5-min intervals. Novel single Doppler radar retrievals show that both tangential wind and reflectivity asymmetries rotate at speeds that are consistent with linear VRW theory. Dual-Doppler winds from airborne radar provide further evidence of the vortex structure that supports growth of asymmetries during RI.

In Part 2, the relationship between VRWs and the polygonal precipitation structure is further explored through a simple modeling framework. A two-layer model consisting of a shallow water fluid on top of a slab boundary layer is used to understand the dynamical relationship. The model maintains approximate gradient wind balance in the free atmospheric layer and parameterizes the diabatic heating produced by convection from the vertical motion out of the boundary layer. The two-layer model provides insight into the essential dynamics of Hurricane Michael's intensification and precipitation structure observed by radar in Part 1. The results show that the convective maxima located at vertices of an elliptical vortex is due to boundary layer processes and not the free atmospheric convergence. The simulations further shows that continuous intensification of vortex can happen in the presence of elliptical asymmetries and even after the potential vorticity ring breakdown when the diabatic heating is continuously maintained by boundary layer processes.

When TCs approach land they can produce voluminous rainfall totals, especially when interacting with complex terrain. Doppler radar can provide the capability to monitor extreme rainfall events over land, but our understanding of airflow modulated by

orographic interactions remains limited. In Part 3, a new Doppler radar technique is developed to retrieve three-dimensional wind fields in precipitation over complex terrain. New boundary conditions are implemented in a variational multi-Doppler radar technique to represent the topographic forcing and surface impermeability.
A series of observing simulation sensitivity experiments using a full-physics model and radar emulator simulating rainfall from Typhoon Chanthu (2021) over Taiwan are conducted to evaluate the retrieval accuracy and parameter settings. Analysis from real radar observations from Chanthu demonstrates that the improved retrieval technique can advance scientific analyses for the underlying dynamics of orographic precipitation using radar observations.

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