Ph.D. Defense Announcement
Chaehyeon Chelsea Nam
Monday, November 1, 2021, at 3:00 p.m.

Chaehyeon Chelsea Nam
Ph.D. Defense

November 1, 2021
3:00 p.m.

Defense
ATS Large Classroom (101 ATS) or via Zoom

Post Defense Meeting
Riehl Conference Room (211 ACRC)

Committee:
Michael Bell (Adviser)
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Eric Maloney
Steven Reising (Electrical and Computer Engineering)

Multi-scale Interactions Leading to Tropical Cyclogenesis in Sheared Environments

To be, or not to be, that is the question of tropical cyclogenesis. Only a small fraction of tropical disturbances eventually develop into tropical cyclones (TCs). Accurate forecasts of tropical cyclogenesis are difficult because TC development involves a wide range of scales from the stochastic convective scale to a quasi-balanced large-scale flow. This dissertation examines the factors that increase uncertainty around the multi-scale tropical cyclogenesis problem, namely, vertical wind shear (VWS), environmental humidity, and convective organization. These factors were explored using multiple data sources including observations such as dual-Doppler radar, dropsonde soundings, and satellite data for mesoscale case studies, reanalyses data for synoptic and climatological analysis, and extensive ensemble mesoscale modeling for controlled experiments.

First, this dissertation presents a detailed observational analysis for multi-scale processes around an incipient wave pouch of Hagupit (2008) that survived through strong VWS and underwent TC genesis. The strong deep-layer VWS (> 20 m s^{-1}) had a negative impact on the development through misalignment of the low and mid-level circulations and dry air intrusion. However, the low-level circulation persisted and the system ultimately formed into a tropical cyclone after it left the high-shear zone. Here we propose that a key process that enabled the pre-depression to survive through the upper-tropospheric trough interaction was persistent vorticity amplification on the meso-gamma scale that was aggregated on the meso-alpha scale within the wave pouch.

In the second part, twelve sets of Weather Research and Forecasting ensemble simulations were created to examine the combined impacts of VWS, environmental moisture, and the structure of the precursor vortex on the uncertainty of TC genesis. Here we hypothesized that the combination of moderate shear and dry air makes an unstable condition for a vortex to intensify or decay, which implies that TC genesis in such environments may be intrinsically unpredictable in a deterministic sense. Based on the close examination of selected ensemble members and statistical analysis of geometric probability distribution and time-lagged correlations for all ensemble sets, we propose a theoretical pyramid diagram of the five processes leading into

TC genesis in sheared and dry environments. The results suggest that all successfully developing TCs share a common set of precursor events that lead to TC genesis, while a deficiency in any of the precursor events leads to a failure of genesis.

In the third part, we investigated the likelihood of subsequent TC genesis from the "monsoon tail" rainband for TCs in the monsoonal area of the western North Pacific (WNP). The monsoon tail rainband---an elongated rainband in the southwestern quadrant of the TC---is shown to be a common feature for TCs in the WNP due to the climatological northeasterly VWS. Variations in the convective activity are shown to be related to the strength of the low-level and upper-level monsoonal flow on synoptic and seasonal timescales, with VWS having the highest correlation to cold cloud tops in the southwest quadrant. Some monsoon tail rainbands sustain convective organization even after they separated from the pre-existing TCs but despite the enhanced convective activity, the persistent VWS that produced the rainbands was an overriding negative factor that inhibits genesis.

This dissertation provides a detailed look at the complex interactions between VWS and the incipient TC depending on spatial scales, the vertical depth of shear, environmental moisture, and the structure of the TC vortex.

The findings herein improve our process-based understanding of why moderate VWS, especially in combination with environmental dry air, produces unstable and uncertain conditions for TC genesis.

Topic: Ph.D. Defense: Chaehyeon Chelsea Nam
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