

**Ph.D. Defense Announcement**  
**Sean Freeman**  
**Thursday, June 23, at 3:00 p.m. MT**

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**Ph.D. Defense**

June 23, 2022  
3:00 p.m. MT

Defense  
ATS Large Classroom (101 ATS) or [Teams](#)

Post Defense Meeting  
Riehl Conference Room (211 ACRC)

Committee:  
Susan van den Heever (Adviser)  
Michael Bell  
Sonia Kreidenweis  
Richard Eykholt (Physics)

Examining the Impacts of Convective Environments on Storms Using Observations and Numerical Models

Convective clouds are significant contributors to both weather and climate. While the basic environments supporting convective clouds are broadly known, there is currently no unifying theory on how joint variations in different environmental properties impact convective cloud properties. The overarching goal of this research is to assess the response of convective clouds to changes in the dynamic, thermodynamic and aerosol properties of the local environment. To achieve our goal, two tools for examining convective cloud properties and their environments are first described, developed and enhanced. This is followed by an examination of the response of convective clouds to changes in the dynamic, thermodynamic and aerosol properties is assessed using these enhanced tools.

In the first study comprising this dissertation, we assess the performance of small temperature, pressure, and humidity sensors onboard drones used to sample convective environments and convective cloud outflows by comparing them to measurements made from a tethered platform suspended at the same height. Using 82 total drone flights, including nine at night, the following determinations about sensor accuracy are made. First, when examining temperature, the nighttime flight temperature errors are found to have a smaller range than the daytime temperature errors, indicating that much of the daytime error arises from exposure to solar radiation. The pressure errors demonstrate a strong dependence on horizontal wind speed with all of the error distributions being multimodal in high wind conditions. Finally, dewpoint temperature errors are found to be larger than temperature errors. We conclude that measurements in field campaigns are more accurate when sensors are placed away from the drone's main body and associated propeller wash and are sufficiently aspirated and shielded from incoming solar radiation.

The Tracking and Object-Based Analysis of Clouds (tobac) tracking package is a commonly used tracking package in atmospheric science that allows for tracking of atmospheric phenomena on any variable and on any grid. We have enhanced the tobac tracking package to enable it to be used on more atmospheric phenomena, with a wider variety of atmospheric data and across more diverse platforms than before. New scientific improvements (three spatial dimensions and an internal spectral filtering tool) and procedural improvements (enhanced computational efficiency, internal re-gridding of data, and treatments for periodic boundary conditions) comprising this new version of tobac (v1.5) are described in the second study of this dissertation. These improvements have made tobac one of the most robust, powerful, and flexible identification and tracking tools in our field and expanded its potential use in other fields.

In the third study of this dissertation, we examine the relationship between the thermodynamic and dynamic environmental properties and deep convective clouds forming in the tropical atmosphere. To elucidate this relationship, we employ a high-resolution, long-duration, large-area numerical model simulation alongside to build a database of convective clouds and their environments. With this database, we examine differences in the initial environment associated with individual storm strength, organization, and morphology. We find that storm strength, defined here as maximum midlevel updraft velocity, is controlled primarily by Convective Available Potential Energy (CAPE) and Precipitable Water (PW); high CAPE ( $>2500 \text{ J kg}^{-1}$ ) and high PW (approximately 63 mm) are both required for midlevel CCC updraft velocities to reach at least  $10 \text{ m s}^{-1}$ . Of the CCCs with the most vigorous updrafts, 80.9% are in the upper tercile of precipitation rates, with the strongest precipitation rates requiring even higher PW. Furthermore, vertical wind shear is the primary differentiator between organized and isolated convective storms. Within the set of organized storms, we also find that linearly-oriented CCC systems have significantly weaker vertical wind shear than nonlinear CCCs in low- (0-1 km, 0-3 km) and mid-levels (0-5 km, 2-7 km). Overall, these results provide new insights into the joint environmental conditions determining the CCC properties in the tropical atmosphere.

Finally, in the fourth study of this dissertation, we build upon the third study by examining the relationship between the aerosol environment and convective precipitation using the same simulations and tracking approaches as in the third study. As the environmental aerosol concentrations are increased, the total domain-wide precipitation decreases (-3.4%). Despite the overall decrease in precipitation, the number of tracked terminal congestus clouds increases (+8%), while the number of tracked cumulonimbus clouds is decreased (-1.26%). This increase in the number of congestus clouds is accompanied by an overall weakening in their rainfall as aerosol concentration increases, with a decrease in overall rain rates and an increase in the number of clouds that do not precipitate (+10.7%). As aerosol particles increase, overall cloud droplet size gets smaller, suppressing the initial generation of rain and leading to clouds evaporating due to entrainment before they are able to precipitate.

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