Ph.D. Defense Announcement
Alex Sokolowsky
Tuesday, July 19, at 9:00 a.m. MT

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Ph.D. Defense

July 19, 2022
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Defense
ATS Large Classroom (101 ATS) or Teams

Post Defense Meeting
Riehl Conference Room (211 ACRC)

Committee:
Susan C. van den Heever (Adviser)
Eric Maloney
Sonia Kreidenweis
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MORPHOLOGY, LIFECYCLES, AND ENVIRONMENTAL SENSITIVITIES OF TROPICAL TRIMODAL CONVECTION

Convective clouds are ubiquitous in the tropics and typically follow a trimodal distribution of cumulus, congestus, and cumulonimbus clouds. Due to the crucial role each convective mode plays in tropical and global transport of heat and moisture, there has been both historical and recent interest in the characteristics, sensitivities, and lifecycles of these clouds. However, designing novel studies to further our knowledge has been challenging due to several limitations: the extensive computing resources needed to conduct modeling studies at sufficient resolution and scale to capture the trimodal distribution in detail; the lack of analysis tools which can objectively detect and track these clouds throughout their lifetime; and a need for more observational and modeling data of the tropical convective environments that produce these clouds. In this dissertation, three distinct but related studies which address these problems to advance the knowledge of our field on the morphology, lifecycles, and environmental sensitivities of tropical trimodal convection are presented.

The first study examines the sensitivities of the tropical trimodal distribution and the convective environment to initial aerosol loading and low-level static stability. The Regional Atmospheric Modeling System (RAMS) configured as a Large Eddy Simulation (LES) is utilized to resolve all three modes in detail through two full diurnal cycles. Three initial static stabilities and three aerosol profiles are independently and simultaneously varied for a suite of nine simulations. This research found that (1) large aerosol loading and strong low-level static stability suppress the bulk environment and the intensity and coverage of convective clouds; (2) cloud and environmental responses to aerosol loading tend to be stronger than those from static stability; (3) the effects of aerosol and stability perturbations modulate each other substantially; (4) the deepest convection and highest dynamical intensity occur at moderate aerosol loading, rather than at low or high loading; and (5) most of the strongest feedbacks due to aerosol and stability perturbations are seen in the boundary layer, though some are stronger above the freezing level.

The second study presented sought to further enhance an artificial intelligence analysis tool, the Tracking and Object-Based Analysis of Clouds (tobac) Python package, from both a scientific and procedural standpoint to enable a wider

variety of research uses, including process-level studies of tropical trimodal convection. Scientific improvements to tobac v1.5 include an expansion of the tool from 2D to 3D analyses and the addition of a new spectral filtering tool. Procedural enhancements added include greater computational efficiency, data regridding capabilities, and treatments for processing data with singly or doubly periodic boundary conditions (PBCs). These new capabilities are presented through figures, schematics, and discussion of the new science that tobac v1.5 facilitates, such as the analysis of large basin-scale datasets and detailed simulations of layered clouds, that would have been impossible before.

Finally, the last study in this dissertation is a process-focused modeling study on the sensitivities of upscale growth of tropical trimodal convection to environmental aerosol loading. This project was enabled by the scientific and procedural improvements to tobac discussed in the second study, in particular the new abilities of tobac to detect and track objects in 3D and with model PBCs. Here, we used a subset of RAMS simulations from the first study, where only aerosol loading was changed and the upscale growth from shallow cumulus through congestus and cumulonimbus during the nighttime hours was investigated. This study revealed that moderately increasing aerosol loading enhances collision-coalescence processes in the middle of the cloud, which delays initial glaciation but promotes it later in the growth period. Greatly increasing aerosol, however, produces a cloud structure with a more extreme aspect ratio and greater entrainment aloft that rapidly loses buoyancy and vertical velocity with height, as well as exhibiting a greater amount of condensate loading towards the top of the cloud. We also found the relative timing of these processes to be especially important, with more rapid initial growth and lofting of condensate often inhibiting deeper convective growth.

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