Ph.D. Defense Announcement
Marquette Rocque
May 9, 2023, at 2:00 pm

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Ph.D. Defense

Tuesday, May 9, 2023
2:00 pm

Defense
ATS Large Classroom (101 ATS) and Teams

Post Defense Meeting
ATS 2nd Floor Conference Room (209 ATS)

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Influence of Terrain on the Characteristics and Life Cycle of Convection Observed in Subtropical South America

Subtropical South America (SSA) is a hotspot for deep, intense convection that often grows upscale into large mesoscale convective systems (MCSs) overnight. The local terrain, including the Andes and a secondary feature known as the Sierras de Córdoba (SDC) are hypothesized to play a major role in the initiation, development, and evolution of convection in the region. Some satellite studies have investigated this role, but storm-scale and life cycle characteristics of these MCSs have not been studied in depth due to the lack of high-resolution, ground-based instruments in the region. However, in 2018-2019, several research-quality platforms were deployed to Córdoba, Argentina as part of the Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations (RELAMPAGO) and the Cloud, Aerosol, and Complex Terrain Interactions (CACTI) field campaigns. The data collected during these campaigns is used in the studies presented in this dissertation to investigate how the Andes and SDC contribute to convection initiation and rapid upscale growth under varying synoptic conditions. Determining why convection is so unique in SSA may provide insight into characteristics of other storms around the world.

The first two studies in the dissertation evaluate how the Andes and SDC modulate the large-scale environment and storm-scale characteristics under strong vs. weak synoptic forcing. High resolution, convection-permitting simulations in which the terrain is modified are designed to investigate synoptic (Chapter 2) and mesoscale (Chapter 3) processes related to the development of two severe MCSs observed during RELAMPAGO-CACTI. Results from the simulations are also compared with radar observations to determine how well the model performs. Under strong synoptic forcing, when the Andes are reduced by 50%, the lee cyclone that develops is weaker, the South American Low-level Jet (SALLJ) is weaker and shallower, and the MCS that develops is weaker and moves quickly off the terrain. When the SDC are removed, there are no substantial changes to the large-scale environment. However, there is no back-building signature of deep convection, likely because cold pools are no longer blocked by the SDC. Under weak synoptic forcing, there are no significant changes to the large-scale environment, even when the Andes are halved. Similar to the strongly forced case though, when the SDC are removed, there are fewer deep convective cores toward the west. In both cases, the model tends to overestimate convection compared to observations. These studies show that the terrain plays varying roles in the evolution of convection in SSA.

The third and fourth studies use ground-based lightning observations from RELAMPAGO-CACTI to better understand the electrical and microphysical characteristics of these intense storms. Three-dimensional storm structures are identified in the radar data and lightning flashes are matched with these storm modes to evaluate how lightning varies throughout the convective life cycle (Chapter 4). Results show that lightning flashes associated with deep convective cores are most common along the higher terrain of the SDC and occur in the afternoon hours. They also tend to be the smallest in size. Flashes associated with wide convective cores occur more frequently along the eastern edge of the SDC and are observed around midnight local time. Stratiform flashes are found most frequently in the early morning hours about 50-100 km east of the SDC, and they tend to be the largest in area and occur lower within the cloud. These distributions highlight the life cycle of systems, which initiate along the SDC and grow upscale as they move towards the plains overnight.

Flash rates are then related to microphysical properties such as graupel mass and ice water path (Chapter 5). The first lightning flash rate parameterizations are developed for storms in SSA. We find these storms have considerably more graupel associated with them compared to storms in the U.S. These new parameterizations are tested on the simulated strongly forced MCS, and results agree well with observed flash rates. If parameterizations based on U.S. storms had been used instead, the flash rates would have been overestimated by up to a factor of 8. This work, in conjunction with other studies in this dissertation, highlights just how different storms in SSA are compared to the U.S.