M.S. Defense Announcement
Ali Cole
Friday, April 22, at 11:00 a.m.

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M.S. Defense

April 22, 2022
11:00 a.m.

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

Post Defense Meeting
Riehl Conference Room (211 ACRC)

Committee:
Michael Bell (Adviser)
Kristen Rasmussen
Peter Nelson (Civil and Environmental Engineering)

Ensemble-Based Analyses of Liminal Extreme Rainfall Events Near Taiwan and Northern Colorado

Heavy rainfall is a phenomenon that impacts a variety of climates around the world, from the moisture-rich, tropical northwestern Pacific to the drier Northern Colorado plains. Improvements over decades of numerical weather prediction have allowed for increased accuracy in simulations of heavy rainfall cases, but there are still improvements yet to be made. This thesis, in conjunction with the Prediction of Rainfall Extremes Campaign in the Pacific (PRECIP) field campaign, aims to study the mechanisms behind these heavy rainfall events to increase understanding of their underlying processes and improve the modeling of them. Two weather events are investigated in detail, one in which heavy rainfall was not forecast by global models but greater than 600 mm of rainfall accumulated, and a contrasting case in which heavy rainfall was forecast but little to no rainfall accumulated.

On 09 June 2020 near Taiwan, heavy rainfall was produced by quasi-stationary back-building mesoscale convective systems (MCS) associated with a mei-yu front. Peak rainfall amounts totaled over 600 mm with widespread rainfall totals greater than 100 mm. Global model forecast skill was poor in both location and intensity of rainfall. The mesoscale ensemble showed liminal conditions between heavy rainfall or little to no rainfall. The two most accurate and two least accurate ensemble members are selected for analysis via validation against radar-estimated rainfall observations. All members feature moisture-rich environments and moist neutral soundings with low levels of free convection (LFC) and sufficient instability for deep convection, and the synoptic setups do not suggest such different outcomes. Through our analysis, we find that stronger gradients in 100 m virtual potential temperature in the two most accurate members associated with a near-surface frontal boundary provide the primary lifting mechanism for enhanced rainfall. In the two heaviest rain producing members, air moves north/northeastward and ascends the virtual potential temperature isentropes and rises above the LFC, producing back-building deep, moist convection. The near-surface gradients are weaker and more confined along Taiwan's coast in the two least accurate members, which leads to less rainfall that is misplaced from reality. The analyses suggest that subtle details in the simulation of frontal boundaries and meso-scale flow structures can lead to bifurcations in producing extreme or almost no rainfall.

A contrasting event occurred in Northern Colorado on 31 July 2021, where heavy rainfall was forecast and flood warnings were issued, but little to no rainfall and flooding took place in the forecast area. Synoptic and mesoscale conditions were ripe for heavy rainfall, with anomalously high precipitable water values and moderate values of CAPE. Similar to the 09 June 2020 case, the mesoscale ensemble showed a wide spread in rainfall totals, related in part to the variability of surface boundaries and forcing across the ensemble. Weak surface forcing led to very little rainfall in this case despite the high moisture, suggesting similar physical mechanisms and predictability challenges across both the analyzed cases. Implications for improved probabilistic forecasts, increased forecast accuracy, and thus increased public safety for heavy rainfall events are discussed.

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