M.S. Defense Announcement
Gabrielle Leung
Thursday, September 1, at 9:00 a.m.

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September 1, 2022
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Defense
ATS Large Classroom (101 ATS) or Teams

Post Defense Meeting
Riehl Conference Room (211 ACRC)

Committee:
Susan van den Heever (Adviser)
Sonia Kreidenweis
Shantanu Jathar (Mechanical Engineering)

Processes driving shallow convective development and their interactions with aerosols: Aerosol transport and aerosol breezes

In this two-part thesis we investigate the development of tropical shallow convective clouds (i.e. shallow cumulus and cumulus congestus) and their interactions with the aerosol environment using idealized large-eddy simulations (LES). Although much about shallow convection is well-understood, we specifically focus on three facets of shallow convection that remain understudied: (1) the factors governing the development of congestus extending above the 0ºC stable layer; (2) the detrainment of aerosol particles and water vapor from congestus clouds into the mid-troposphere; and (3) the impacts of strong horizontal gradients in aerosol concentration on mesoscale circulations.

Part one of this study explores environmental controls on congestus development and the implications of that development on aerosol lofting and transport. Congestus is the middle mode of tropical convection, with cloud tops around or exceeding the 0ºC level (~5km AGL). While some congestus are terminal, meaning capped by the 0ºC stable layer, others are transient and may develop into deep convection. Although this distinction impacts the congestus-to-deep convection transition and the convective transport of water vapor and aerosols into the mid-troposphere, there is still much to be understood about the processes causing congestus to overshoot the 0 level and continue growing. We find that terminal and transient congestus updrafts are characterized by a similar overturning circulation between the updraft and subsiding shell. However, transient congestus have stronger updrafts, and importantly, the downward branch of their corresponding circulations is constrained by the 0ºC level. Our findings support previous results suggesting buoyancy as a control on congestus height, and we specifically demonstrate that congestus developing in more humid midlevel environments are more likely to be transient. We additionally determine that terminal congestus regenerate more aerosol via evaporation along their cloud edges, while transient congestus create stronger midlevel detrainment layers of aerosol and water vapor due to the trapping of the regenerated aerosol above the 0ºC level. Such midlevel detrainment layers are important for the formation of altocumulus clouds.

Part two of this study introduces and explores the concept of an "aerosol breeze", a thermally-driven circulation resulting from mesoscale gradients in aerosol loadings. We call the resulting circulation an aerosol breeze so as to be analogous to well-documented circulations associated with heterogenous surfaces, like sea breezes. The aerosol-induced circulation sets up a gradient in convection and precipitation that is opposite in direction to that of the aerosol gradient. Clouds in the presence of an aerosol gradient precipitate sooner and more intensely than those in the same integrated aerosol loading distributed horizontally homogeneously. These results suggest unrepresented sub-grid scale heterogeneity in aerosol emissions may lead to biases in simulated cloudiness and precipitation. We also present two observational case studies of aerosol breezes that are similar to our model results in scale and cloud distribution. Further study of the aerosol breeze phenomena is warranted, especially in regions where strong aerosol gradients may be expected, such as along the edges of wildfire plumes or urbanized regions.

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