MIMIM Seminar Series



## Cumulus Entrainment and the Dynamics of Cloud Thermals

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It has been long established that entrainment and dilution are critical to cumulus clouds. Despite its importance, the factors determining entrainment rates in cumulus clouds are not well understood, and even the basic concept of cumulus entrainment has remained somewhat nebulous. Results from simple theoretical models in conjunction with detailed large-eddy simulations (LES) indicate a close connection between entrainment-driven dilution and updraft structure. Cumulus updrafts (both shallow and deep) often comprise a succession of coherent rising thermals, and indeed this structure -- which we term a "thermal chain" -- is itself driven by feedback between entrainment of dry environmental air, buoyancy dilution, and changes in the updraft flow. Entrainment in thermal chain-like updrafts is characterized by localized pulses of relatively large fractional entrainment rates near the bottom of individual large cloud thermals (i.e., on the scale of the updraft as a whole) associated with the inflowing air of their toroidal circulations. These locally large entrainment rates contribute significantly to overall updraft dilution, while other updraft regions can remain relatively undilute. Moreover, the nature of entrainment for cloud thermals is substantially different than that for dry thermals. Dry thermals (both laminar and turbulent) entrain mainly by a process of vorticity generation which results from their initial buoyancy becoming concentrated near the thermals' rotation centers, while they undergo little detrainment. As a result, there is net entrainment of environmental fluid into dry thermals, and they grow in volume as they rise. In contrast, cumulus cloud thermals have a substantially different buoyancy structure because of condensation and latent heating concentrated in their centers which limits their volume growth. This is consistent with LES showing that cumulus thermals grow little in size as they ascend. Thus, the dilution that does occur in cloud thermals is mainly associated with entrainment (inflow) balanced by detrainment (outflow). A conceptual model based on these ideas will be presented, and implications for improving convection parameterizations and interpreting results from convection-permitting models (in which updrafts are not resolved) will be discussed.

## Thursday, 1 September 2022, 2:00 PM Refreshments 1:45pm

NCAR-Foothills Laboratory, 3450 Mitchell Lane FL2-1022, Large Auditorium

Seminar will also be live webcast <u>https://operations.ucar.edu/live-mmm</u> Participants may ask questions during the seminar via Slido.



