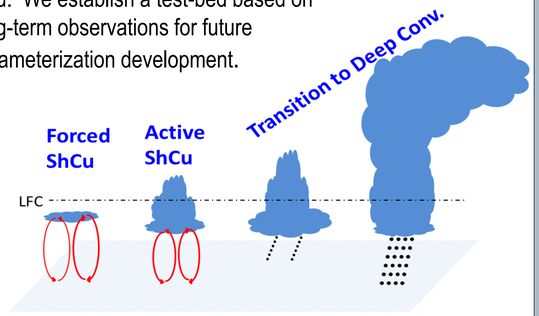
What Controls the Vertical Extent of Convective Clouds over Land? Inferences from Observations of Diurnal Cycle at the ARM SGP Site

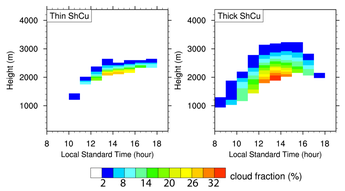
Yunyan Zhang and Stephen A. Klein
Lawrence Livermore National Laboratory

Warm-Season Local-Forced Convective Regimes over Land

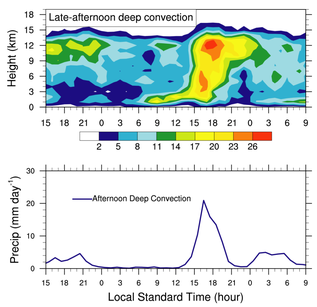
Global climate models have a hard time to simulate a correct diurnal cycle over land. We establish a test-bed based on long-term observations for future parameterization development.



Conceptual illustration of local-forced convective cloud regimes

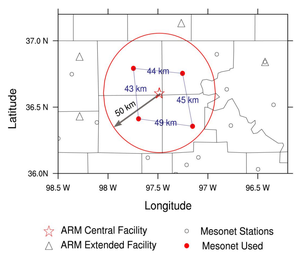


Observed cloud fraction for thin and thick shallow cumulus to represent fair-weather forced and active shallow cumulus



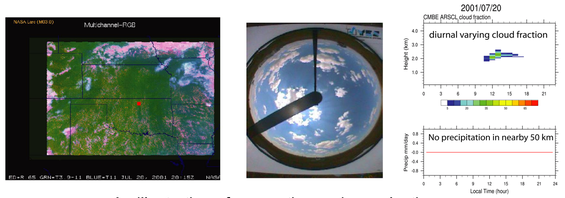
Observed diurnal composite of cloud fraction and precipitation for late-afternoon deep convection

Data and Methods



13-year May to Aug. ARM Data are used in the analysis:

1) ARSCL cloud
2) ABRFC precipitation
3) ARMBE (CMBE)
4) LSSONDE
5) SMOS and OK MESONET
6) BAEBBR surface fluxes
7) Wind Profiler
8) Raman Lidar humidity
9) Continuous forcing advection
10) QCRAD and etc.

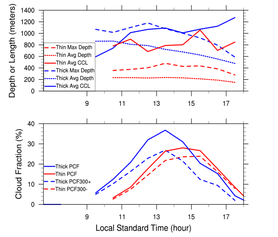


An illustration of convective regime selection.

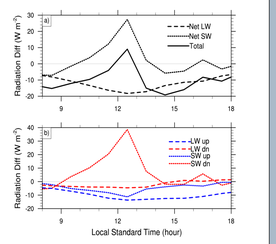
Factors Controlling Vertical Extent of Fair-Weather Shallow Cumulus

Science Focus

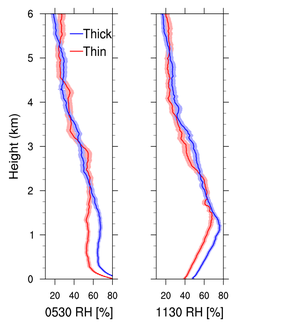
1) How different are the cloud properties and their radiative impacts between days of "thin" and "thick" fair-weather shallow cumulus clouds?
2) How do environmental conditions differ between days of thin and thick clouds and do the differences provide any clues on what controls the shallow cumulus' vertical extent?



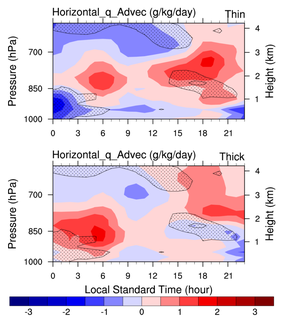
Cloud macro-physical properties: Cloud depth and cloud chord length



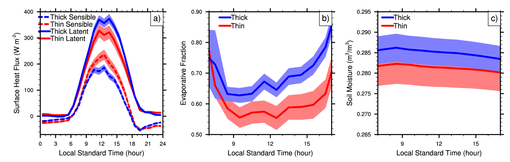
Difference in cloud radiative effect (Thin minus Thick cloud composite)



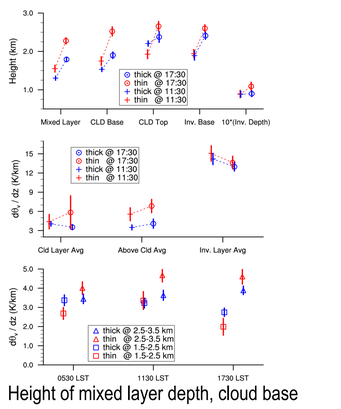
Larger BL RH on thick cloud days in early morning and before noon



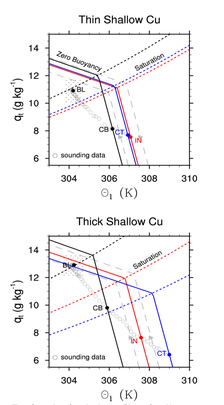
Horizontal moisture advection difference before sunrise



Diurnal variation of surface fluxes, evaporative fraction and soil moisture



Height of mixed layer depth, cloud base and top, and inversion base and depth. Atmospheric stability at different levels.

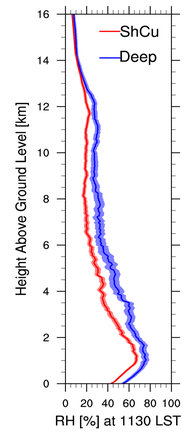


Paluch (mixing line) diagram for composite soundings

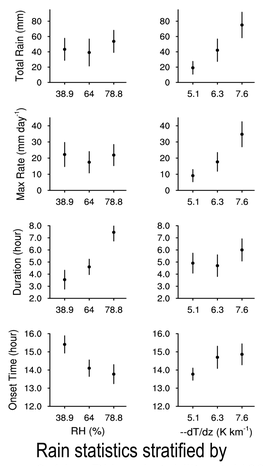
Mechanisms Affecting Transition from Shallow to Deep Convection

Science Focus

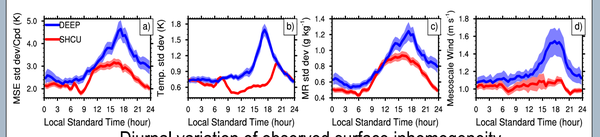
1) What environmental parameters differ between the two regimes, fair-weather shallow cumulus versus late-afternoon deep convection, especially at a few hours before late-afternoon deep convection starts?
2) Is there any correlation between environmental parameters and rain statistics during late-afternoon deep convection?



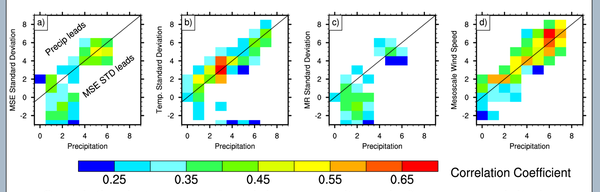
Difference in RH a few hours before deep convection occurs



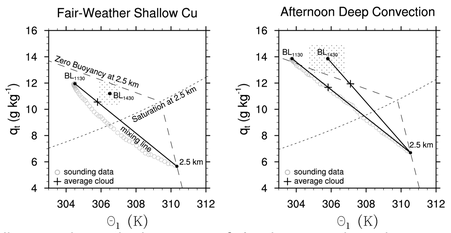
Rain statistics stratified by 2-4 km RH and stability at 1130



Diurnal variation of observed surface inhomogeneity



Correlation between surface inhomogeneity and afternoon precipitation



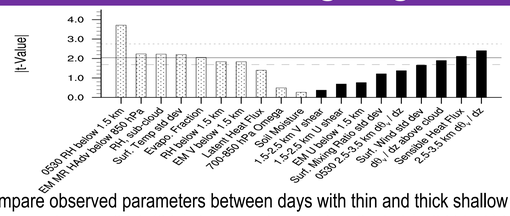
Paluch diagram shows the buoyancy of cloud average based on composite

Reference

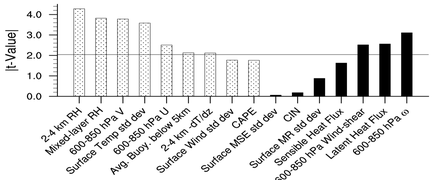
Zhang, Y., and S. A. Klein, 2010: Mechanisms affecting transition from shallow to deep convection over land: Inferences from observations of the diurnal cycle collected at the ARM Southern Great Plains site. *J. Atmos. Sci.*, **67**, 2943-2959.

Zhang, Y., and S. A. Klein 2012: Factors controlling the vertical extent of fair-weather shallow cumulus clouds over land – Investigation of diurnal-cycle observations collected at the ARM Southern Great Plains site. *J. Atmos. Sci.* Submitted.

Comparison of Environmental Parameters among Regimes



Compare observed parameters between days with thin and thick shallow Cu. Greater values on thick (thin) days are denoted by stippled (solid black) bars.



Compare observed parameters between days with fair-weather shallow cumulus and late-afternoon deep convection. Greater values on deep convection (shallow Cu) days are denoted by stippled (black) bars.

Conclusion

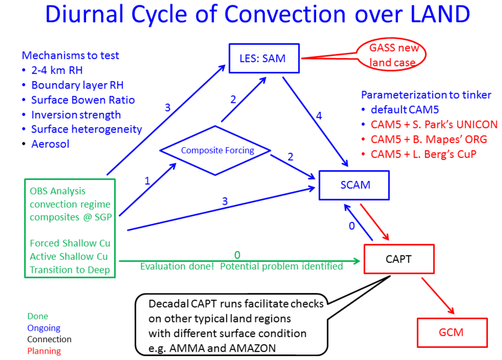
On the controlling factors of the vertical extent of fair-weather shallow cumulus:

1) A more humid boundary layer favors thick shallow cumulus cloud to form. This results from a horizontal advection of moisture into SGP region in the early morning on thick cloud days.
2) A larger evaporative fraction is found in late morning and afternoon on thick cloud days which may serve as a secondary moisture supply and help maintain the higher RH in boundary layer.
3) A stronger stability is found above clouds before noon on thin cloud days, which limits the thermal overshooting and cloud depth, however such difference in early morning soundings is not as significant.

On the transition from shallow cumulus to deep convection:

1) A more humid environment above the boundary layer favors the occurrence of late-afternoon heavy precipitation events.
2) Greater boundary layer inhomogeneity in moist static energy, temperature, moisture and wind is correlated to larger rain rates at the initial stage of precipitation.
3) Higher 2-4 km RH before noon is related to an earlier onset and longer duration of afternoon rain, while greater 2-4 km temperature lapse rates are related to the larger total rain and the maximum rain rate.

Future Work



An illustration of our current progress and long-term goals

Acknowledgements

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