Mechanisms affecting the transition from shallow to deep convection over land: Inferences from observations collected at ARM SGP site

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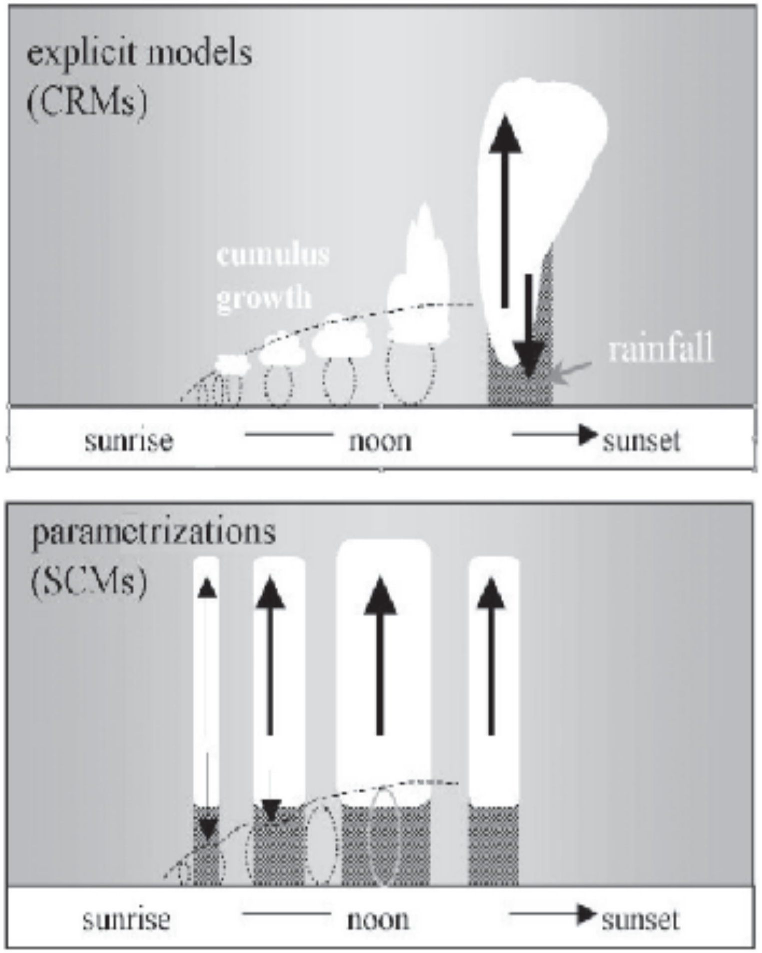
Outline

- Motivation (2 slides)
- Data and Methodology (2 slides)
- Results (4 slides)
- Summary & future work (1 slides)

Motivation



A land example, Figure from Guichard et al, 2004

- A well-known problem in traditional global climate model's convection parameterization is the lack of the transition from dry to shallow non-precipitating cumulus, then to deep precipitating convection.
- Most of our insights on the transition from shallow to deep convection has been gained through fine-scale modeling tools: cloud resolving models or large eddy simulations.

Convection Theories

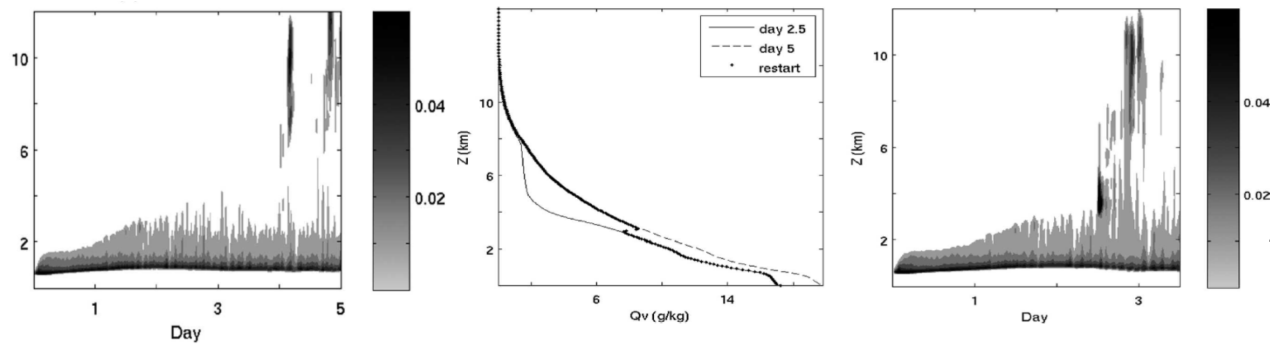
- Convection parameterizations are usually linked to 1) CAPE/CIN 2) Large-scale ascent (Omega) and 3) surface fluxes and so on.

- Some new mechanisms on the transition from CRM/LES studies
  - **The role of free-troposphere humidity** (Derbyshire et al, 2004 and etc.)

Original cloud fraction

Modified Sounding at day 2.5

Increased deep clouds



Affect the property of an entraining air parcel

Figure from Kuang and Bretherton, 2006

  - **The role of boundary layer inhomogeneity**

Link to precipitation-evaporation-driven downdraft and cold pools

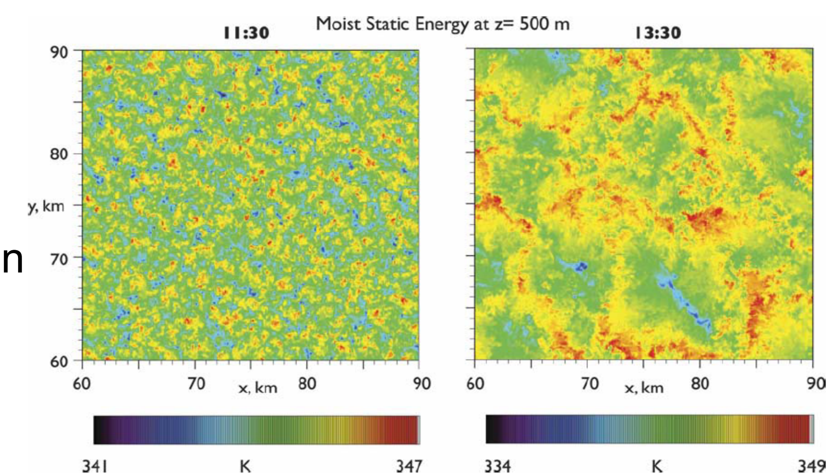


Figure from Khairoutdinov and Randall, 2006

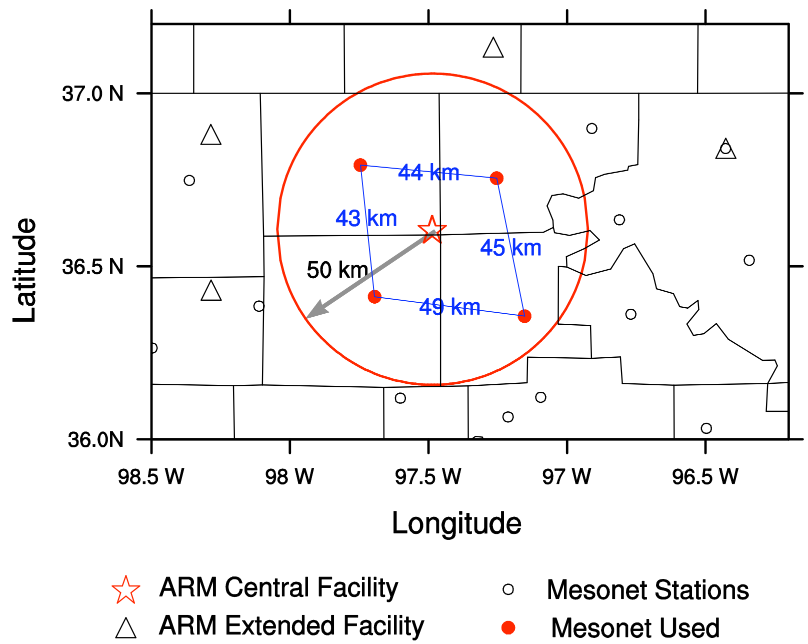
Remarks

- LES are great tools, however what do observations say?
- Golden-day case study is great, however what do convection-regime oriented statistics say?

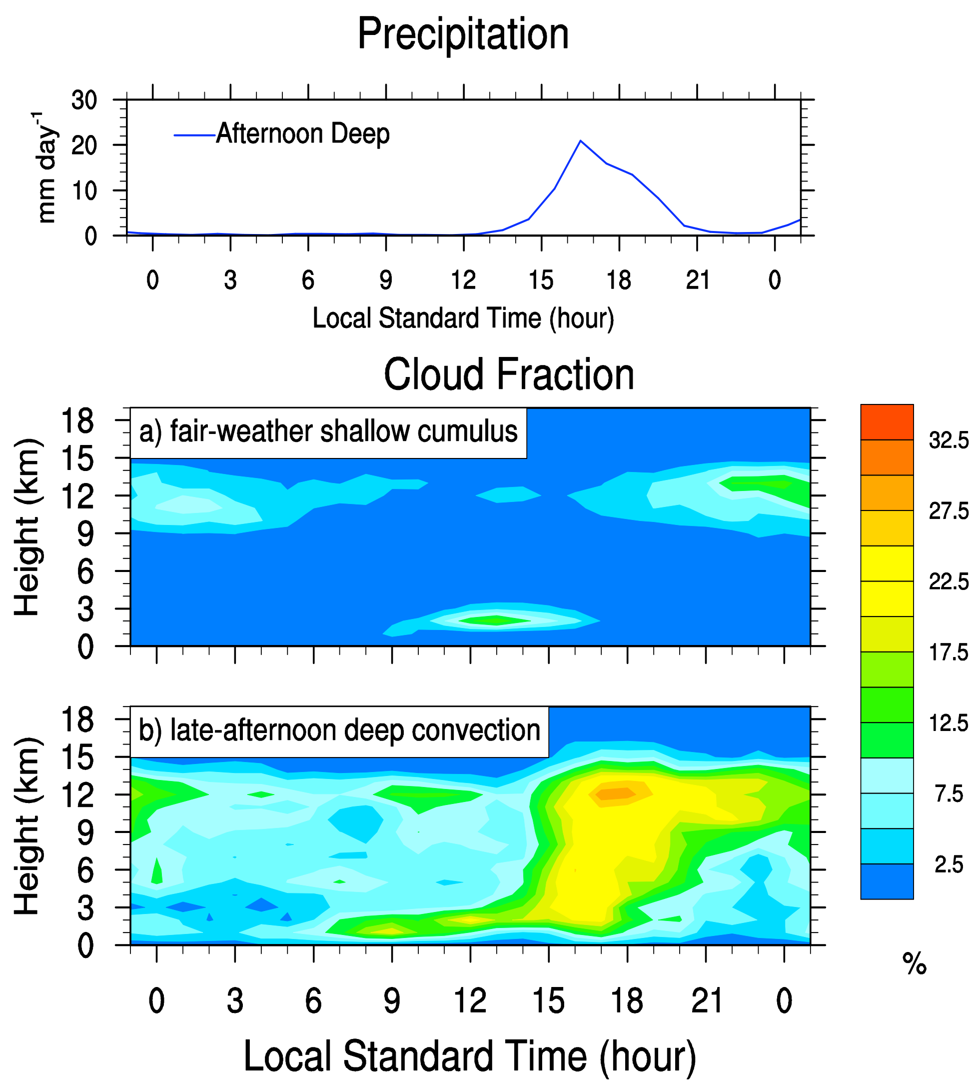
Here, we examine ARM **long-term comprehensive observations at ARM's** Oklahoma site. (For this study, May – August 1997-2007)

ARM's Oklahoma site provides:

- Precipitation radar
- Millimeter wavelength cloud radar
- Microwave radiometer
- Balloon soundings (gives us free-tropospheric humidity)
- A surface station network for heat fluxes, radiation, temperature, humidity, winds (gives boundary layer inhomogeneity)



Methodology



- 80 days with afternoon deep convection and 95 days with shallow non-precipitating cumulus

- Student t-test between the two convection regimes (this test tells us what conditions favor shallow clouds going deep or staying shallow)

- Inside deep convection regime, examine correlation between environmental parameters and afternoon rain statistics: total amount, maximum hourly rate, onset time, duration

Remarks on the Observational Analysis

- Observations suggest that late-afternoon deep convection is associated with:
  - Greater CAPE
  - Greater Free-tropospheric Humidity
  - Greater PBL inhomogeneity in T, q, and mesoscale wind
  - Greater large-scale ascent

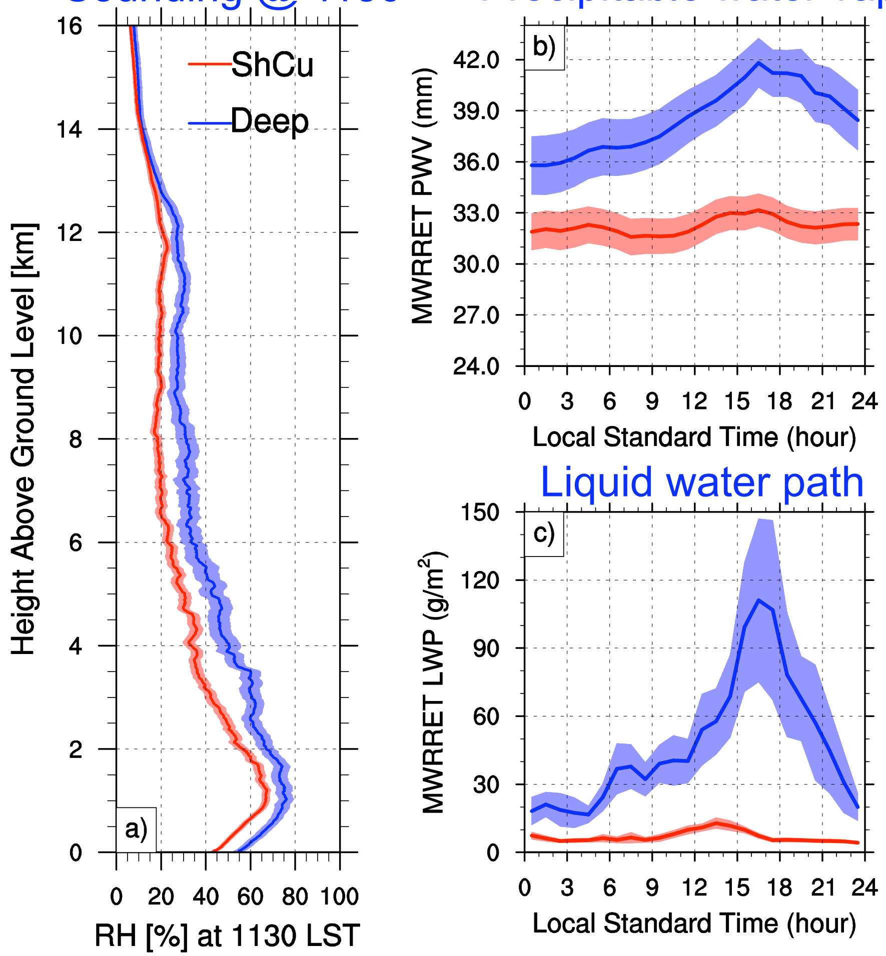
  Before the convection begins

- All theories - except surface fluxes - are confirmed! (The latent heat flux is significantly lower on days with afternoon deep convection – probably as a response to greater surface RH)

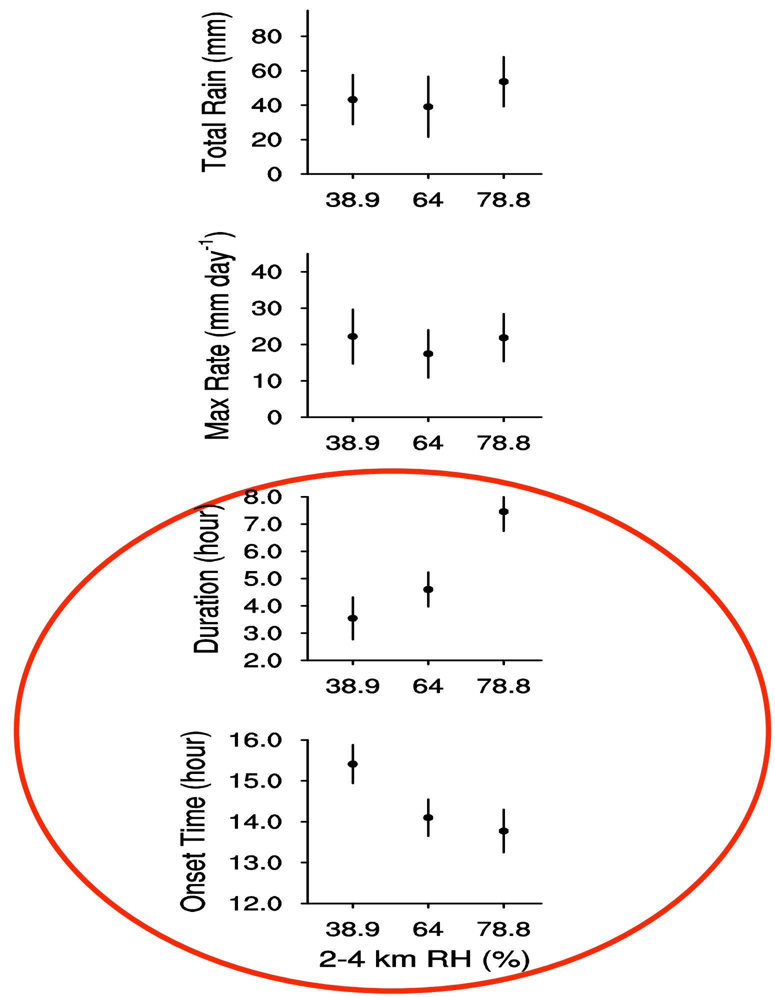
- Two most strongest relationship shown in both t-test and correlation examination is associated with
  - Free-tropospheric humidity
  - PBL inhomogeneity

Free-Tropospheric Humidity

Sounding @ 1130 — Precipitable water vapor



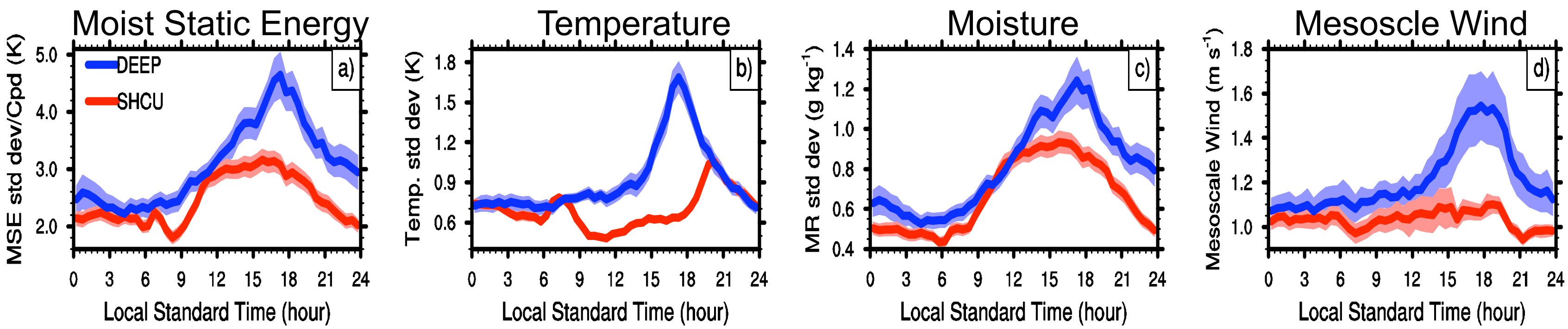
2-4 km RH and afternoon rain



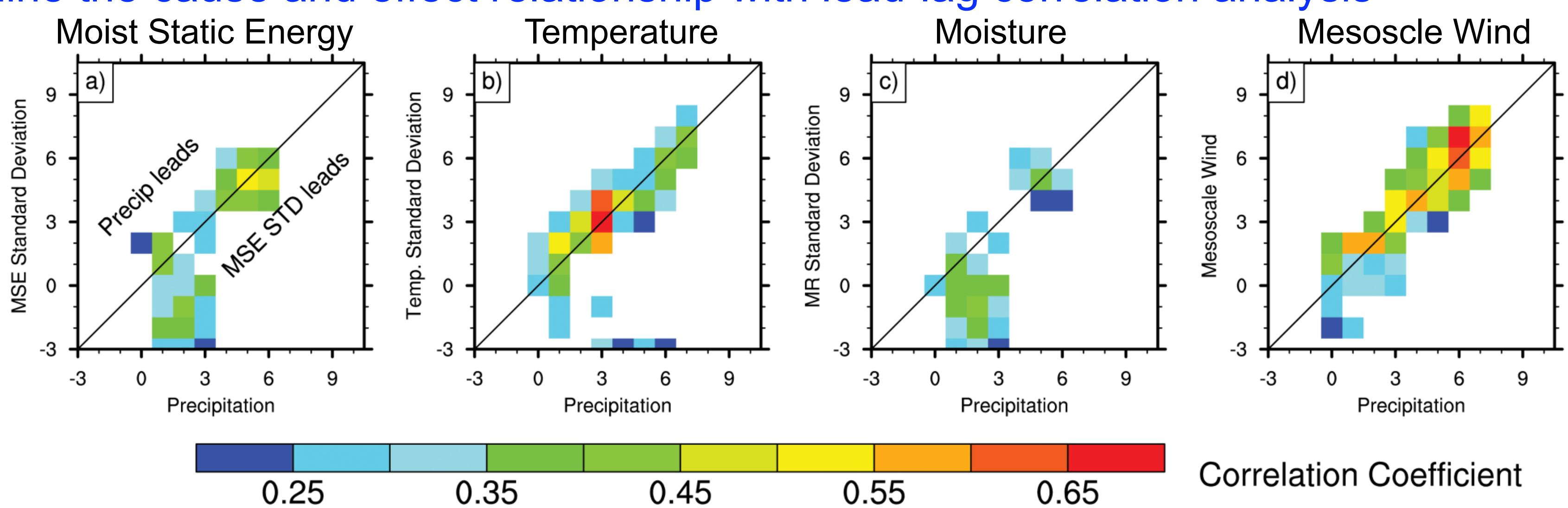
While boundary layer RH is higher, it is not as closely related to afternoon rain statistics as 2-4 km RH. Thus 2-4 km RH appears to be MORE important than boundary layer RH. This is consistent with previous observational studies, e.g. Holloway & Neelin, 2009

Boundary Layer Inhomogeneity

5-surface-station standard deviation

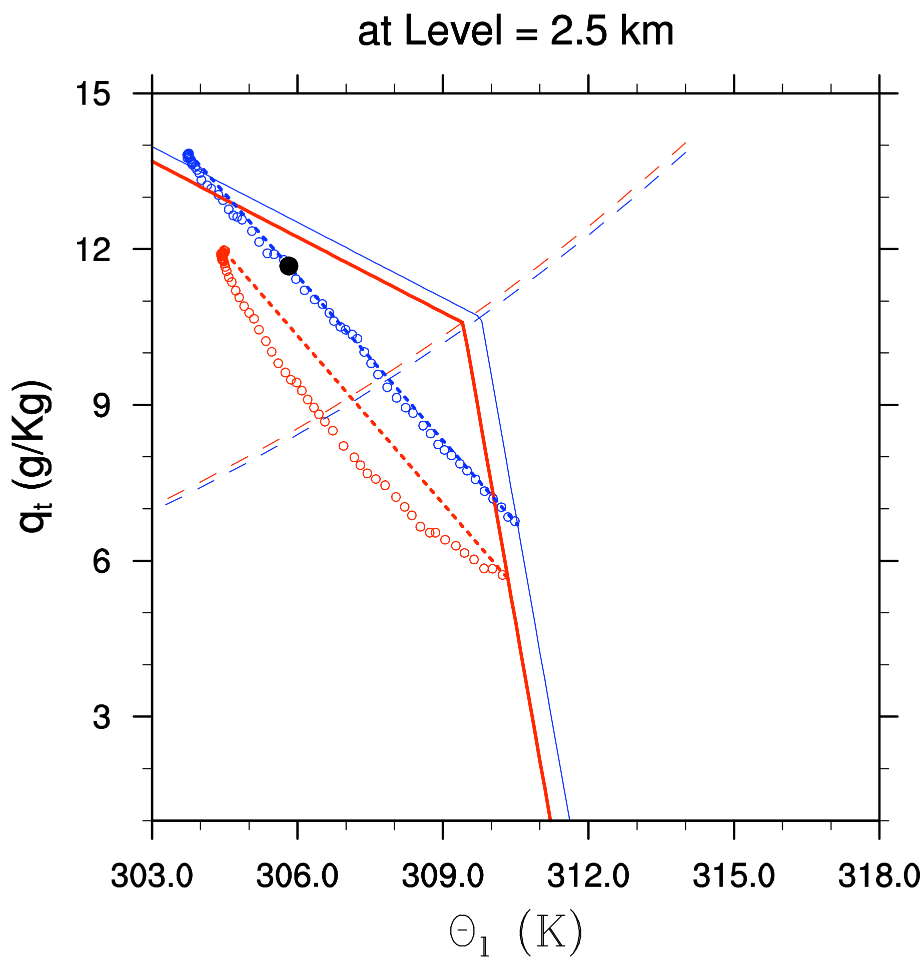


Examine the cause and effect relationship with lead-lag correlation analysis



- The precipitation slightly leads temp and wind inhomogeneity → downdrafts cause cold pools and wind gusts
- The precipitation at initial stage of deep convection is found correlated with boundary humidity inhomogeneity several hours before precipitation begins. → larger mesoscale anomalies of moisture lead to larger precipitation rate and more convection

Buoyancy analysis



Following Neggers et al 2002; Wu et al 2009

- the role of mean state
- the role of boundary layer inhomogeneity

Summary & Future Work

- We use ARM observation to make assessment on several prevailing convection theories. Our study strongly support the role of free-tropospheric humidity and boundary layer inhomogeneity
- These observations also support new convection parameterizations that focus on the ability of boundary layer air parcels to reach the level of free convection (e.g. CIN Closures of Mapes / Bretherton). They also suggest that it would be worthwhile to parameterize mesoscale boundary layer inhomogeneity and its relationship to deep convection
- Composite case might need to be set up for further LES and SCM investigations.

  maybe better than "golden day"?