

Convective Clouds & Soil Moisture: Investigation using ground-based DATA at US Southern Great Plains

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Motivation – diurnal cycle over Land

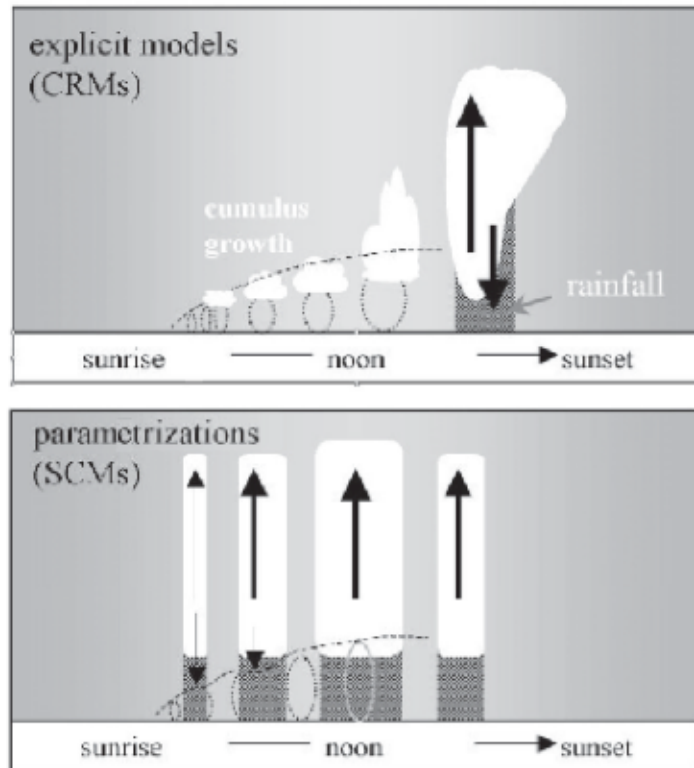
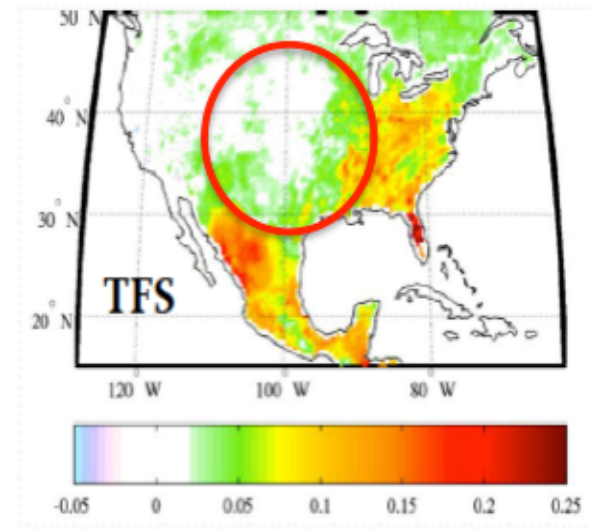


Figure from Guichard et al, 2004

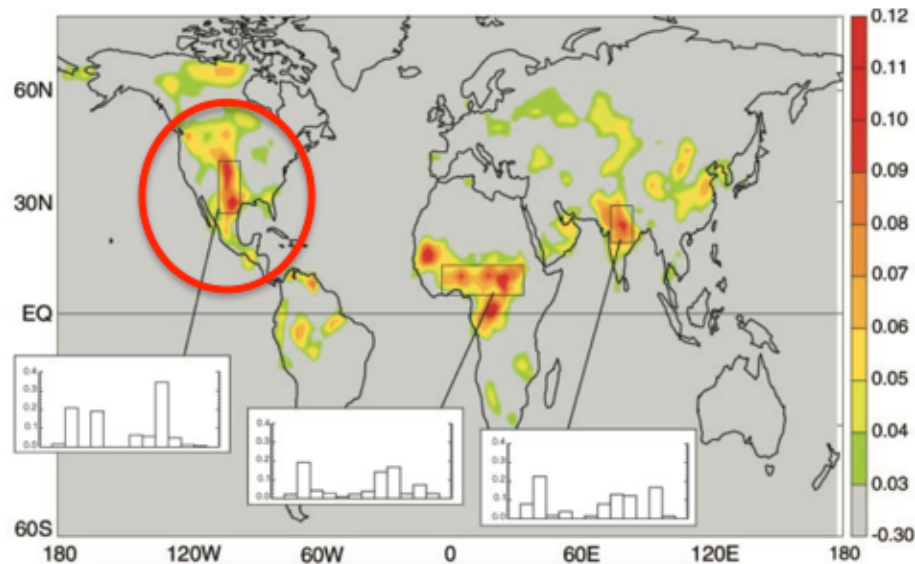
- Convective clouds are important for summertime climate over land
- GCMs poor performance in diurnal cycle largely due to lack of shallow cumulus
- Although GCMs start to resolve mesoscale phenomena, the shallow to deep convection transition regime still needs parameterization

Negative or Positive soil moisture effect?

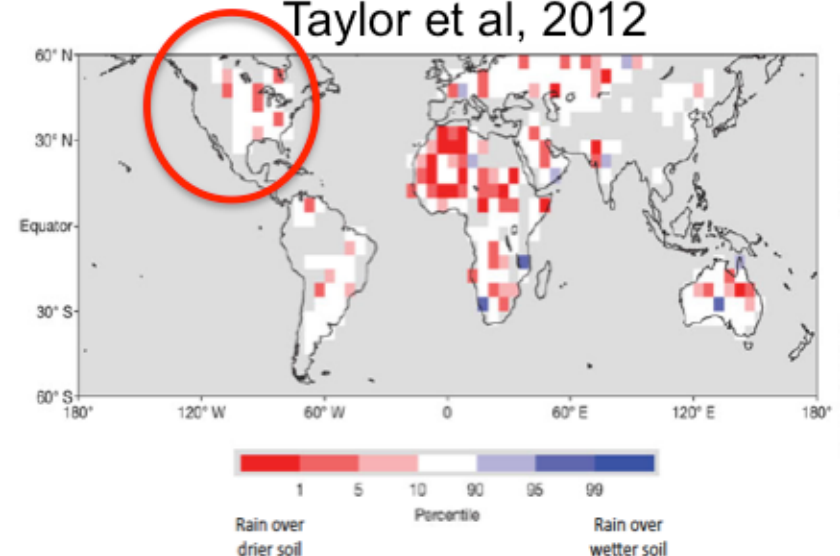
Findell et al, 2011



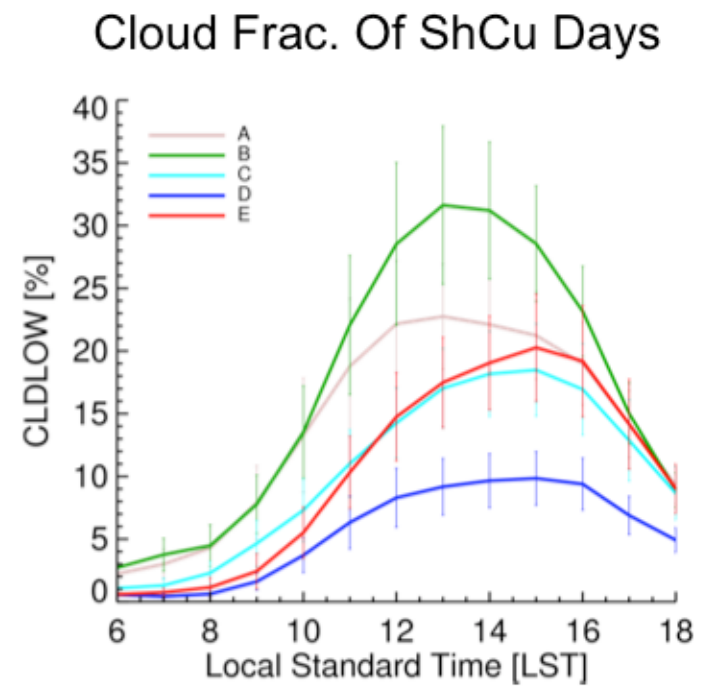
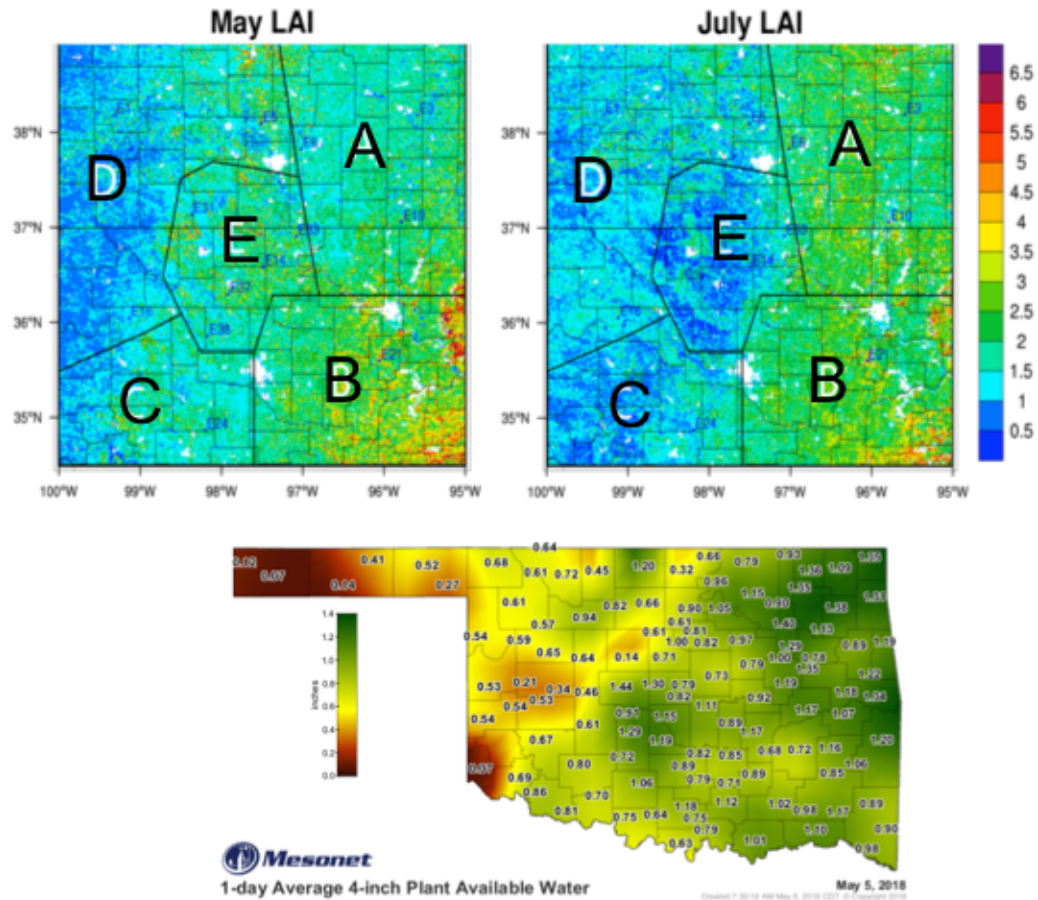
Koster et al, 2004



Taylor et al, 2012



Cloud fraction varies with land surf. at SGP



Locally generated convection regimes at SGP

Case libraries of different convective days are built upon 13-yr summertime data at SGP

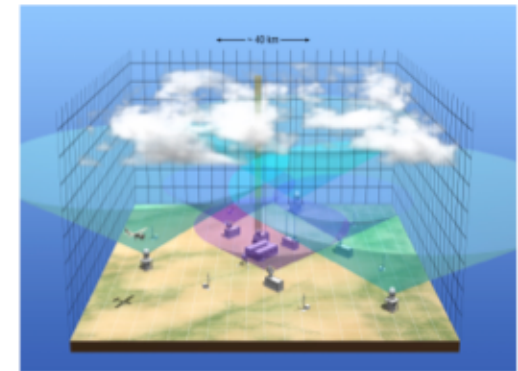
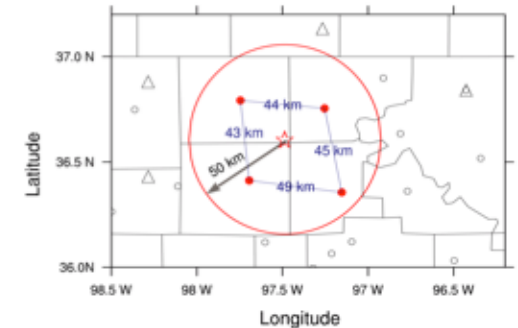
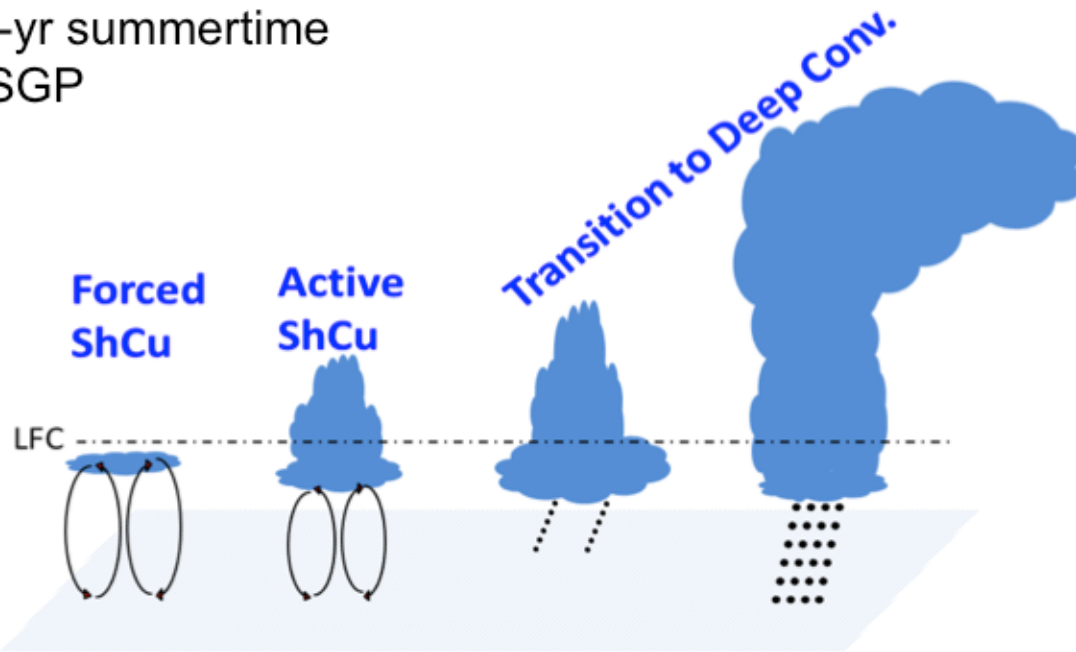


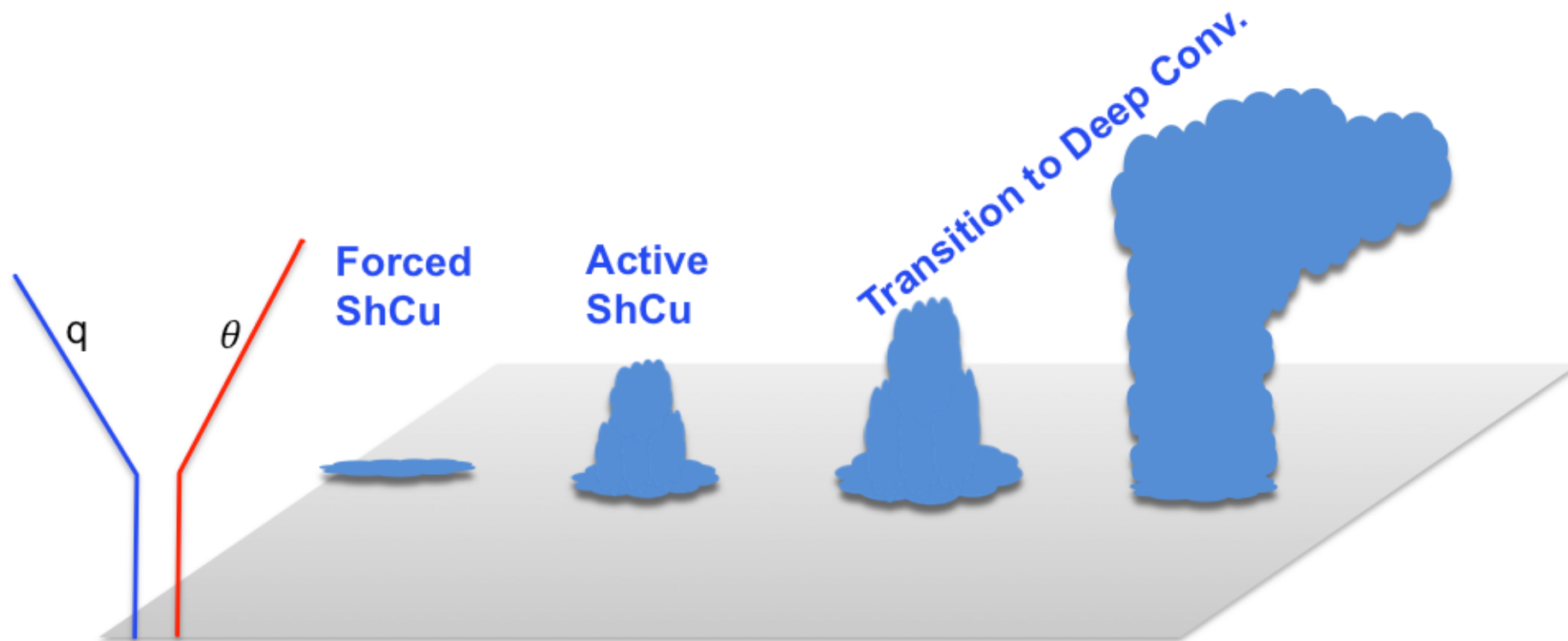
Figure courtesy of US DOE ARM program

Isolated popcorn-like convections associated with local environmental and land-surface conditions
Excluding mesoscale propagating convection systems and orographic-forced convections

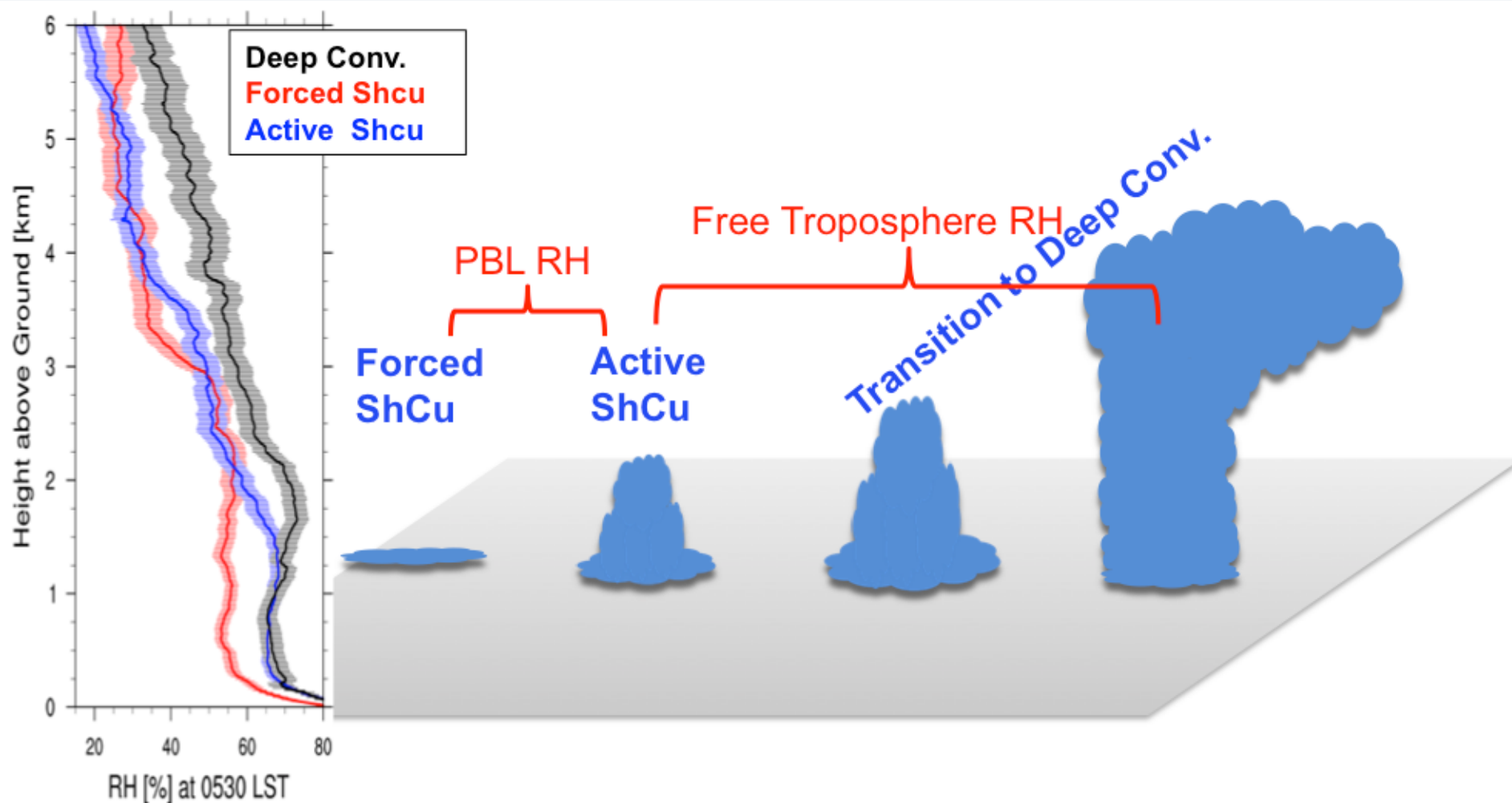
What do we learn from ground-based
ARM SGP long-term network
observations on continental convection
regime transition and their coupling
with land-surface?

1. Atmospheric control
2. Boundary layer control
3. Surface control

What are the Atmospheric controlling factors?



RH is the dominating Atmospheric factor



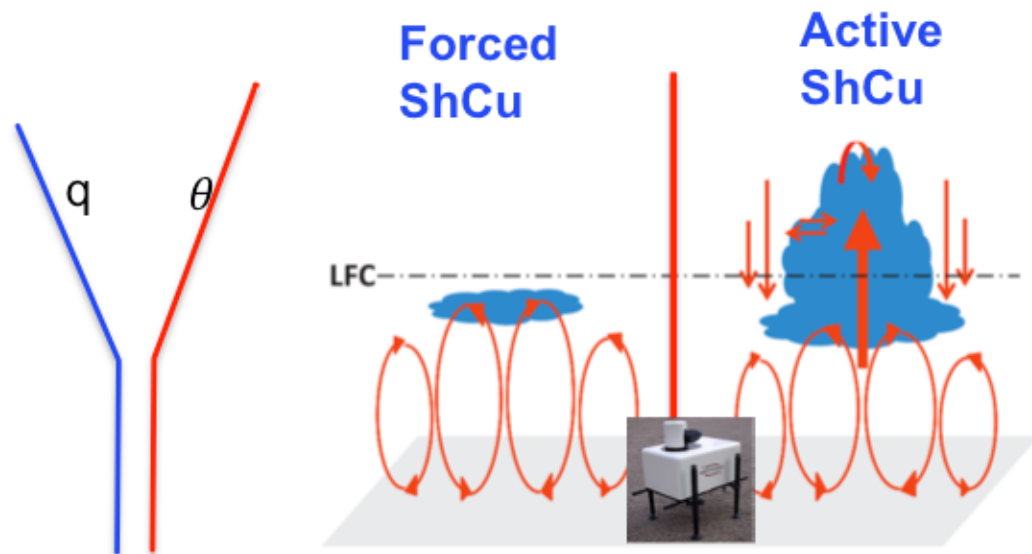
Zhang & Klein, 2010, 2013, 2017

What do Doppler Lidar data tell us about the boundary layer control on ShCu?

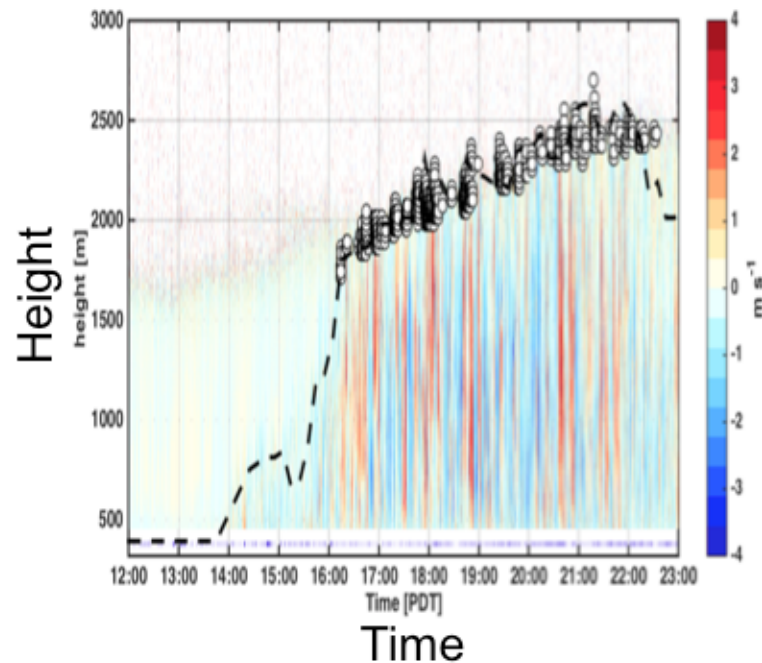
Doppler Lidar
Vertical Velocity

2011-2018

(Rob Newsom
Neil Lareau)



Single-day Sample



Traditional parameterization is built upon the sub-cloud layer turbulence's influence on shallow convection

Lareau et al, 2018, JAS



Can we use DL data test cumulus parameter. based on sub-cloud vertical velocity?

$\frac{\sqrt{CIN}}{W_{cb}}$ as a non-dimensional parameter based on DL data, the ability to break CIN barrier

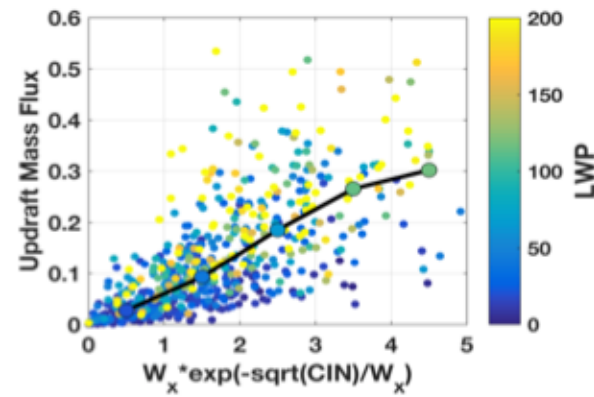
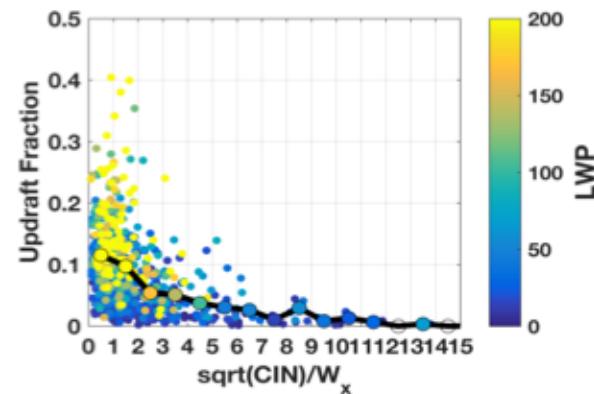
Updraft Fraction:

$$a_{cb} = c_1 \exp\left(-c_2 \frac{\sqrt{CIN}}{W_{cb}}\right)$$

W_{cb} is assumed to be proportional to TKE

Updraft Mass Flux:

$$m_{cb} = c_1 W_{cb} \exp\left(-c_2 \frac{\sqrt{CIN}}{W_{cb}}\right)$$

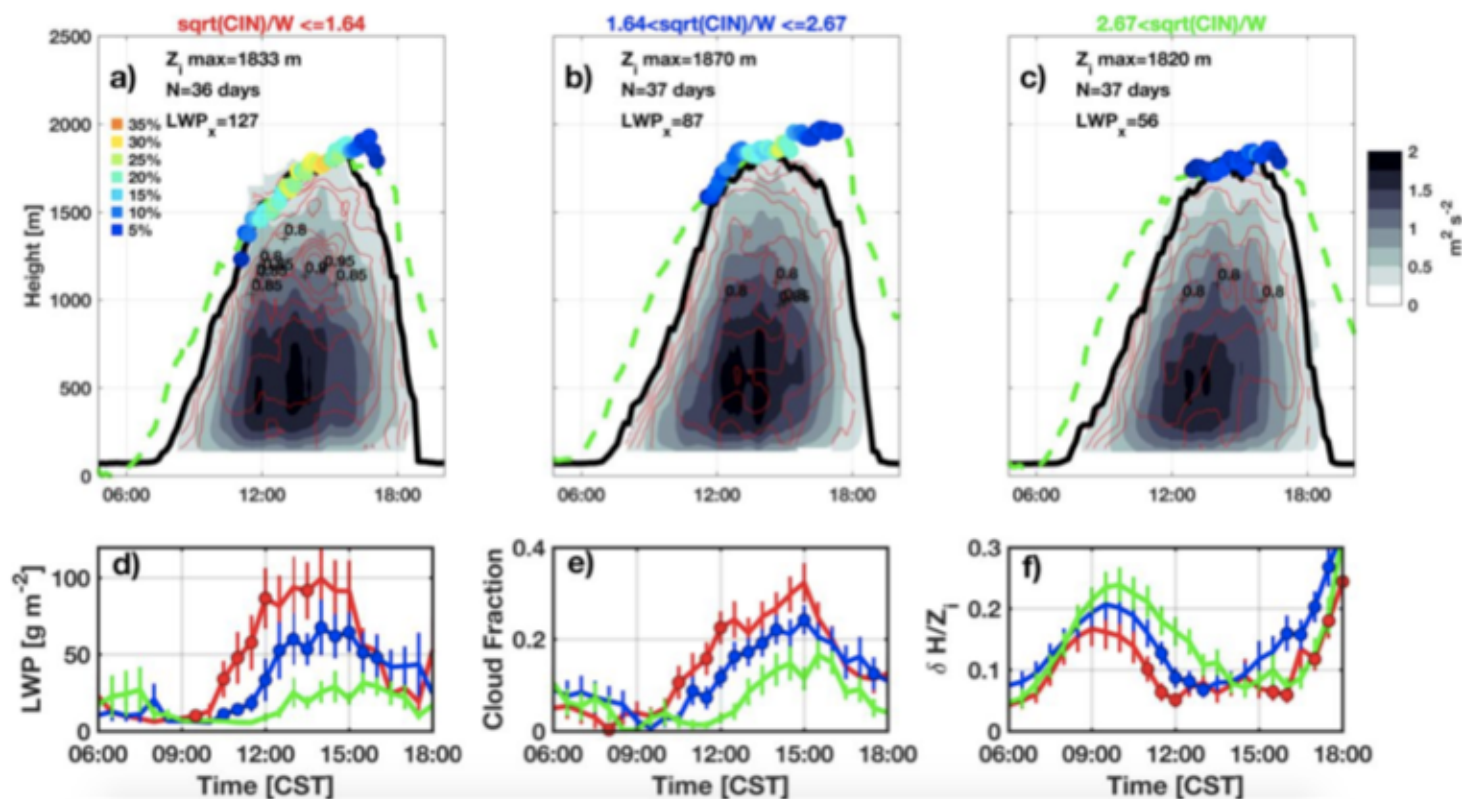


Similar analysis will be applied to DL data at boundary facilities over different land cover/types

Lareau et al, 2018, JAS

Does the non-dimensional parameter $\frac{\sqrt{CIN}}{W_{cb}}$ differentiate cloud development?

$\frac{\sqrt{CIN}}{W_{cb}}$ as a non-dimensional parameter based on DL data, the ability to break CIN barrier

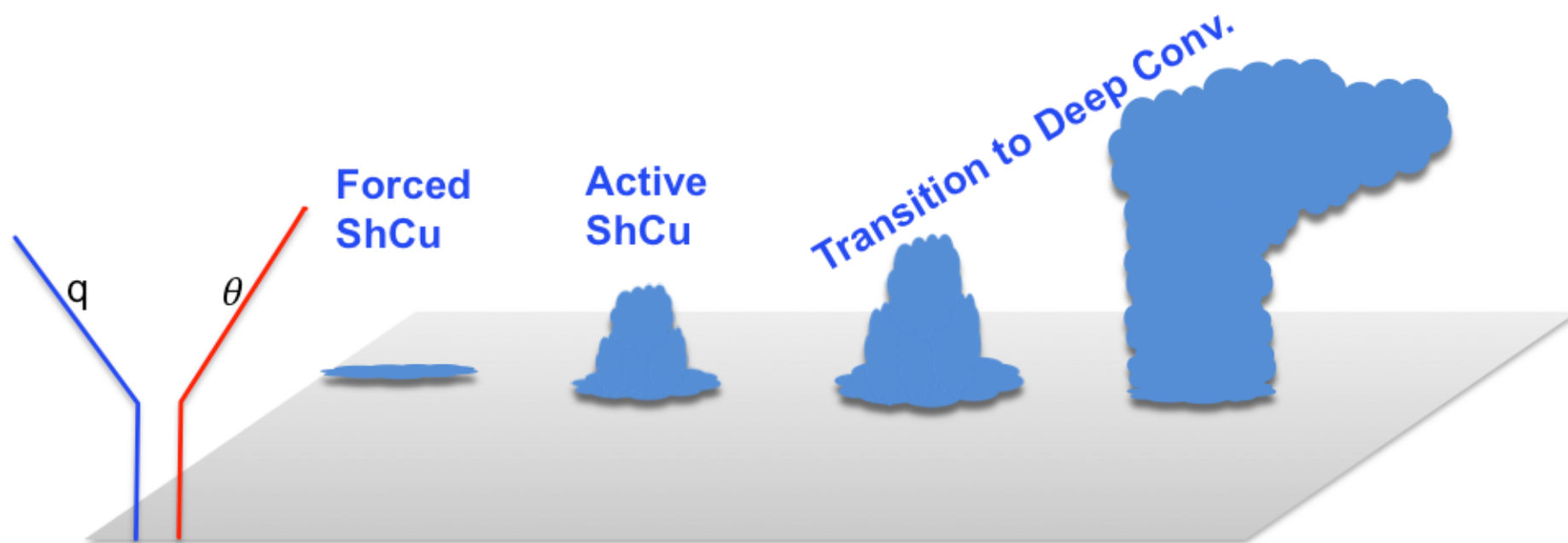


Contour: vertical velocity variance
 Red lines: vertical velocity skewness
 Green Line: LCL
 Black line: PBL top
 Colored dots: cloud base & fraction

Similar analysis will be applied to DL data at boundary facilities over different land cover/types

Lareau et al, 2018, JAS

What are the Surface controlling factors?

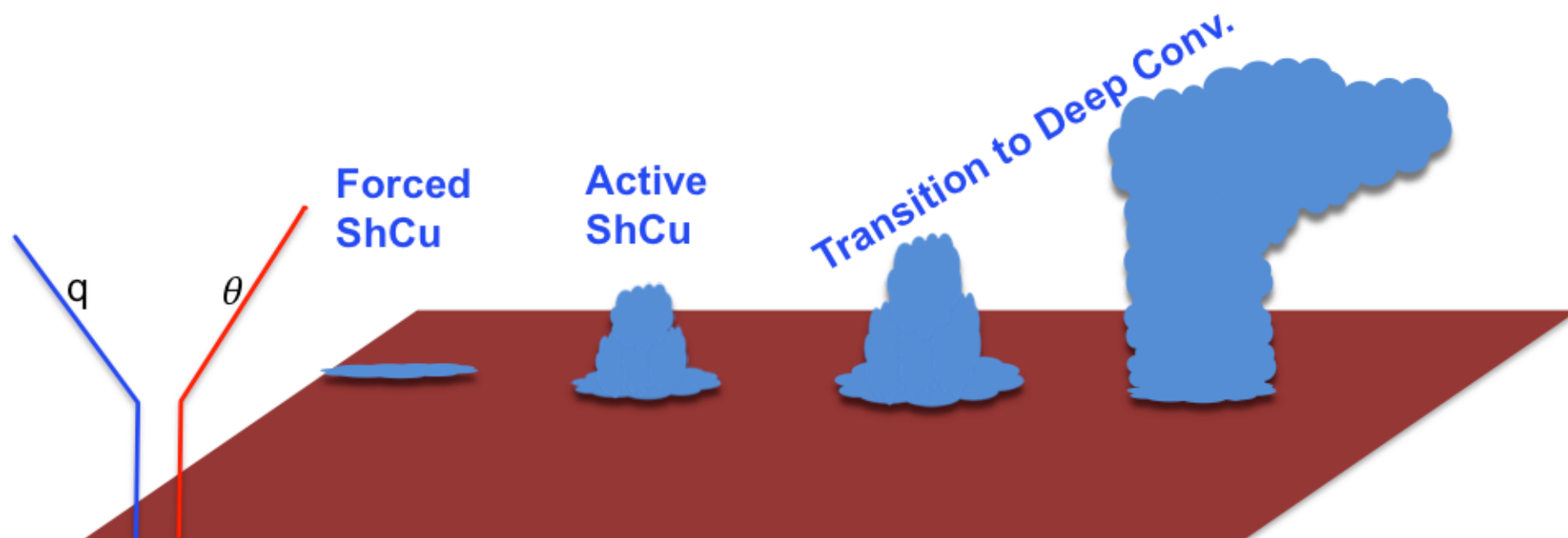


What is the effect of soil moisture anomaly?

'LoCo Process Chain' $\Delta SM \rightarrow \Delta EF \rightarrow \Delta PBL \rightarrow \Delta ENT \rightarrow \Delta T_{2m}, Q_{2m} \rightarrow \Delta P/Clouds$

(a) (b) (c) (d)

Santanello, et al, 2011



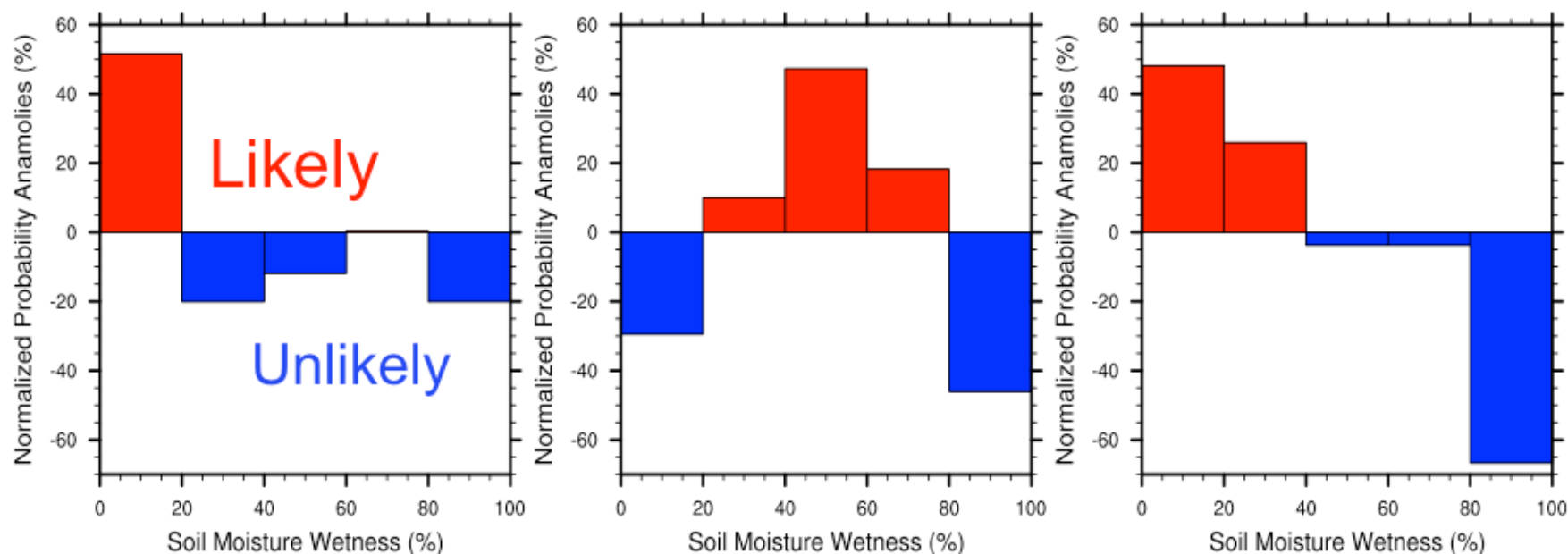
Do Convective clouds preferentially occur on the days with dry/wet soil conditions?

Occurrence Probability Anomalies for different convective types

Deep Conv.

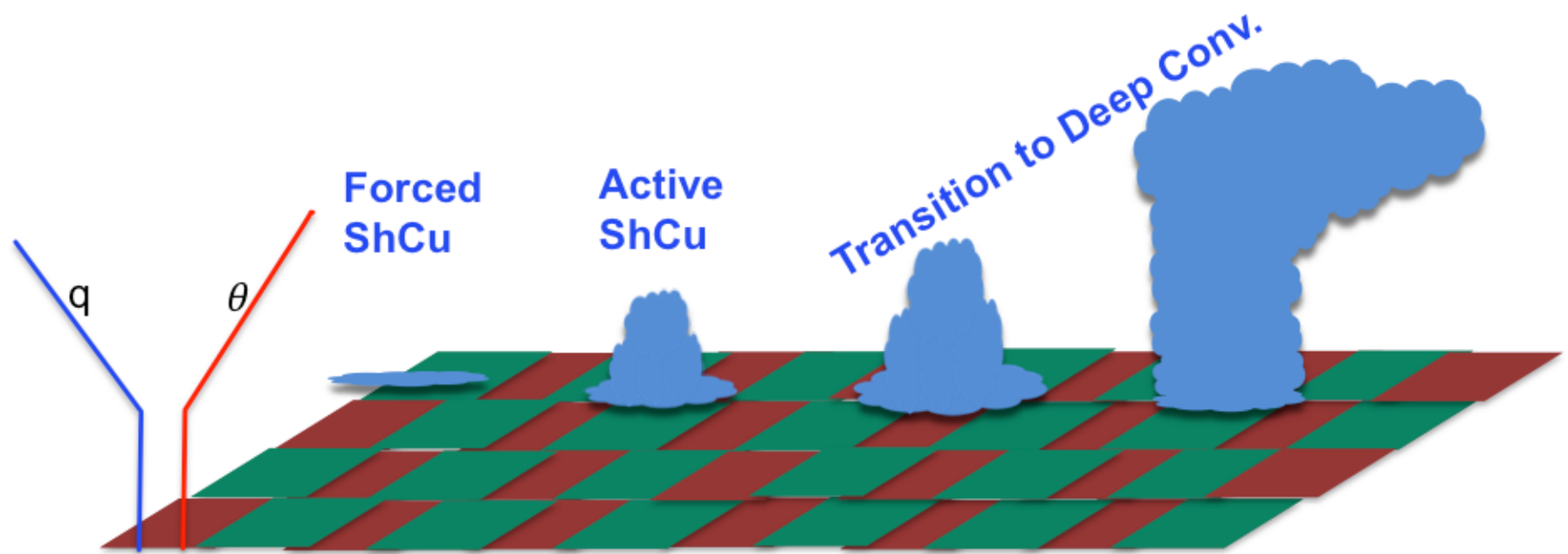
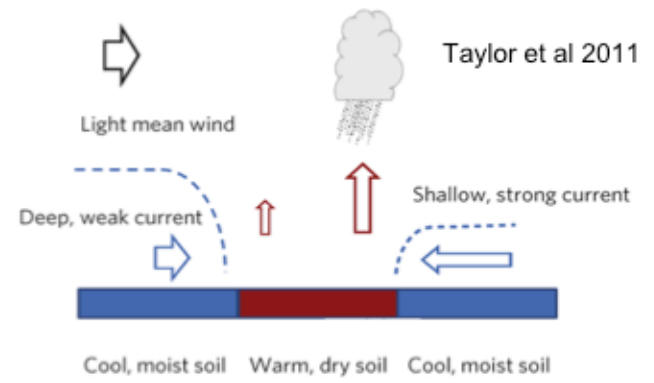
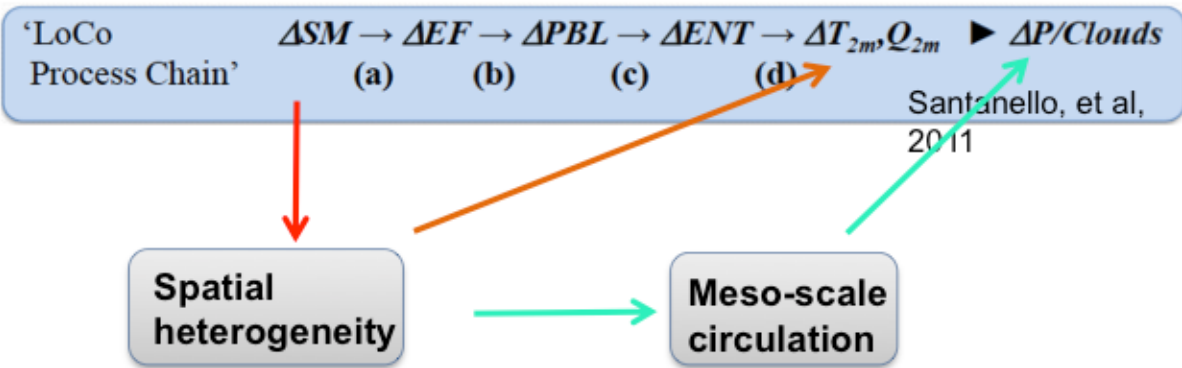
Active ShCu

Forced ShCu

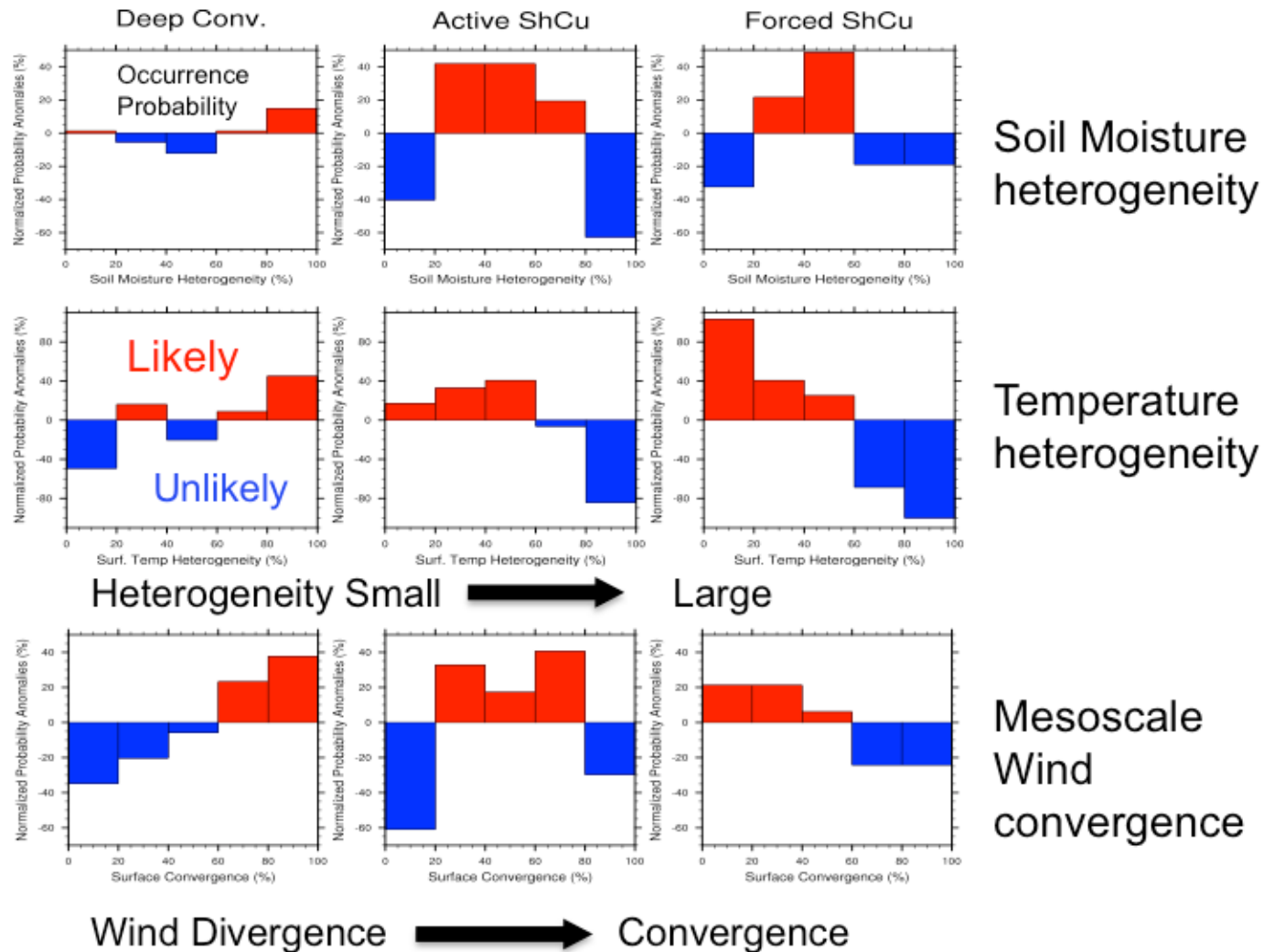


Dry $\longrightarrow$ Wet

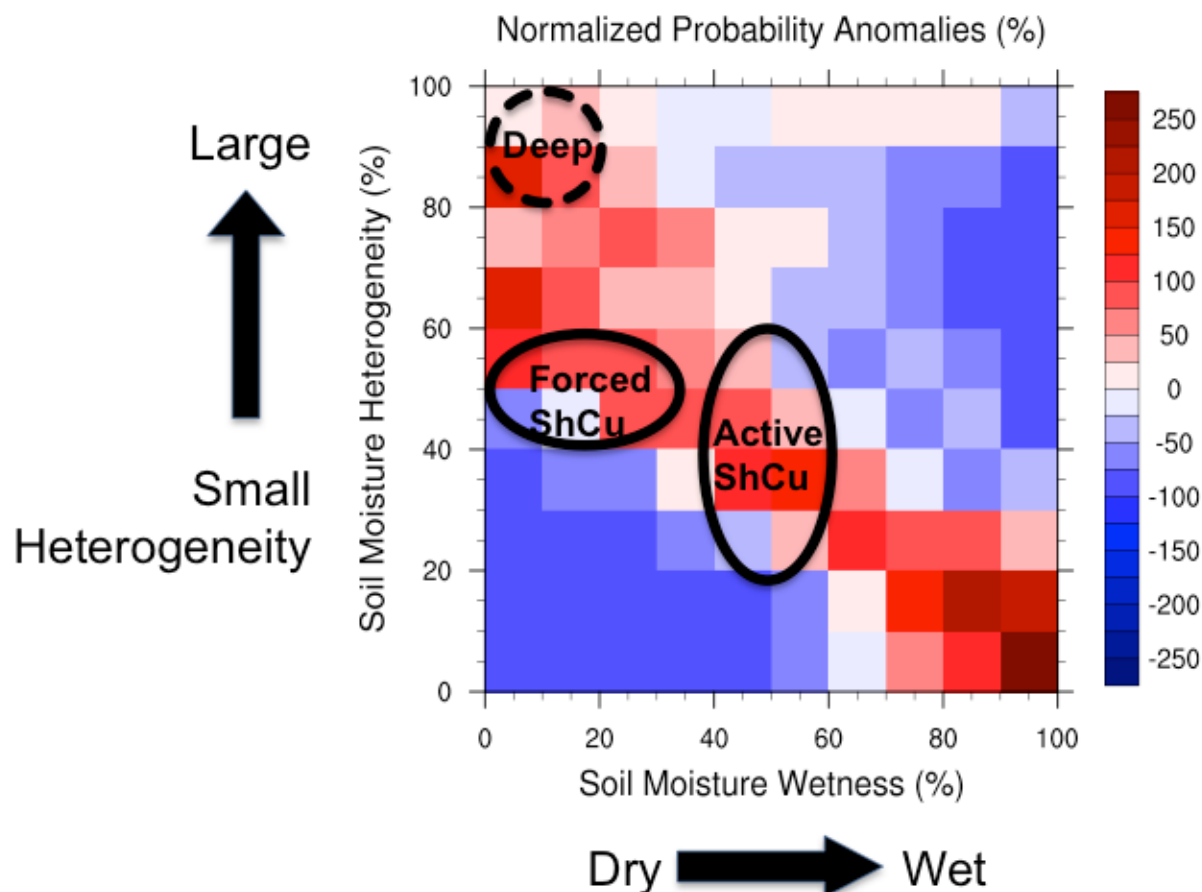
What is the effect of soil moisture heterogeneity?



Do convective clouds preferentially occur over small/large spatial heterogeneity or wind pattern?



What is the effect of soil moisture and heterogeneity on convective clouds?



Summary

1. Long-term ARM SGP and OK Mesonet observations are used to study continental convections and their coupling with land-surface from three aspects: Atmospheric control, Boundary layer control and Surface control.
2. Late afternoon deep convection occurs more often over drier soil but larger soil moisture spatial heterogeneity, as well as related to larger temperature heterogeneity and surface wind convergence . While active and forced shallow cumulus have different preference over land surface conditions from deep convection.

