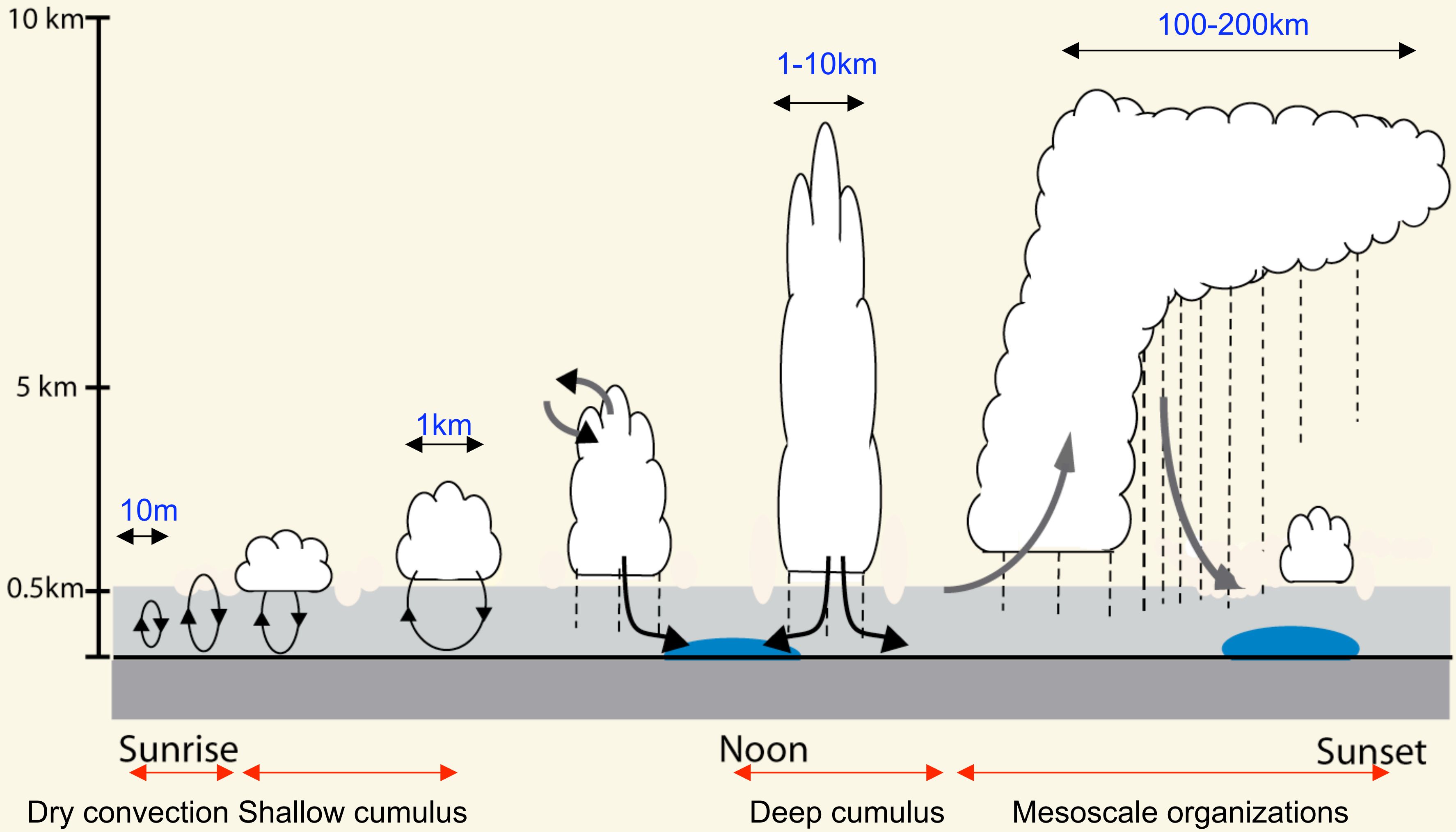
Diurnal cycle over land:

What controls the transition from shallow to deep convection?

Chien-Ming Wu
University of California, Los Angeles
January 16, 2008

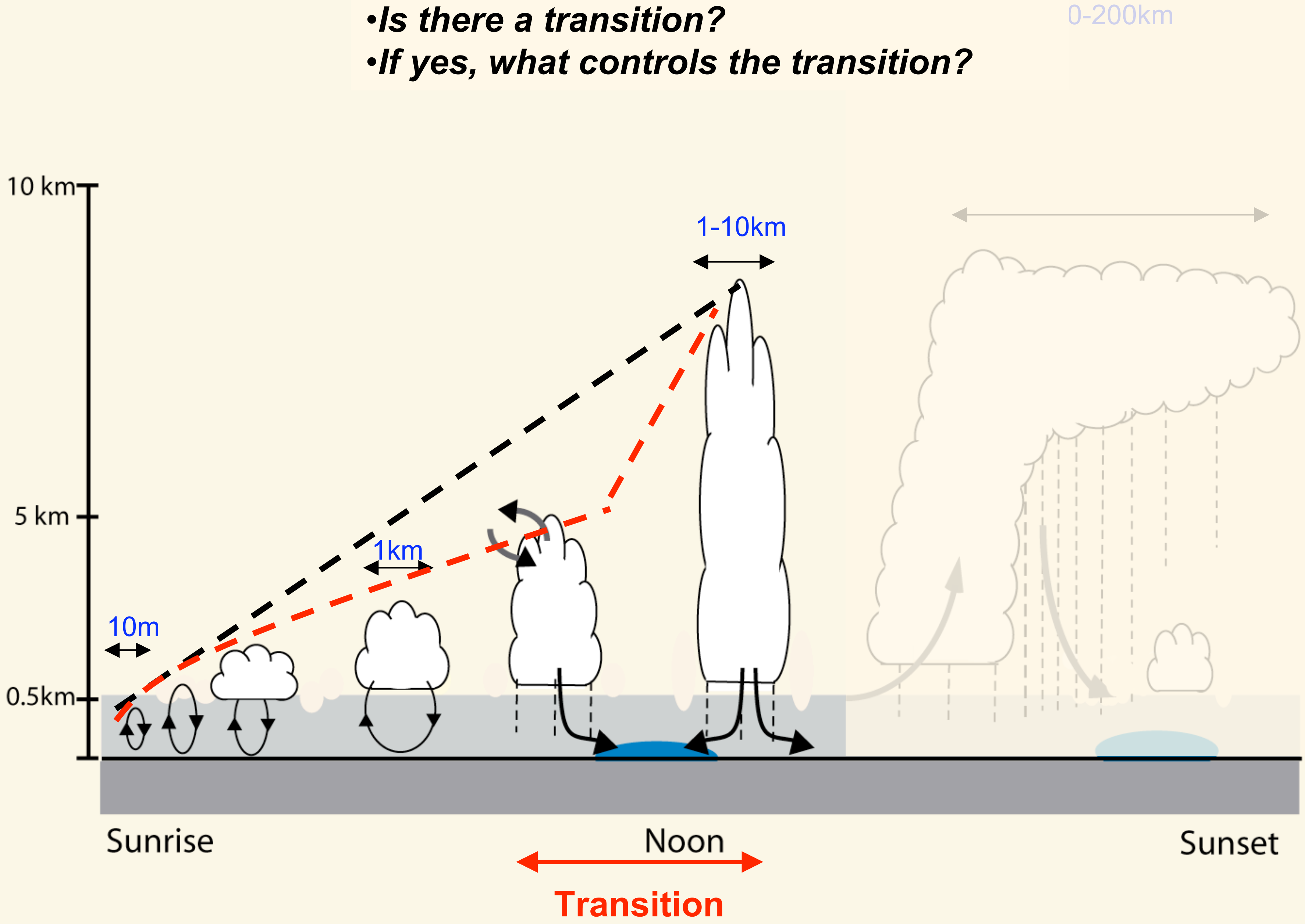
Summertime diurnal cycle over plains

- **A simple framework to understand of the fundamentals of convection.**



Summertime diurnal cycle over plains

•Is there a transition?
•If yes, what controls the transition?

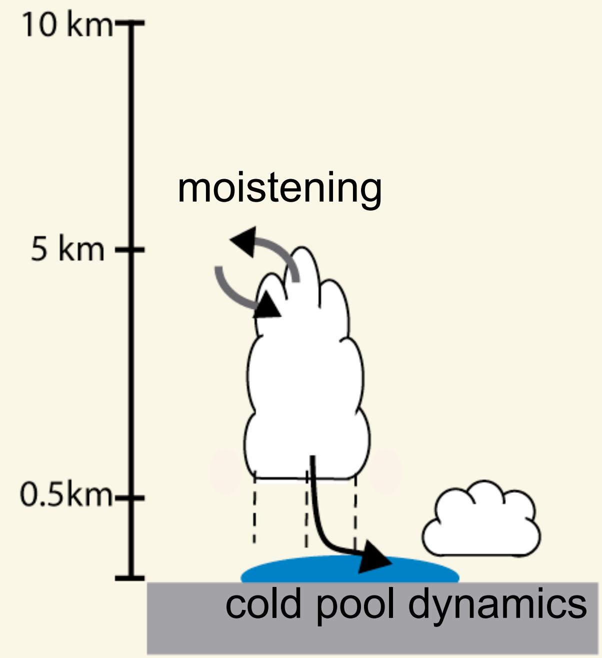


Two major theories for the transition from shallow to deep convection

The deep convection develops when

- Critical moisture in mid-troposphere(drier environment)
  - Kuang and Bretherton (2006)

- Cold pool dynamics(moister environment)
  - Khairoutdinov and Randall (2006)



To evaluate the two theories and understand the mechanism of transition,

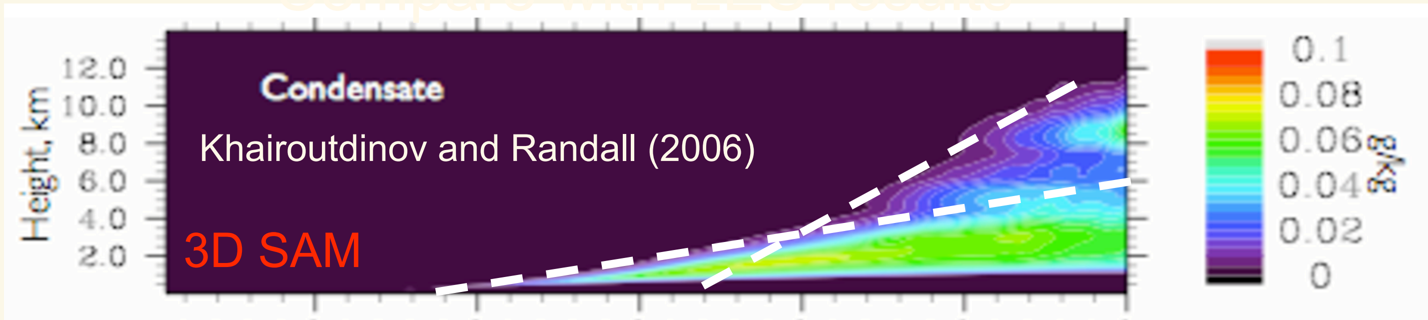
experiments are performed with our numerical model.

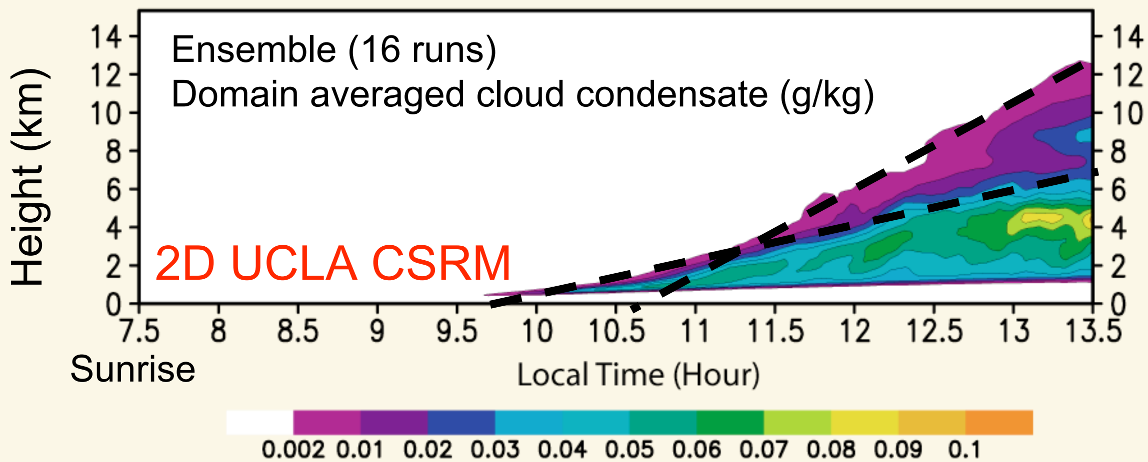
Experiments with
a cloud system resolving model(CSRM)

The model used:

- A 2D(x-z) nonhydrostatic model developed by Krueger (1988) using a third-order turbulence closure model.
- Has been applied to a variety of cloud regimes including cirrus, cumulus, altocumulus and stratocumulus clouds (Krueger, 2000).

Benchmark simulations under Amazon condition





Two slope behavior of convection development:

Transition or a result of random perturbation/surface fluxes/unsmoothed initial condition?

An idealized framework to extract the essence of transition

What are the input parameters to the system?

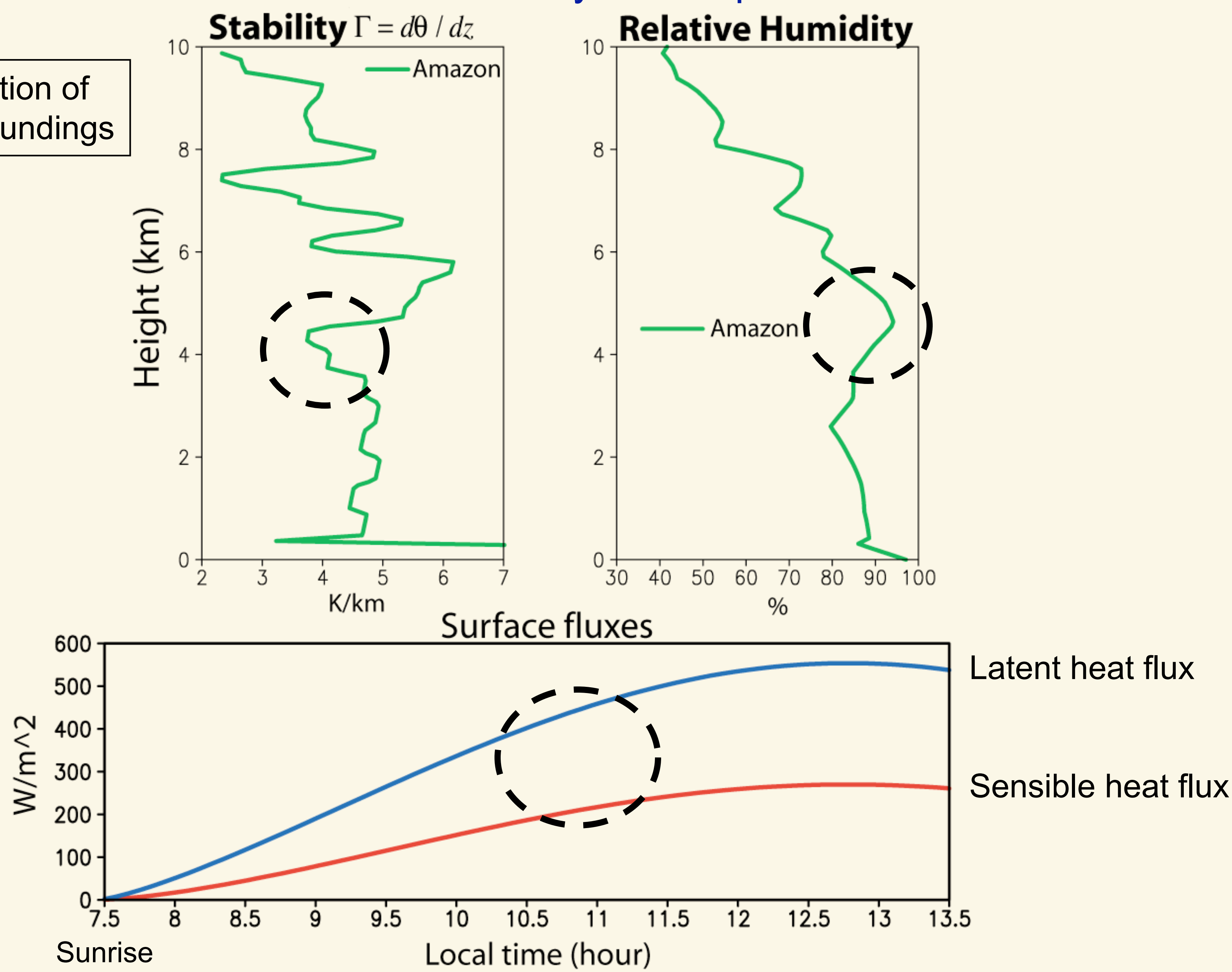
- Physical parameters
  - –Initial wind fields.
  - –Initial thermodynamics profiles.
  - –Radiative processes.
  - –Surface processes.
  - –Prescribed surface fluxes.

- Numerical parameters
  - Domain size, geometry, grid resolution, numerical algorithms, sub-grid scale turbulence parameterization, microphysical parameterization, choice of radiative scheme, etc.

An idealized framework to extract the essence of transition

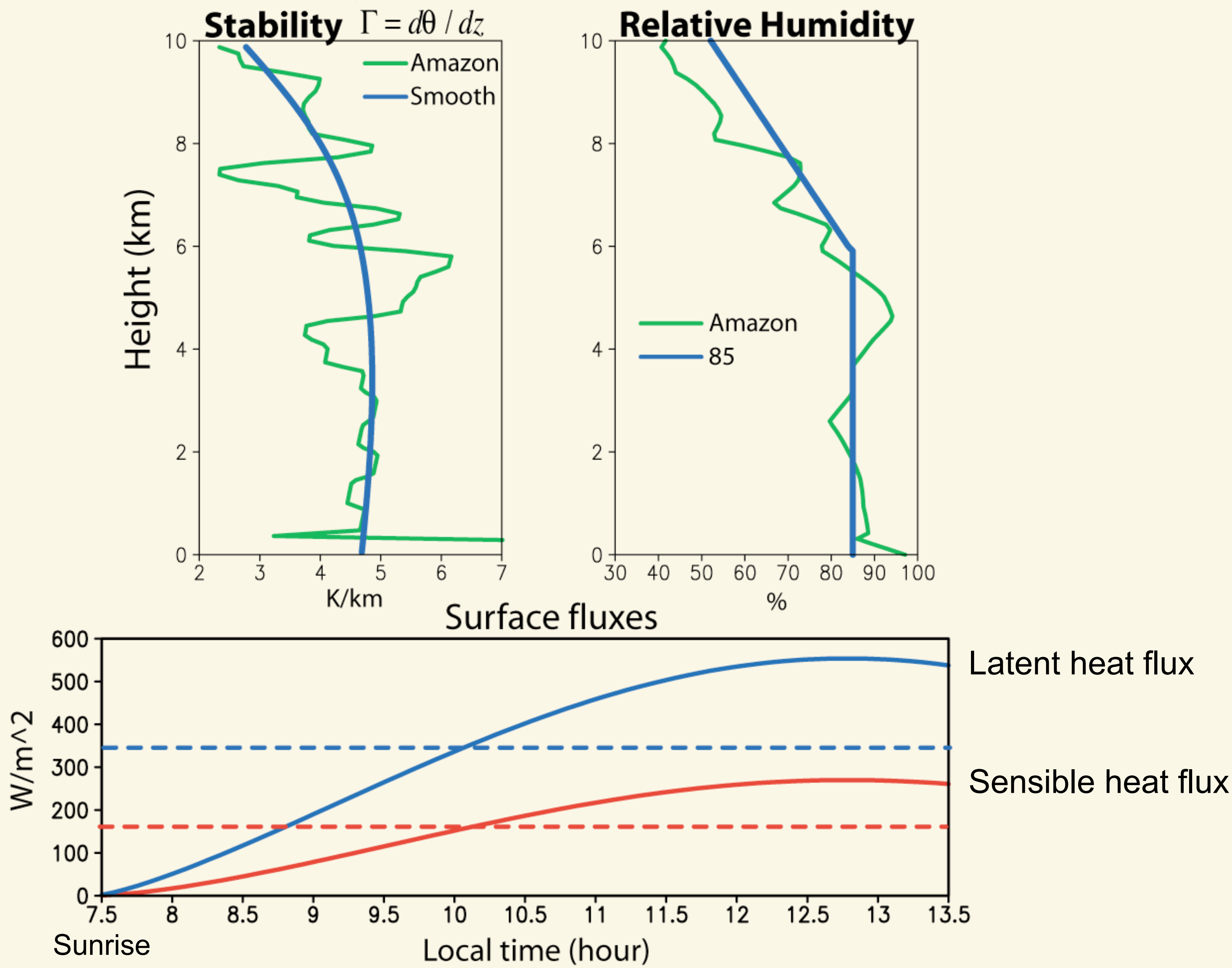
Unsmoothed thermodynamics profiles

Initial condition of Amazon soundings



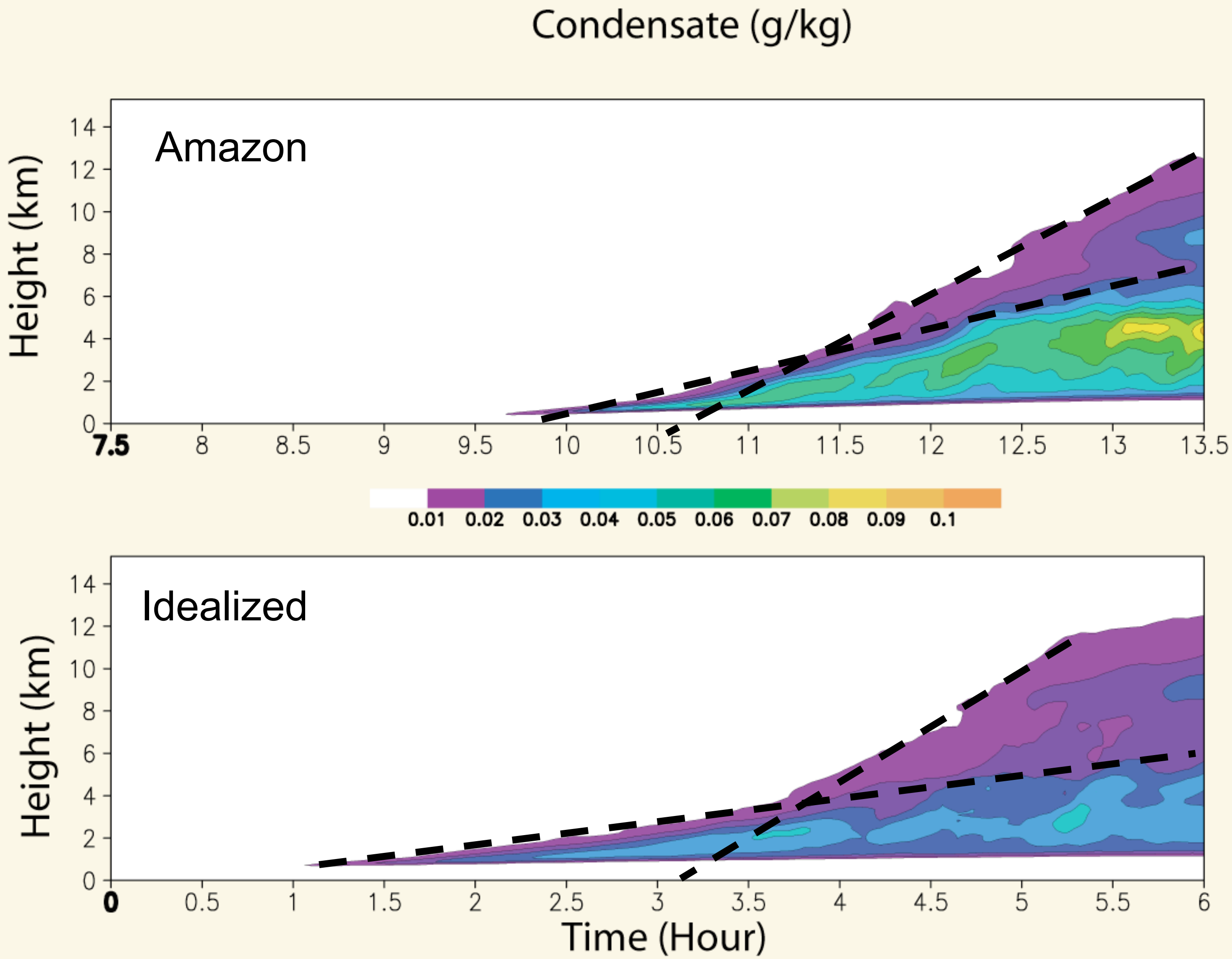
An idealized framework to extract the essence of transition

Initial thermodynamics profiles for the experiments



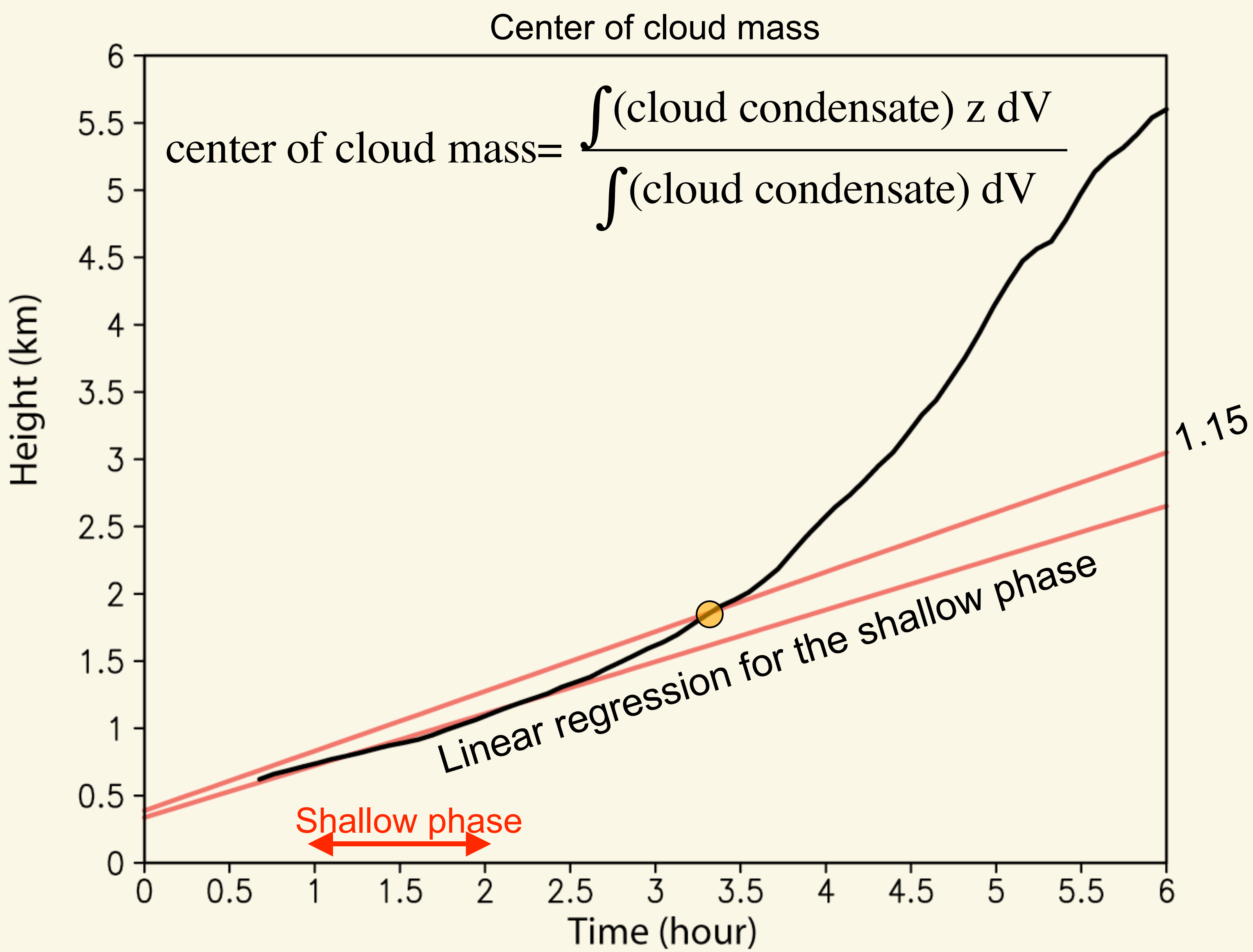
Transition or no transition

- **The idealized framework can capture the transition.**
- **The transition is not random.**



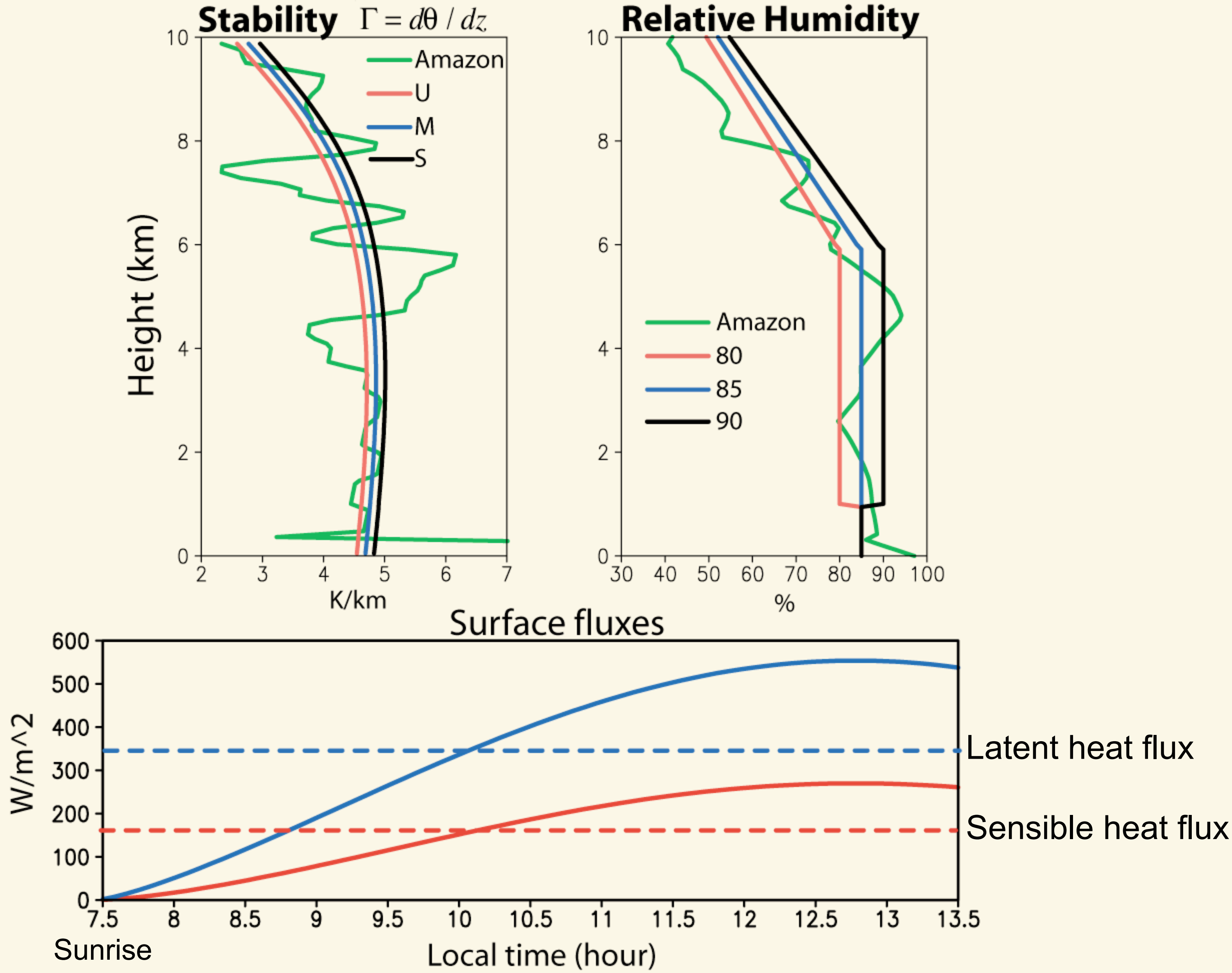
Define transition time

- **Transition time is defined as the slope is 15% away from the regression line.**



What controls the transition?

Sensitivity experiments on initial stability and relative humidity



Summary I

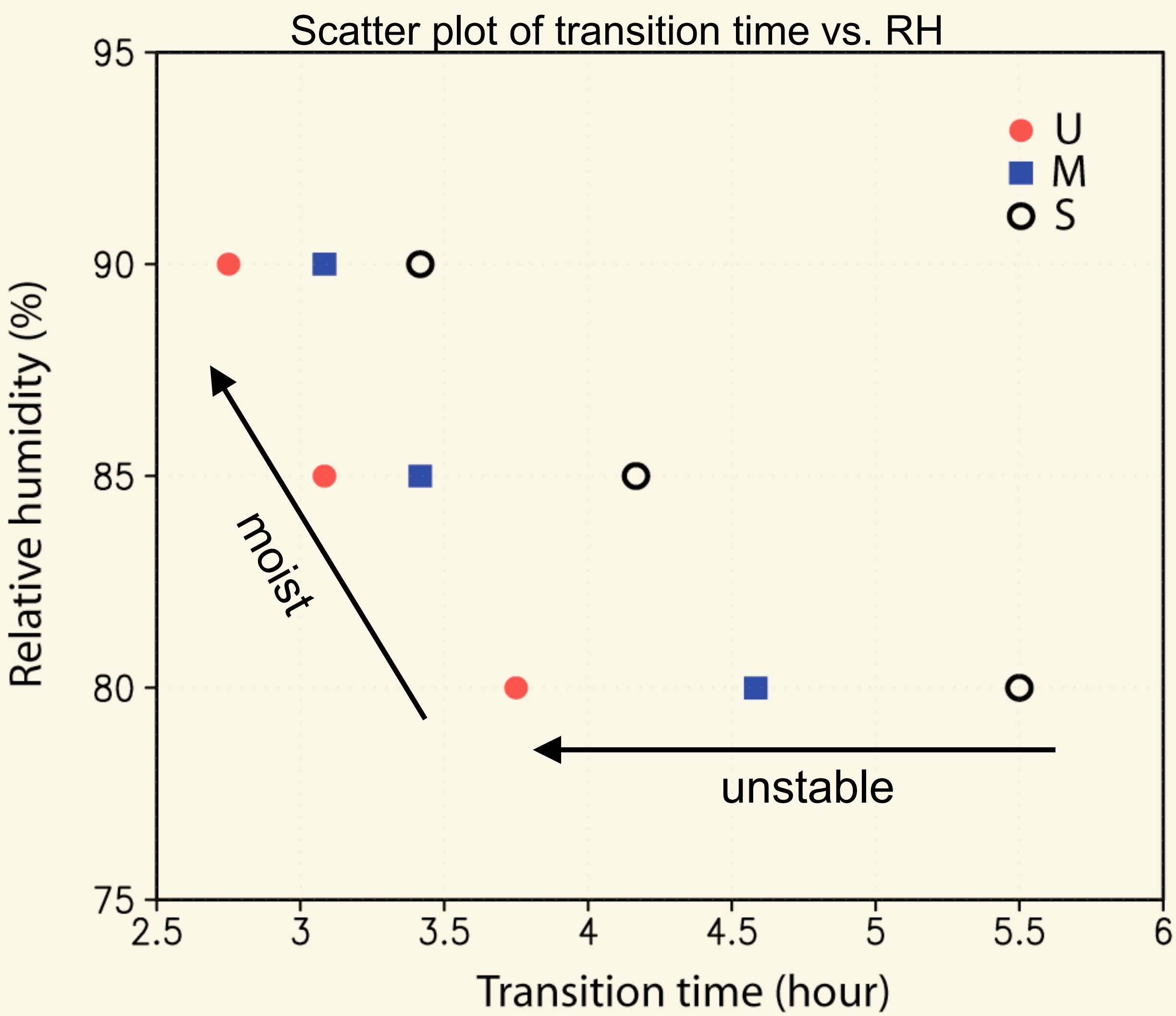
•The transition is significant, not random.

•Transition time is defined when the slope of the center of cloud mass is away from its shallow phase.

•9 ensemble experiments are performed to evaluate the effects of moisture and the cold pool dynamics.

Dependency on the environmental profiles

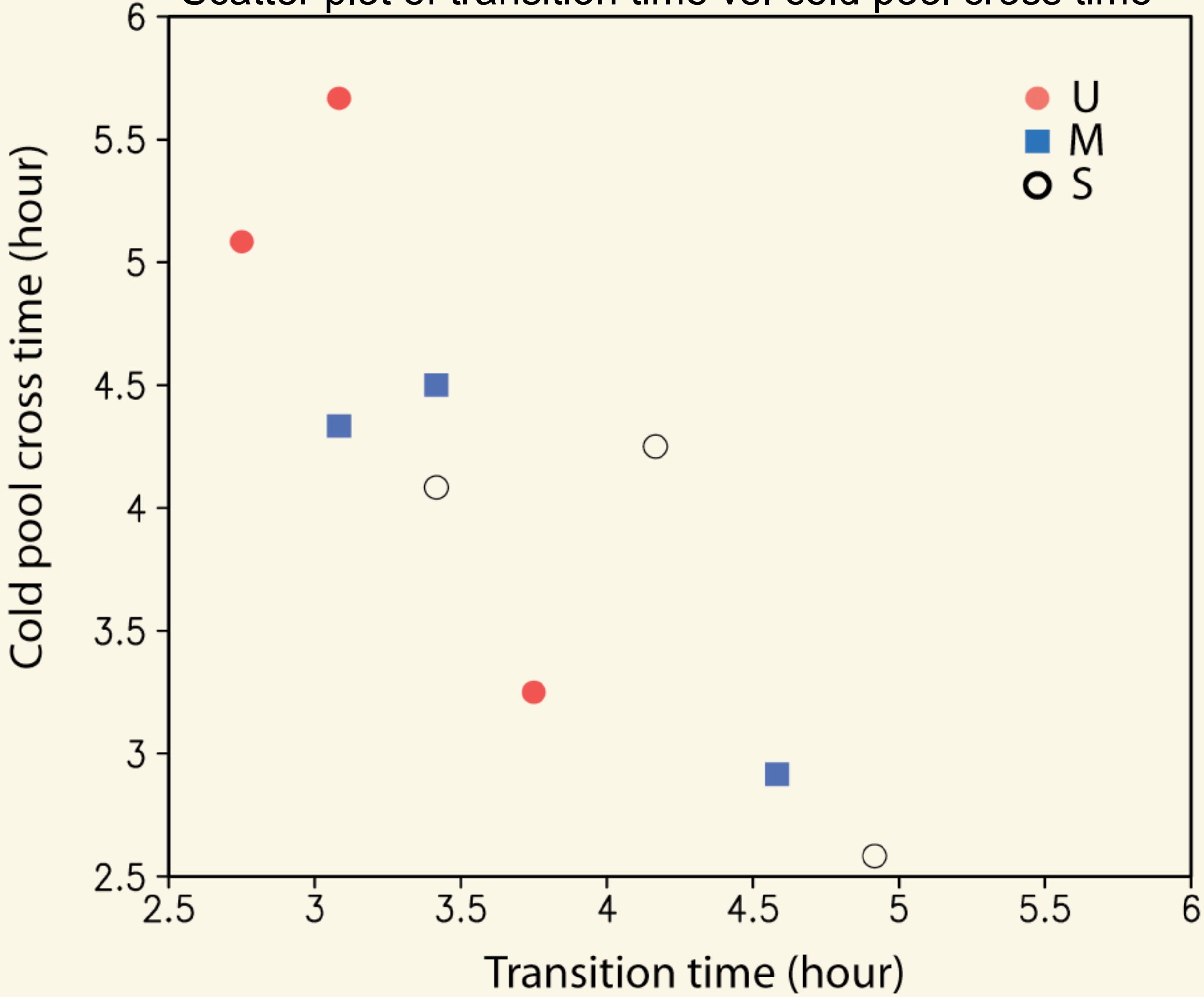
•The transition time depends on both the moisture and the stability.



Dependency on the cold pool strength

•Strong cold pool doesn't indicate early transition.

Scatter plot of transition time vs. cold pool cross time

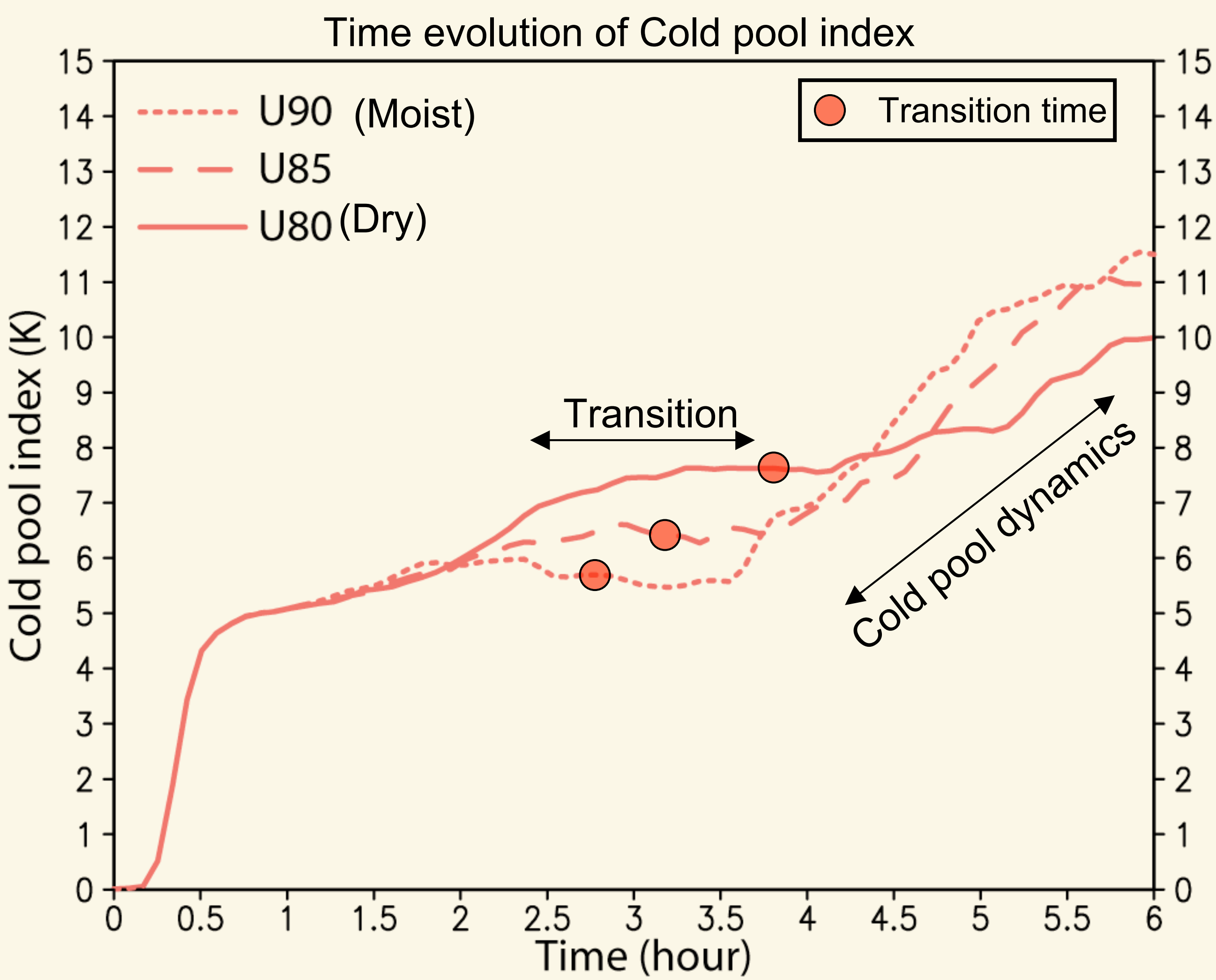


Cold pool index:
moist static energy(h) difference at 500m = Max(h)-min(h) at 500m.

Cold pool cross time:
The time when cold pool index > 6K

Dependency on the cold pool strength

- **Cold pool dynamics are more evident after transition.**



Summary II

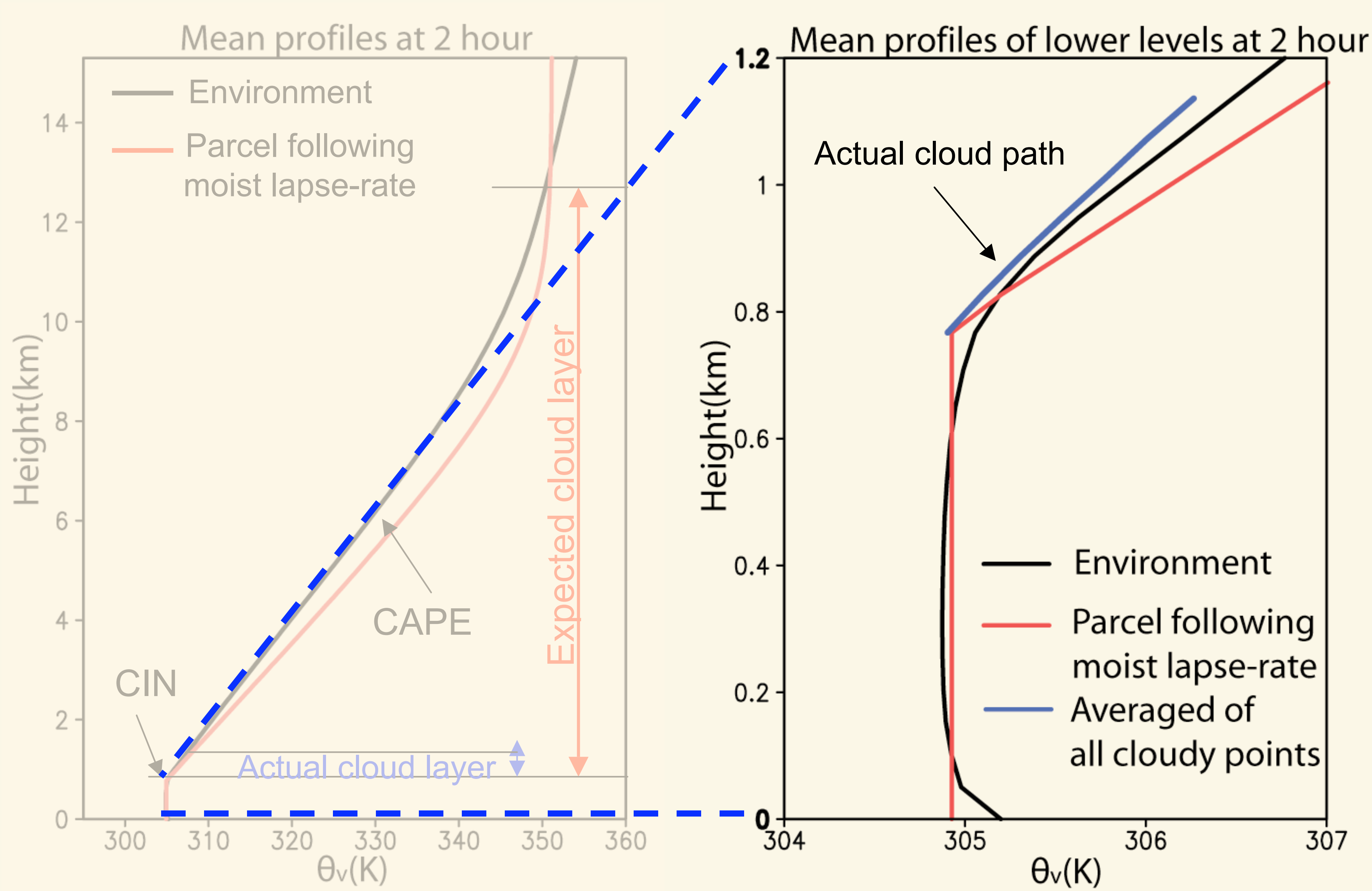
•Transition depends on both moisture and stability.

•Higher relative humidity and lower stability environment lead to early transition.

•Cold pool effects are more evident in deep cumulus after the transition.

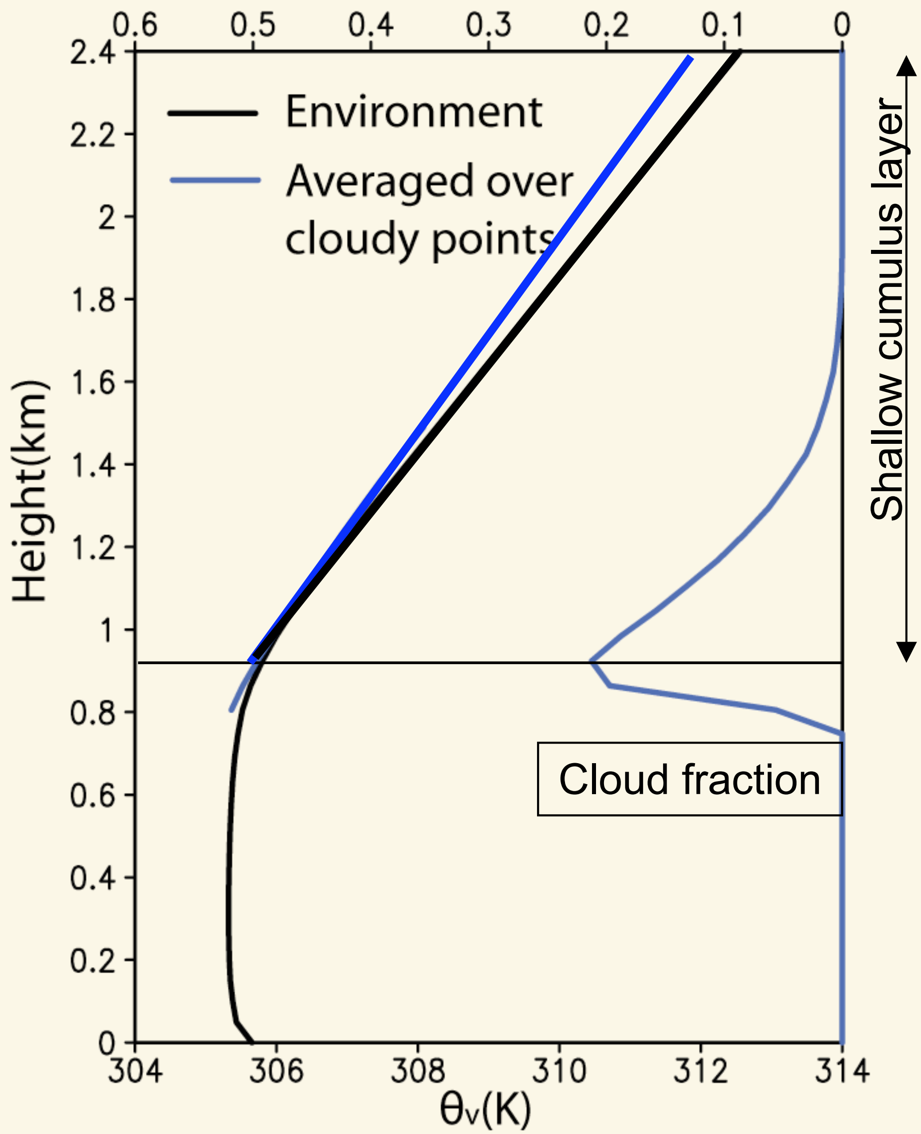
What controls the transition?

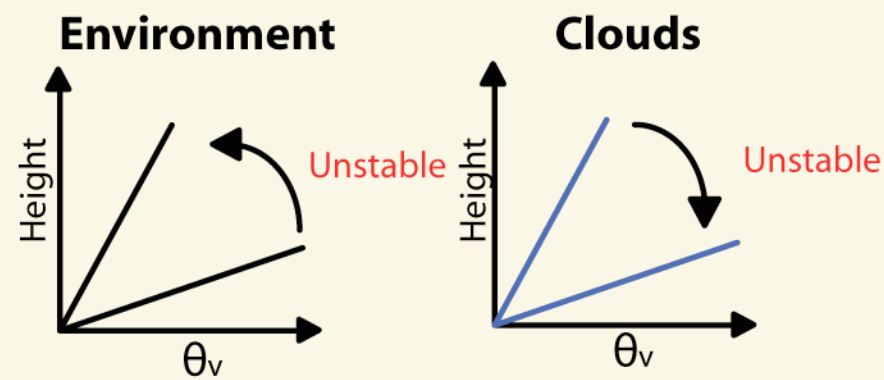
- **Clouds follow their own lapse-rates.**
- **Clouds are "stable" under this condition.**



What controls the transition?

Hypothesis: the transition happens when clouds become "unstable".



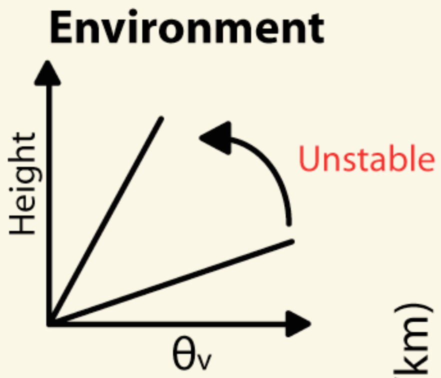


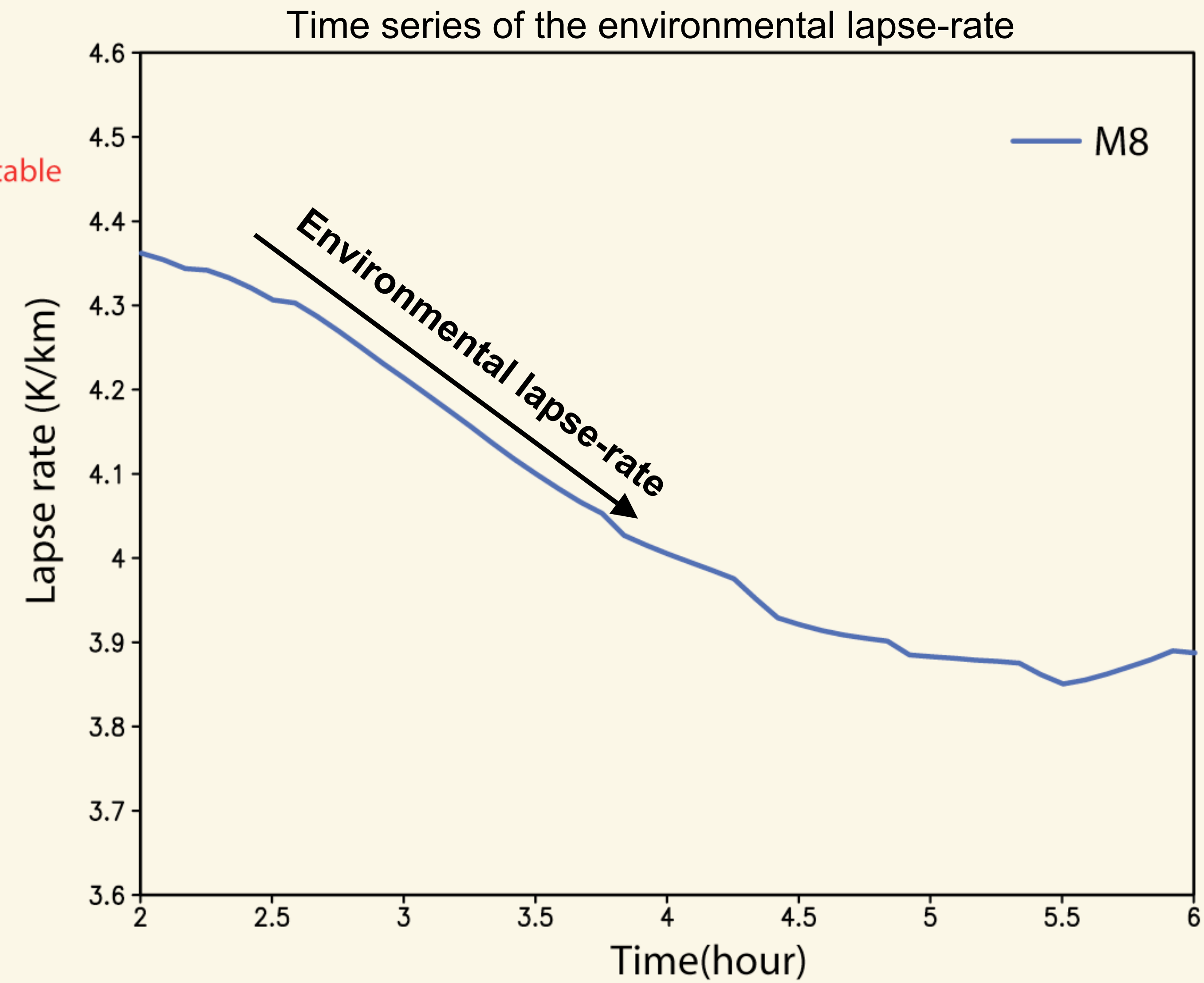
- **Lapse-rate is obtained by linear regression of environment and clouds in the shallow cumulus layer.**

- **Clouds become unstable when the lapse-rate is larger than the environment.**

What controls the transition?

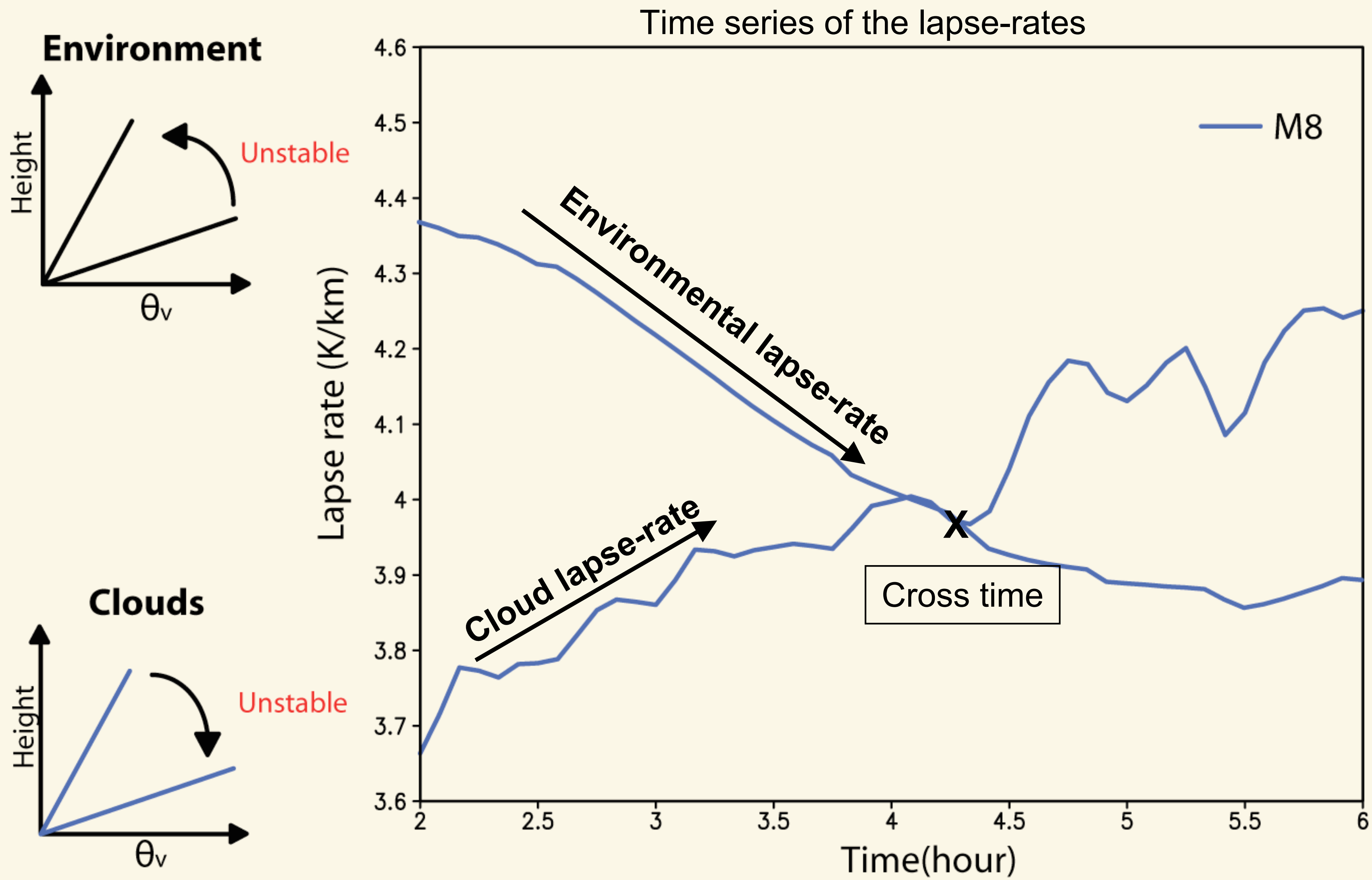
•Destabilizing effects of the shallow cumulus clouds





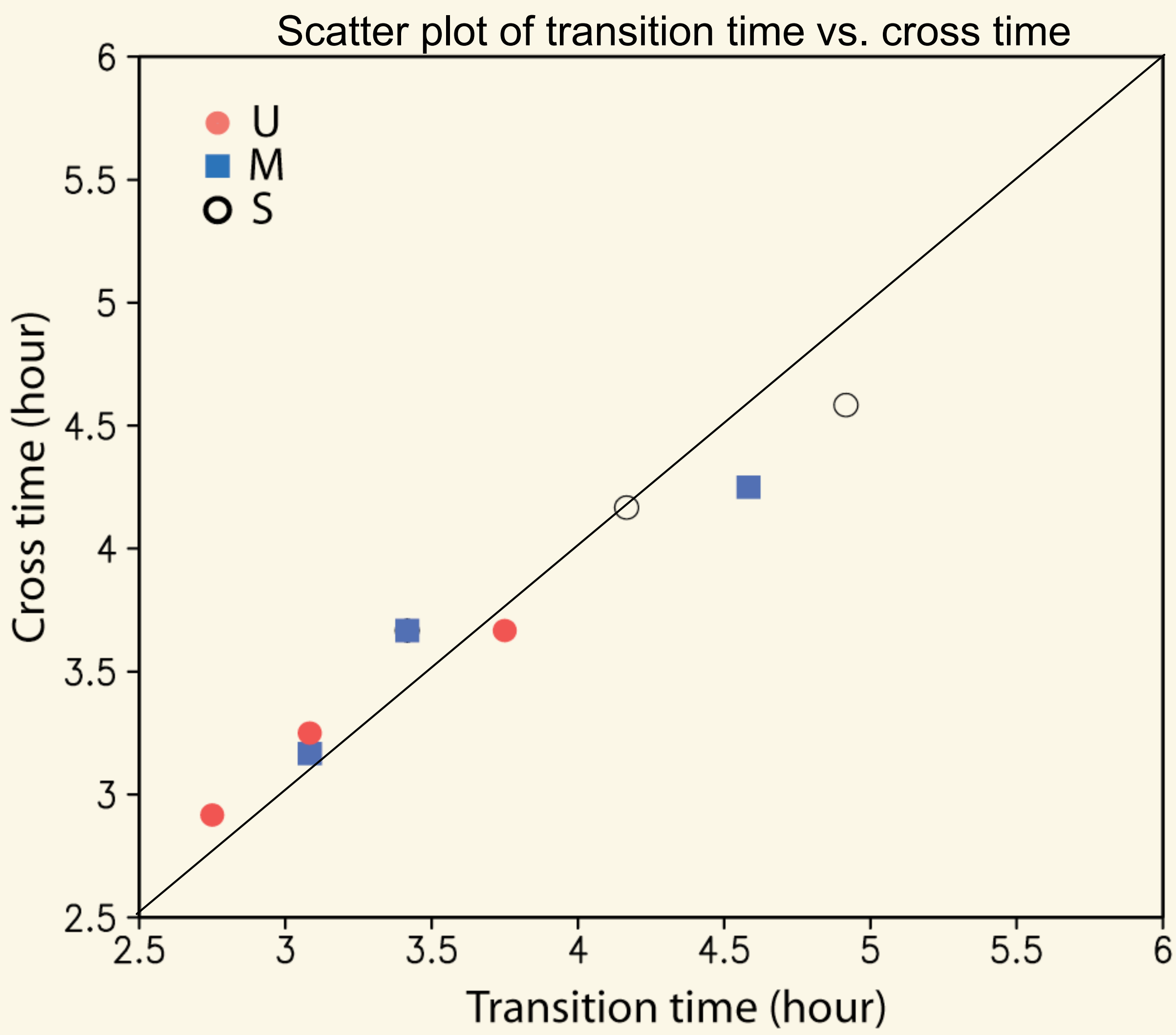
What controls the transition?

•Increase of cloud lapse-rate during transition



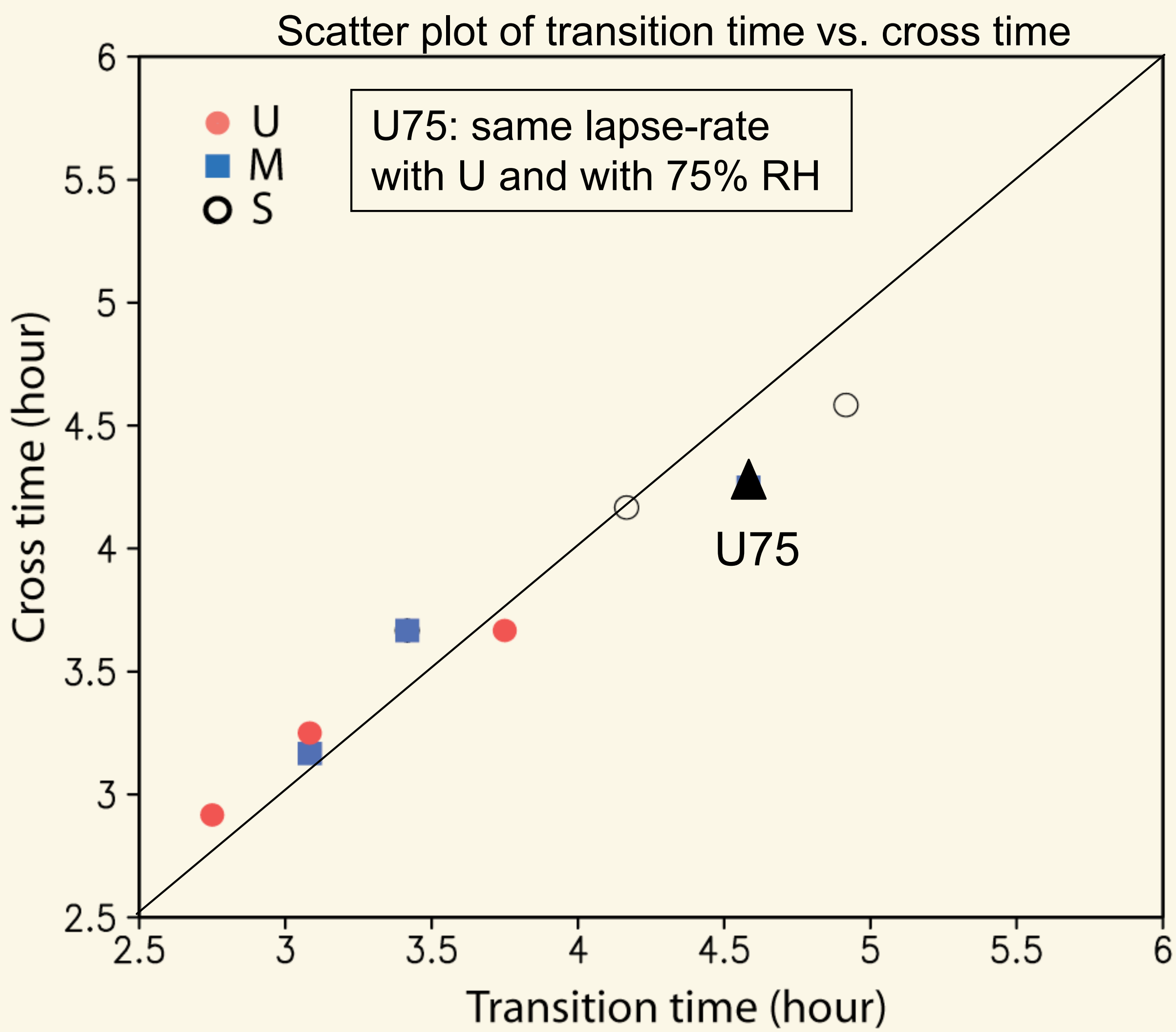
What controls the transition?

Deep convection happens when the shallow cumulus layer becomes unstable to the average cloud properties.



Future work

- ***Can we make a simple model that incorporates this information?***



Summary

- The transition time from the shallow to deep convection coincides with the time when the environment of the shallow cumulus layer becomes unstable to the average cloud properties.

  – A 2-D CSRM is used to assess the control mechanism for the transition from shallow to deep convection. By comparing with the 3-D SAM under Amazon soundings, the results show that the 2-D CSRM can capture the transition very well.

  – To extract the essence of the transition from shallow to deep convection, we use an idealized framework for the sensitivity experiments with only two control parameters, the stability and the relative humidity. The systematic dependence of the development of convection on the stability and the humidity show that the transition is solid not random.

  – A transition time is defined to evaluate the dependency of the transition on the environmental moisture and the cold pool dynamics. The results show that the transition time depends on both the moisture and the stability but the cold pools only become evident after the transition.