Environmental Conditions Controlling the Shallow-to-Deep Transition in Convective Clouds During GOAmazon 2014/5

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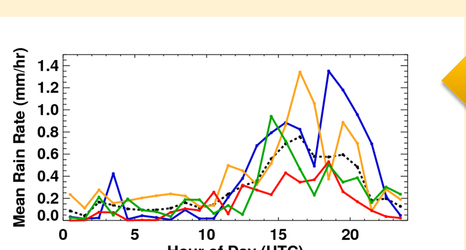
ABSTRACT

Nearly two years of observations from the ARM Mobile Facility (AMF) deployed at Manacapuru, Brazil during the GOAmazon 2014/15 campaign are analyzed to investigate the environmental conditions controlling the transition from shallow to deep convective clouds. W-band ARM Cloud Radar (WACR) observations are used to define: 1) Transition cases where a period of shallow convective clouds in the morning is followed by a period of deep convective clouds in the afternoon and 2) Non-transition cases where shallow convective clouds persist throughout the day without any subsequent development. For these subsets, observations of the time-varying thermodynamic properties of the atmosphere, including the surface heat and radiative fluxes, and the profiles of atmospheric state variables are composited to define averaged properties for each transition state. Initial analysis indicates that the transition state strongly depends on the pre-dawn low-level cloudiness and the free tropospheric humidity. Associated environmental thermodynamics are then used to force large-eddy simulations for the different transition states to further evaluate the sensitivity of the transition to the composite thermodynamics versus the importance of larger-scale forcing.

1. MOTIVATION

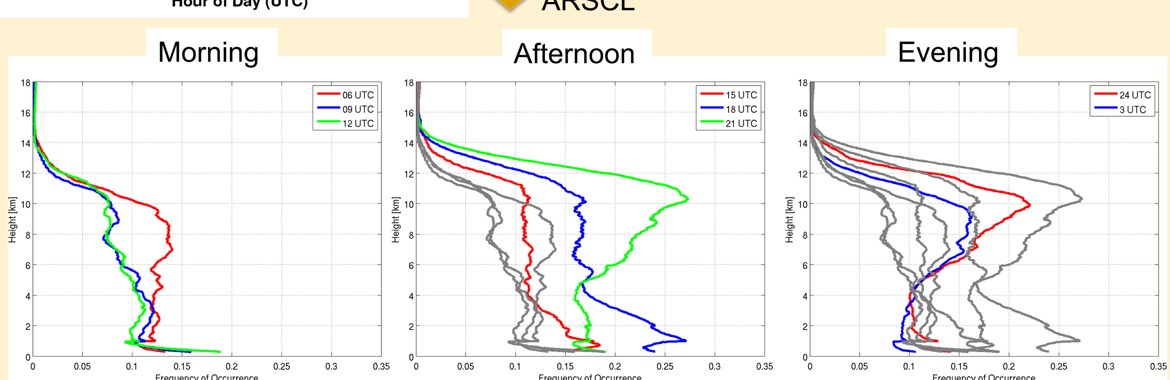
- Climate models do not get timing of rainfall peak over land correct (Dai et al. 1999; Yang and Slingo 2001)
- Lack of intermediate stage in convective growth, and associated effects, e.g. moistening of the free troposphere (Guichard et al. 2004)
- Similar to Zhang and Klein (2010) [Z&K], determine atmospheric conditions that favor different convective regimes (i.e. those that transition to deep vs. those that don't)

2. DIURNAL CYCLE – CLOUDS and PRECIP



Mean Rain Rate from disdrometer observations

Cloud Frequency of Occurrence from WACR-ARSCL



- Low cloud fractions throughout column.
- Little rainfall.

- Increased low clouds at 15-18 UTC.
- Upper level clouds (and rainfall) increase from 15-18-21UTC.
- Clouds throughout column.

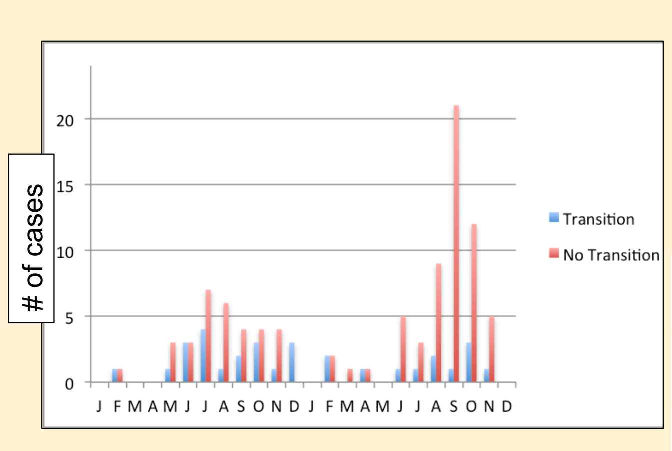
- Much less low clouds at 24,3 UTC.
- Still significant upper level clouds, but decreasing.
- Little precipitation.

3. TRANSITION VS. NON-TRANSITION CLASSIFICATION

How? - Visual inspection of WACR time-height cross sections

Transition cases (Z&K - late afternoon deep convection) :
- Shallow clouds < 5 km thick transition to deep clouds > 8 km thick with cloud bases in the BL (lowest 1-2 km)
- No cloud > 8 km thick occur after 3 UTC and prior to the transition
- Transition occurs before sunset

Non-transition cases (Z&K – fair-weather shallow cumulus):
- Low clouds < 5 km in thickness with some clouds > 2 km thickness
- Clouds persist between sunrise and sunset
- No clouds > 5 km thickness occur within observation area
- Non-transition cases verified using satellite observations

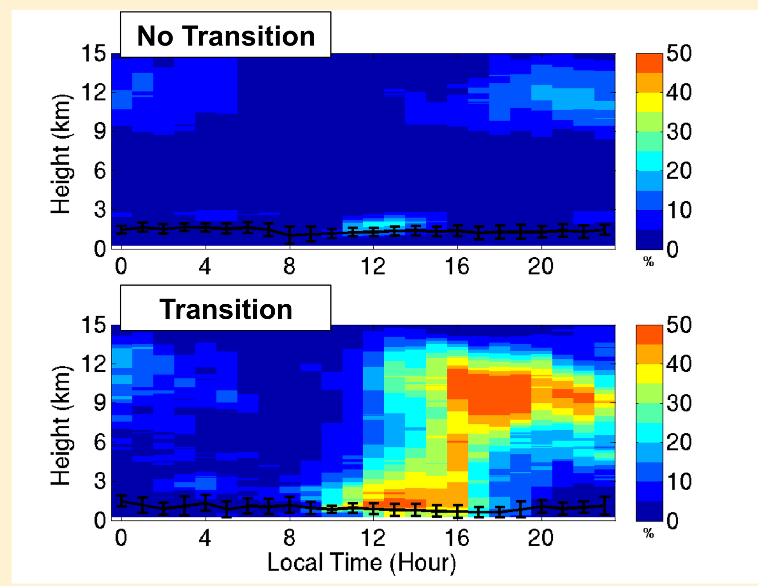


Wet season – [December – April]

Dry Season – [July – September]

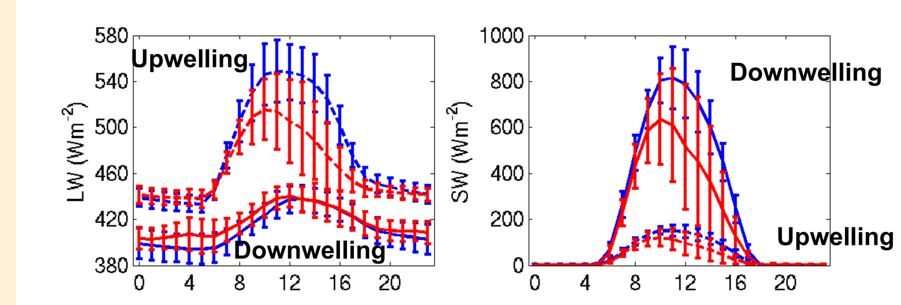
# cases	All	Dry	Wet
Transition	31	11	7
No Transition	91	50	5

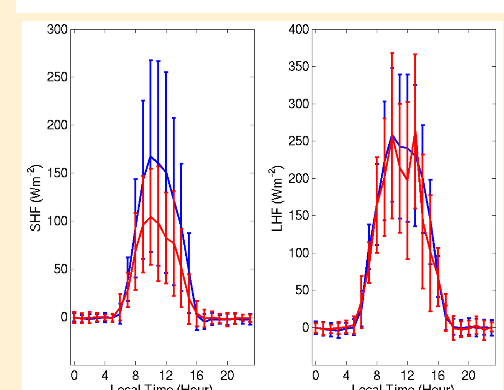
4. COMPOSITED CLOUD OCCURRENCE



Question? How do environmental factors differ between these two classes?

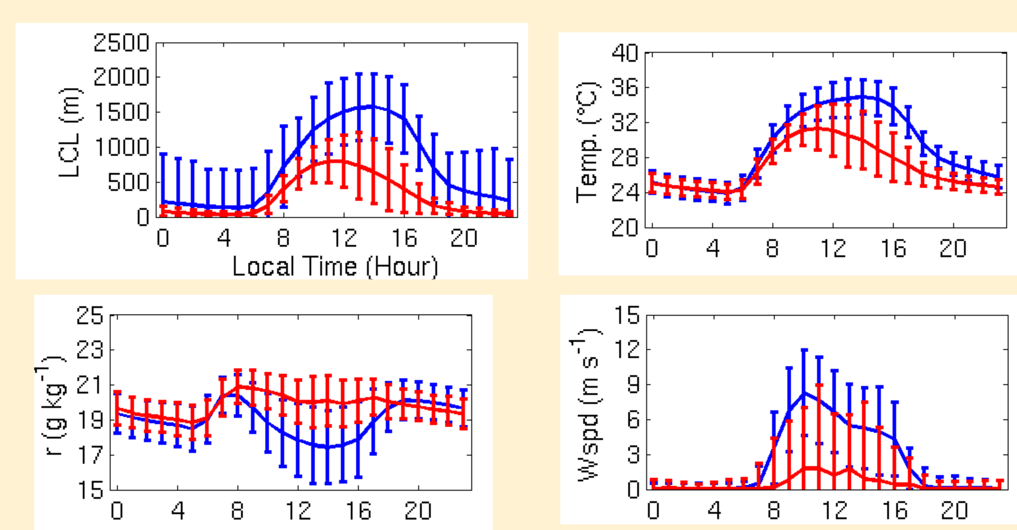
5. COMPOSITE DIURNAL CYCLE – SURFACE FLUXES (Transition / No Transition)





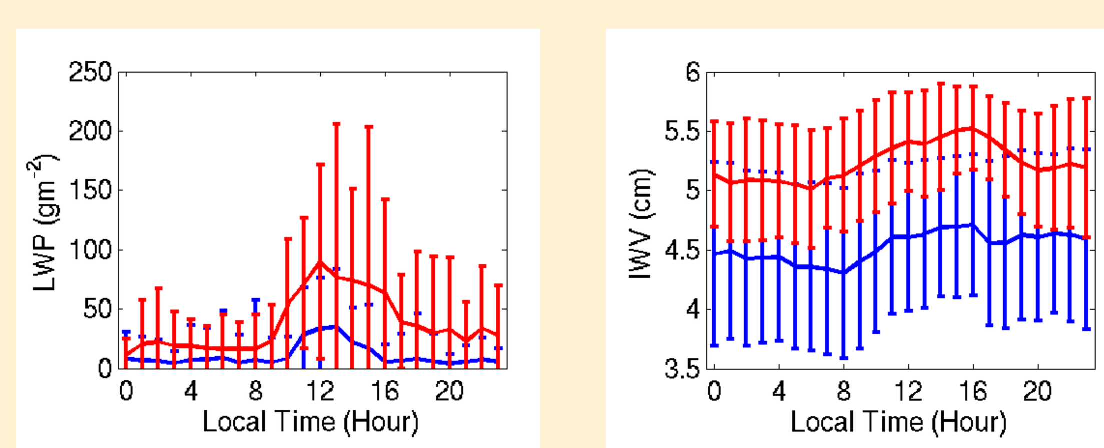
- Differing regimes impact surface fluxes.
- SH/LH fluxes are in phase with downwelling shortwave fluxes.
- Transition days have smaller SW, SH and LH fluxes at the surface.
- Differences due to cloud forcing and low-level humidity

6. COMPOSITE DIURNAL CYCLE – SURFACE METEOROLOGY



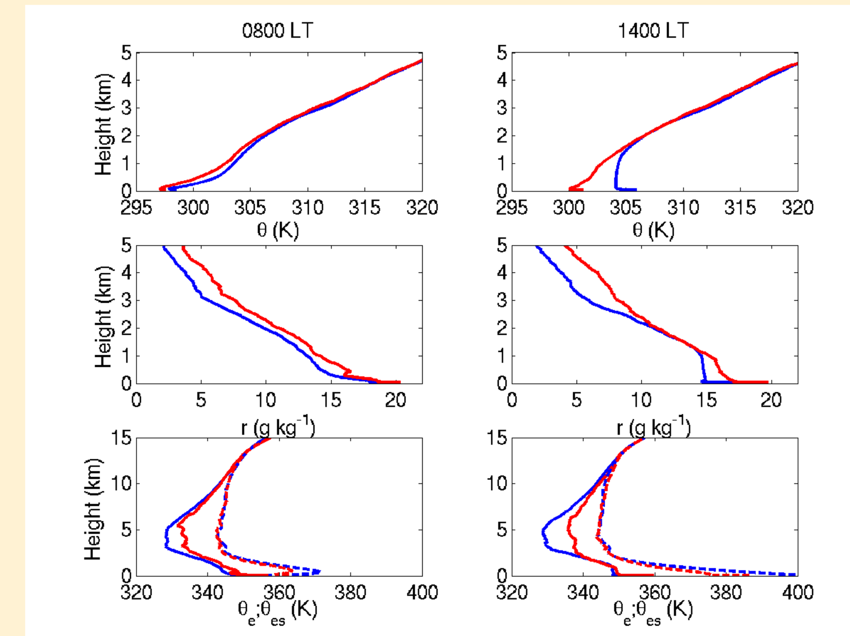
- Pre-sunrise T, r nearly identical for two regimes ("No-transition" slightly moister, higher LCL).
- "No-transition" surface warmer and drier during day (consistent with response to increased SW flux).

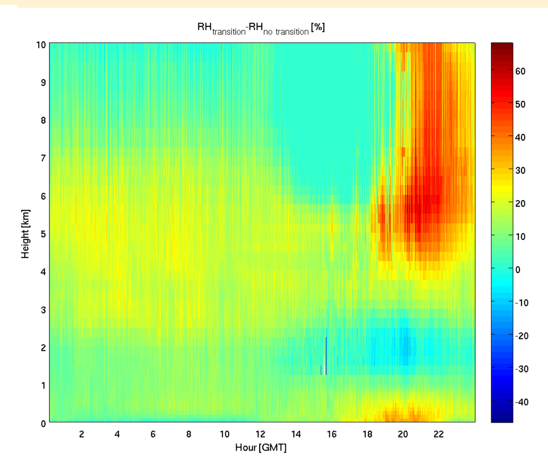
7. DIURNAL COMPOSITES – PWV and LWP



- LWP confirms regime classifications.
- Larger pre-sunrise LWP in "transition" cases.
- Significantly more column moisture over entire day for transition cases.

7. DIURNAL CYCLE – THERMODYNAMICS

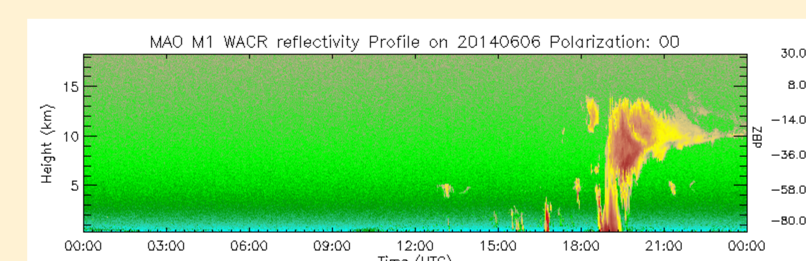




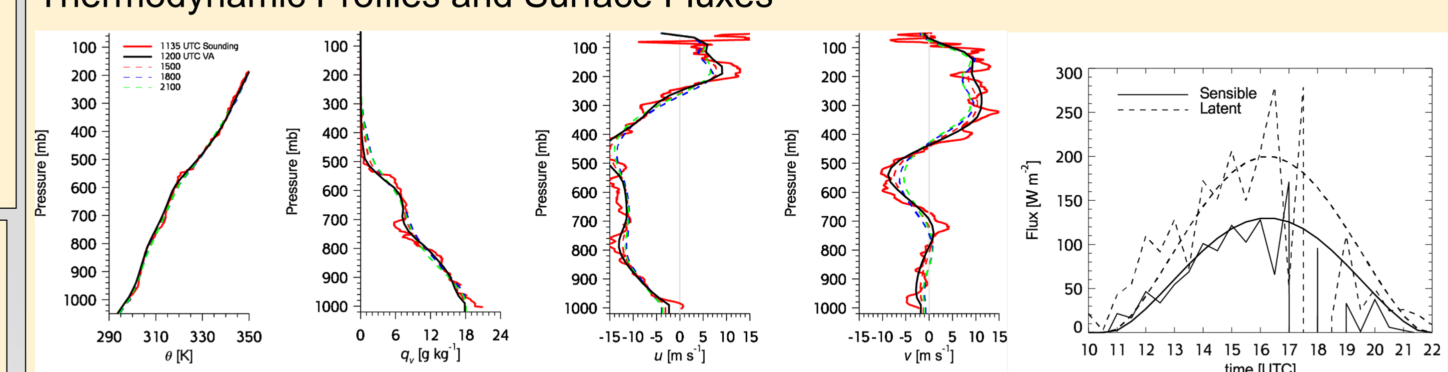
* Difference in composite diurnal cycle of the relative humidity profile (as retrieved from the profiling microwave radiometer) between cases with a deep-to-shallow transition and those with no transition.

- Less stable in early morning for "no-transition" regime
- Daytime surface heating destabilizes "no-transition" regime
- Significant additional low-level moisture in "transition" composite
- Pre-sunrise – Higher RH above boundary layer for transition cases, especially in wet season.
- Surface humidity greater for transitioning cases also (consistent with surface meteorology measurements).

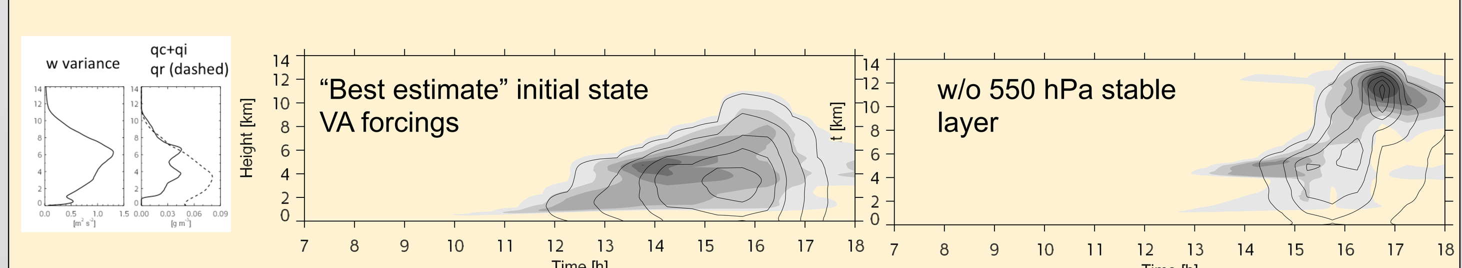
8. SAM RESULTS 6 JUNE 2014



Thermodynamic Profiles and Surface Fluxes



Simulations



Filled contours are cloud water (liquid +ice) and countours are precipitation (liquid + ice)
Countour intervals are [0.01, 0.03, 0.05, 0.07, 0.09, 0.11] g/kg.

- "Best estimate" transition is too shallow compared to observations.
- Removing freezing level stable layer permits growth to deeper convection.
- Both simulations produce observed mid-level cloud signal.
- Next steps include examining the evolution of the moisture profile.

9. CONCLUSIONS

- Diurnal cycle similar to that observed in OK, i.e., afternoon precipitation and deep convection.
- Transitions to deep clouds occur on days with pre-sunrise cloudiness and larger mid-level humidity.
- This is consistent to what was observed in OK.

10. FUTURE WORK

- Additional variables (e.g. PBL height, wind shear).
- Variability of large-scale forcing.
- Influence of sea and river breeze forcing.
- Additional LES/CRM model simulations.

9. REFERENCES

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