Observing Shallow-to-Deep Convective Transitions Using ARM GoAmazon2014/5 and Geostationary Satellite Observations

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Introduction

The transition between cumulus congestus (TCu) and cumulonimbus (Cb) cloud populations is an important component of the convective lifecycle, but is often only crudely captured in most GCMs. In this study we use the GoAmazon2014/5 ARM profilers and S-band scanning radar (SIPAM) dataset in combination with geostationary satellite measurements of IR brightness temperatures to statistically characterize the typical spatial and temporal scales and, to the extent possible, environmental controls on transitions between cloud populations dominated by TCu to those dominated by Cb.

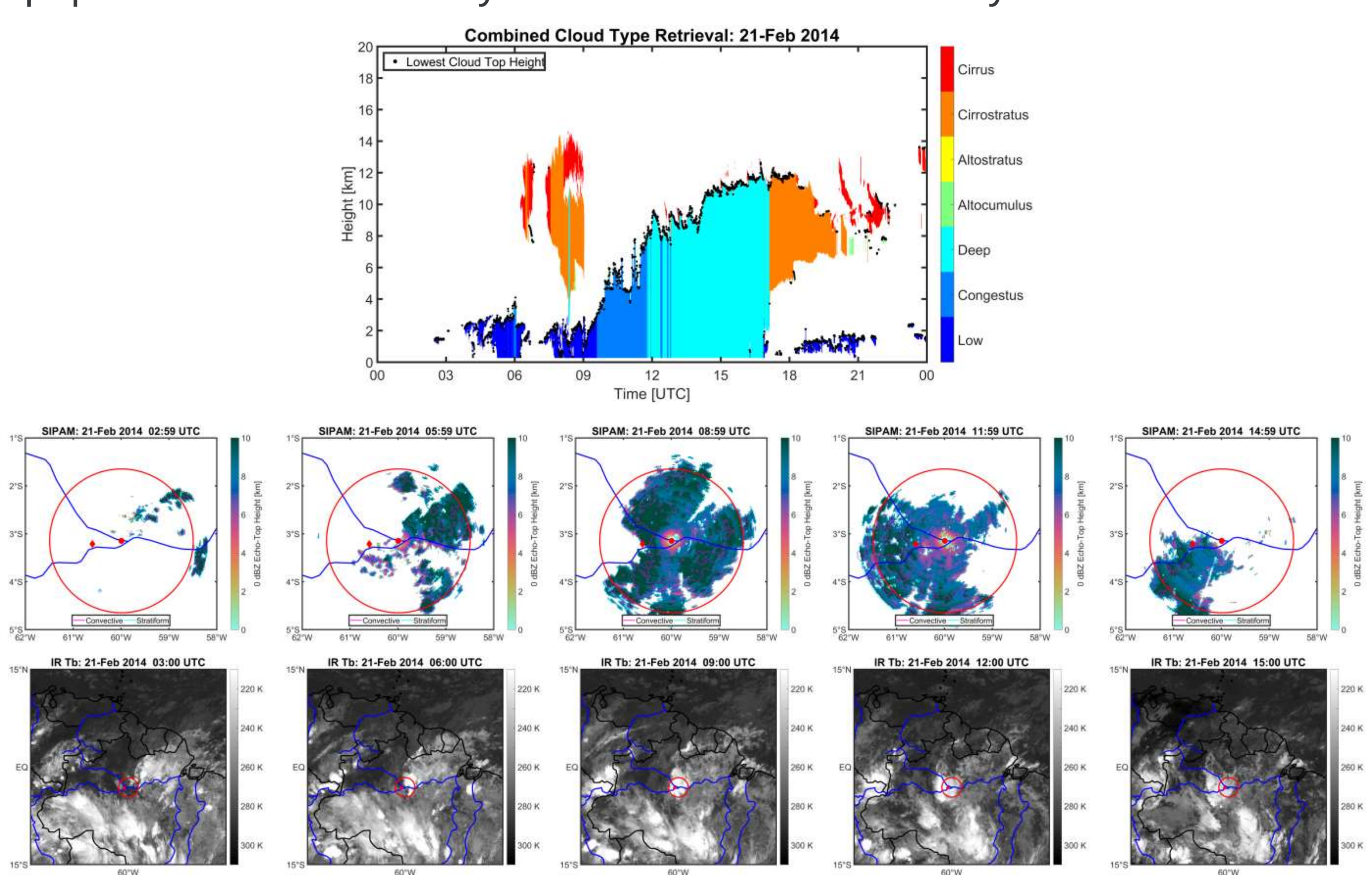

Fig. 1. The GoAmazon2014/5 campaign provides an opportunity to investigate shallow-to-deep transitions using multiple datasets that cross scales. This figure shows an example transition during IOP1 viewed from local to regional scales.

Current Science Questions

- ❖ To what degree can you resolve important features of shallow-to-deep transitions using a long-term, coarse resolution, satellite dataset?
- ❖ How do the various existing methods for identifying TCu and Cb cloud populations compare?
- ❖ What is the probability that a region filled with TCu clouds eventually transitions to Cb?

Future Science Questions

- ❖ How long do these transitions typically take?
- ❖ How does the probability of a transition vary by location, time, spacing between TCu clouds, and under varying environmental conditions?

Datasets

- ❖ Cloud profiles from ARM multi-sensor retrieval (30 m, 30 s, ~2 years)
- ❖ Precipitation from SIPAM S-band radar (2 km, 12 min, ~2 years)
- ❖ IR data from NASA merged-IR product (4 km, 30 min, 16+ years)

Characteristics of TCu and Cb Clouds

We use ARM data to characterize TCu and Cb clouds with a focus on their typical cloud-top heights and diurnal frequencies.

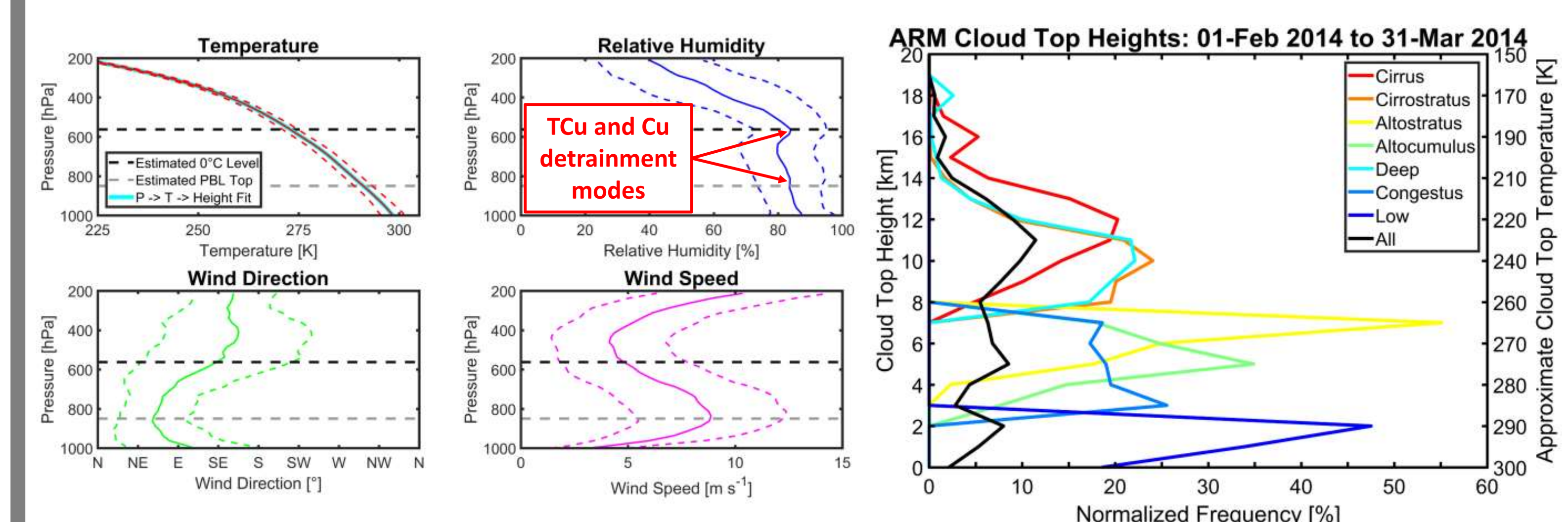

Fig. 2. We used a simple classification scheme based on cloud base and top height to translate the ARM cloud profiles into different cloud types. The sounding data is used to develop relationships to convert between height, pressure, and temperature that will facilitate translating cloud types among the different datasets.

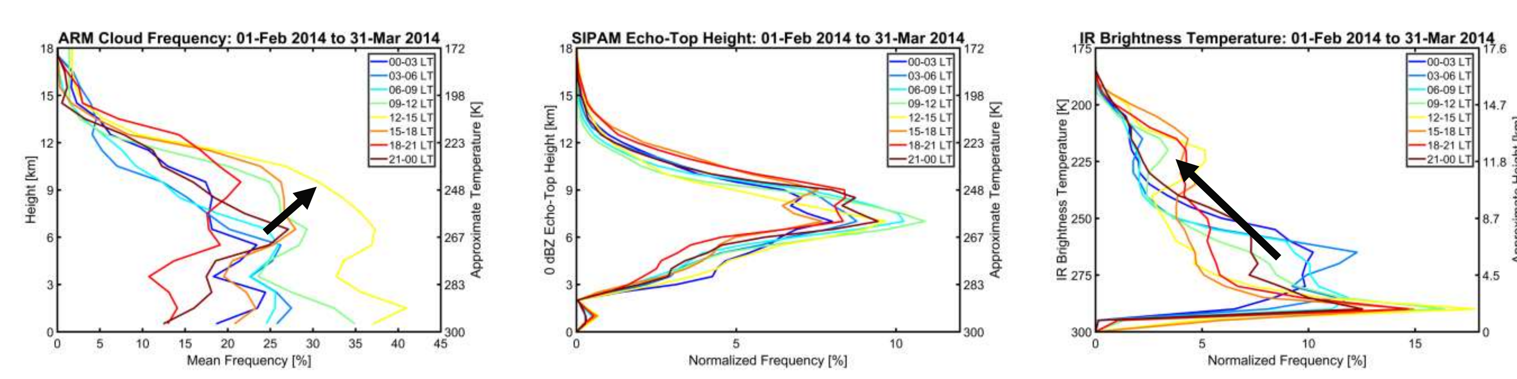

Fig. 3. The ARM and satellite IR datasets resolve a diurnal signature consistent with a persistent afternoon TCu-to-Cb transition while the SIPAM radar does not – likely because it does not detect shallow convection or anvils.

Previous Methods for Identifying TCu and Cb

There are several published methods that we can build on and use to compare and contrast.

<u>Wall et al. 2013 (WEA13)</u>

A climatology of tropical congestus using CloudSat

- ❖ TCu: Connected areas smaller than 200 km^2 with IR Tb 273-260 K and radar-detected rainfall at the surface
- ❖ Cb: Not identified in their study so we use the ASR18 method below

<u>Hohenegger and Stevens 2013 (HAS13)</u>

Preconditioning deep convection with cumulus congestus

- ❖ TCu stage: > 2% of a 1° x 1° box covered by IR Tb 273-240 K and no Cb present
- ❖ Cb stage: > 4% of a 1° x 1° box covered by IR Tb < 240 K.

<u>This Analysis (ASR18)</u>

- ❖ TCu: IR Tb 273-245 K, size 48-200 km^2, major axis length < 40 km
- ❖ Cb: IR Tb < 245 K, size > 64 km^2
- ❖ TCu Stage: > 0.5% of a 1° x 1° box covered by TCu and no Cb
- ❖ Cb Stage: > 2.0% of a 1° x 1° box covered by Cb

Conclusions

1) Satellite IR data can capture some features of the shallow-to-deep convective transition, but the specific details are sensitive to the choice of thresholds and constraints used to identify TCu and Cb clouds.
2) The two satellite-based methods that use size thresholds to constrain TCu clouds give ratios of transitioning to non-transitioning events that are closer to the ARM and SIPAM observations compared to the Hohenegger and Stevens 2013 approach.
3) Future work will need to distinguish convection that forms remotely and propagates into the domain from convection formed locally in order to fully understand the frequency and timing of the transition.

TCu-to-Cb Transitions During IOP1

Using the three possible classifiers plus the ARM and SIPAM data during IOP1 of GoAmazon2014/5, we characterized the frequency in which a TCu stage transitioned or failed to transition to a Cb stage within 6 hours. In the plots below t_0 marks the beginning of a TCu stage.

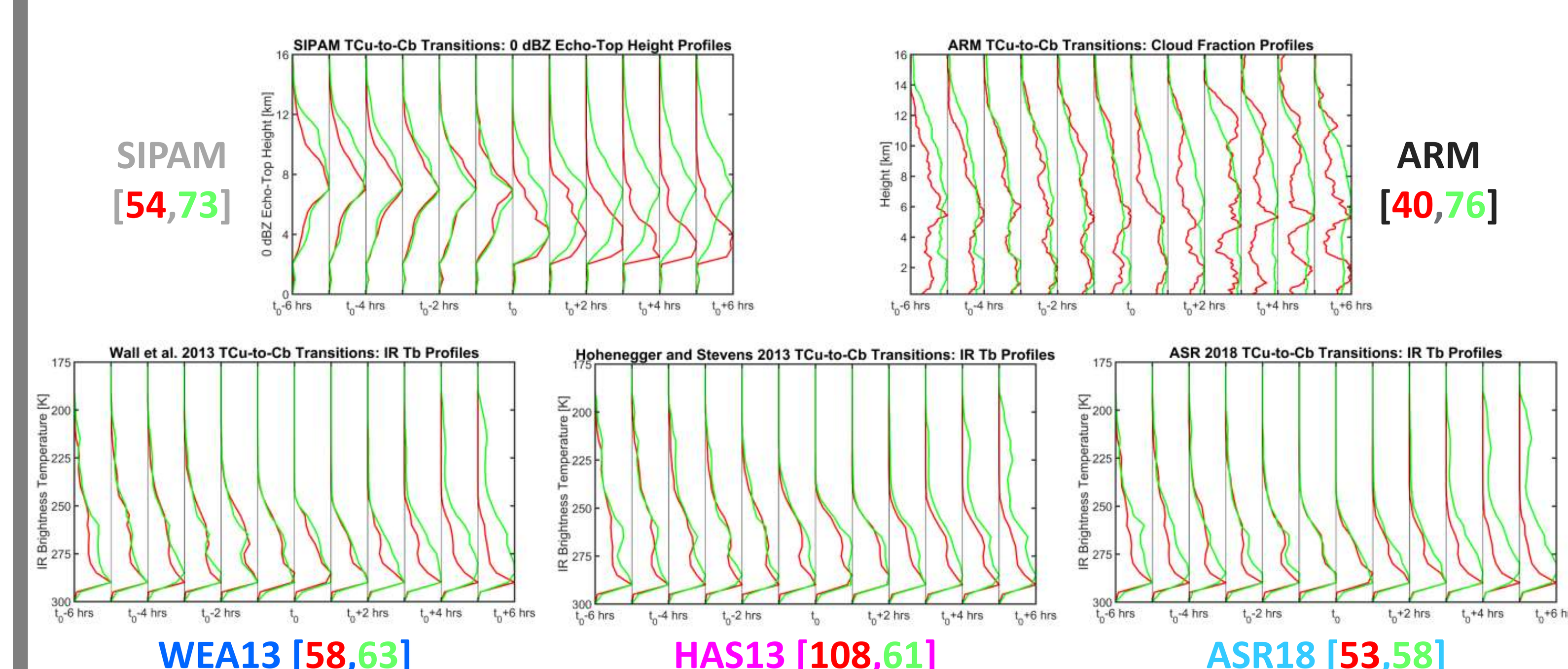

Fig. 4. The various classifiers more or less resolve the transition, with the WEA13 and ASR18 methods more closely matching the ratio of transitioning to non-transitioning events derived from the SIPAM and ARM data.

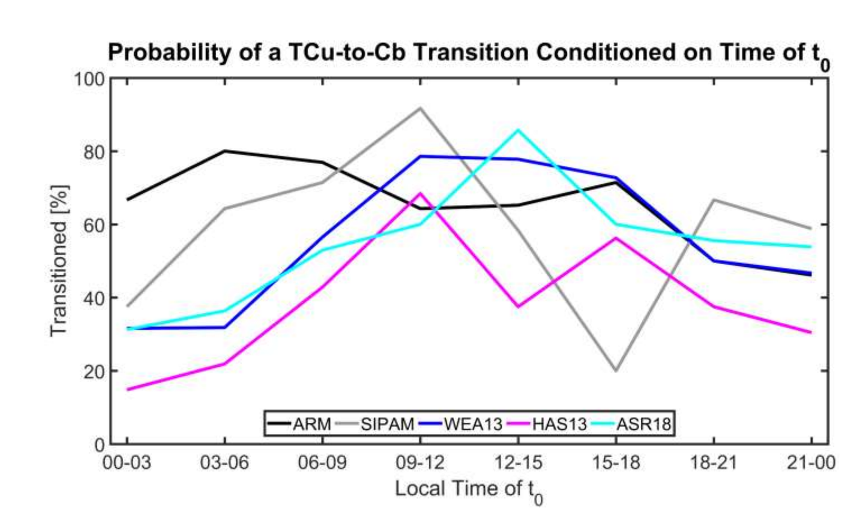

Fig. 5. The satellite- and radar-based methods identify a midday/early-afternoon peak in the probability of transition whereas the ARM data has a weak early morning peak.

Acknowledgements

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