# Clustering mechanisms of oceanic and continental convective systems

**Wei-Yi Cheng[1], Daehyun Kim[1], Angela K. Rowe[1], Yumin Moon[1] and Sungsu Park[2]**

*[1]University of Washington, Seattle, WA; [2]Seoul National University*

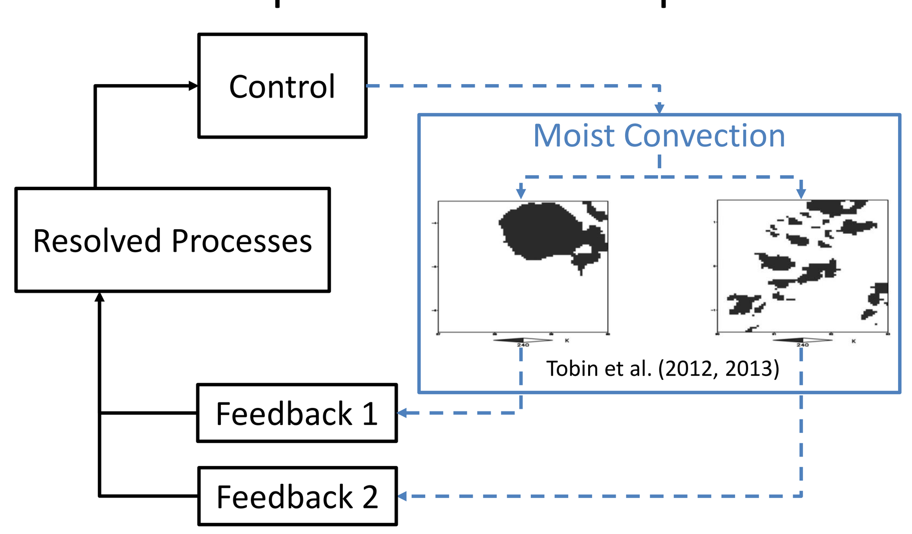
## 1. INTRODUCTION

### Objectives

**1. Objectively quantify convective clustering using ground-based radar observations, providing an observational basis for future evaluation of convective organization in convection schemes.**
**2. Examine the physical mechanisms of convective clustering transition that is observed over the Indian Ocean (AMIE/DYNAMO) and SGP.**

### Motivation

Cumulus parameterization problem

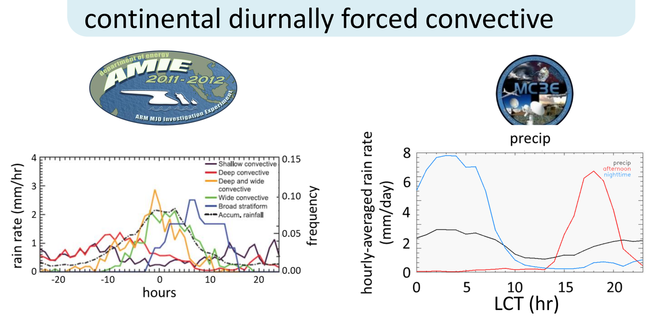



- Mesoscale organized convective systems can impact global radiation budget and hydrological cycle.
- But they are not well represented in most of the cumulus parameterization schemes.
- Some cumulus parameterization schemes has attempted to represent the convective clustering (e.g., UNICON; Park, 2014), but challenges remain in evaluating these schemes against observations.

### Strategy

#### Step 1. Observational Target

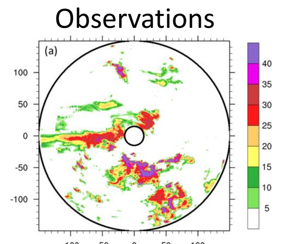
Our observational targets include tropical oceanic 2-day rain events and mid-latitude continental diurnally forced convective




#### Step 2. Quantification of Convective Clustering

The observed degrees of convective clustering are quantified using ground-based radar.

Observations



Simple scalar metric to quantify the degree of convective clustering from observations

#### Step 3. Numerical Simulations

The numerical models are forced with the ARM forcing dataset.

ARM forcing dataset AMIE/SGP
- u,v,w
- moisture
- surface flux
- temperature adv

UNICON
- SCM
- Ω: degree of convective organization

WRF(3.8.1)
- Doubly periodic
- 1 km resolution
- 256 x 256 km
- Thompson/YSU/RRTMG

#### Step 4.Mechanism Study

The convective clustering mechanisms are diagnosed by using ARM observations and WRF simulations, providing the basis for evaluating the relevant processes in cumulus parameterization schemes (e.g., UNICON).

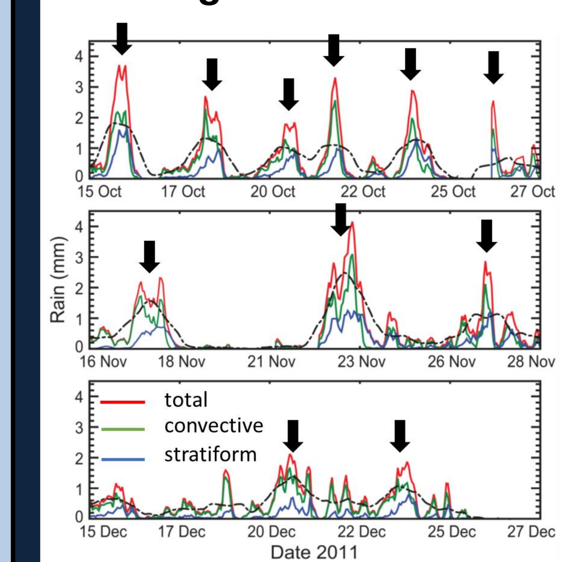
ARM observations — Convective clustering mechanisms — WRF

Cumulus parameterizations (UNICON) — Convective clustering mechanisms

## 2. Indian Ocean (AMIE/DYNAMO)

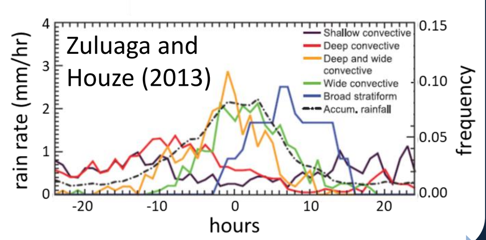
### Observational Target

➢ **10 2-day rain episodes during AMIE/DYNAMO**



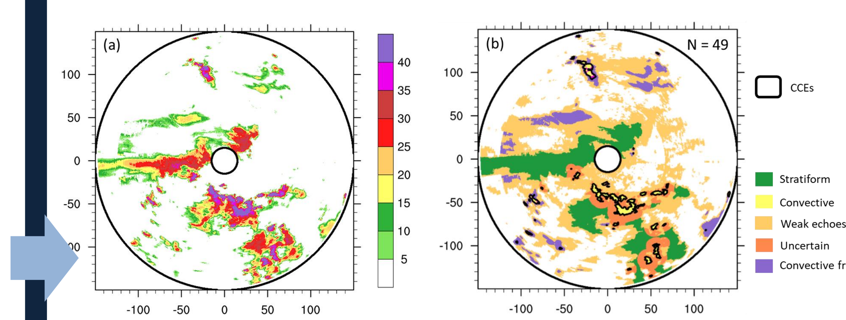

| Equipment | S-Polka Radar |
|---|---|
| Altitude | 2.5 (km) |
| Location | Addu Atoll in the Maldives |
| Duration | From 1 October 2011 through 15 January 2012 |
| Resolution | 0.5 (km) |

Previous study showed the dominant cloud type in the 2-day rain events transitions from shallow convective, deep convective, deep and wide convective, wide convective, to broad stratiform clouds.




### Quantification of Convective Clustering

➢ **Identify convective entities**

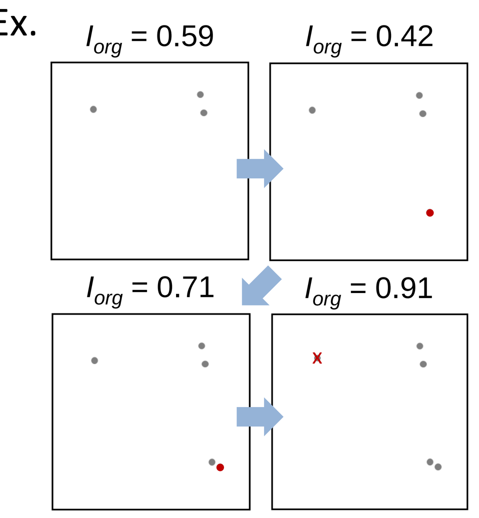


Two-step process:

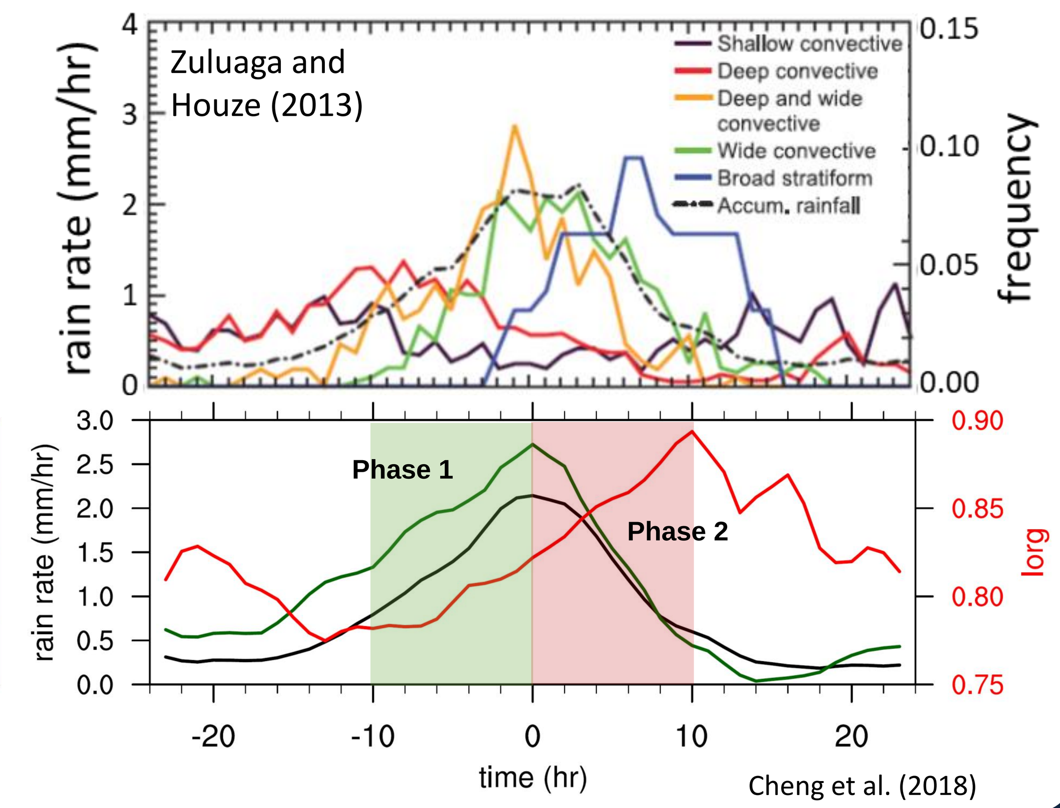
1. Rain type classification algorithm.
   - Powel et al. (2016; PHB16)
2. **Contiguous Convective Echoes (CCEs).**
   - Convective pixels are grouped into CCEs following four connectivity criterions: two convective pixels belong to the same CCE only if these two pixels share a common side.

**Organization Index ($I_{org}$)**
- Tompkins and Semie (2017).
- Comparing the cumulative distribution of **nearest neighbor distance** of CCEs to random distribution.
- $I_{org} < 0.5$: scattered distribution
- $I_{org} = 0.5$: random distribution
- $I_{org} > 0.5$: clustered distribution

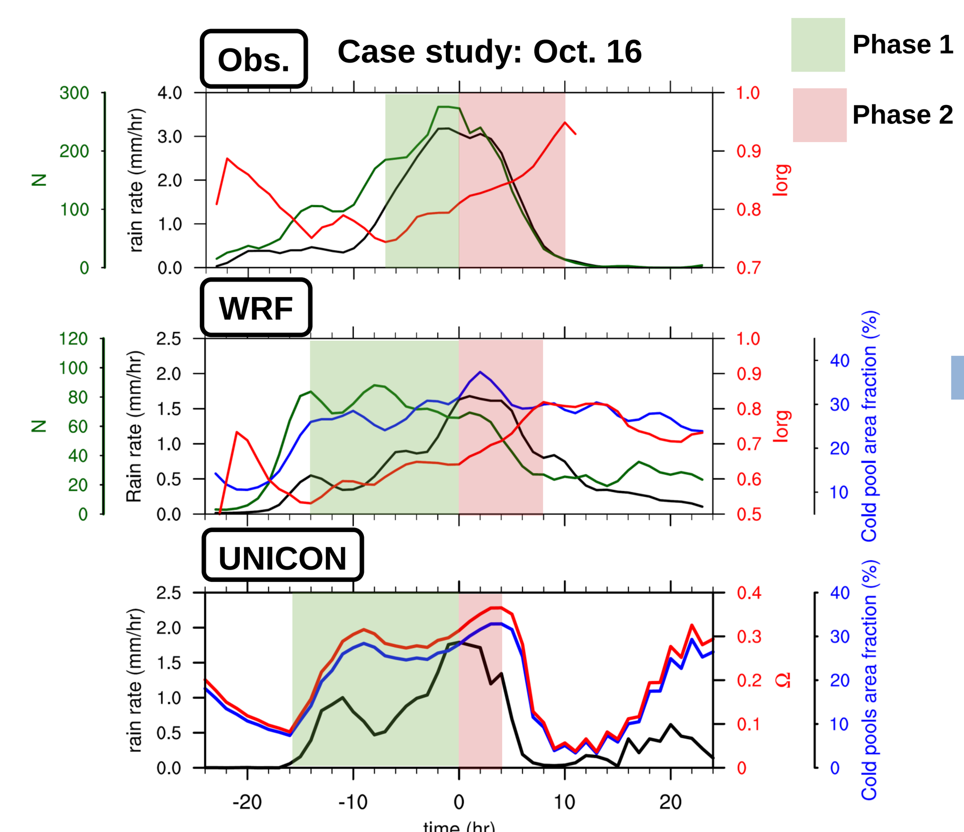
Ex.




**Two distinct phases of convective clustering:**
- **Phase 1: $N\uparrow$, $I_{org}\uparrow$**
- **Phase 2: $N\downarrow$, $I_{org}\uparrow$**




### Numerical Simulations

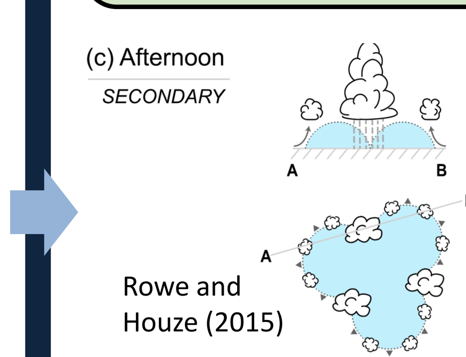


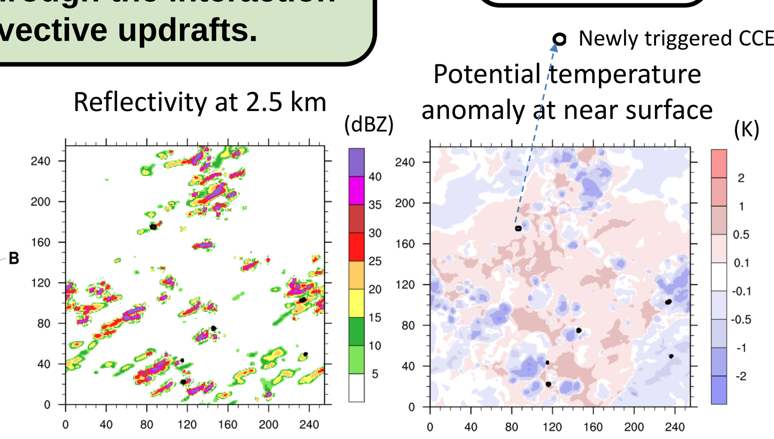

### Mechanism Study

➢ **WRF simulations**

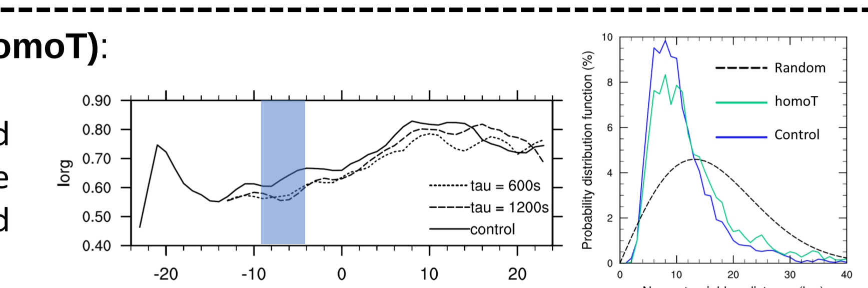
**Phase 1: convective cells cluster as new cells are formed near existing convective entities, presumably through the interaction of cold pools with convective updrafts.**

8 hours before peak rain rate



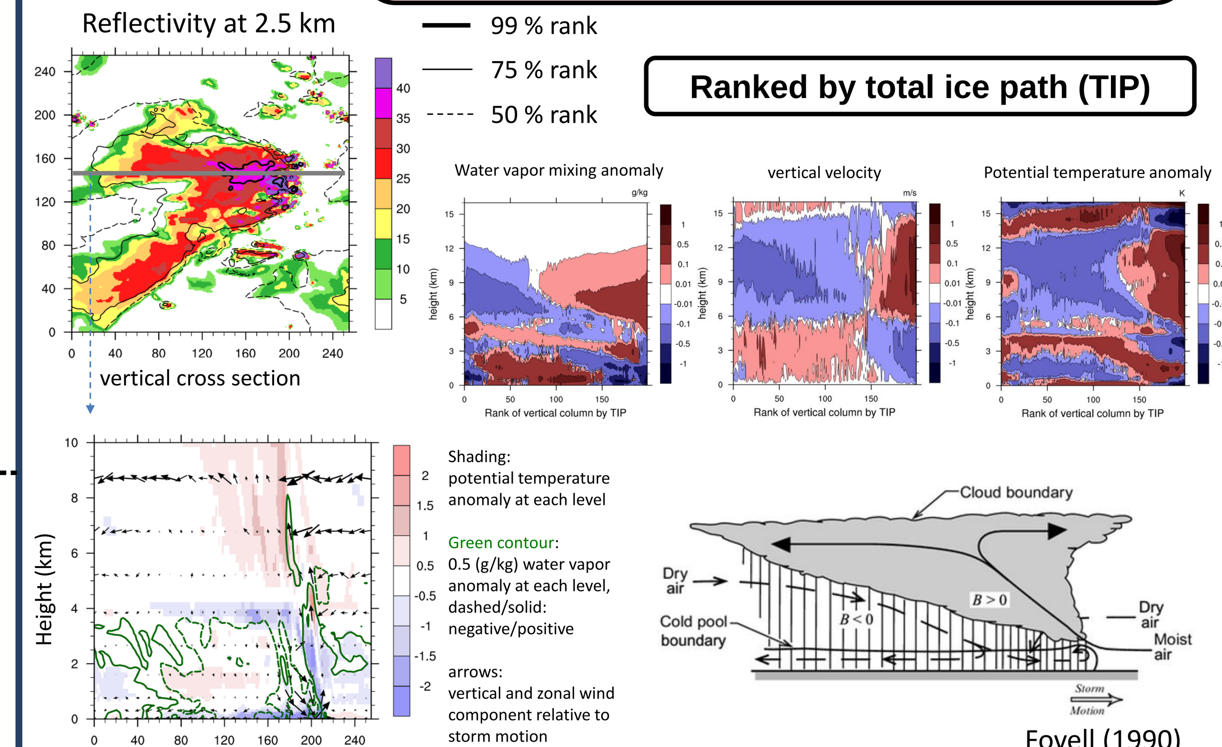

**Sensitivity test (homoT):**
A forcing is added to the temperature field in PBL to homogenize the temperature field in PBL ( $\frac{dT}{dt} = -\left(\frac{T-\bar{T}}{\tau}\right)$ ).




7 hours after peak rain rate

**Phase 2: the clustered convective entities are sustained longer than the isolated ones, possibly through feedback from the stratiform clouds and associated mesoscale circulations.**

Ranked by total ice path (TIP)




## 4. CONCLUSIONS

➢ **The degrees of convective clustering are objectively quantified using $I_{org}$, which is based on the spatial distribution of contiguous convective echoes (CCEs).**

➢ **Our analysis of 2-day rain events during AMIE/DYNAMO reveals two distinct phases of convective clustering: Phase 1: $N\uparrow$, $I_{org}\uparrow$; Phase 2: $N\downarrow$, $I_{org}\uparrow$.**

➢ **WRF simulations show that, during Phase 1, new convective cells preferentially forms near the edge of the cold pools boundary. The sensitivity tests confirm that the boundary layer temperature inhomogeneity is an important factor for Phase 1 convective clustering.**

➢ **During Phase 2, WRF simulations show that the mesoscale circulation is promoting convective cells to form near the convective region of the convective system, which lead to the increase in degree of convective clustering in Phase 2.**

➢ **Similar analysis framework will be applied to mid-latitude continental convective systems. The long-term ARM observations at SGP site allow us to study the diurnally forced convection. A thorough case study will be done by fully utilizing the observations collected during MC3E field campaign.**

Cheng, W.-Y., Kim, D., & Rowe, A. (2018). Objective quantification of convective clustering observed during the AMIE/DYNAMO 2-day rain episodes. *Submitted to Journal of Geophysical Research*
Park, S. (2014). A Unified Convection Scheme (UNICON). Part II: Simulation. *Journal of the Atmospheric Sciences*, *71*, 3931–3973.
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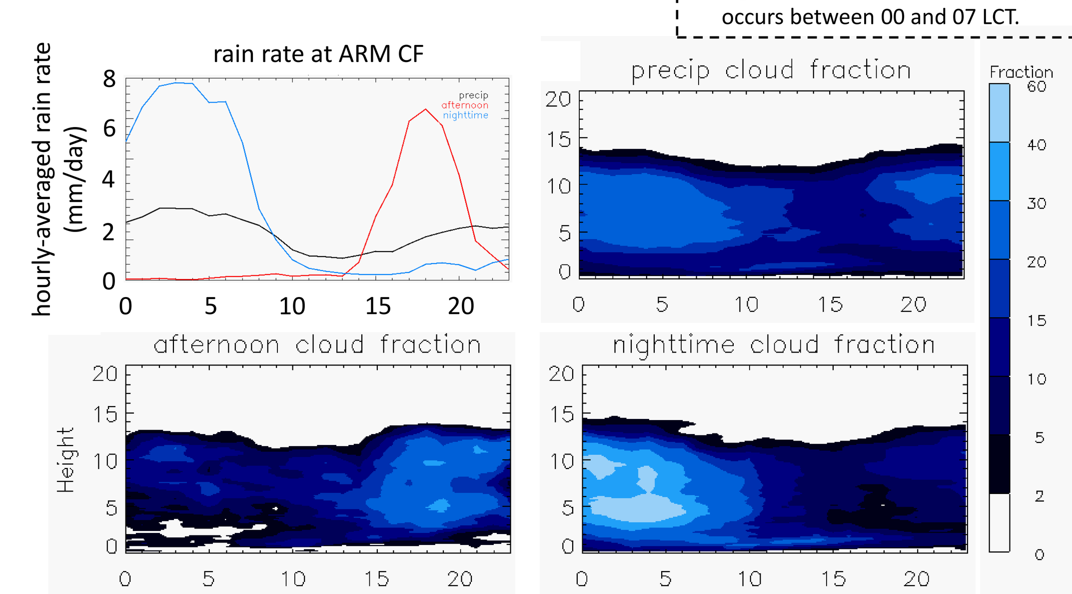
## 3. SGP (MC3E)

### Observational Target

➢ **Late afternoon and nighttime deep convection events at the SGP site.**

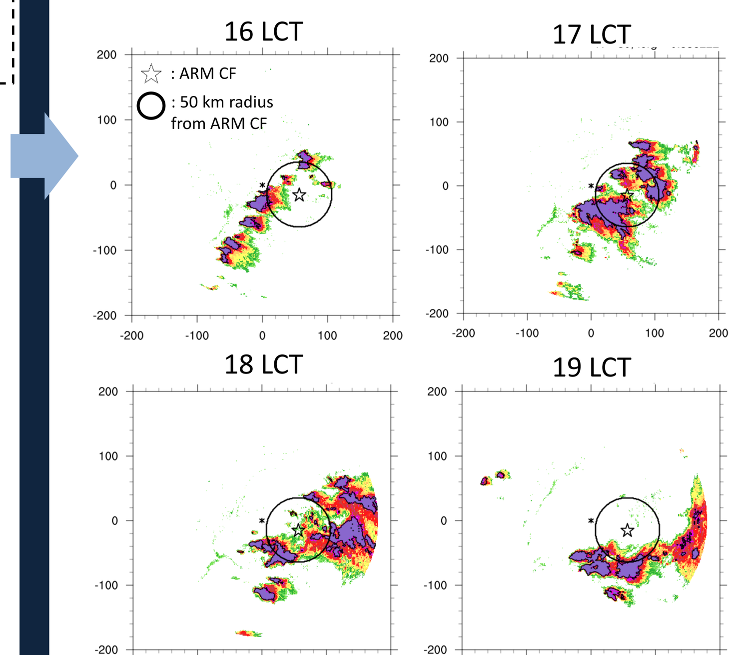
- Definition follow Zhang and Klein (2010) using ARM observations.
- From 2004 – 2015:
  - 154 afternoon convective cases.
  - 374 nighttime convective cases.

Case description:
- *precip*: rain > 0 mm/day at any hour
- *afternoon*: rain max > 1 mm/day occurs between 15 and 20 LCT
- *nighttime*: rain max > 1 mm/day occurs between 00 and 07 LCT.



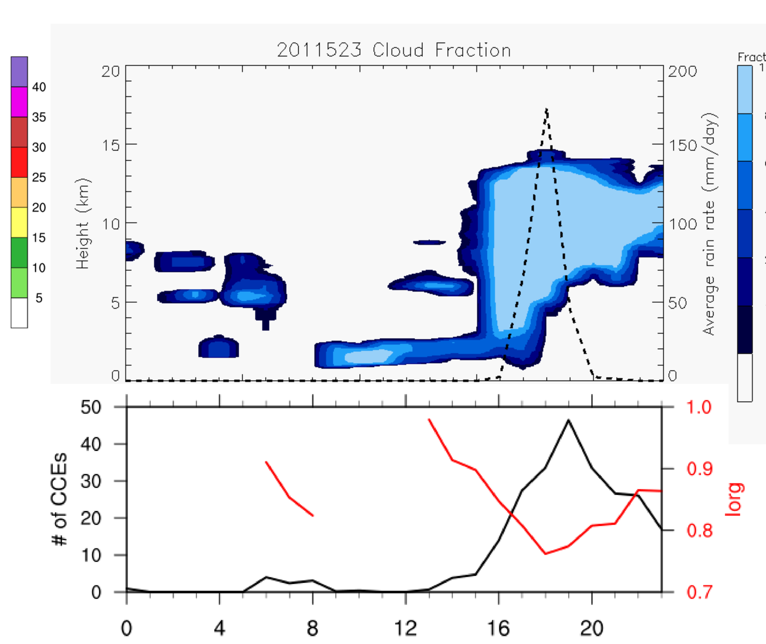

### Quantification of Convective Clustering

- The cloud fraction data are based on retrievals applied to measurements made by the vertical pointing cloud radar, lidar, and laser ceilometer at ARM CF.
- Precipitation data are from ABRFC based on radar-estimates and rain gauge reports. The time series shown here are the hourly mean rain rate over the region within a 50 km radius of ARM CF.
- Radar reflectivity from KVNX, gridded to 1 km resolution. The reflectivities shown here are at 2.5km height with scanning radius of 180 km.




➢ **A case study on May 23, 2011 during MC3E**

- As the convection is triggered, many convective cells are formed over a wider region, causing the decrease in $I_{org}$.
- Convective systems move out of the domain quickly, leaving a few localized convective cells in the domain.
- The analysis will be expanded to all the identified afternoon and nighttime cases.




**ARM observation at SGP**
- Long-term observations (from 2004 – 2015)
  - Radar (NEXRAD)
  - Precipitation (ABRFC)
  - Cloud fraction (ARMBE)
  - Surface observations (Mesonet)
- MC3E (22 Apr. 2011 - 6 Jun. 2011)
  - X-SAPRs, C-SAPR

### Numerical simulations & Mechanism Study

- The numerical simulation will be done following the same framework as AMIE/DYNAMO using the ARM forcing data at SGP for selected cases.
- The long term ARM observations provides a great amount of cases of diurnally forced convection, and also provides a wide range of measurement that is important for understanding the convective clustering mechanism.
- The long-term ARM forcing data will be composited based on different cases (e.g., afternoon or nighttime convection), to help us study the mechanisms of convective clustering under different environmental conditions.