Bridging observations and LES towards reducing uncertainties in convection-permitting models

Zhe Feng

2022 ASR PI Meeting Breakout – CPWG

Contributions: Adam Varble, James Marquis, William Gustafson, Joseph Hardin, Enoch Jo

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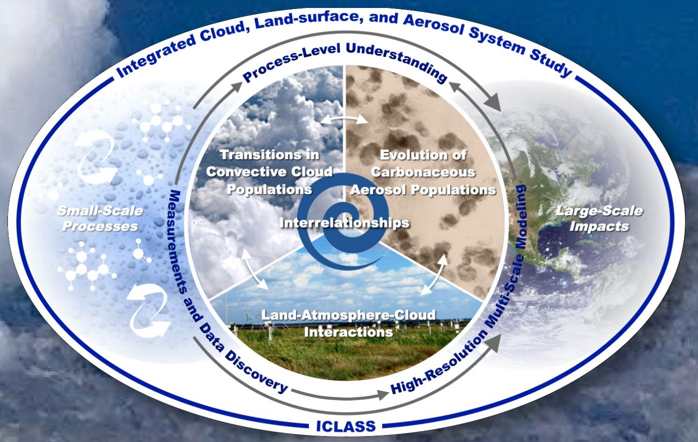
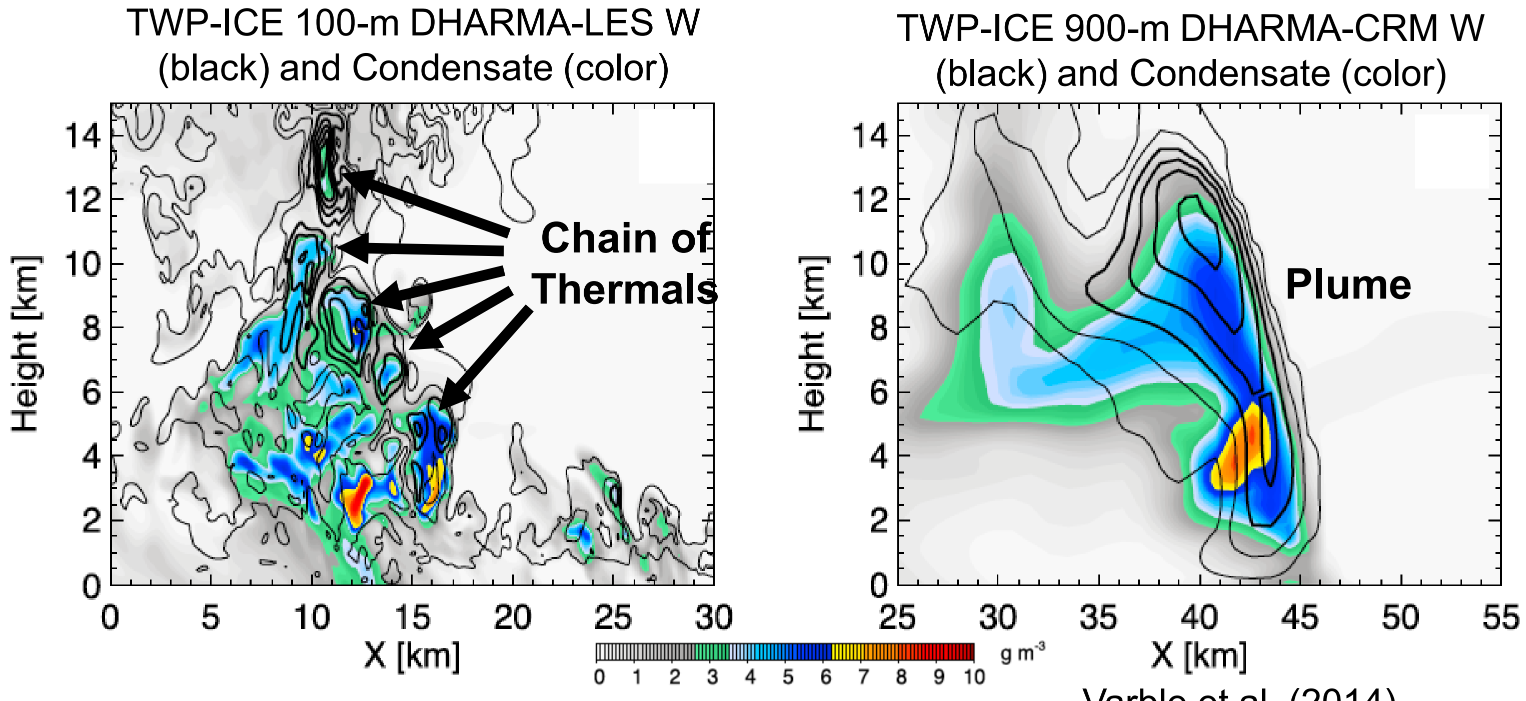
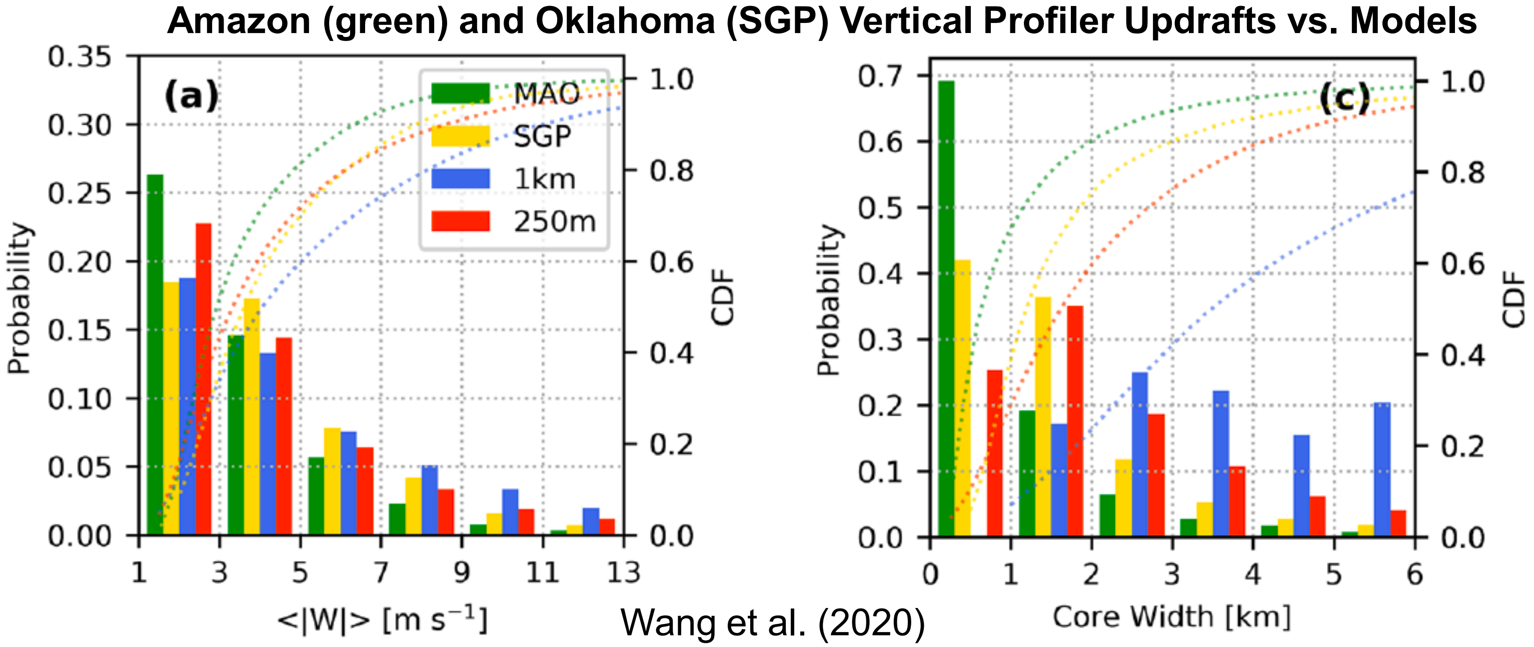


Motivation and Objective

- Convection-permitting models (CPM) are the future of Earth System Models
- But CPMs have various dynamical and microphysical biases
- Deep convection initiation and growth under realistic environments are poorly understood, near-cloud environmental factors and key cloud structures are difficult to observe
- **Goal:** Better understand processes controlling deep convective cloud growth under a variety of realistic environmental conditions during CACTI through **developing an observation-model integration framework**, and *ultimately* jointly improve model and observation capabilities



Varble et al. (2014)



Wang et al. (2020)

Organized Convection in GCPMs

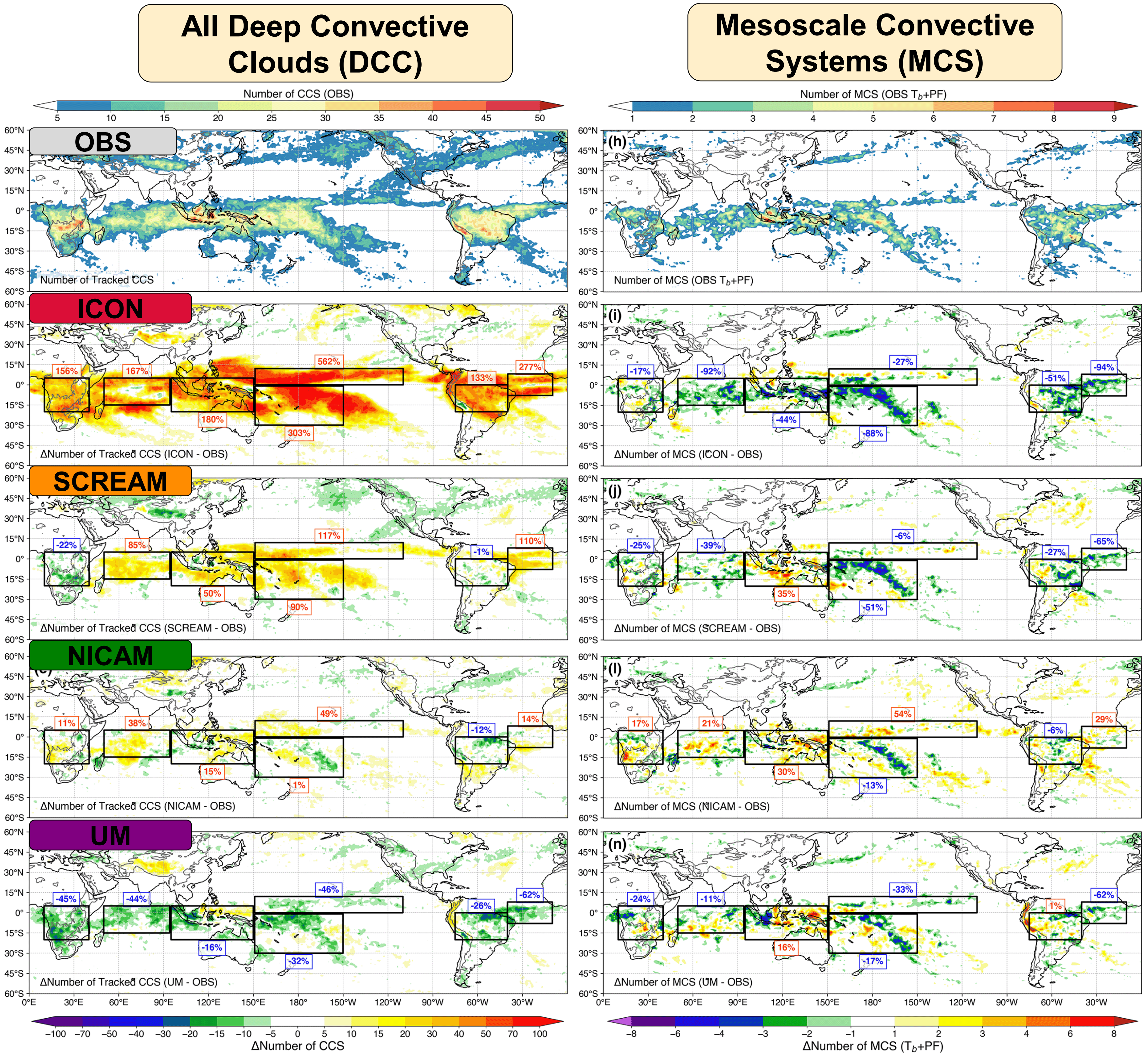
Science questions:

1. Are deep convection populations and their associated precipitation realistic in DYAMOND GCPMs?
2. How well are mesoscale convective systems (MCSs) represented?

Key findings:

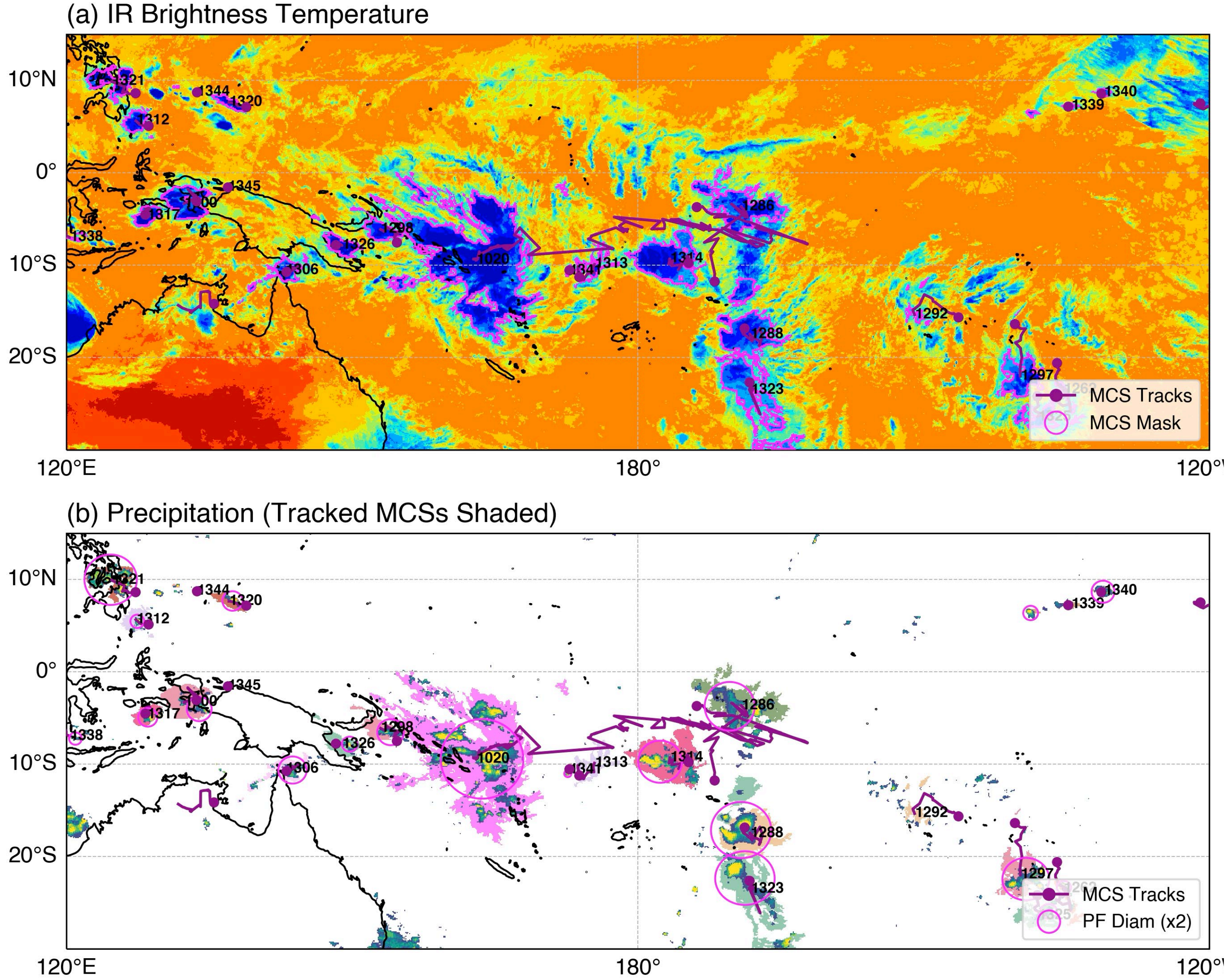
- Diverse range in simulating tropical DCC and MCS
- **Most models** overestimate DCC/MCS in Maritime Continents (MC), but underestimate tropical MCSs over continents, Indian/Atlantic Oceans, SPCZ
- **All models** overestimate MCS precipitation in MC, but most underestimate those in other tropical regions

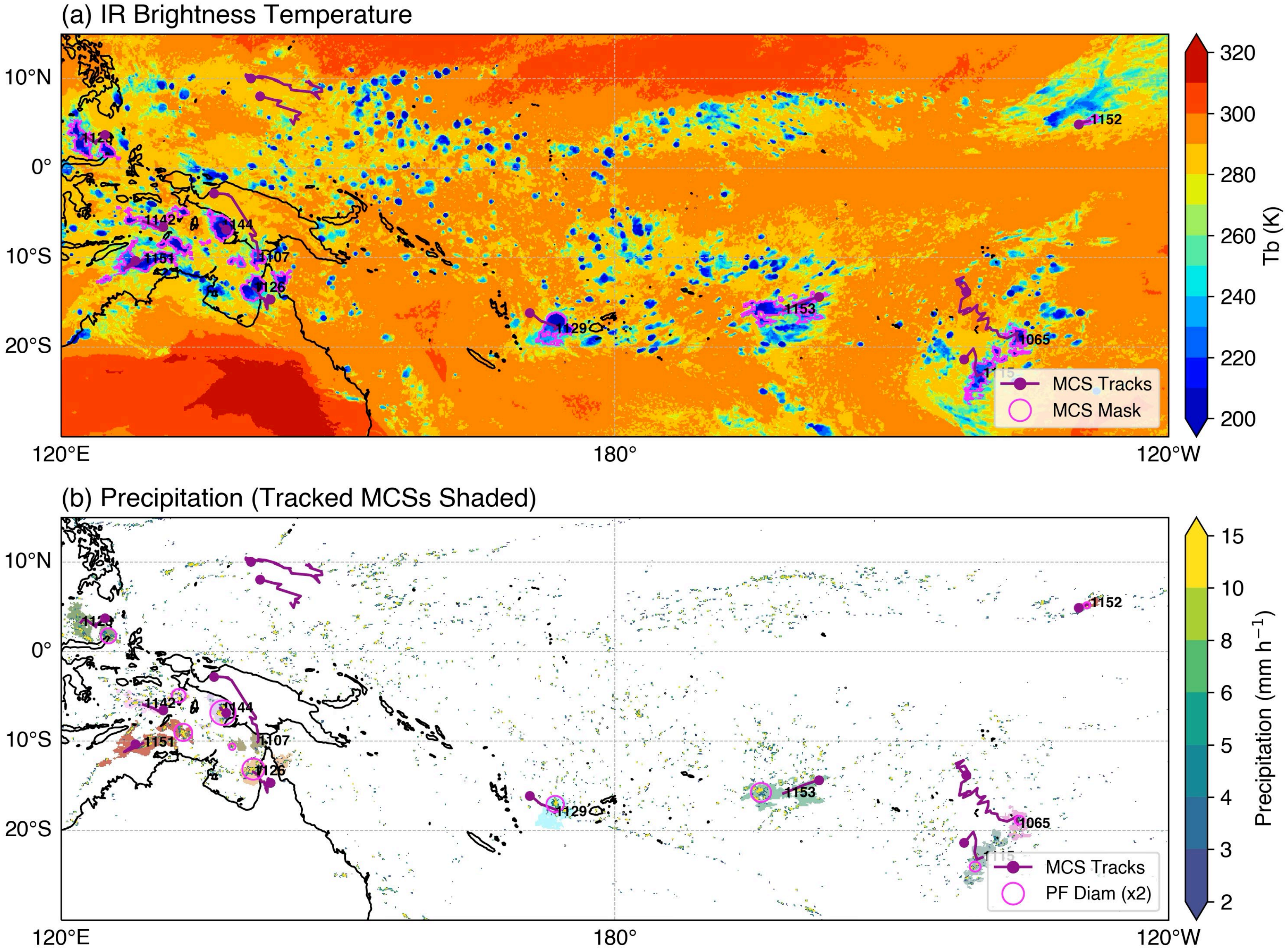
Feng et al. (2022), in prep.



Examples of Simulated DCC and MCS

OBS | **SCREAM**

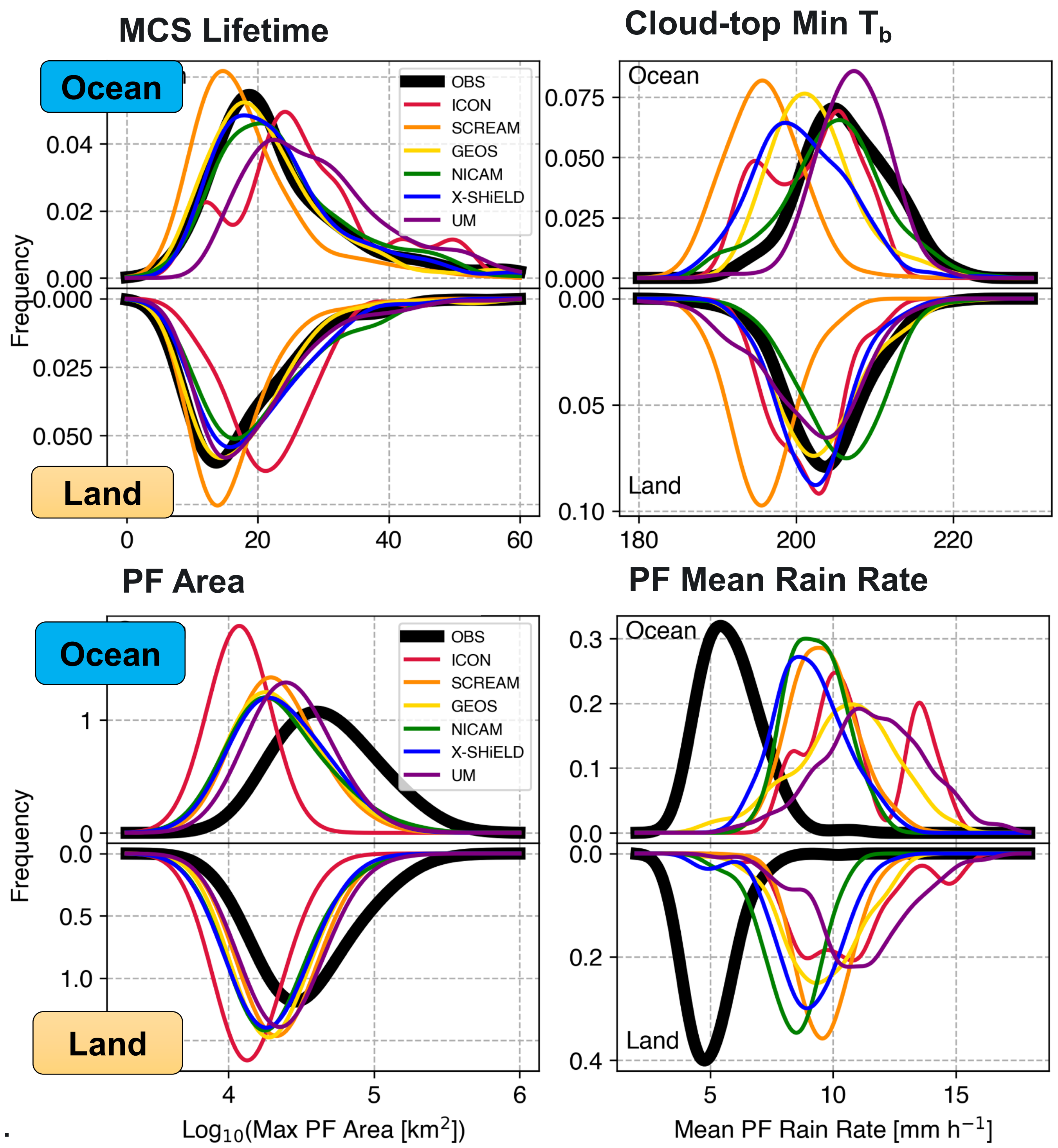




- SCREAM simulated a lot more unorganized DCC ("pop corn" convection) and less MCSs than OBS
- DYAMOND models results are quite diverse in the morphology of organized convection

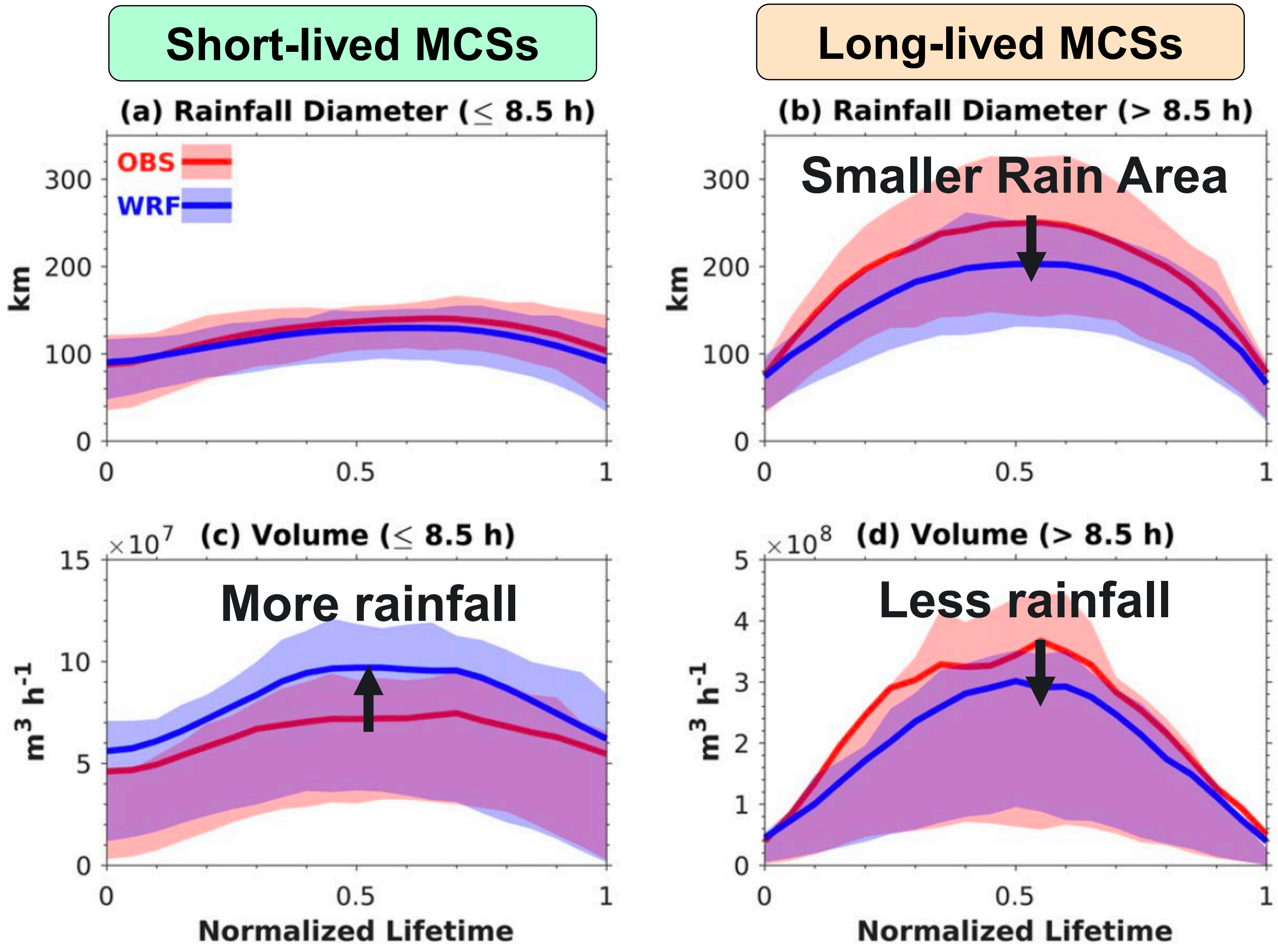
Model MCS Properties and Interpretations

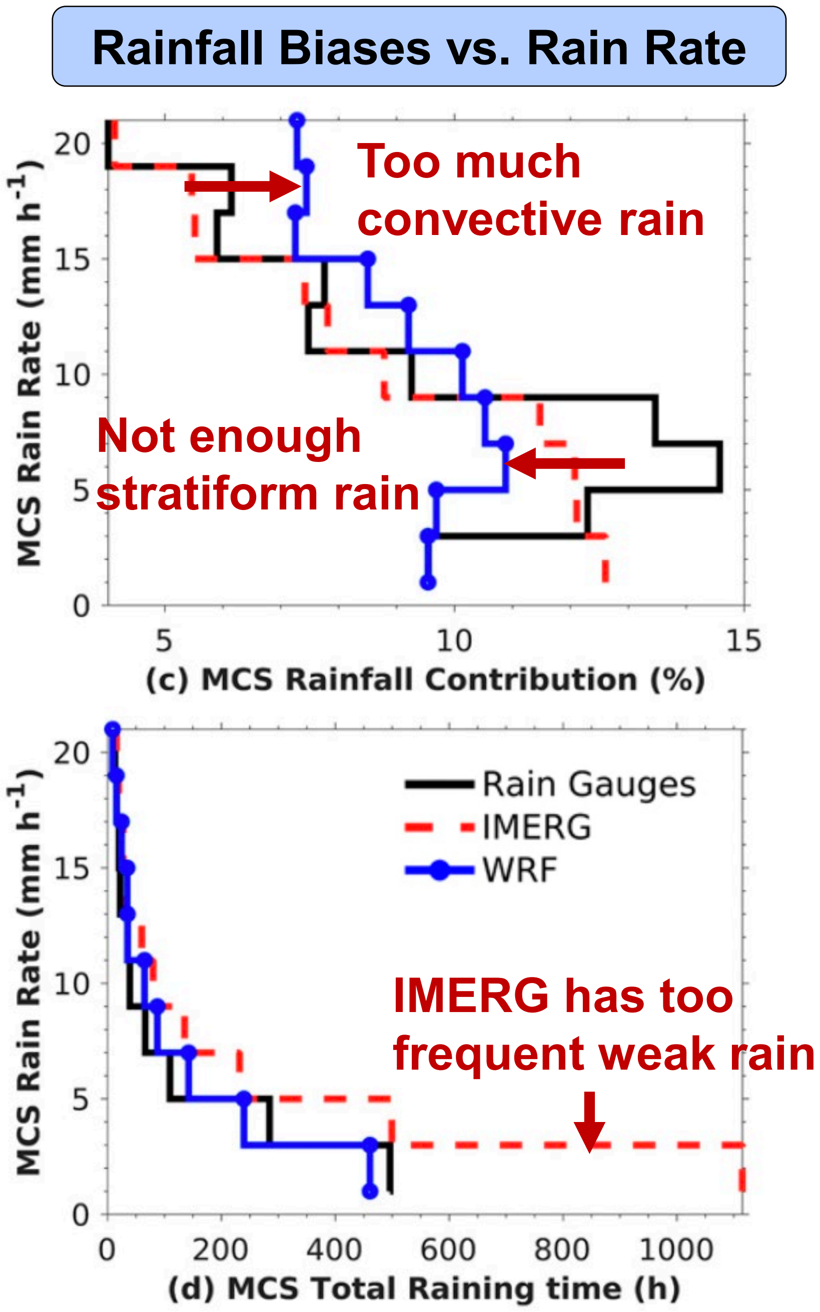
- **Most models** capture MCS lifetime, cloud-shield area and total volume rain quite well
- Widespread max cloud-top height (min T_b) but **generally deeper than obs.**, indicate updraft intensity may be too strong over ocean
- **All models** underestimate PF area (stratiform bias is common), overestimate rain intensity (too much convective rain)



Feng et al. (2022), in prep.

MCSs in WRF Show Similar Biases

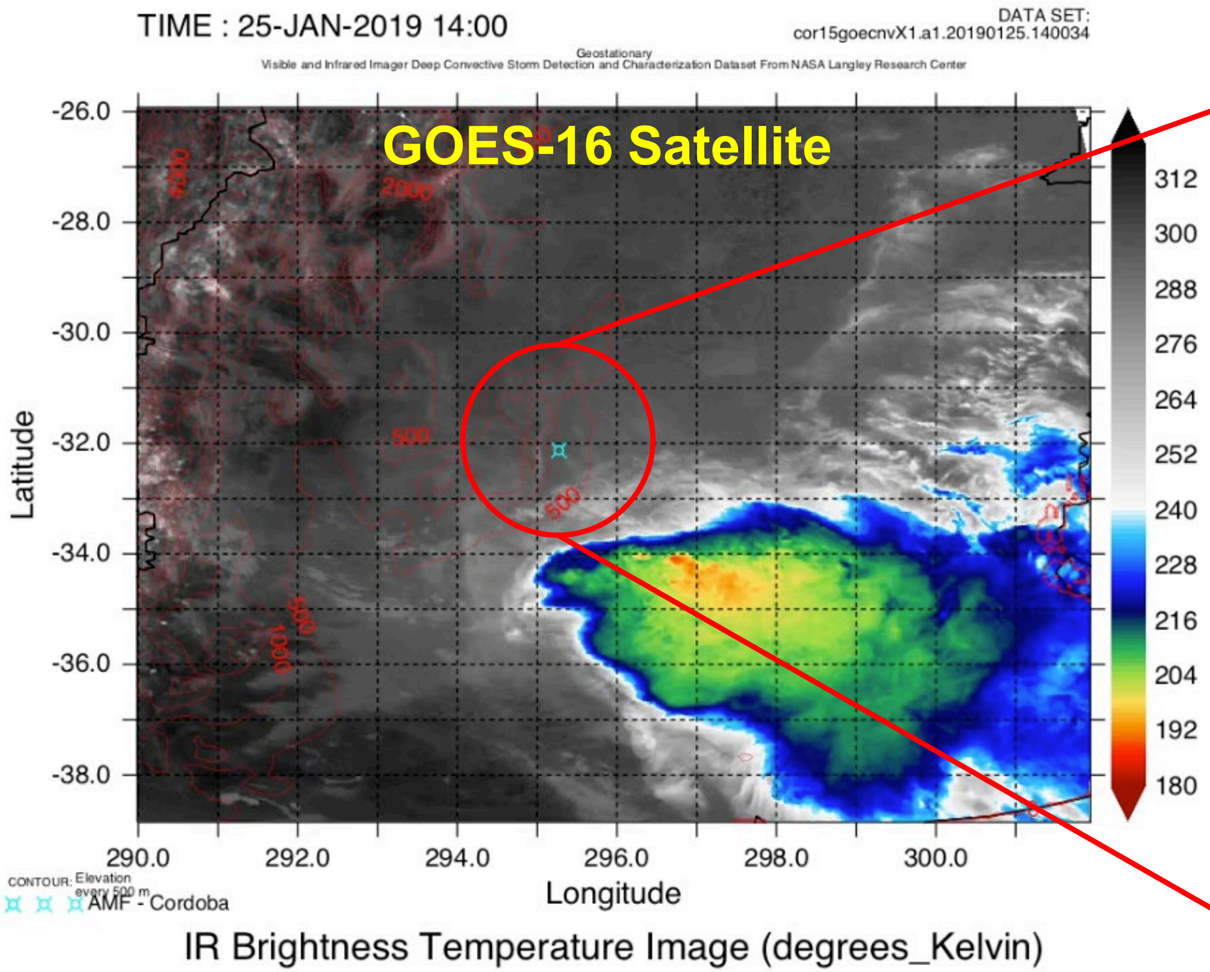


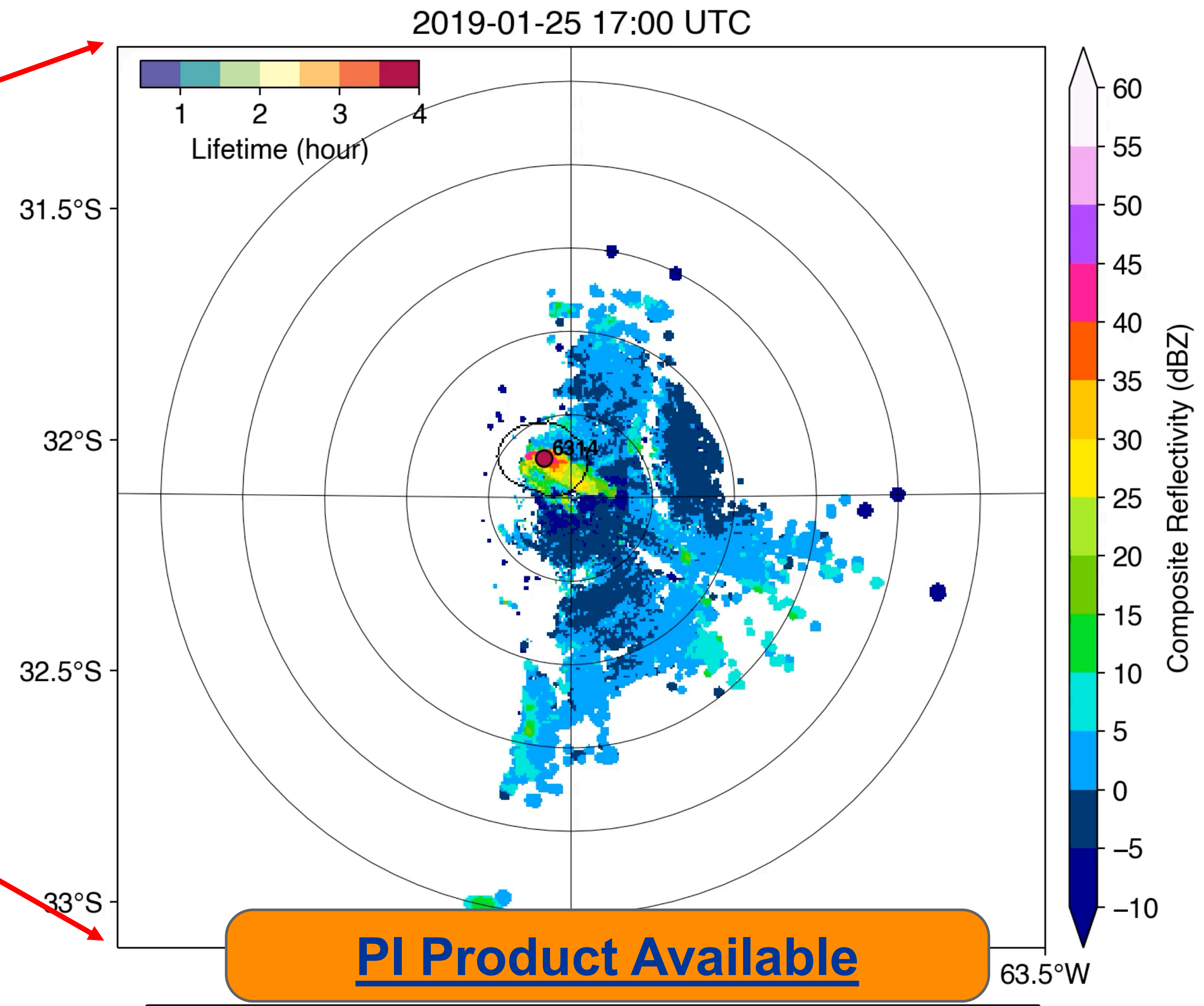


- Simulated rainfall biases differ between short-lived and long-lived MCSs → **biases depends environmental conditions**
- Model biases cannot be solely explained by satellite-retrieved rainfall uncertainties, as rain gauge comparisons show similar bias with smaller magnitude

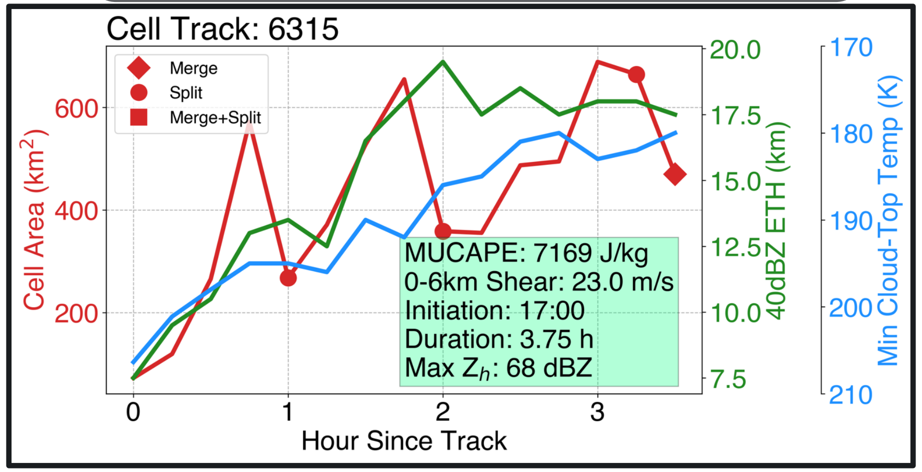
Zhang et al. (2021) *MWR*

Approach: Convective Cell Tracking Database



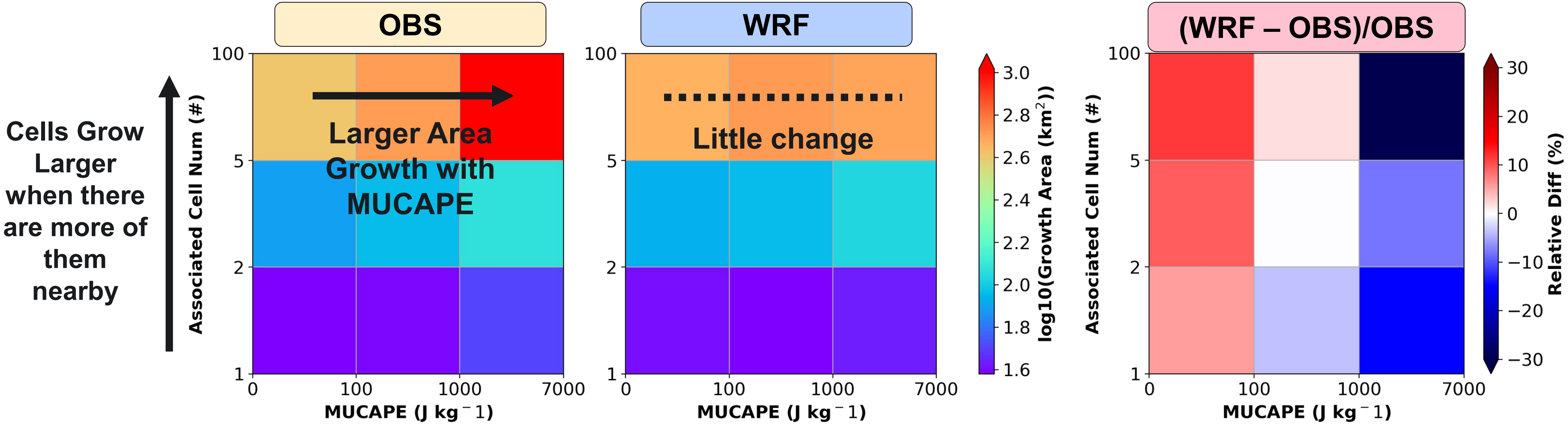


PI Product Available



- Developed a **convective cell tracking database** using CSAPR radar reflectivity (Feng et al. 2022 *MWR*):
  - ~6900 tracked convective cells
  - Cell time, location, duration, size, echo-top, merge/split
  - Profiles of Z_e, Z_{DR}, K_{DP}, rain rate, D_m, etc.
  - Parallax corrected NASA Langley GOES-16 cloud product matched to tracked cells
  - Environmental conditions at CI time based on INTERPSONDE

Continental Convective Upscale Growth Biases in WRF during CACTI

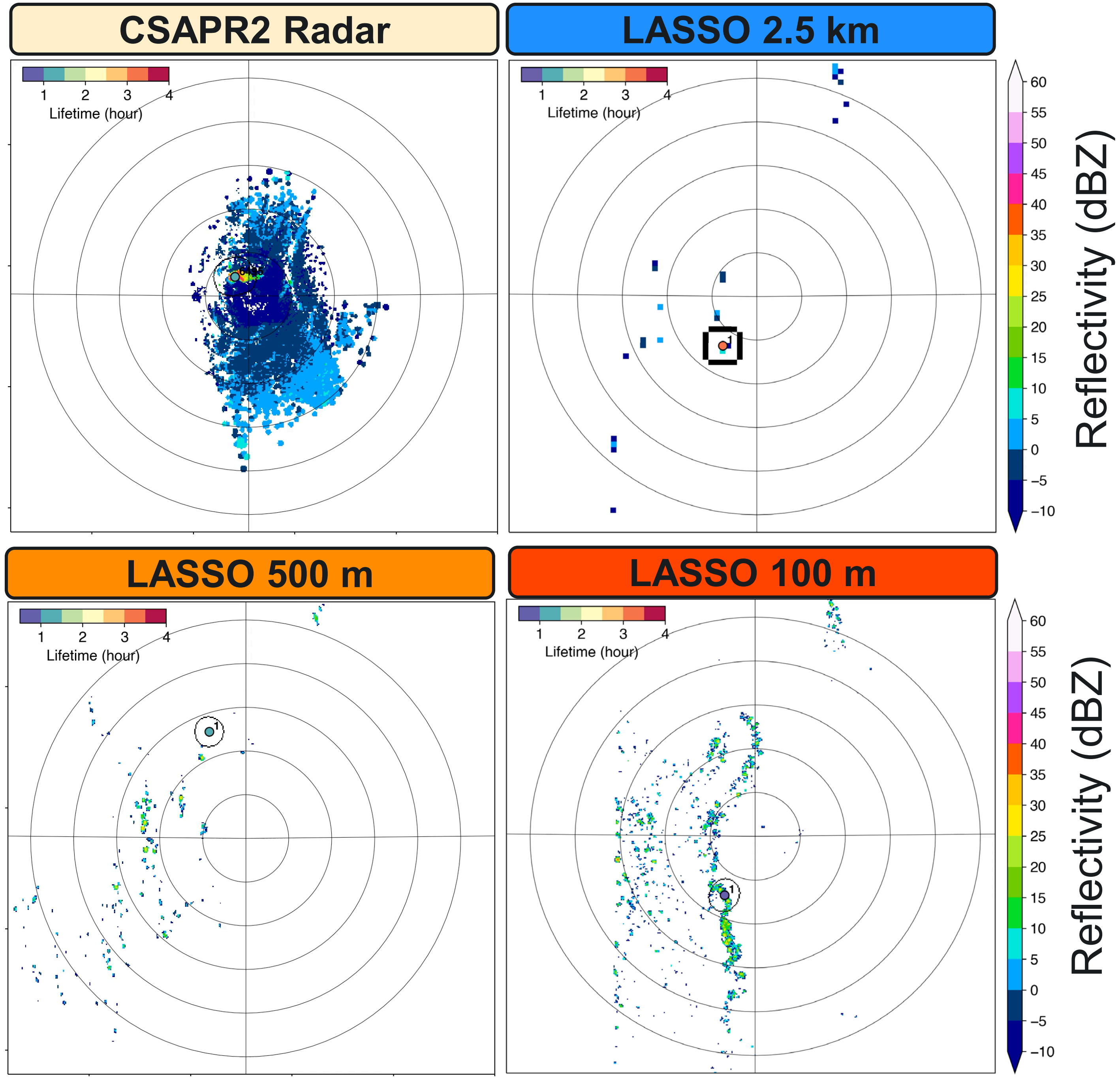


Zhang et al. (2022), *in prep.*

- Applied cell tracking to 6-month WRF simulations (3 km)
- CPM tend to over produce convective cells in low MUCAPE environments
- Model fails to simulate observed dependence of cell area growth on MUCAPE when cell formations are abundant

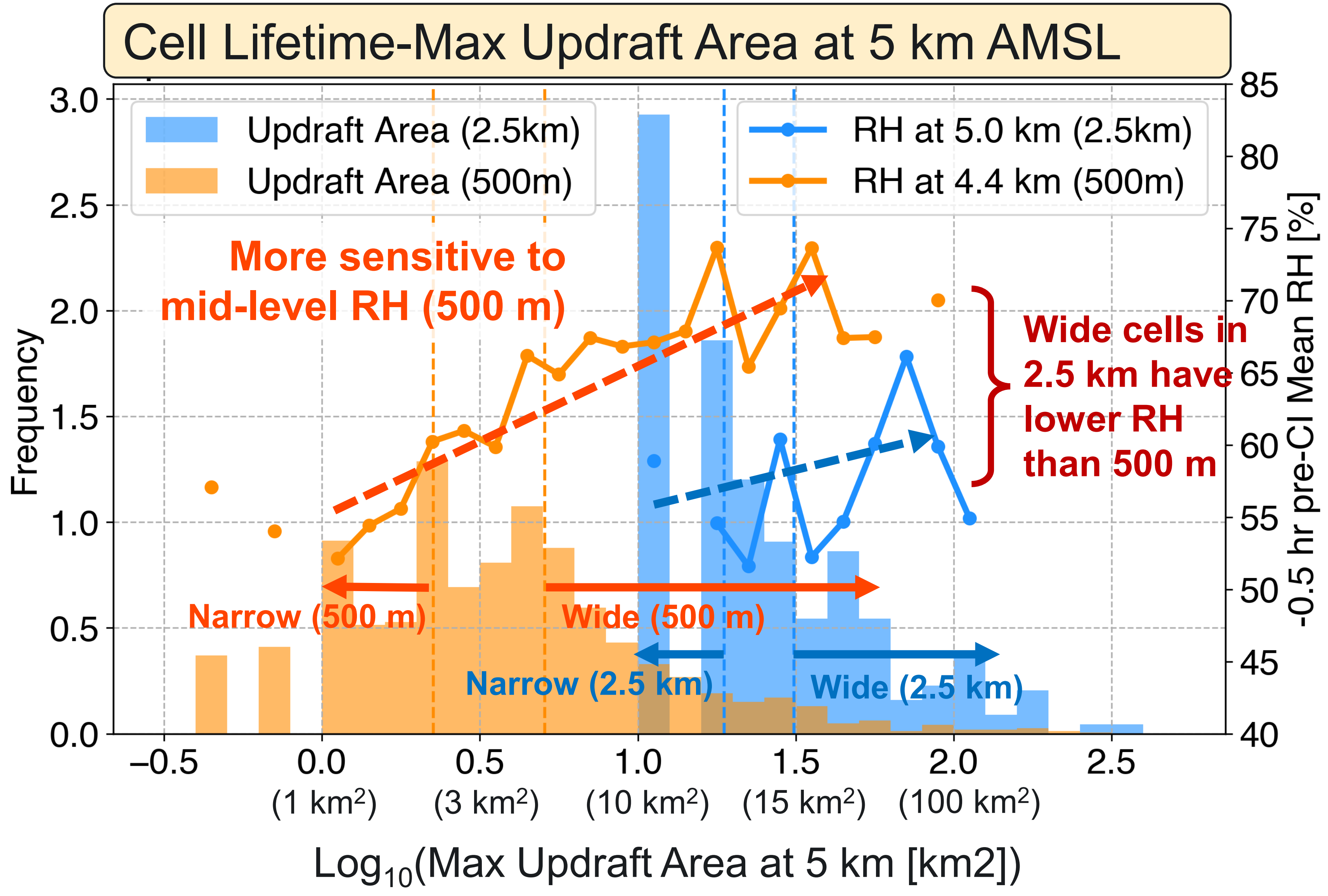
Opportunities from LASSO-CACTI Simulations

- LASSO offers opportunities to understand **resolution dependence** on convective upscale growth in realistic environments
- We adapted PyFLEXTRKR to track convective cells in LASSO simulations at CPM and LES grid spacings
- Tag environmental conditions for each tracked cell at CI locations in LASSO
- Multiple LASSO simulations days are coming online, large CPM ensembles for 20 events (~660 simulations) are available: https://www.arm.gov/news/blog/post/77833



Updraft Width Dependence on Relative Humidity

- Wide updrafts in 2.5 km runs are associated with drier mid-level RH than in 500 m runs, which may suggest updrafts in CPM are less sensitive to environmental humidity (i.e., weaker turbulent entrainment effects)
- More work is needed to disentangle other processes contributing to these differences



*__Narrow cells:__ ≤ 1/3 updraft area distribution; __Wide cells__: ≥ 2/3 updraft area distribution

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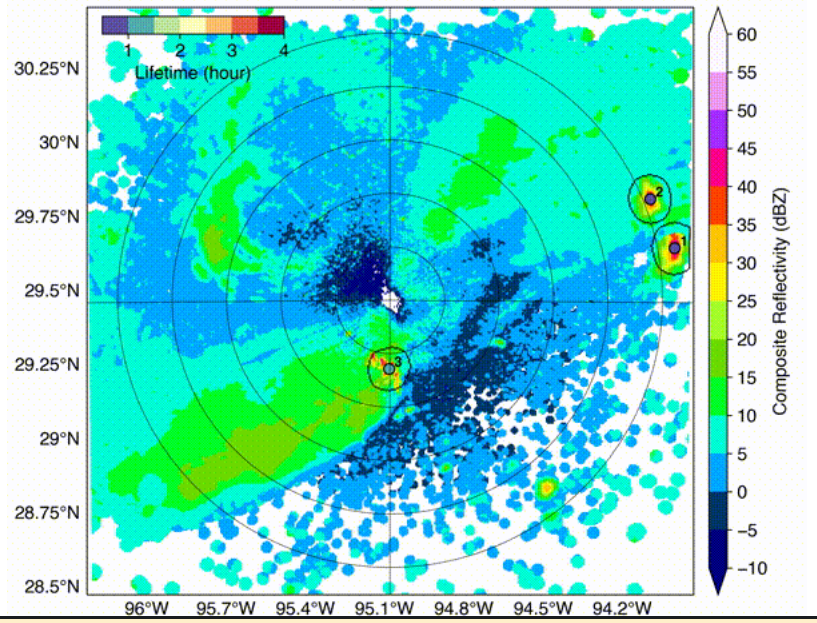
PyFLEXTRKR Software Package for Community Use

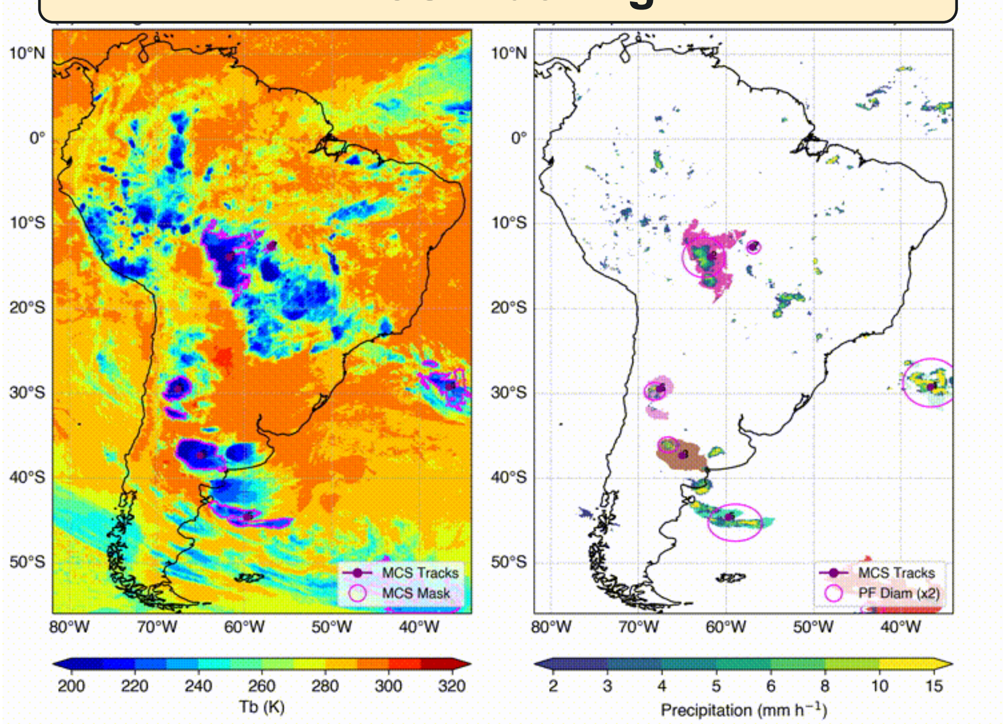
Feng et al. (2022), *submitted*

- PyFLEXTRKR (Python-based atmospheric feature tracking software package)
- **Current capabilities:**
  - Tracking convective cells using radar reflectivity data [[Feng et al. (2022) *MWR*](#)]
  - Tracking MCSs using satellite (T_b) data, or model outgoing longwave radiation (OLR) data, with optional collocated precipitation data to identify robust MCSs [[Feng et al. (2021) *JGR*](#)]
  - Generic 2D objects defined by simple thresholds
- Works on observations and model outputs, **optimized to run on large datasets**, scalable parallelization
- Provides visualization scripts, Jupyter notebooks for statistical analysis
- Now available: https://github.com/FlexTRKR/PyFLEXTRKR

Convective Cell Tracking

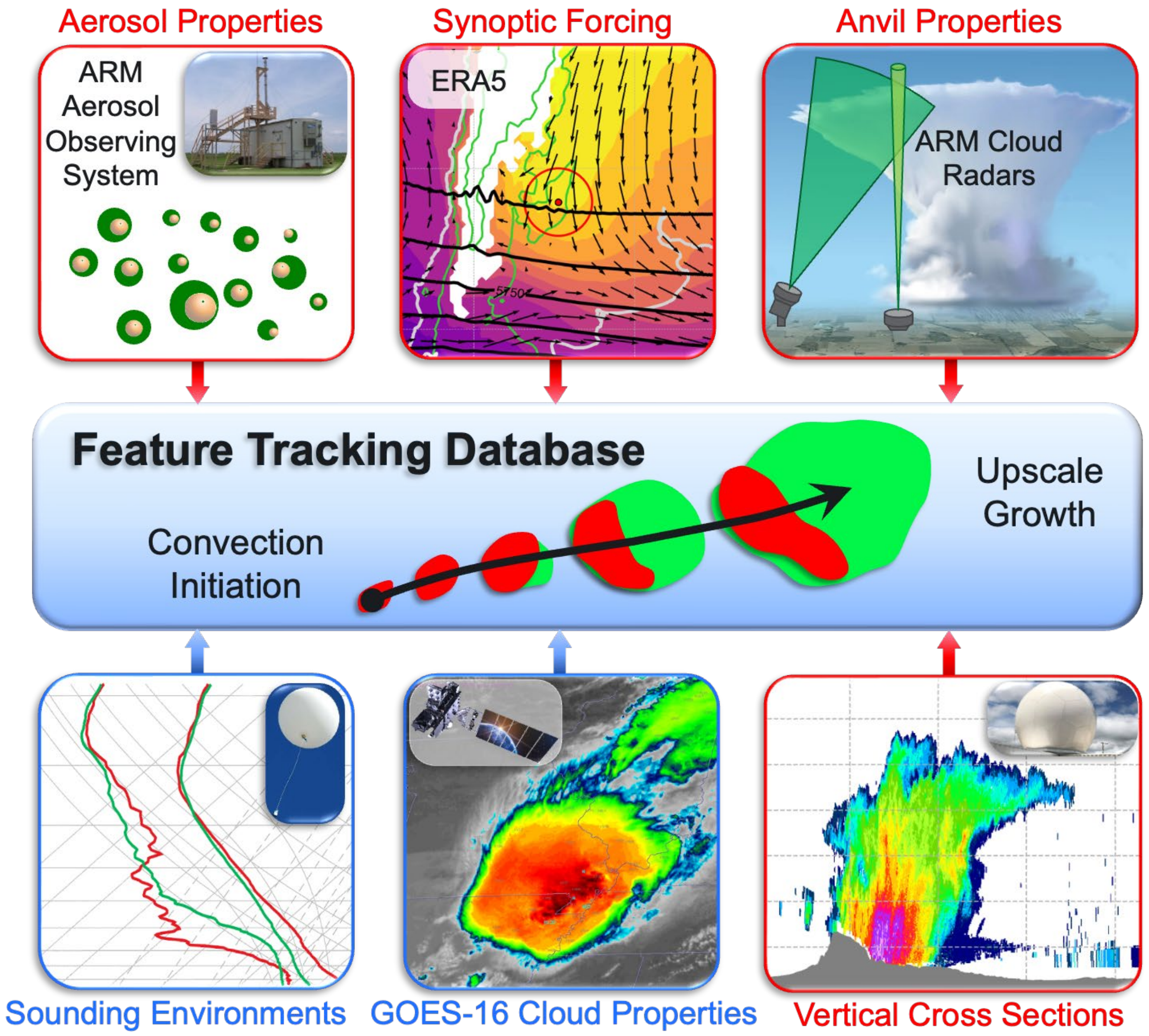


MCS Tracking



Path Towards Reducing Uncertainties in CPMs

- Develop an **observation-model integration framework** centered around *Lagrangian convective cloud lifecycle*
- Build a large, comprehensive **convective feature tracking database** from ARM OBS and available CPM/LES in multiple regimes, use observationally-constrained simulations to understand and improve processes contributing to CPM biases
- Example from **CACTI-LASSO** efforts:
  - **Radar cell tracking database** released: https://doi.org/10.5439/1844991
  - **OBS:** will add synoptic forcing, aerosols, and cloud vertical structures
  - **LASSO:** matched updraft/downdraft statistics, near-cloud environments, updraft entrainments
- We welcome collaborations and contributions



Contact: **Zhe Feng** (zhe.feng@pnnl.gov)

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