Tracking Convective Cells in Observations and LASSO towards Understanding Deep Convective Cloud Growth

Zhe Feng

2022 ASR PI Meeting Breakout – CACTI

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

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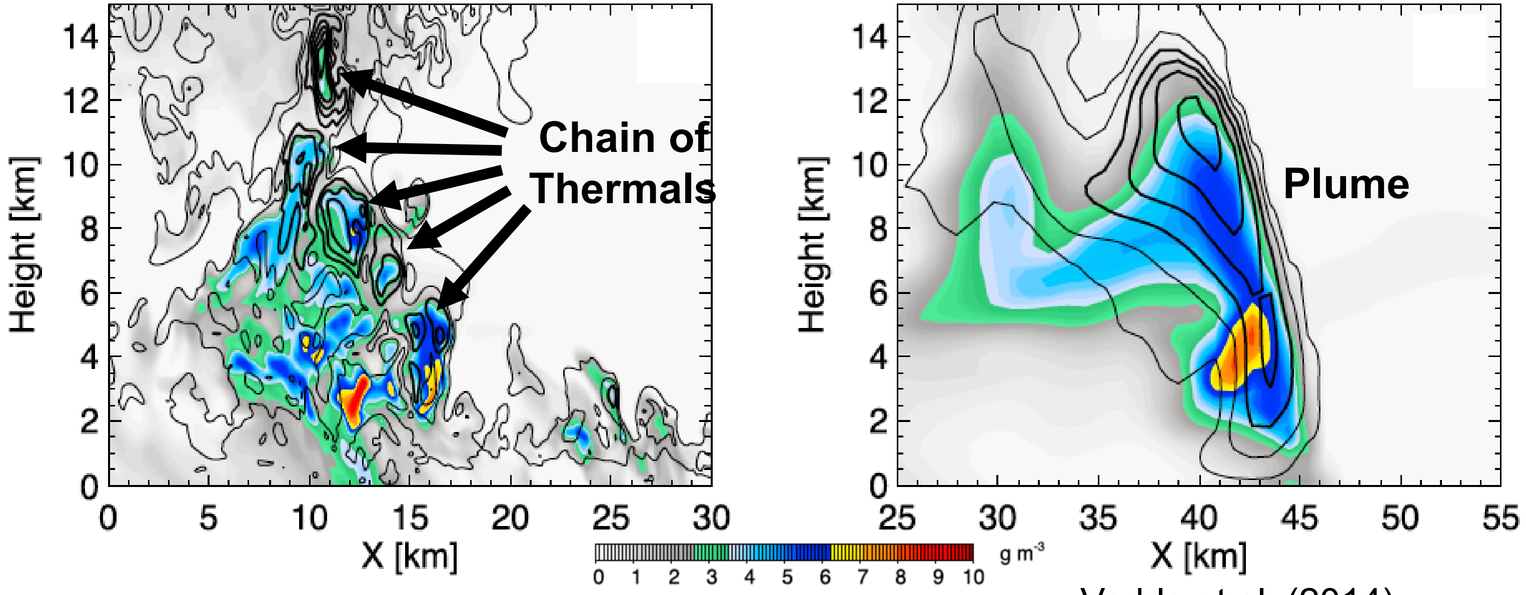
Integrated Cloud, Land-Surface,& Aerosol System Study
ICLASS

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

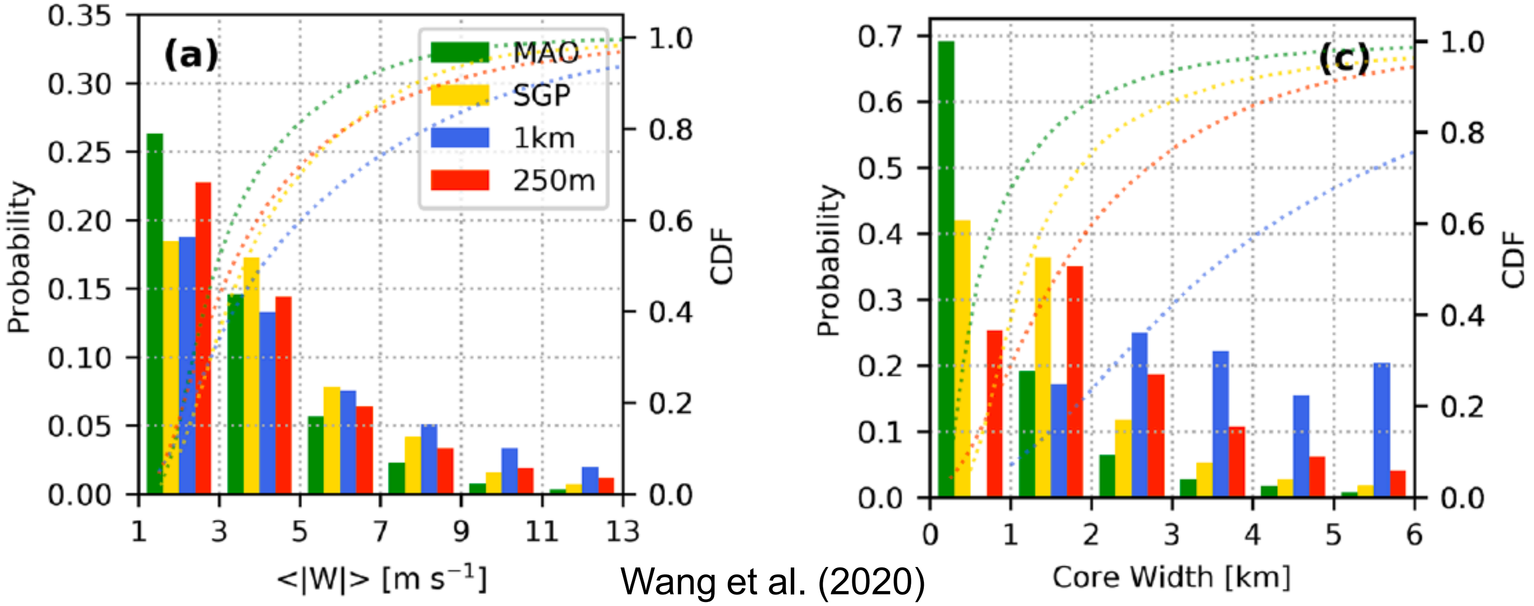
TWP-ICE 100-m DHARMA-LES W (black) and Condensate (color)

TWP-ICE 900-m DHARMA-CRM W (black) and Condensate (color)



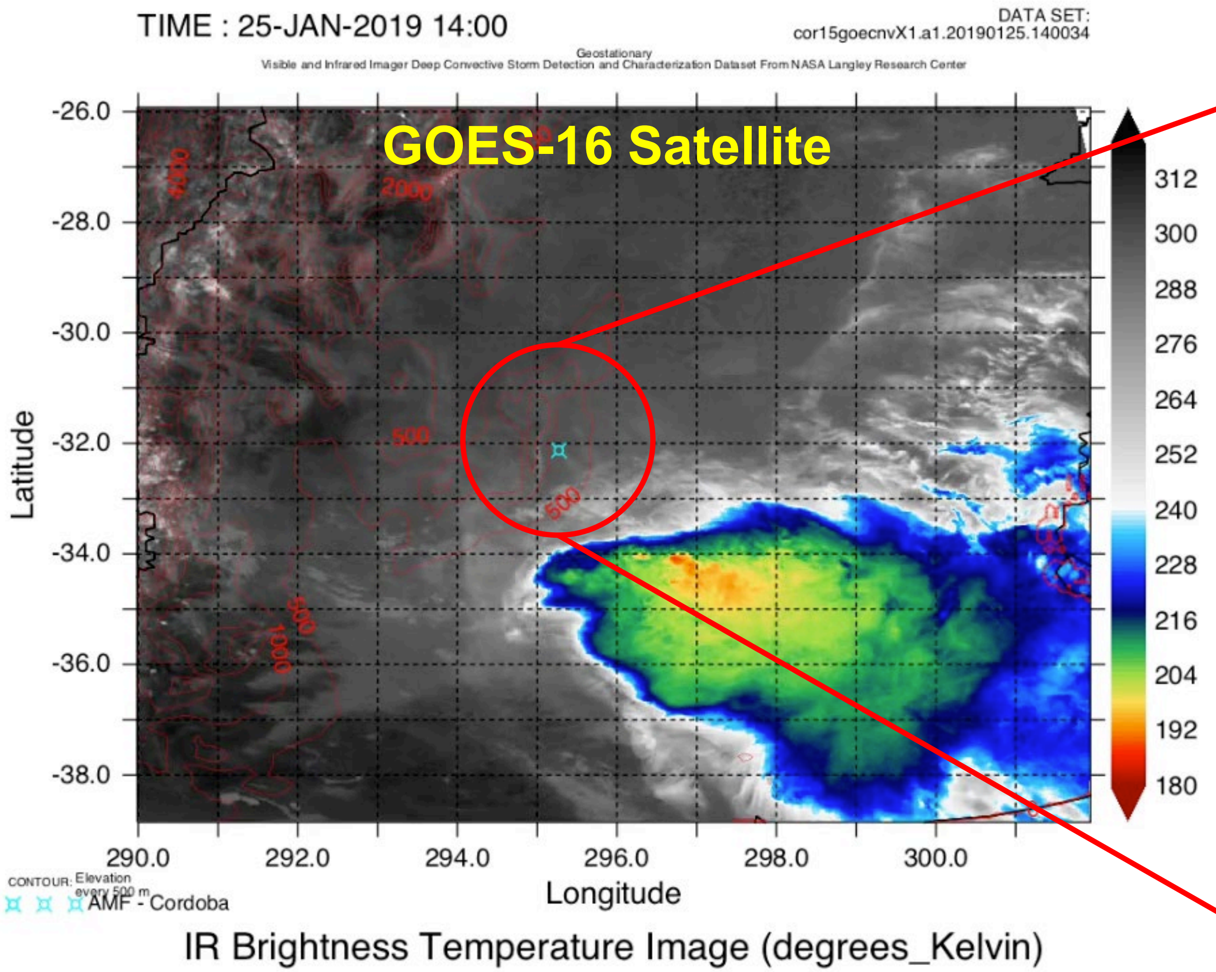
Varble et al. (2014)

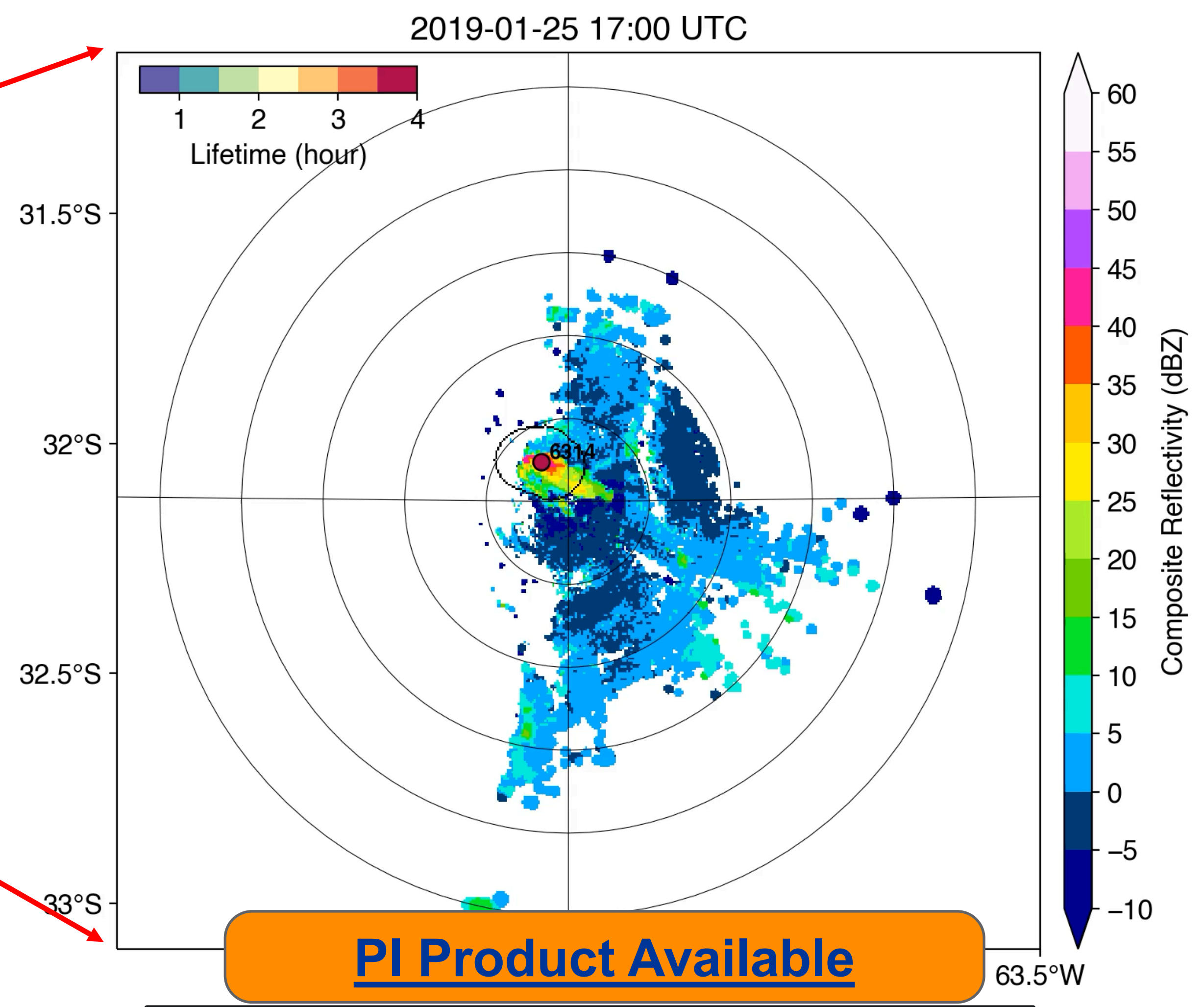
Amazon (green) and Oklahoma (SGP) Vertical Profiler Updrafts vs. Models



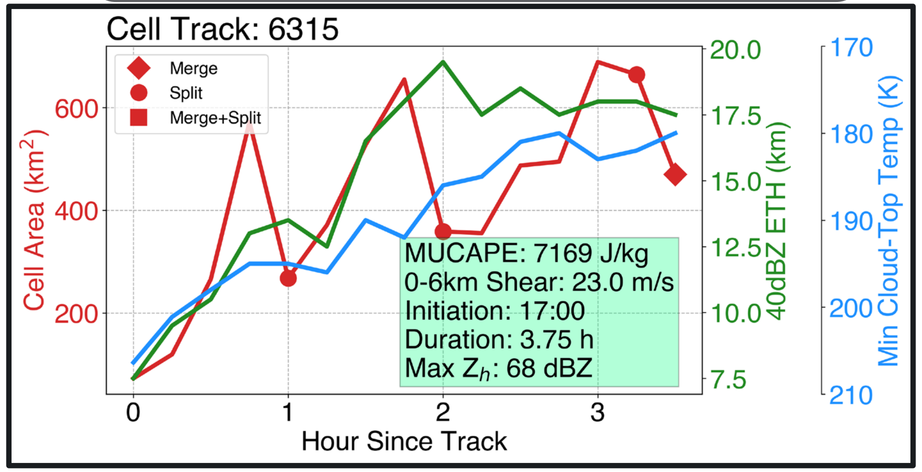
Wang et al. (2020)

Approach: Convective Cell Tracking Database





PI Product Available

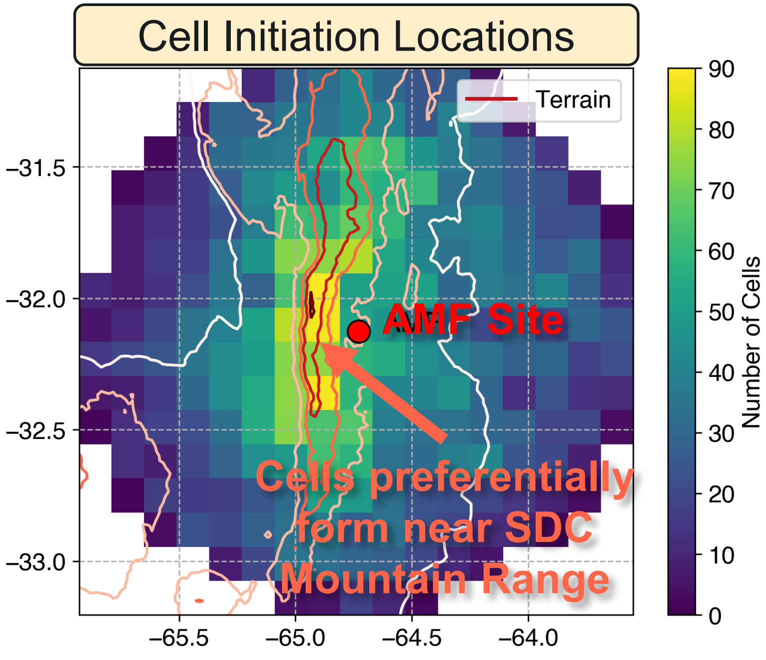


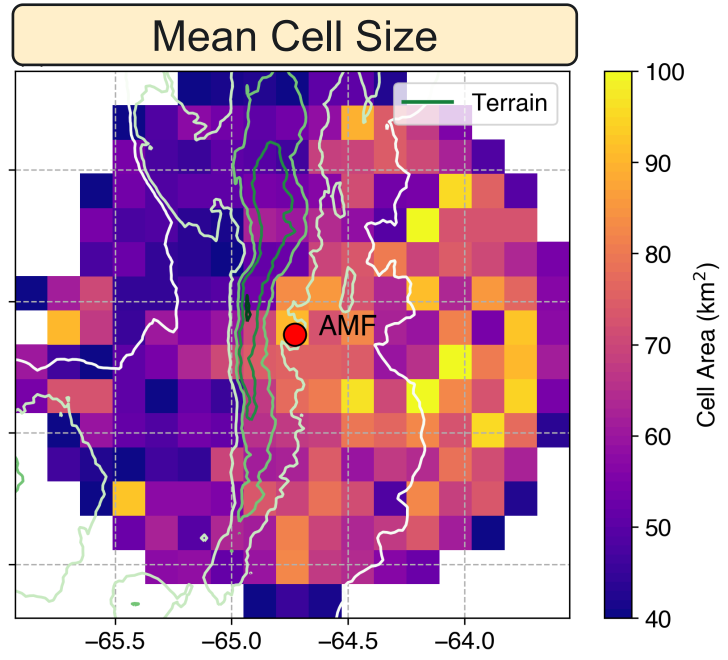
- Develop a **convective cell tracking database** using CSAPR radar reflectivity (Feng et al. 2022 *MWR*):
  - ~6900 tracked convective cells
  - Cell time, location, duration, size, echo-top, merge/split
  - Profiles of Z_e, Z_{DR}, K_{DP}, rain rate, D_m, etc.
  - Parallax corrected NASA Langley GOES-16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

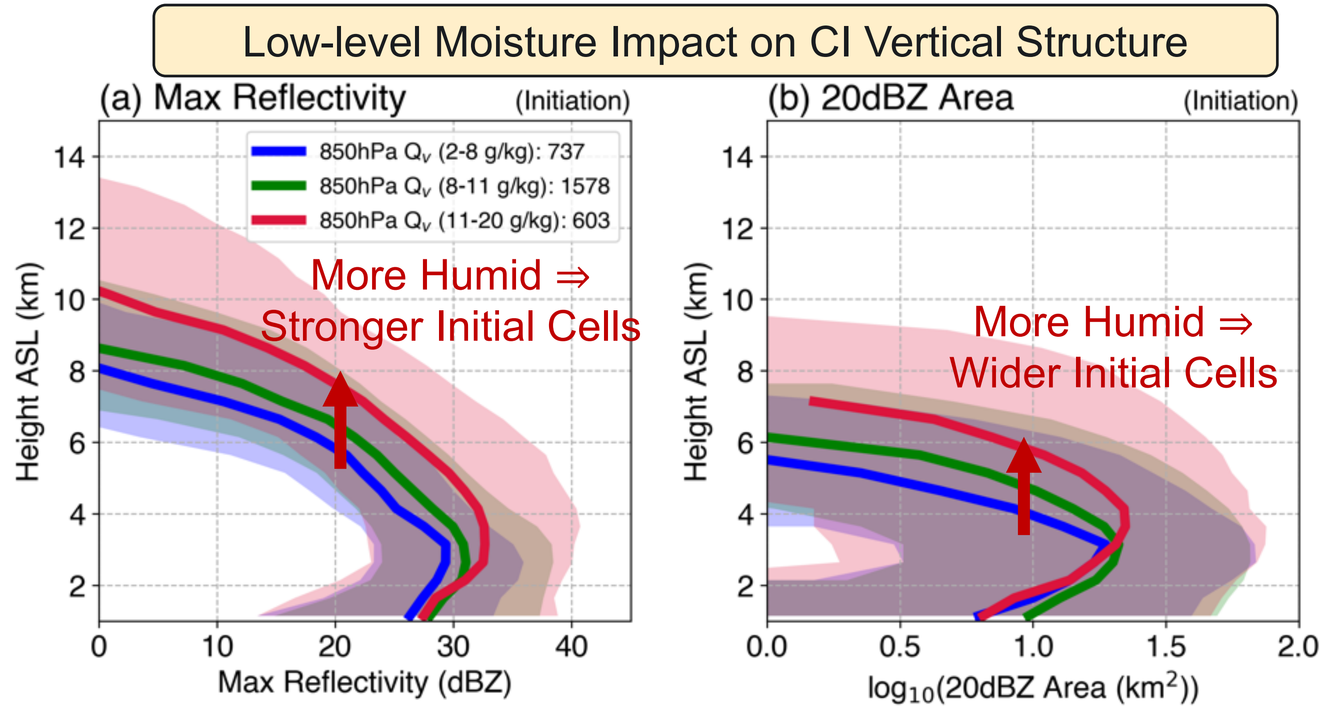
Quantifying Environmental Controls of Deep Convection Initiation

Feng et al. (2022) *MWR*

- Convection initiation **(CI) preferably occurs** just **east of** the Sierras de Córdoba **(SDC) ridge**
- **Largest and deepest** convective **cells** are observed **east of the SDC**
- Cells initiating in **more humid** low-level environments are **wider above the boundary layer** and **more intense** ⇒ wider initial updrafts
- Jim Marquis will present more analysis of CI ingredients next

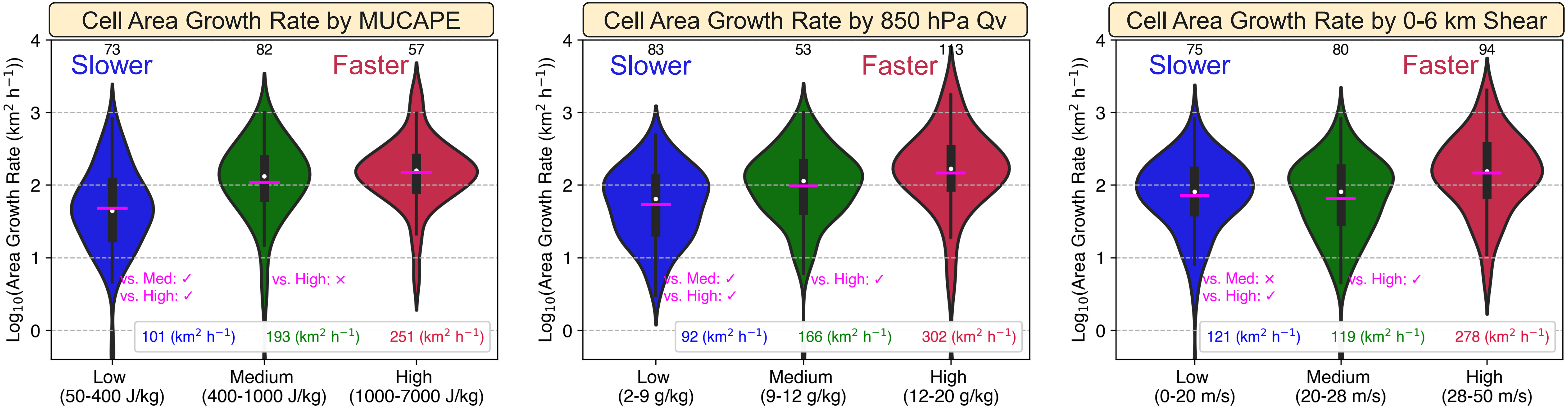






Rapid Cell Area Growth Depends on Large Low-level Moisture and Wind Shear

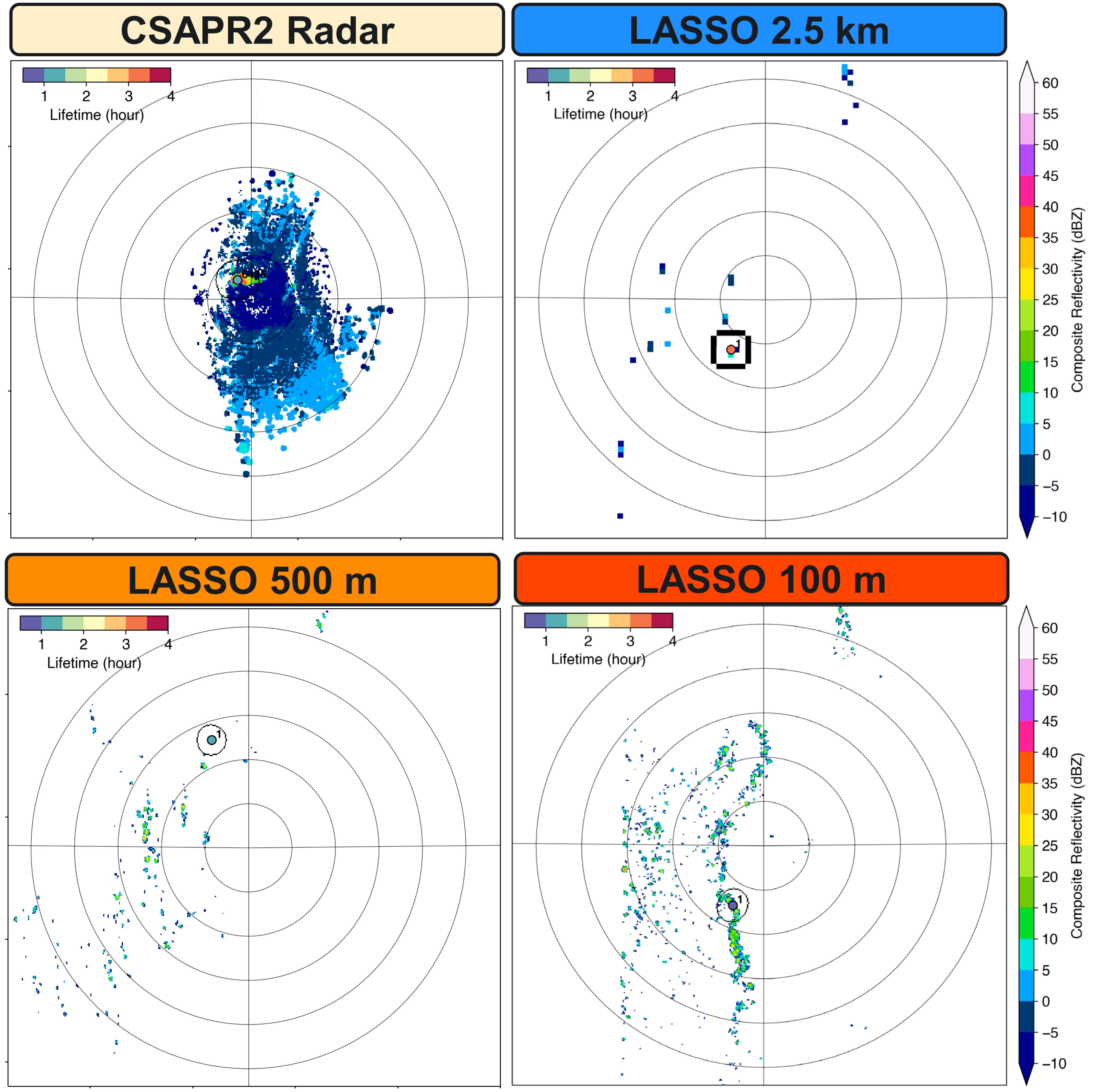
Feng et al. (2022) *MWR*



- Cells occurring in the **greatest** MUCAPE, 850 hPa humidity, and 0-6 km shear exhibit clearly **faster growth** compared to the environments with lowest values
- Growth rates in moderate environments are not always significantly different from lesser or greater environments
- Other factors may affect cell growth rates: synoptic and mesoscale circulations, low level moisture flux, cold pool-wind shear interactions, cell-cell interactions

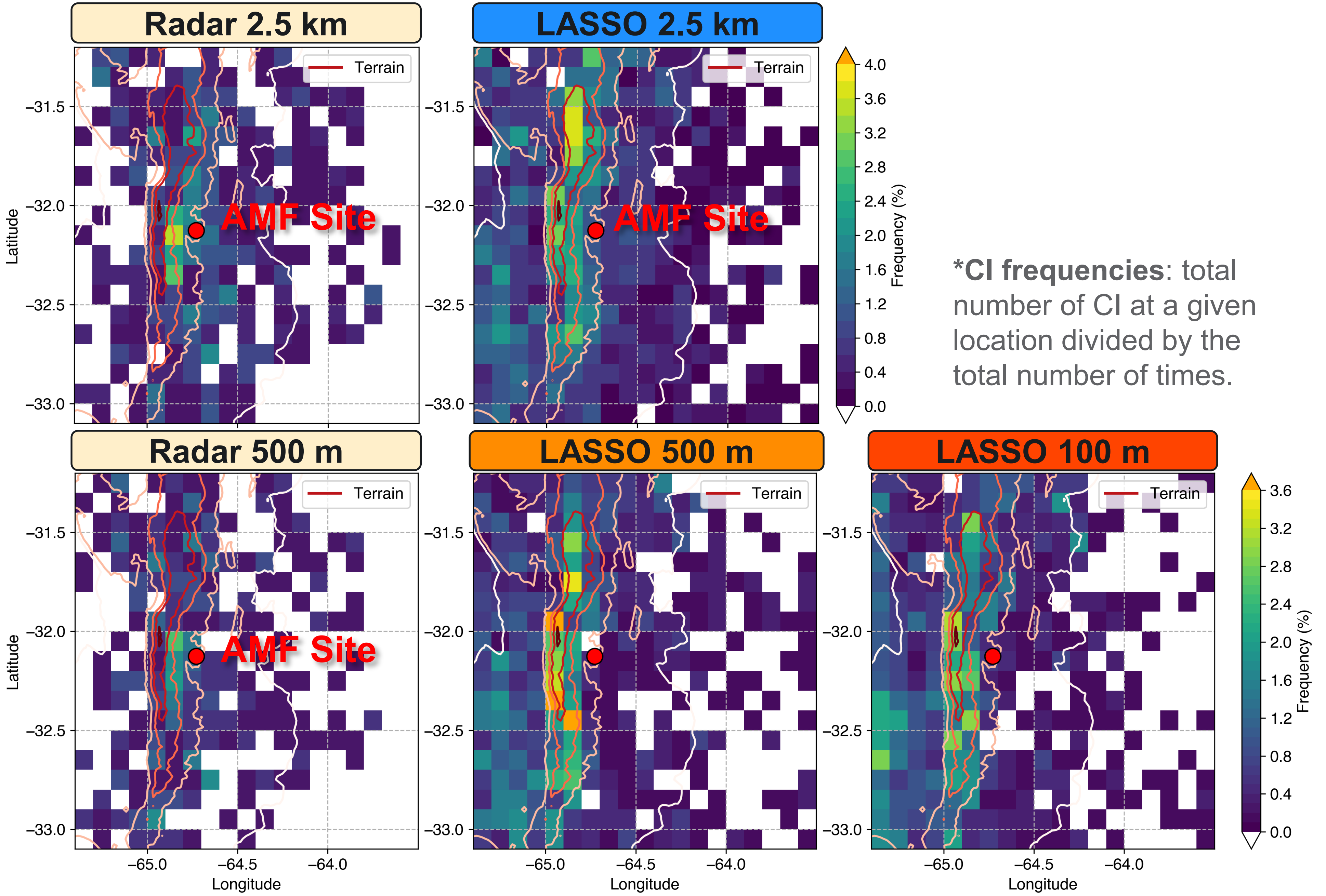
Adapt Cell Tracking to LASSO Simulations

- We adapted PyFLEXTRKR to track convective cells in LASSO simulations at CPM and LES grid spacings
  - **Radar** tracking: Δx: 2.5 km & 500 m
  - **LASSO** tracking:
    - ✓ Native Δx: 2.5 km & 500 m
    - ✓ Coarsen Δx: 100 m ➞ 500 m
- Environmental conditions for each tracked cell are obtained at CI locations in LASSO
- A total of 8 LASSO simulation days are used for analysis
  - Helping LASSO to evaluate the simulations



LASSO Captures Observed Peak CI Location over Mountain Ridgeline

- LASSO produces cells **more frequently*** over the mountain ridge than OBS
- **Differences** are **reduced** at **LES** scale but not eliminated, suggesting other causes (e.g., large-scale forcing, orographic circulations, microphysics)



***CI frequencies**: total number of CI at a given location divided by the total number of times.

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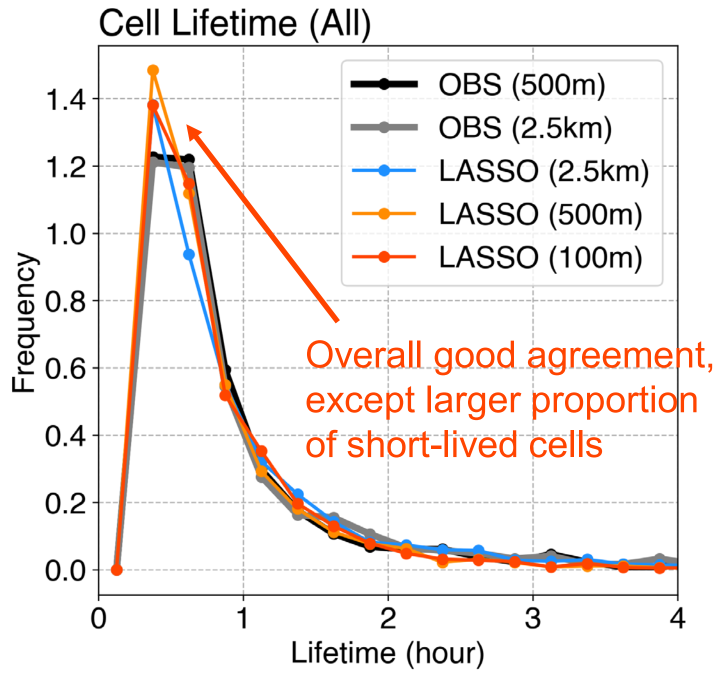
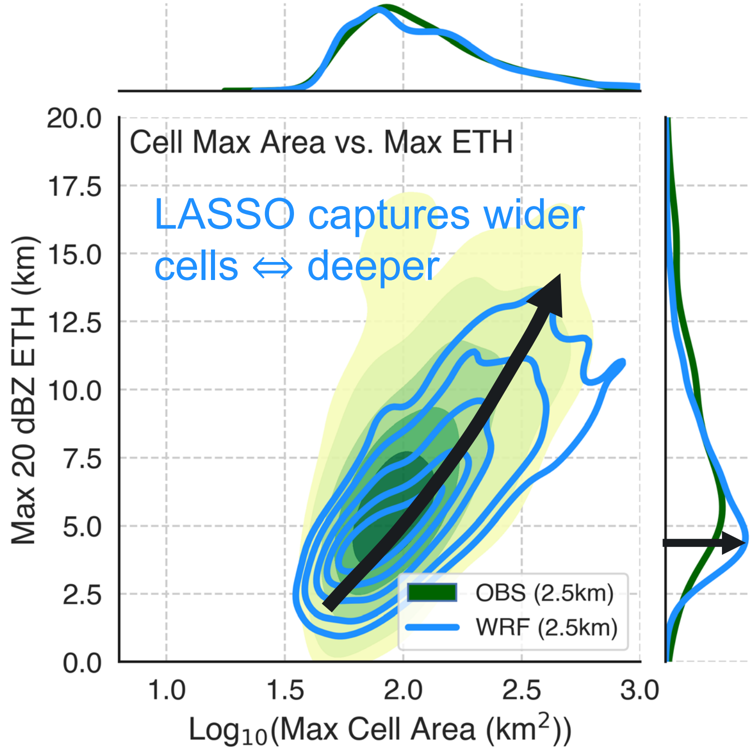
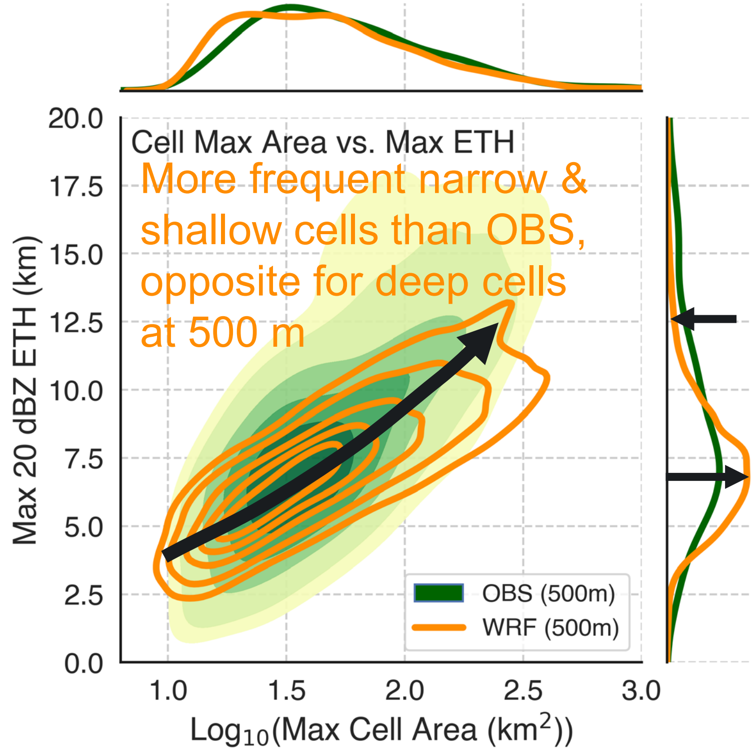
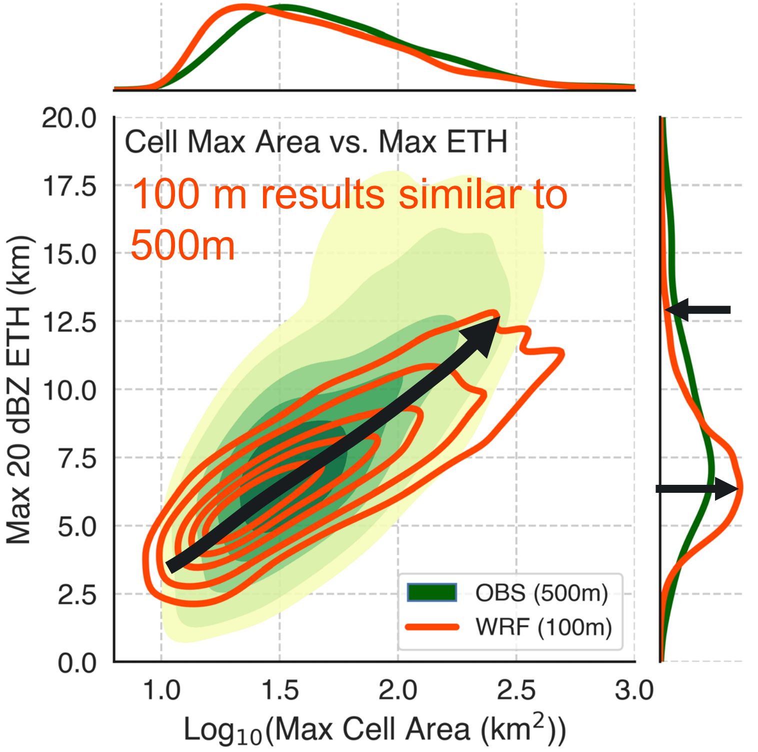
LASSO Reproduces Important Observed Convective Cell Statistics

- Model cell lifetime agrees well with observations, except for larger proportion of short-lived cells
- LASSO captures relationship between wider and deeper cells, but has more frequent shallow cells than OBS
- Higher resolutions still produce more frequent narrow and shallow cells, but less frequent deep cells
  - Maybe related to microphysics (e.g., forming ice too quickly)
  - Partly related to radar interpolation artifacts at upper-levels
  - Need further investigation



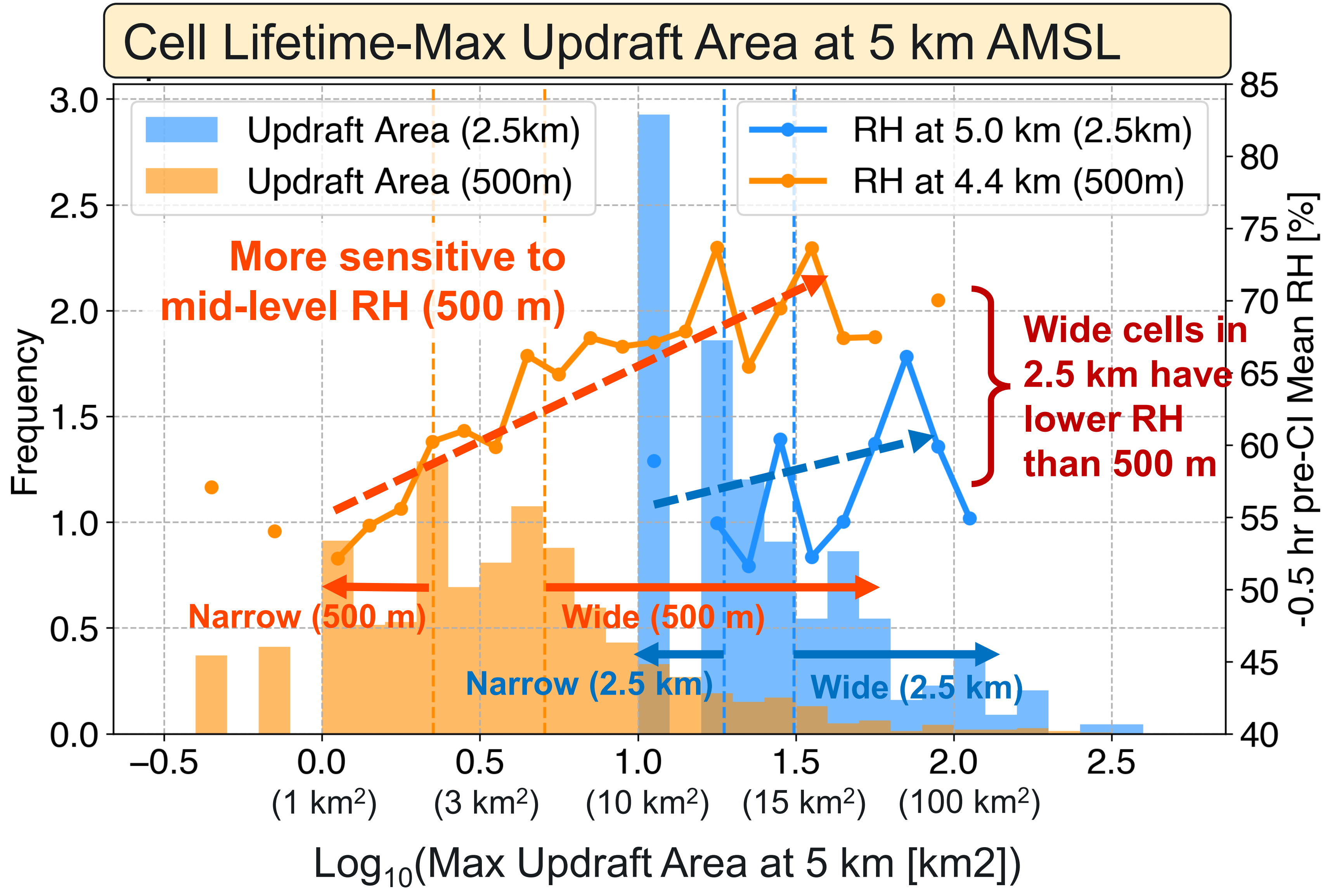






Updraft Width Dependence on Relative Humidity

- 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



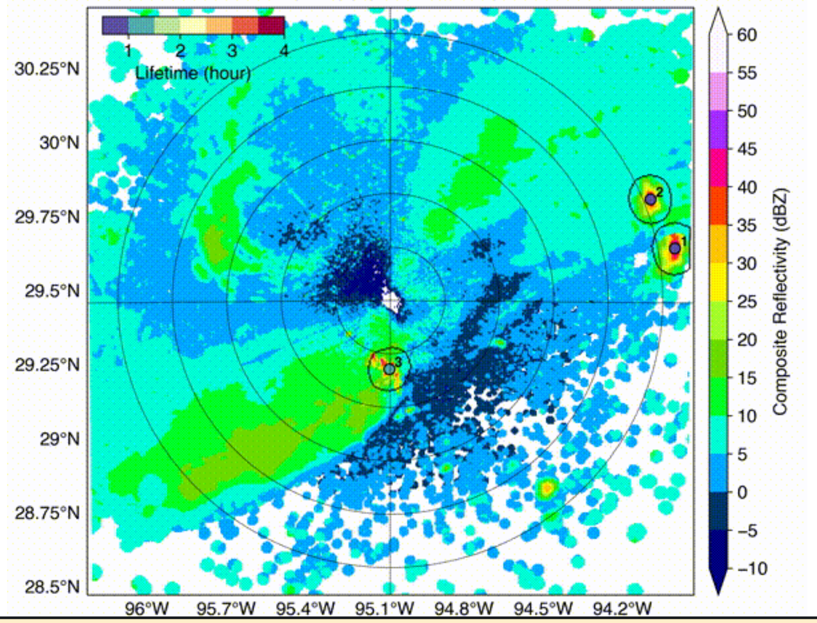
*Narrow cells: ≤ 1/3 updraft area distribution; Wide cells: ≥ 2/3 updraft area distribution

PyFLEXTRKR Software Package for Community Use

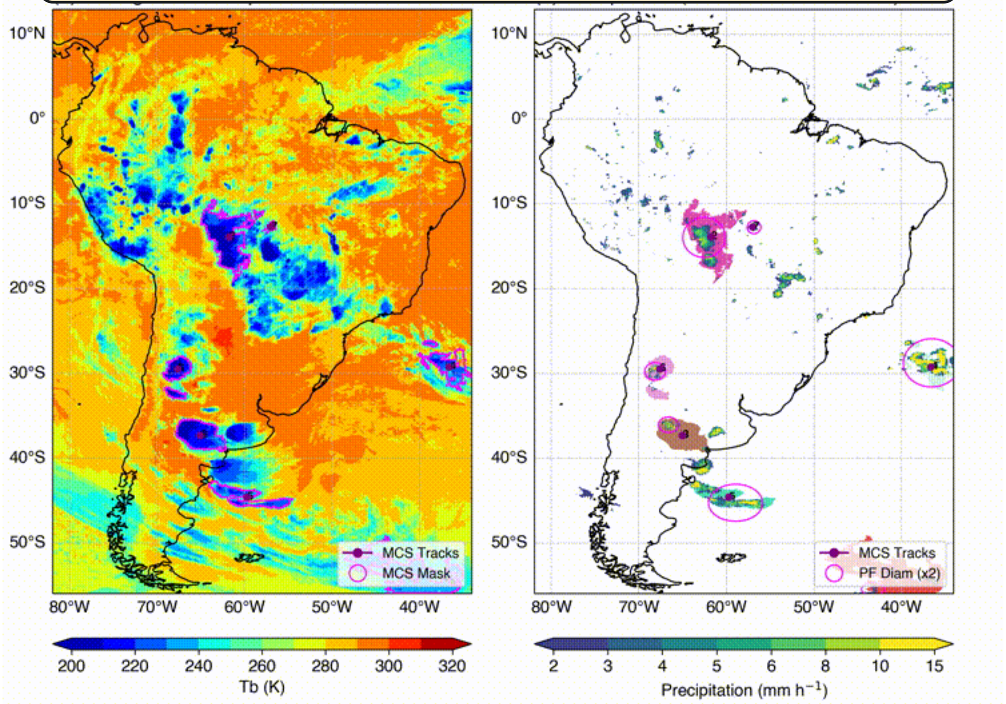
Feng et al. (2022), *submitted*

- 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



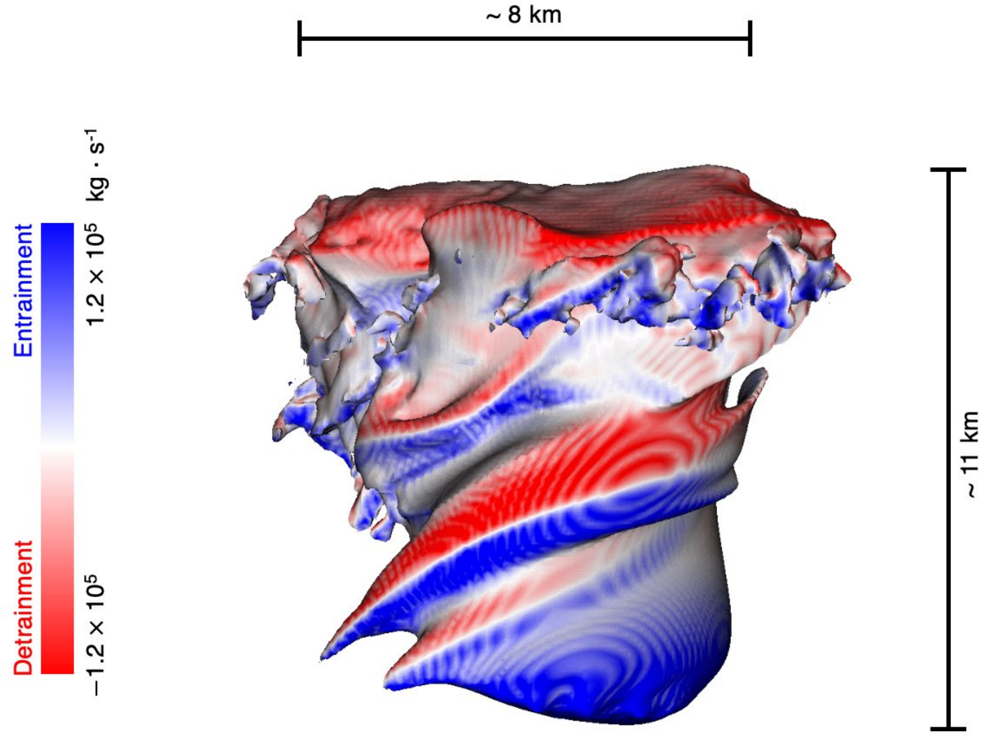
MCS Tracking



Summary and Future Work

- We developed a prototype observation-model integration framework based on **Lagrangian tracking of convective cell lifecycle**
  - CSAPR cell tracking database is available as PI data
  - Adapted to LASSO simulations at CPM and LES scales
- On-going research on **understanding convective cloud growth** using LASSO simulations:
  - LASSO reproduces important observed convective cell statistics
  - Simulations have more frequent shallow, short-lived cells than radar observations, higher resolution reduces but does not eliminate such differences
  - Under-resolved convective updrafts in CPM have muted response to mid-level RH compared to LES
- Future work will examine resolution dependance on entrainment effects

Direct Calculation of Entrainment / Detrainment from Updrafts



Jo & Lasher-Trapp (2022) *JAS*

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

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