Transitions in Convective Cloud Populations

PNNL SFA – "Integrated Cloud, Land-surface, and Aerosol System Study"

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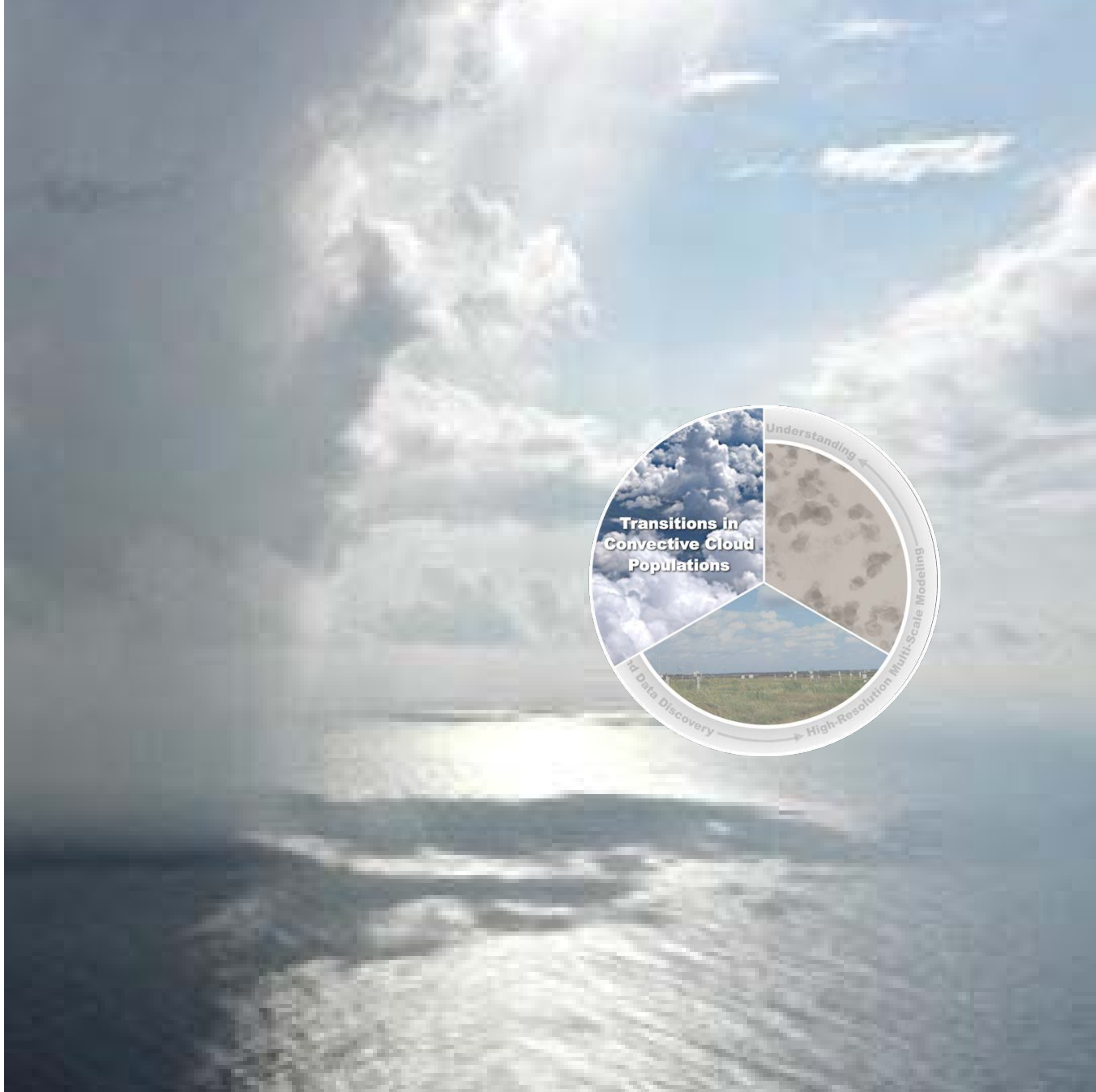
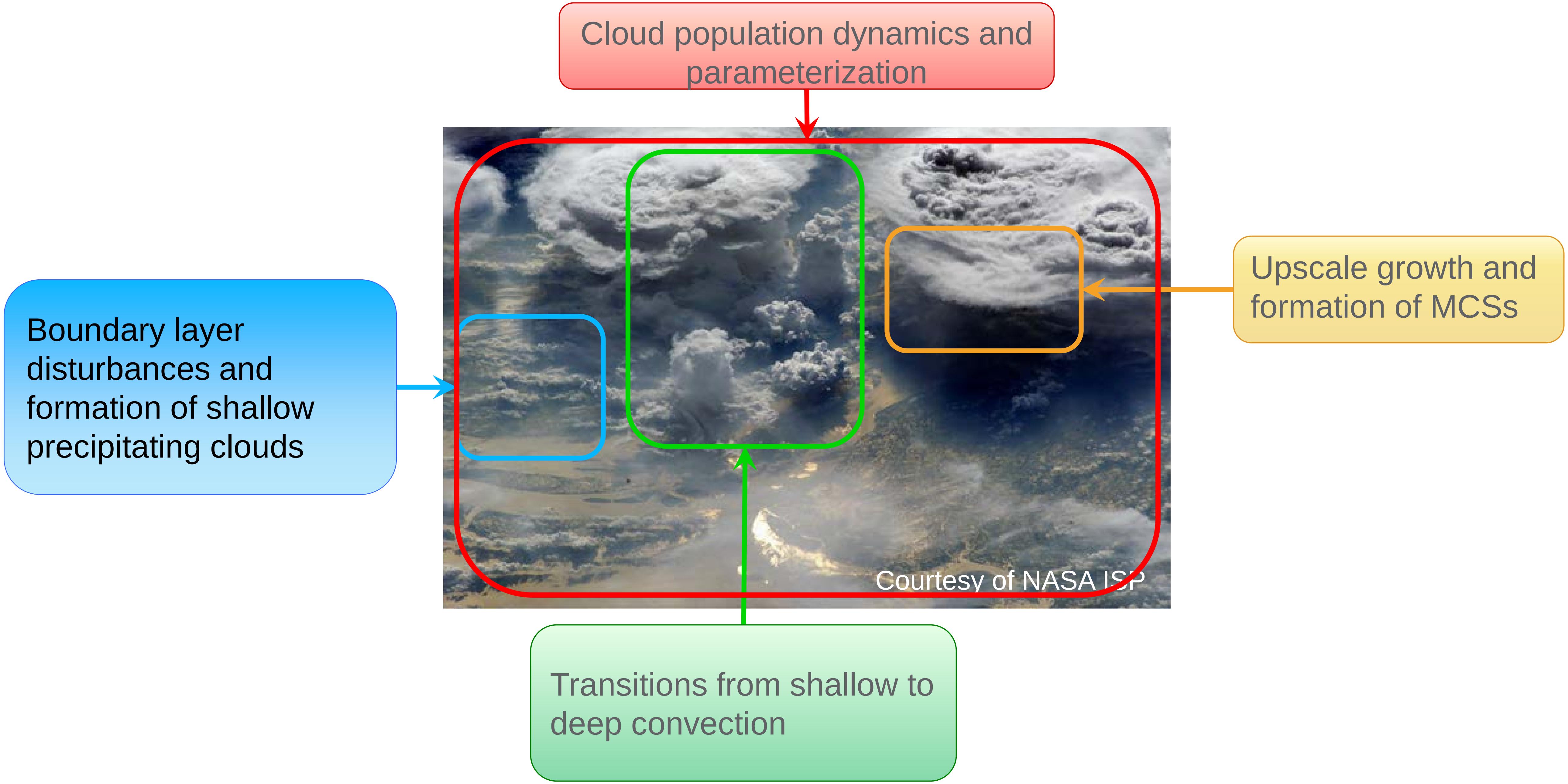
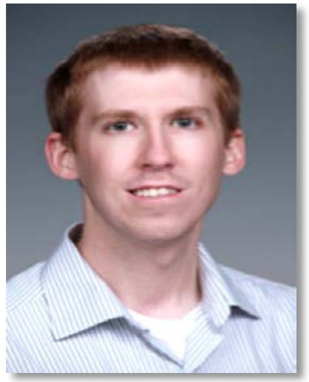


Overarching Science Question

- What are the key factors that control transitions in cloud populations?



The PNNL ICLASS Convection Team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Katelyn Barber (new)

Observational data and simulation locations

Regions

Approaches/tools

High resolution modeling, radar, satellite and sounding observations, **data assimilation, flexible tracking algorithm, Machine learning.**

Specific processes/factors we are examining this year

Impacts of land surface heterogeneity and cold pools

Impacts of large-scale advection and thermodynamic structure

Environmental conditions over a complex topography (CACTI)

Microphysical and macrophysical processes

Interactions between convective and stratiform clouds

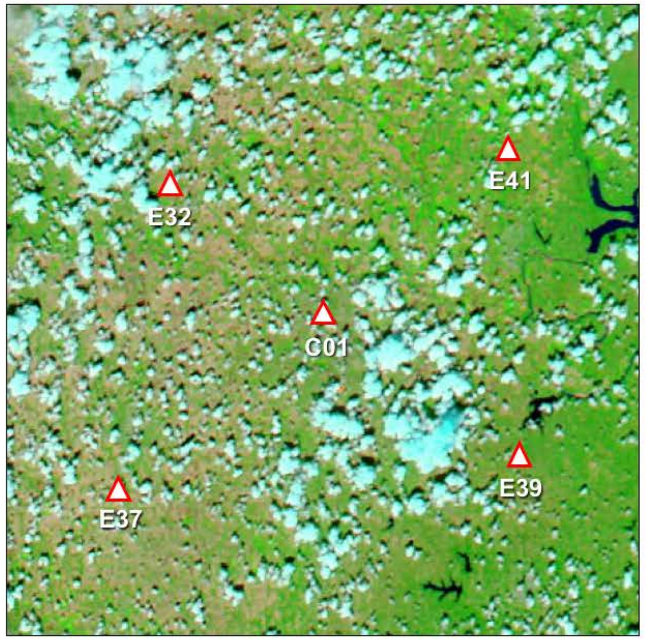
A link between convective drafts and MCS evolution

Parametrization improvements

Soil moisture and cold pools (Fast)

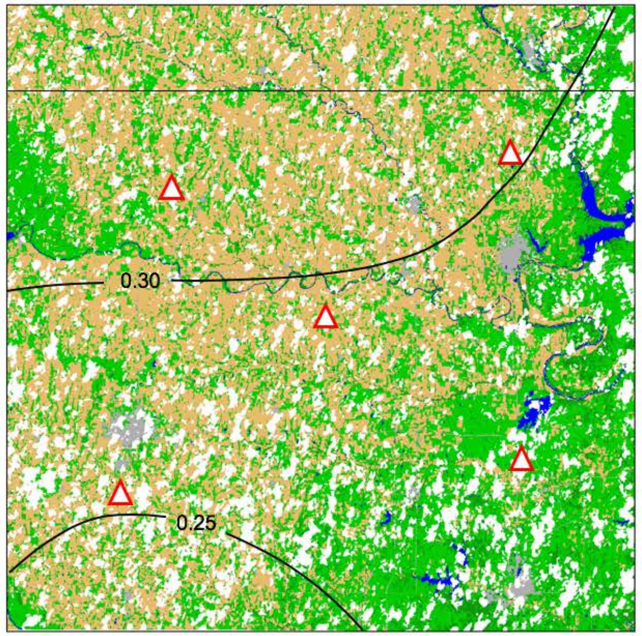
- **“Large” LES experiments** conducted to study the impact of variable land-atmosphere coupling on convective cloud populations observed on August 30, 2016 during HI-SCALE

MODIS ~1350 CST

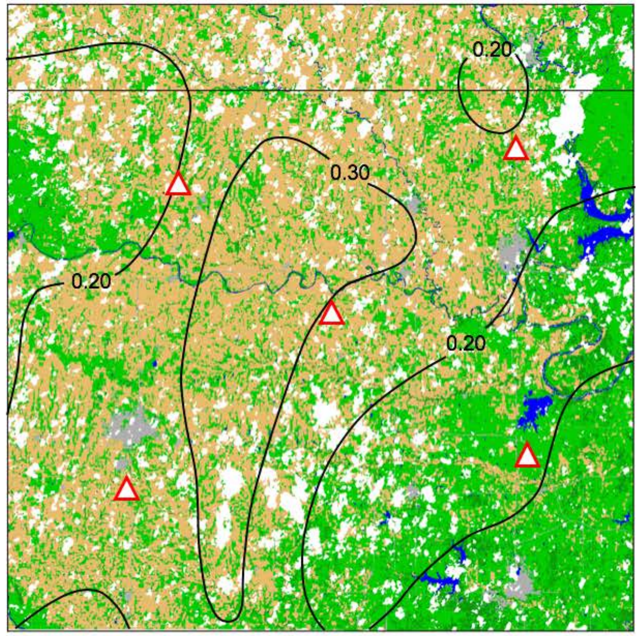


1 pixel = 250 m

Default (grass and crop only), **Δx = 100 m**



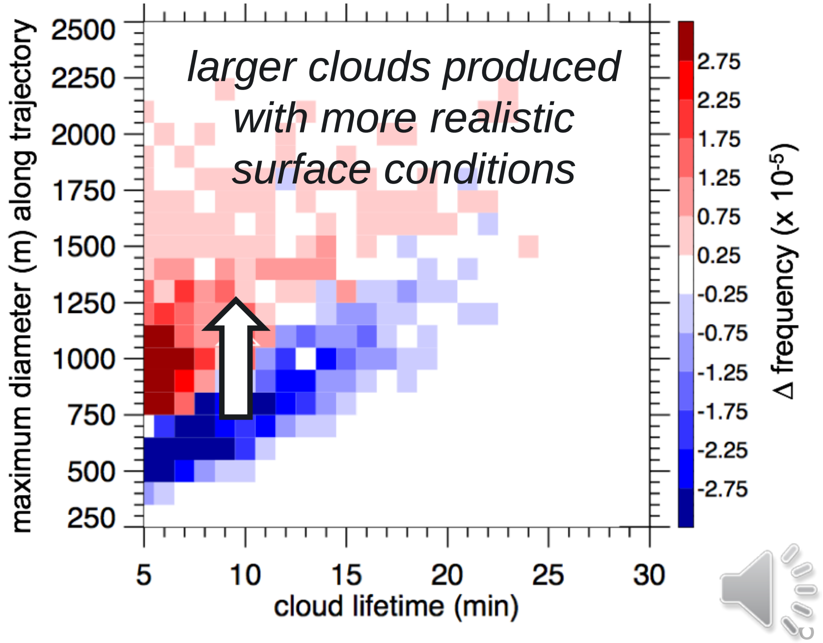
Revised: ARM+OK mesonet data and some satellite products**, Δx = 100 m**



120 km

- Need to account for variable (sub-grid) land-atmosphere interactions and cold pools in shallow convection parameterizations

Revised - Default



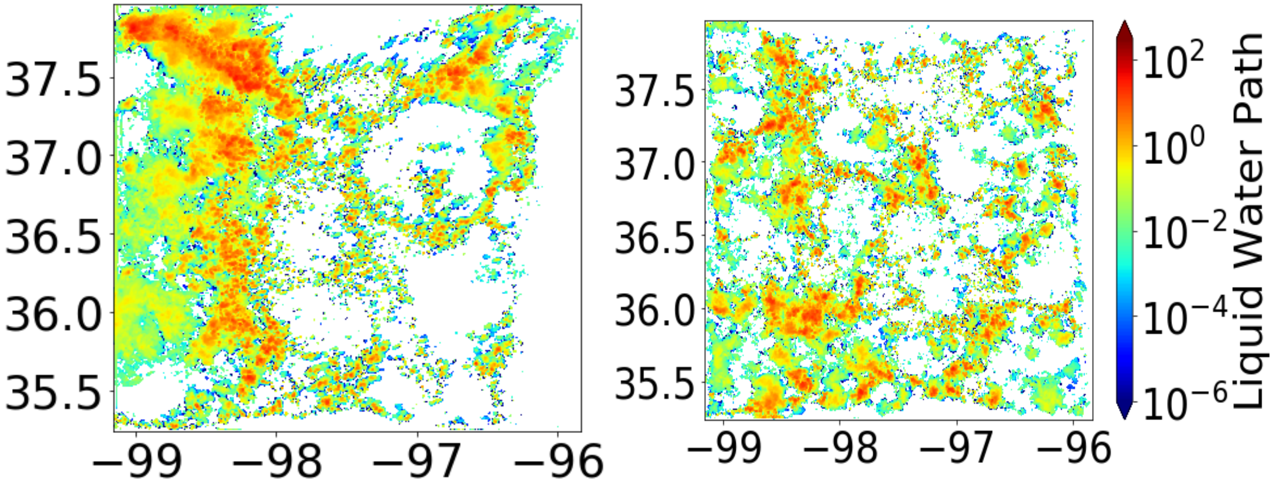
- Model can reproduce observed heterogeneity in clouds and shallow-to-deep transitions only if realistic variations in soil moisture are used.
- **Soil moisture** drives initial cloud fields, then **cold pools** become important during the afternoon.

Fast et al. (2019), submitted to JAMES

Advection and soil moisture (Chen)

- To examine the effects of large-scale advection on land-atmosphere interactions and the initiation of shallow precipitating clouds using high-resolution model simulations.

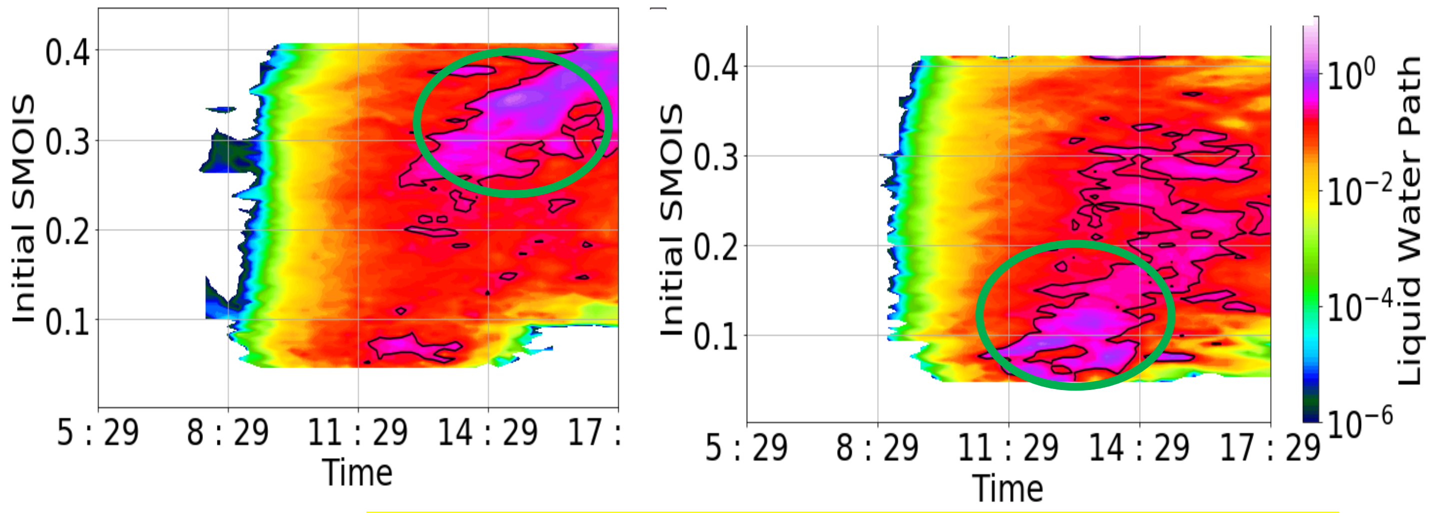
Control simulation | “No-advection” simulation



In the “no-advection” case, wind and horizontal gradients of moisture, pressure, and temperature are removed from the initial and boundary conditions.

Relationships between Initial SMOIS and Liquid Water Path

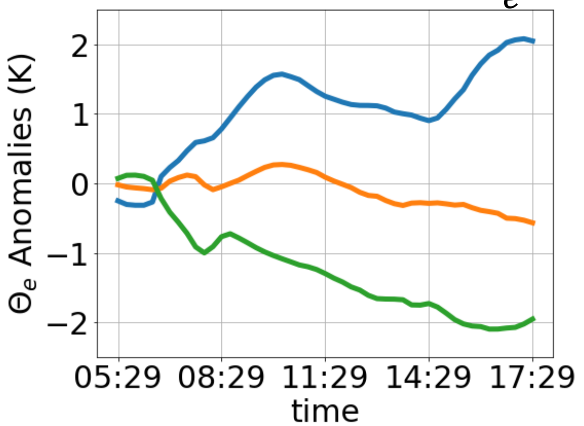
Control simulation | “No advection” simulation



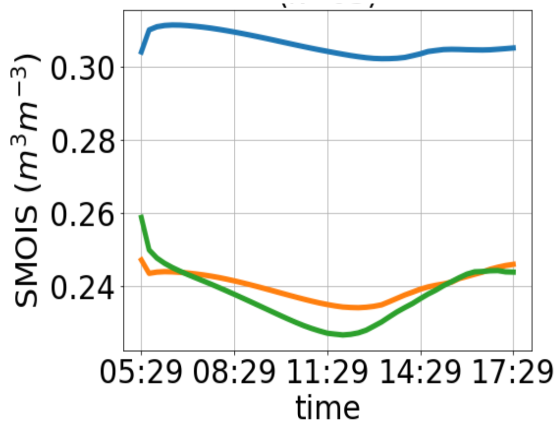
- Cluster analysis algorithm successfully divides the time series of θ_e of all grids into 3 clusters, which represent different convection features.
- Found that in the absence of advection, 1) liquid water path is more sensitive to soil moisture; 2) liquid water path increases earlier than those in the control simulation.

Cluster Analysis of “No Advection” Simulation

Time series of θ_e Anamolies



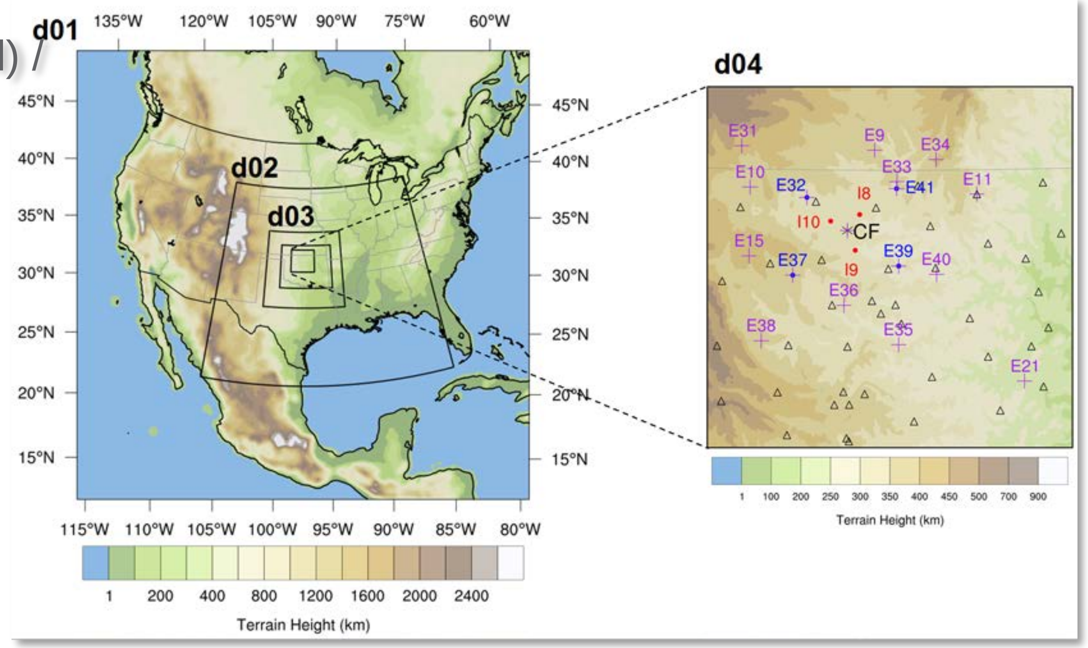
soil moisture (m^3 m^{-3})



The role of thermodynamic structure (Tai)

- updated wind, pressure, moisture, and temperature by assimilating the conventional and ARM SGP observations.

- **Tools:** WRF (Model) / GSI (DA)
- **Observations:** NCEP global / ARM SGP
- **Grid sizes:** 36 / 12 / 4 / 1.3 km



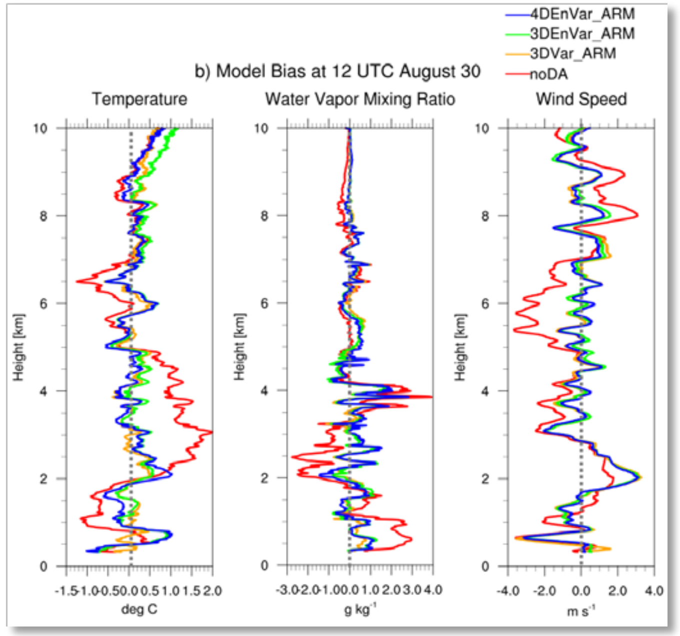
- **Product and potential:** Accurate higher-resolution I.C. and B.C. Direct initialization of LES simulation

- **Major findings:**

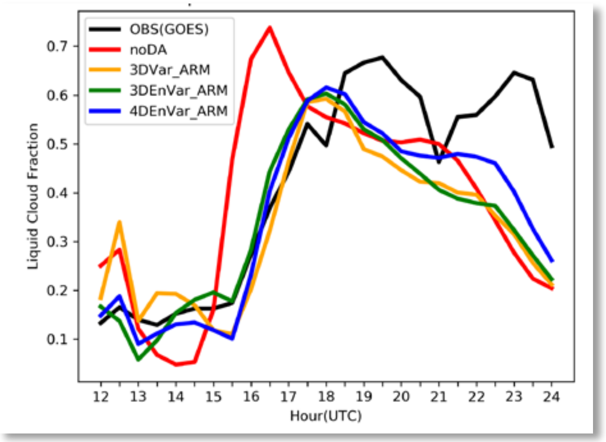
More realistic:

ambient environment

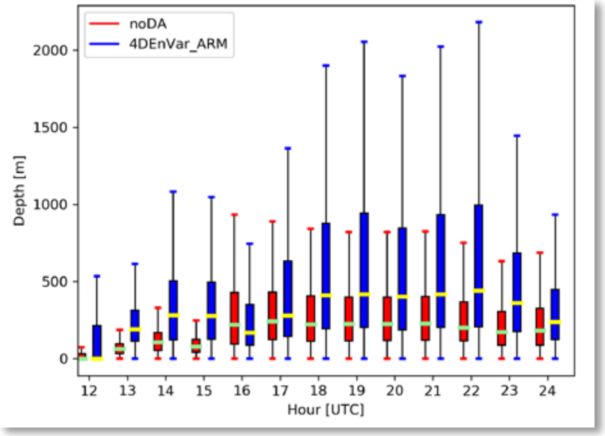
boundary layer heterogeneity



ShCu initiation



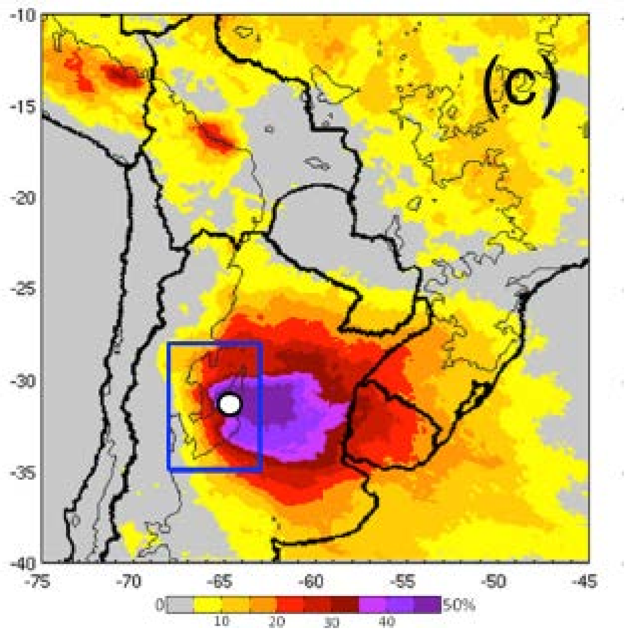
Shallow-to-deep transition



- Improved atmospheric stability (T and Q profiles) corrected the ShCu initiation timing,
- The increased 2-4 km moisture due to assimilation led to more realistic shallow-to-deep cloud transition.

Environmental conditions over a complex topography (Varble)

CACTI



A location with extremely frequent cumulus development, deep convective initiation, mesoscale convective organization uniquely observable from a fixed site.

<u>Timing / Location</u>:

15 Oct 2018 – 30 Apr 2019
Sierras de Córdoba Mountain Range, Argentina

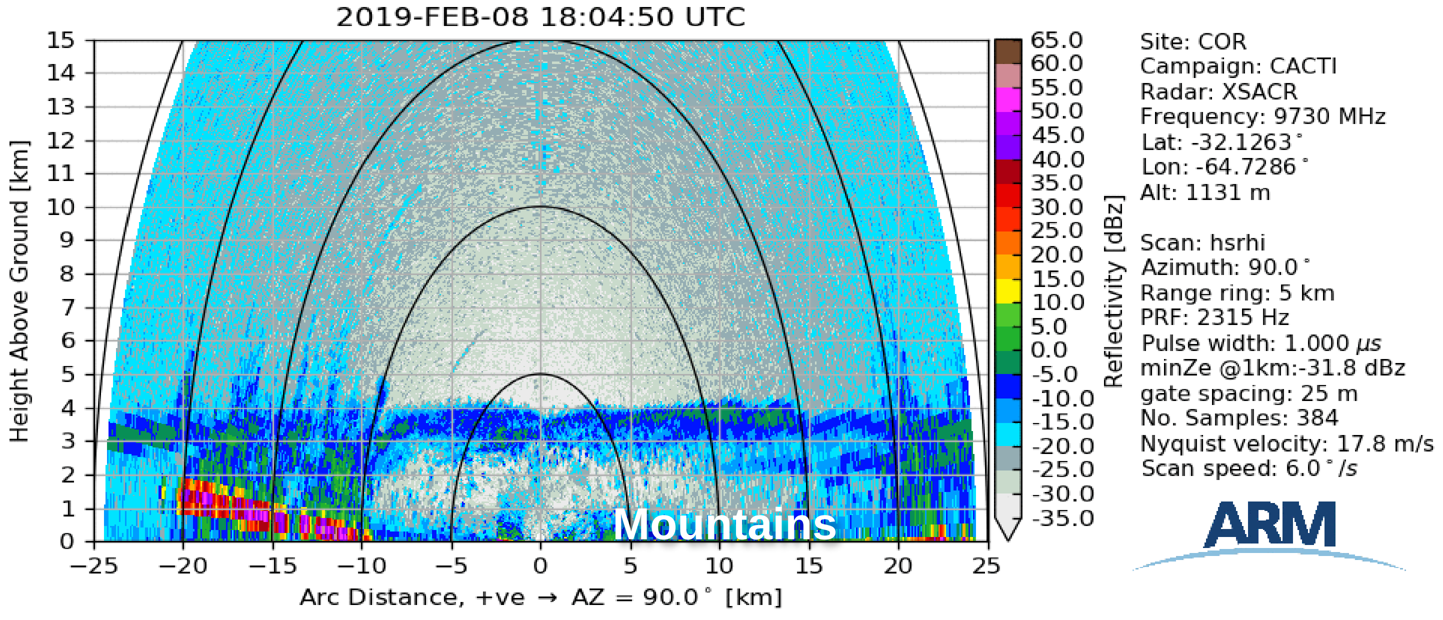


Figure from Joe Hardin and Nitin Bharadwaj

Example X-SACR vertical cross section through an event .

- An inversion layer breaking up as orographic shallow showers form and transition to deep convection over the primary surface observing site.

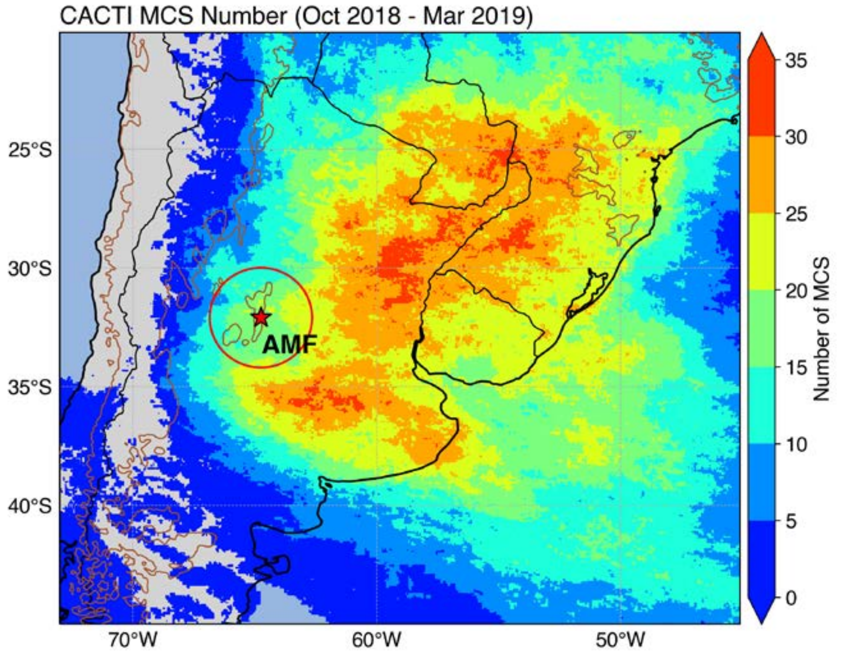
<u>Facilities</u>: AMF-1, C-SAPR2, G-1 aircraft (22 flights), with complementary PI, NSF, NOAA, and NASA measurements.

Microphysical and macrophysical processes (Feng)

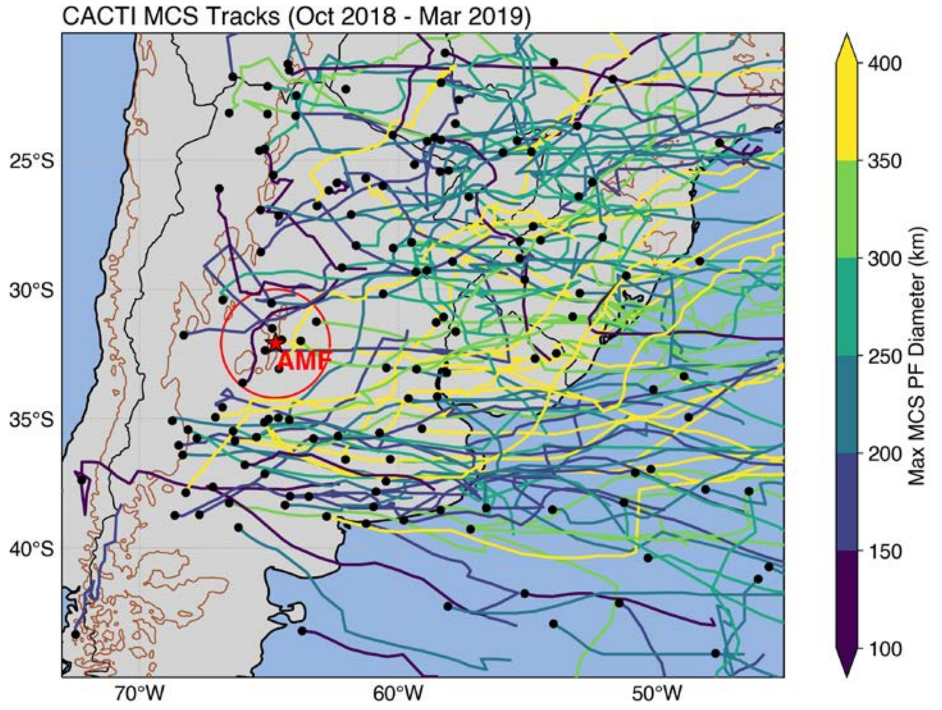
Pacific Northwest NATIONAL LABORATORY

- Characterize storm properties (macro- & micro-physical evolution) as a function of life cycle stage and environmental conditions using CACTI measurements high-res model simulations

Number of Intense MCSs during CACTI



Intense MCS Tracks during CACTI

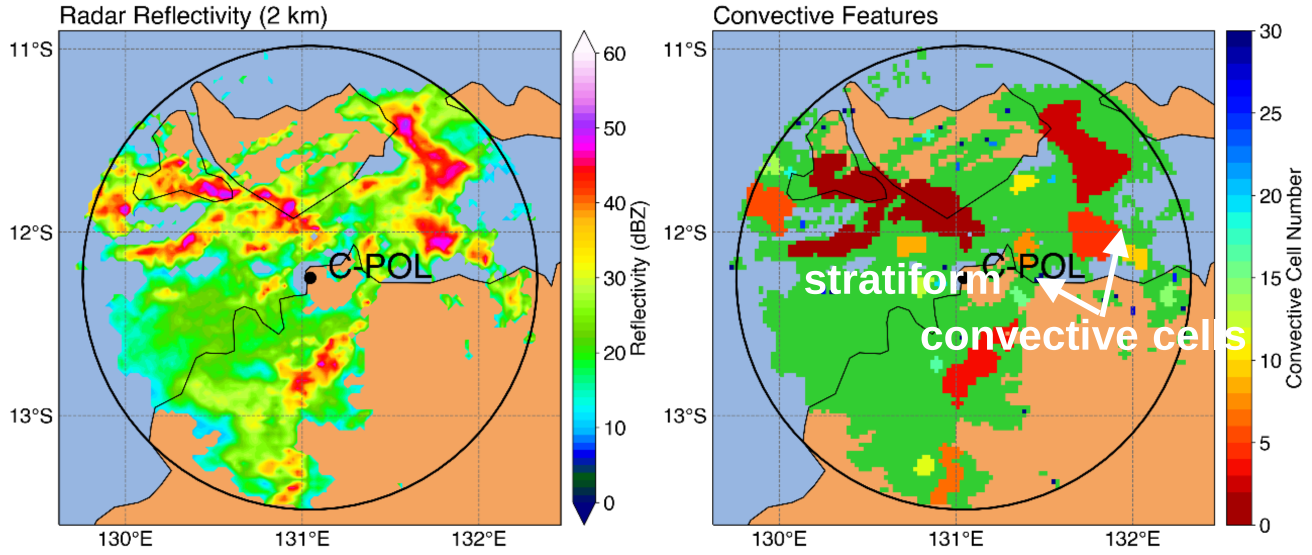


- Methodologies and data products:
  - Large-scale MCS tracking (FLEXTRKR, Feng et al. 2018) using operational satellite products
  - Produce radar microphysical retrieval products (developed under CMDV-MCS project) for CACTI
  - Produce a database of tracked storm objects using GOES-16 rapid scan in conjunction with CACTI radar assets

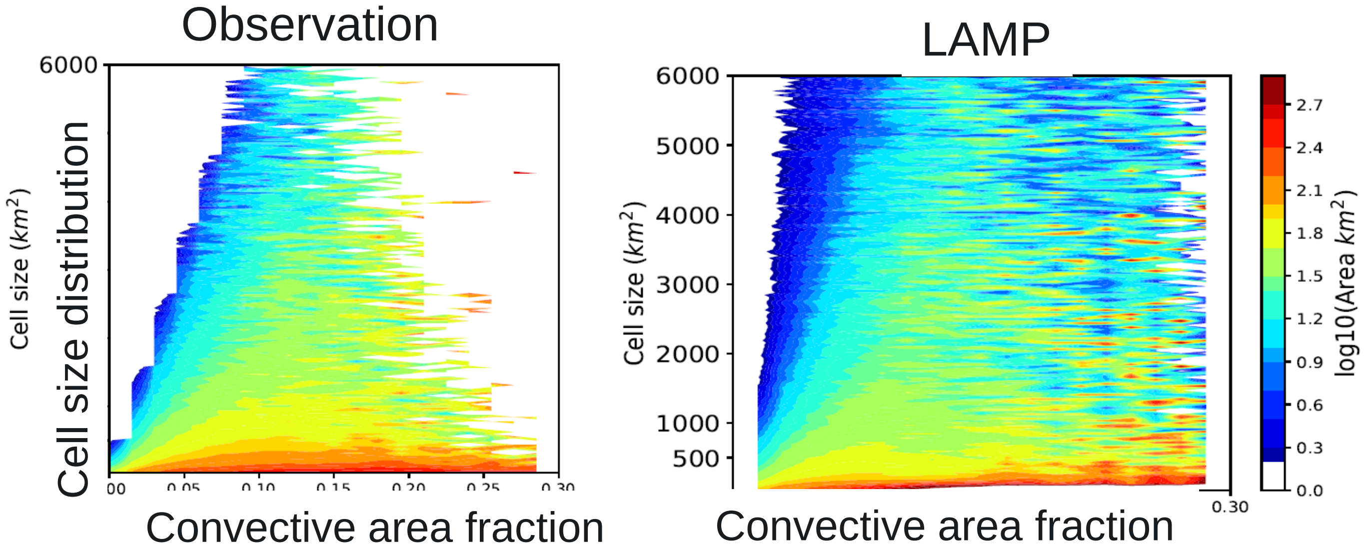
Using machine learning to model the interactions between convective and stratiform clouds (Hagos)

- Developed a model of non-equilibrium dynamics of cloud populations, called machine **L**earning **A**ssisted **M**odel for Population of clouds **(LAMP)**:

Radar reflectivity (2km) Convective features



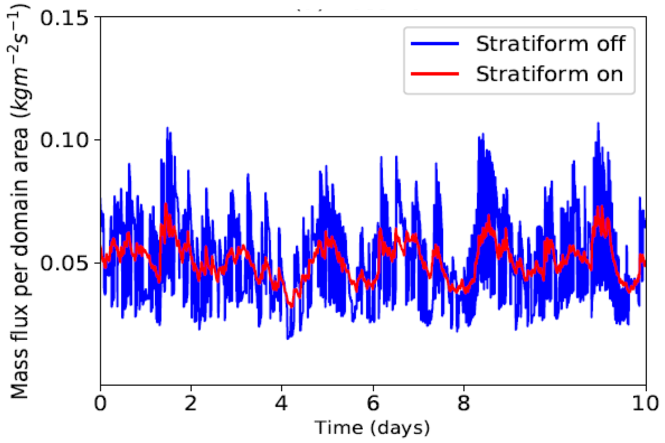
training data: half of 150,000 cases of observed transitions



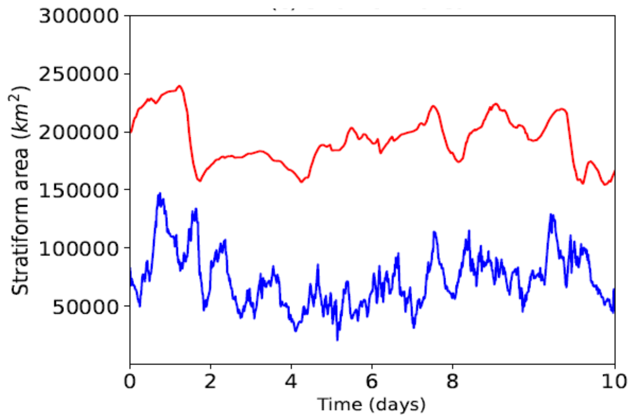
- Found that 1) stratiform clouds **damp** the variability in size and number of convective cells, 2) for the same convective area fraction, a larger number of smaller cells favors larger stratiform area than small number of large cells, This interaction leads to large stratiform area (i.e., MCS like features)

Response to stochastic forcing

Mass flux



Stratiform area

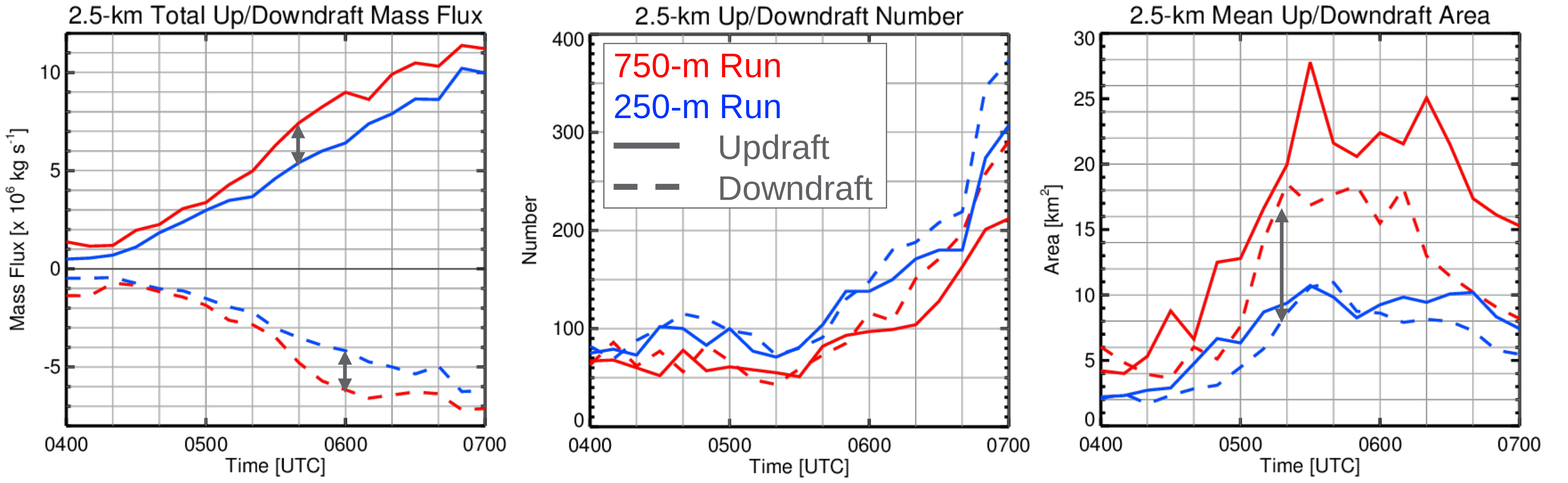


A link between convective drafts and MCS evolution

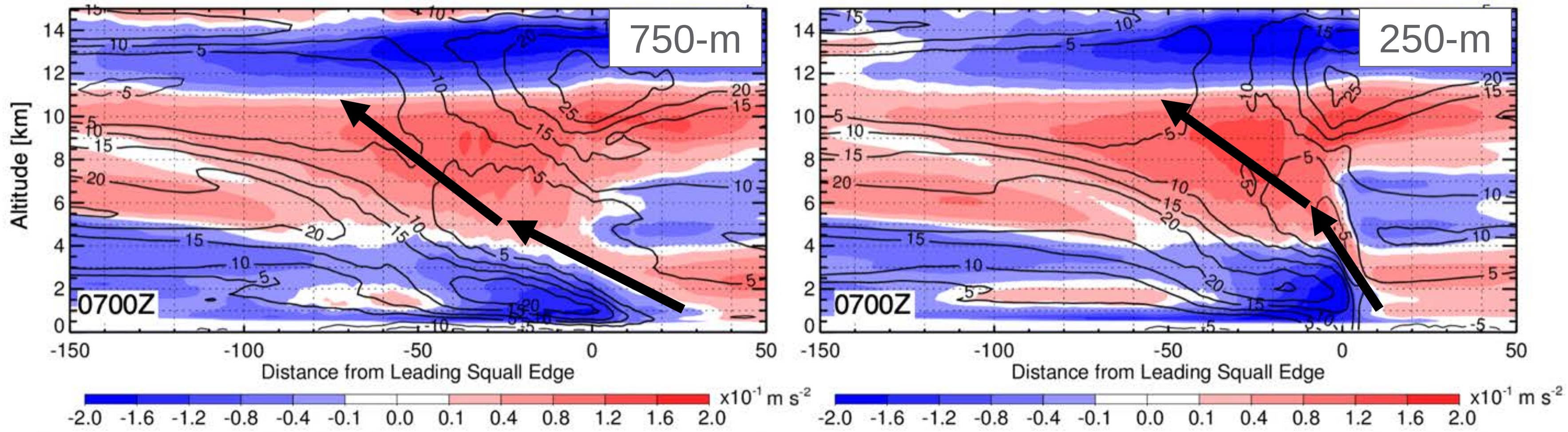
(Varble)

To Understand how under-resolved convective drafts impact squall line evolution

WRF-simulated 2.5-km altitude updraft and downdraft property time series



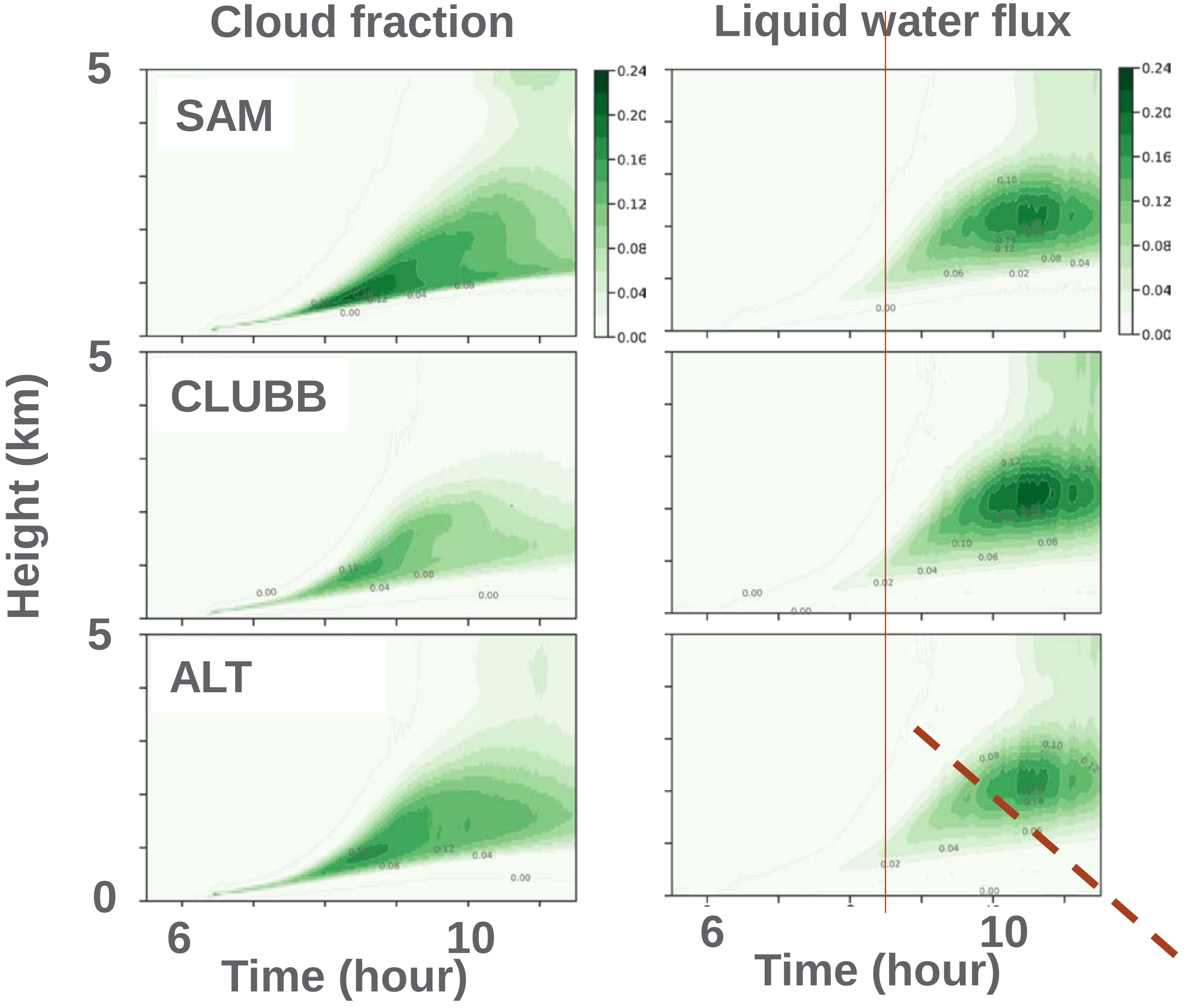
WRF-simulated composite squall line buoyancy (fill) and zonal wind (contour)



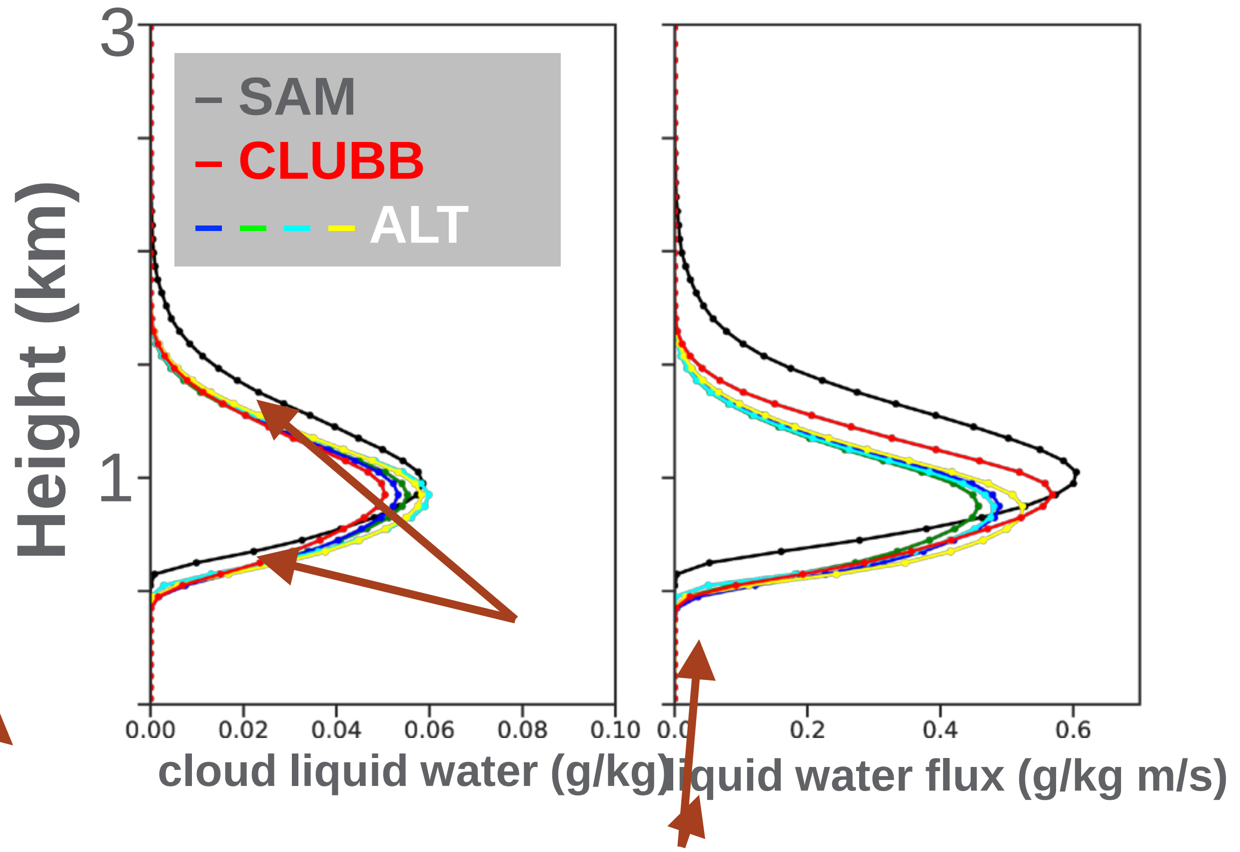
- When model grid spacing is increased from 250 to 750 m, convective draft areas increase
- Larger downdrafts have greater mean velocities, condensate mass, and latent cooling, which more effectively transport mid-level air to low levels
- In the case of a squall line, under-resolved convective drafts in the 750-m run lead to biased convective tilt, rear inflow, and front-to-rear flow that negatively affect MCS evolution

Improving CLUBB PDF closure for shallow to deep transition

(Xiao)



- We are currently exploring ways to improve the PDF closure in CLUBB by relaxing the “equal in-plume w variance” and “zero in-plume flux” assumptions.
- We tested a new formulation where we added skewness of w to parameterize in plum variance and fluxes and found overall performance similar to CLUBB for the LBA case.



Cloud top and base errors remain!

- We are going to test this in an interactive single column model.

We welcome collaboration