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Updates from the (HI-SCALE) Field Campaign

Holistic Interactions of Shallow Clouds, Aerosols, and Land Ecosystems

July 8, 2019

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U.S. DEPARTMENT OF ENERGY BATTELLE

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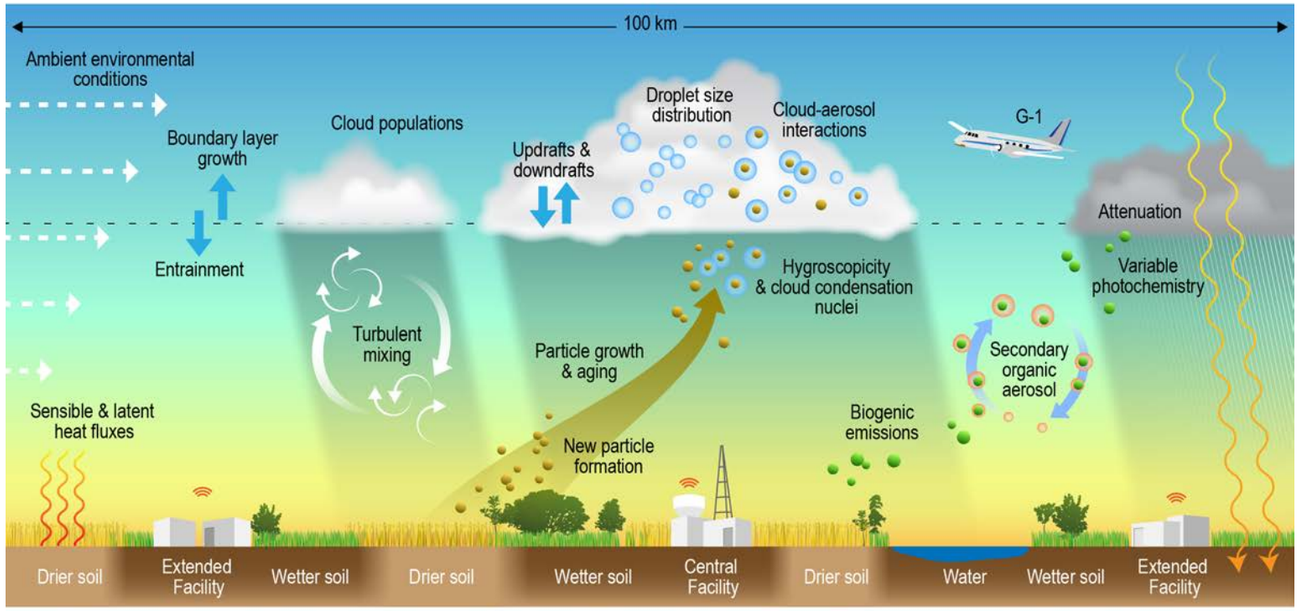
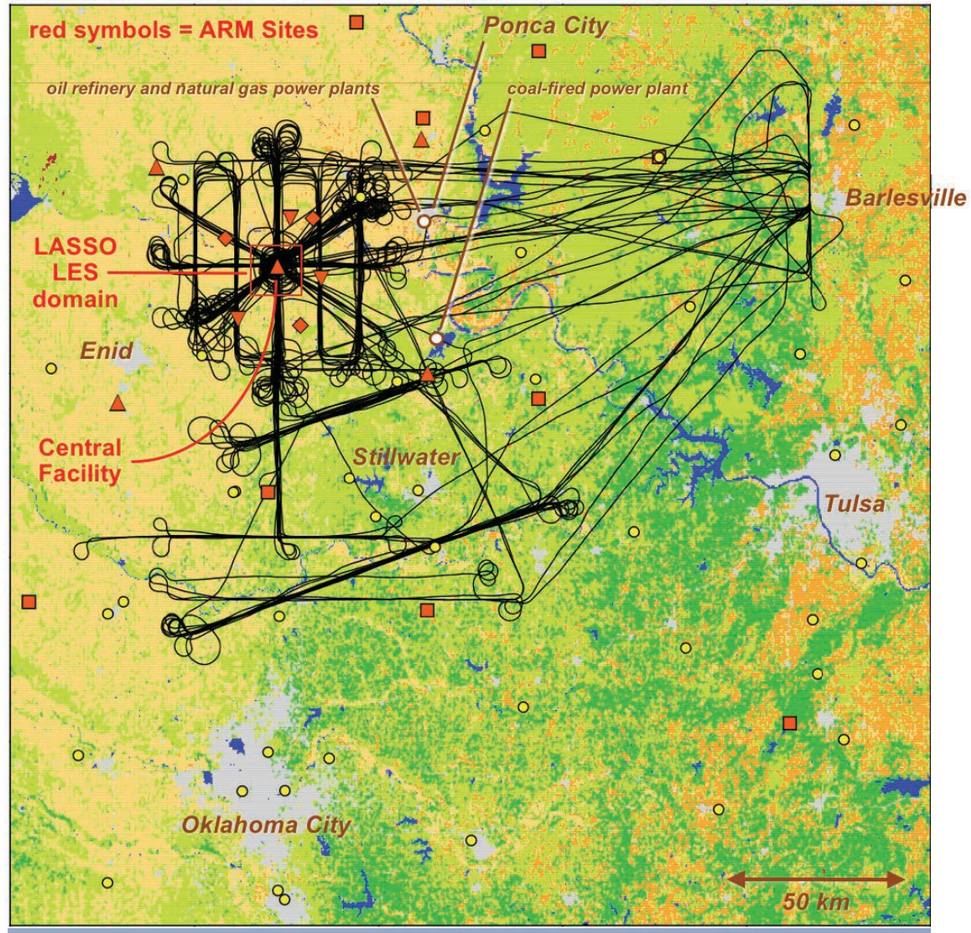
photo courtesy Harald Stark

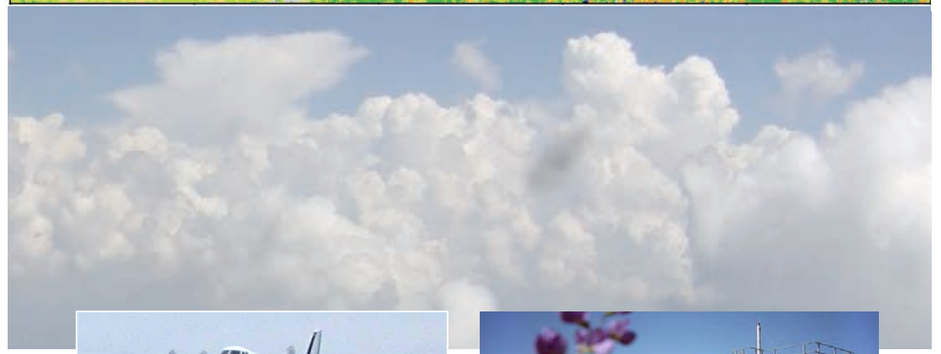
Published Paper

Fast, JD, LK Berg, L Alexander, D Bell, E D'Ambro, J Hubbe, C Kuang, J Liu, C Long, A Matthews, F Mei, R Newsom, M Pekour, T Pinterich, B Schmid, S Schobesberger, J Shilling, J Smith, S Springston, JA Thornton, J Tomlinson, J Wang, H Xiao, and A Zelenyuk. 2018. "Overview of the HI-SCALE Field Campaign: A New Perspective on Shallow Convective Clouds." *Bulletin of the American Meteorological Society.* 100:821-840. DOI:10.1175/BAMS-D-18-0030.1.



Heterogeneity in soil moisture, land cover, radiation, albedo, sensible heat and moisture fluxes, skin temperature, transpiration, biogenic emissions



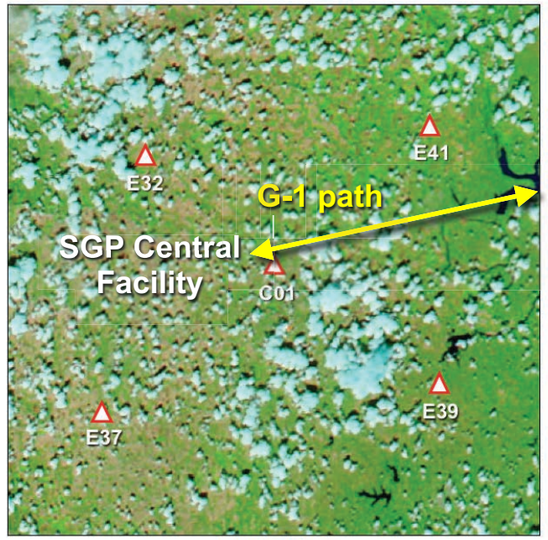


Submitted Paper

Fast, JD, LK Berg, Z Feng, F Mei, R Newsom, K Sakaguchi, and H Xiao. 2019. "The Impact of Variable Land-Atmosphere Coupling on Convective Cloud Populations Observed During the 2016 HI-SCALE Field Campaign." Submitted to *Journal of Advances in Modeling Earth Systems.*

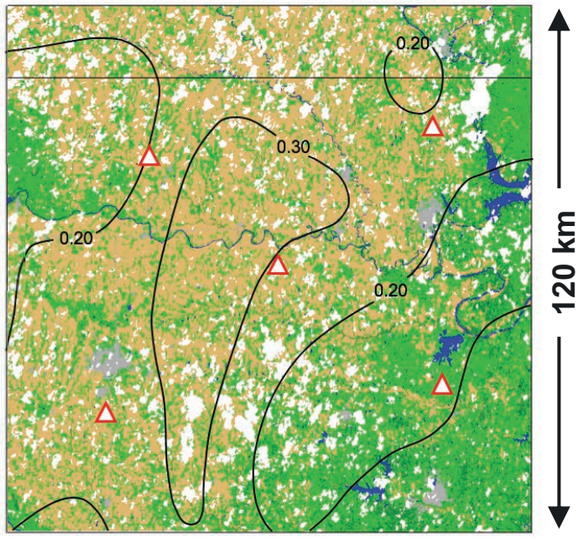
- **"Large" LES experiments** conducted to study the impact of variable land-atmosphere coupling on convective cloud populations observed on August 30, 2016
- Model can reproduce observed heterogeneity in clouds and shallow-to-deep transitions **only if realistic variations in soil moisture are used**. **Soil moisture** modulates regional variations in boundary layer properties that drives initial cloud distributions, then **cold pools** become important during the afternoon.
- Need to account for variable land-atmosphere interactions and cold pools in shallow convection parameterizations.

MODIS clouds ~1350 CST



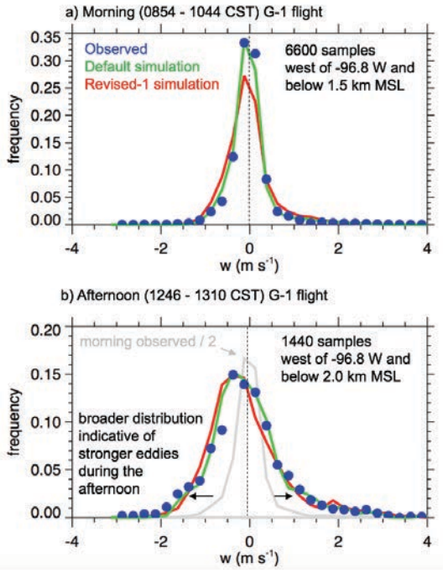
1 pixel = 250 m

"Observed" Soil Moisture Simulation

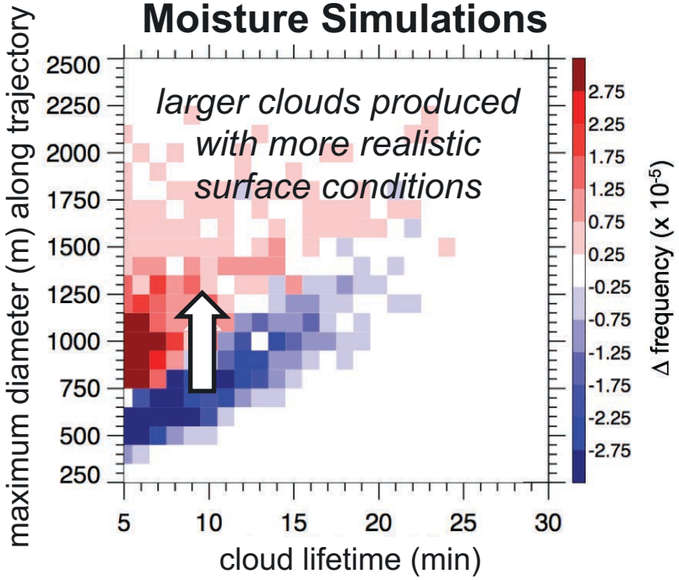


black lines = soil moisture contours

LES Evaluation



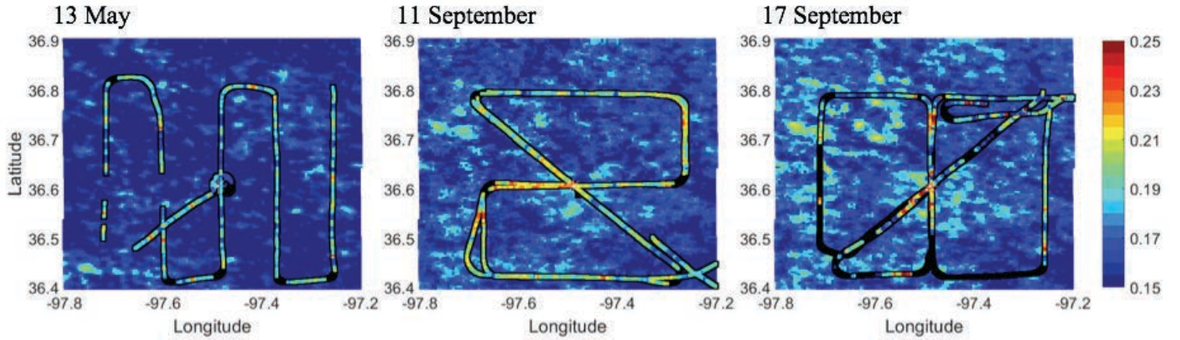
Observed – Smooth Soil Moisture Simulations

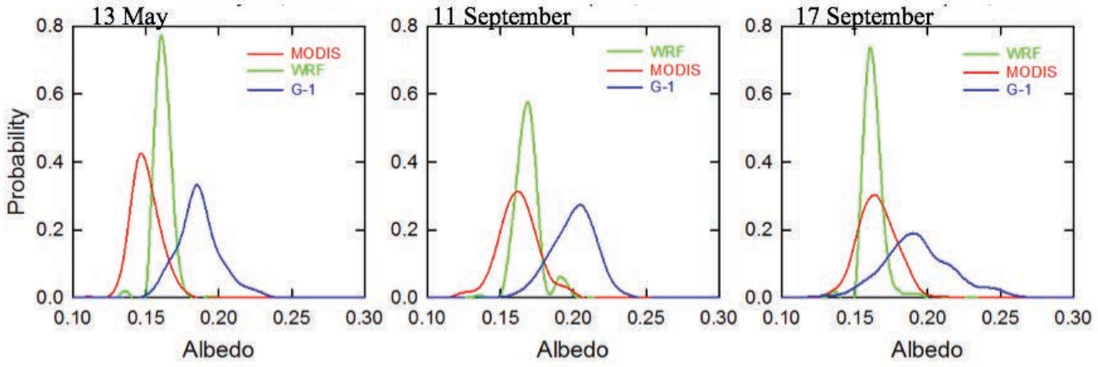


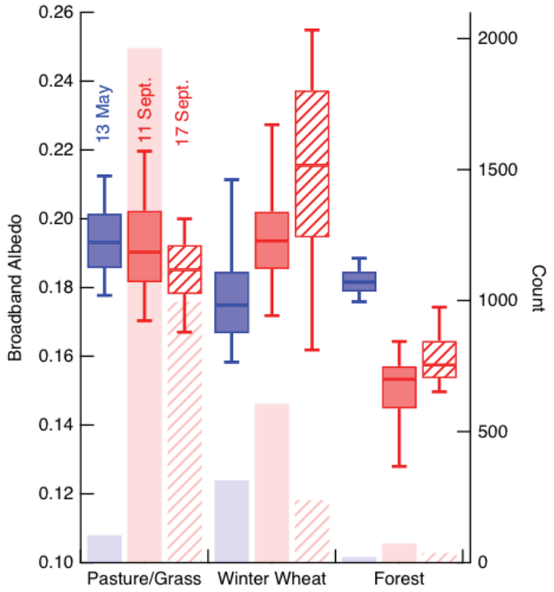
Submitted Paper

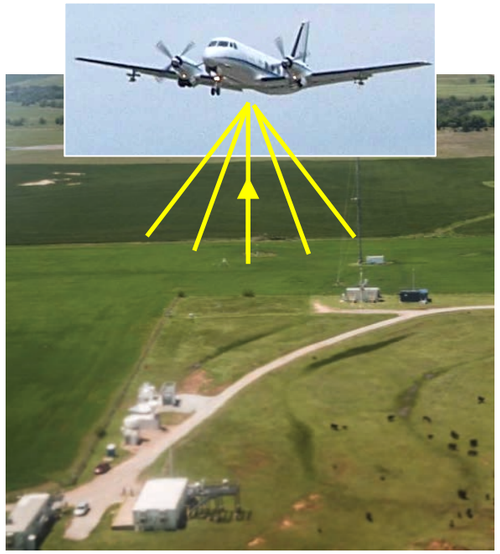
Berg LK, CN Long, EI Kassianov, D Chand, S-L Tai, LD Riihimaki, SC Biraud, J Tagestad, A Matthews, A Mendosa, F Mei, J Tomlinson, and JD Fast. 2019. “Fine Scale Variability of the Observed and Simulated Surface Albedo of the Southern Great Plains.” Submitted to *Journal of Geophysical Research*.

- Compared multiplatform (tower, aircraft, and satellite) based measurements of the variability of broadband (BB) albedo and Normalized Difference Vegetation Index (NDVI) over the SGP to WRF simulations.
- In general, consistency was found between the BB albedo and NDVI measured from the tower, air and space. The largest seasonal differences in BB albedo and NDVI were associated with forest and winter wheat
- The variability in the aircraft measured BB albedo was larger by 9 to 52%, depending on the day, than the that observed via MODIS and 53 to 80% larger than that simulated using WRF.



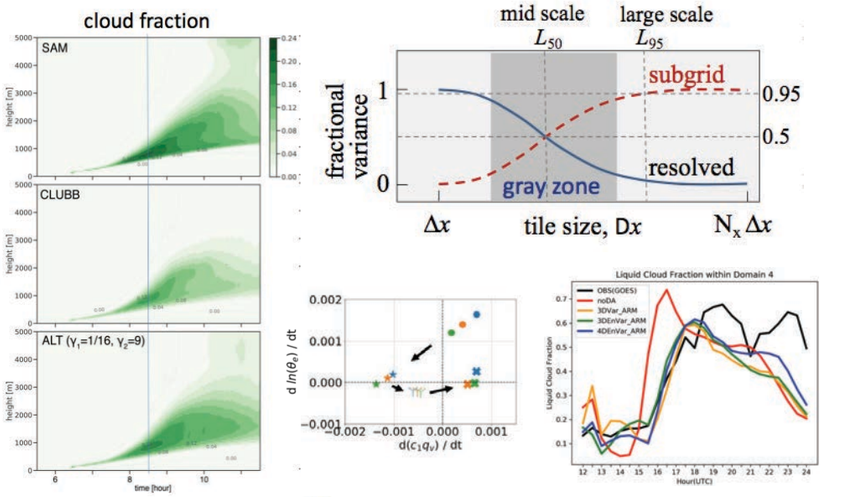


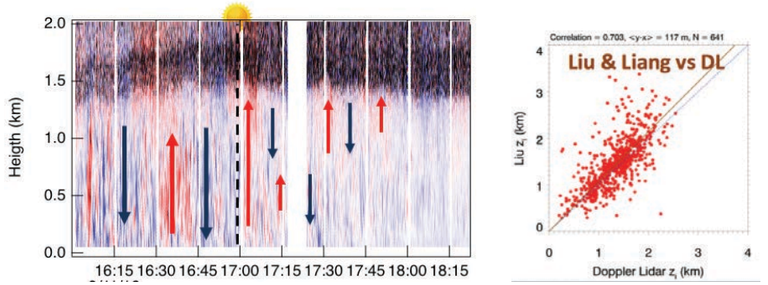


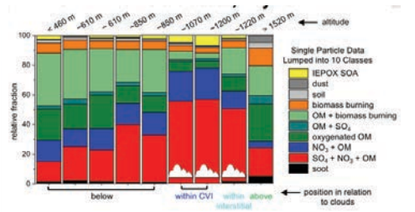


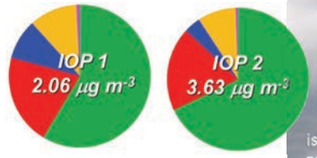
Studies Underway * = poster

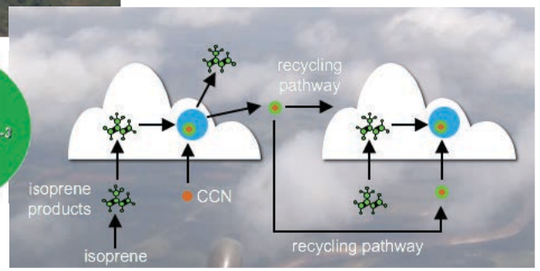
- ***Ovchinnikov & *Xiao**: Examining CLUBB PDF closure assumptions
- ***Chen:** Understanding how land properties and synoptic forcing are related to convection and cloud populations
- ***Sakaguchi:** Exploring land-atmosphere coupling metrics
- ***Newsom:** Quantifying variability of boundary layer properties over the SGP site using new lidar products
- ***Berg:** Characterizing and understanding the behavior of turbulence during evening transitions
- **Tai:** Using data assimilation to improve cloud simulations
- **Ma:** Examining BL, cloud, and aerosol predictions from E3SM
- **Kulkarni**: Performing CCN closure to evaluate measurement consistency and identify sources of uncertainties
- ***Fast & Scanza:** Determine performance of simulated BVOCs
- **Shrivastava & Zelenyuk**: Understanding the processes associated with aqueous chemistry using measurement analysis and modeling
- **Shilling & Liu:** Characterizing aerosol variability using AMS











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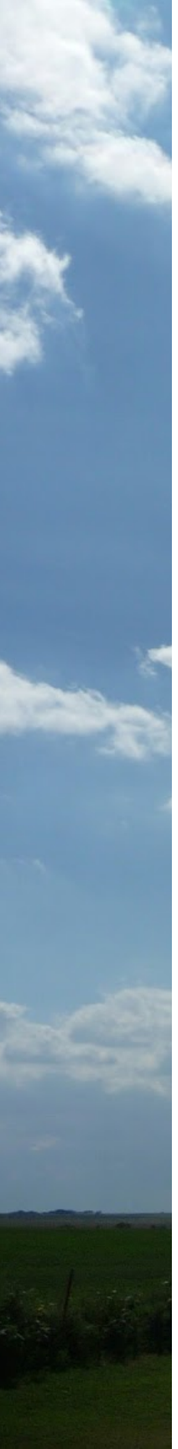
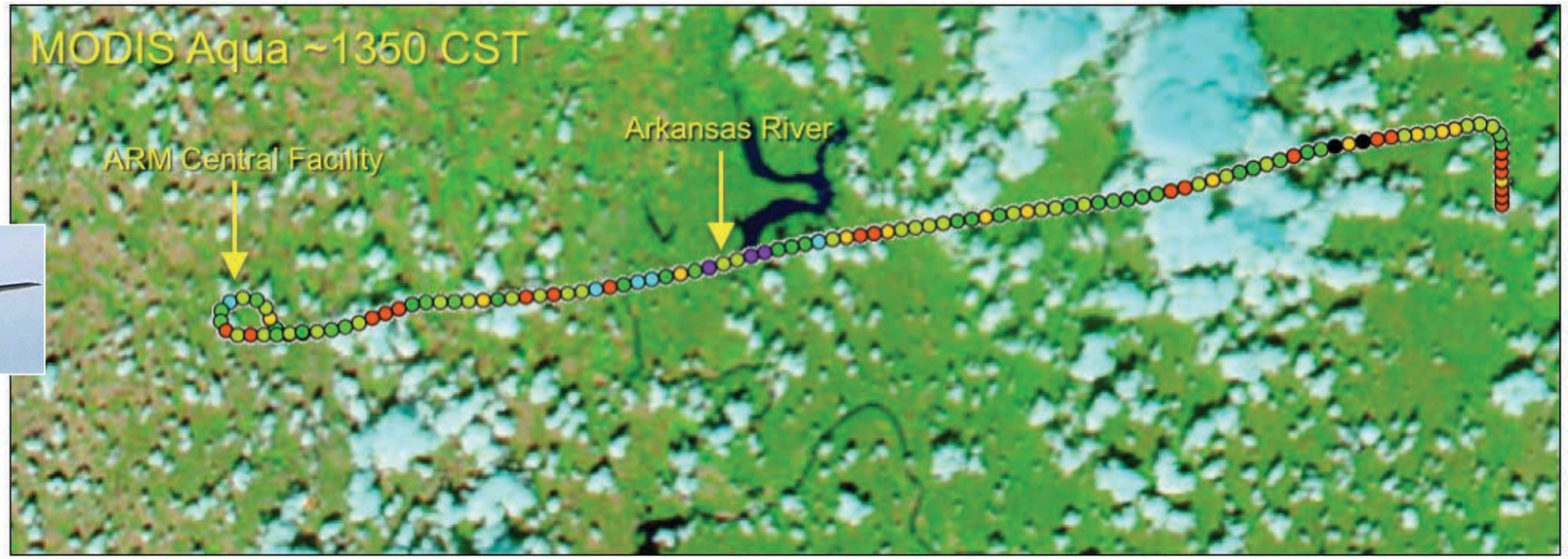
Other Outstanding Scientific Opportunities

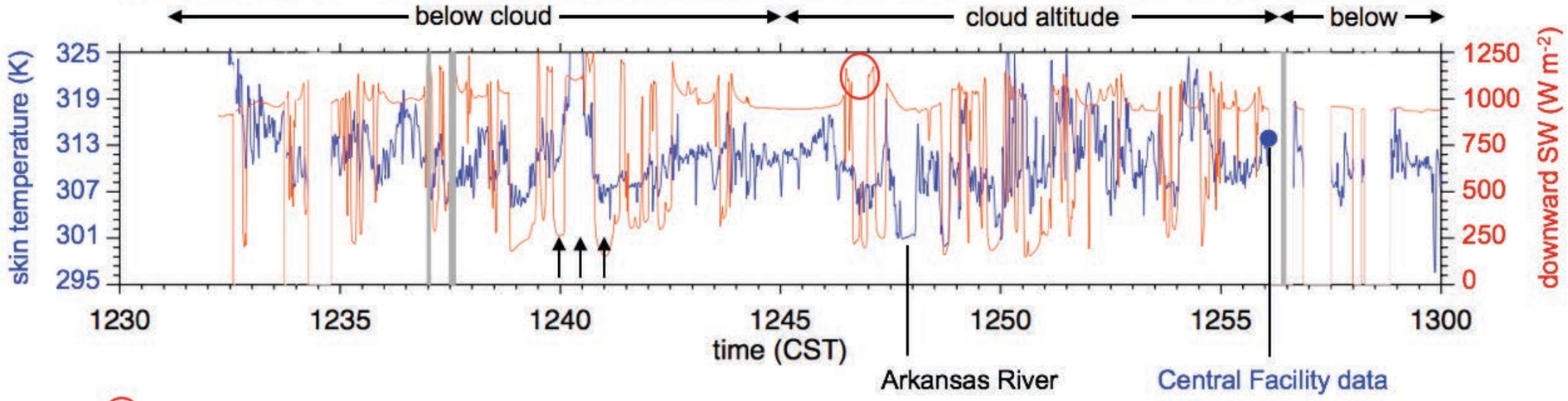


Select Science Questions: Using HI-SCALE Data Coupled with SGP Megasite Measurements

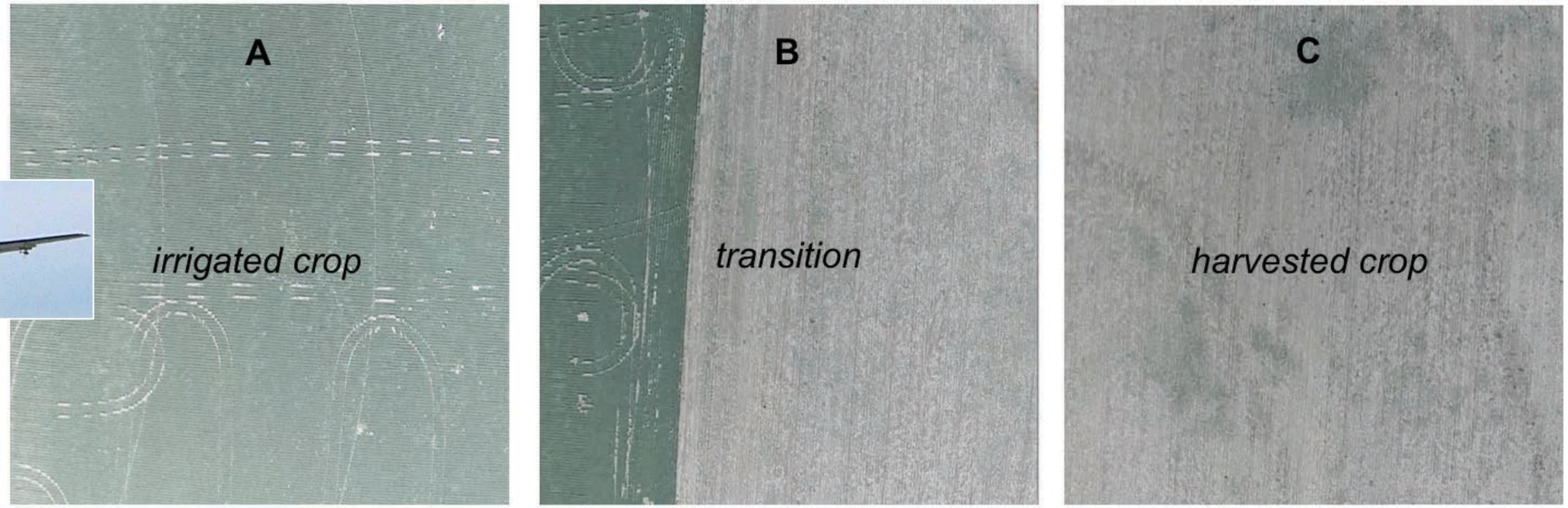
- How do heterogeneities in vegetation, soil moisture, surface albedo, and downwelling radiation affect surface sensible and latent heat fluxes and subsequently the **subgrid-scale variability** in temperature, humidity, vertical velocity, and shallow clouds?
- Are simulations of near-surface meteorological variables (e.g. temperature, humidity, PBL) and their spatio-temporal variability **predicted reasonably well for the right reasons**?
- How does **land-atmosphere coupling** influence the evolution of shallow convective cloud populations
- What are the factors that determine whether some clouds **transition** to deep convection?
- What is the relative role of **local and regional-scale processes** on the initiation and lifecycle of shallow clouds?
- Are **3-D radiation effects** important in models?

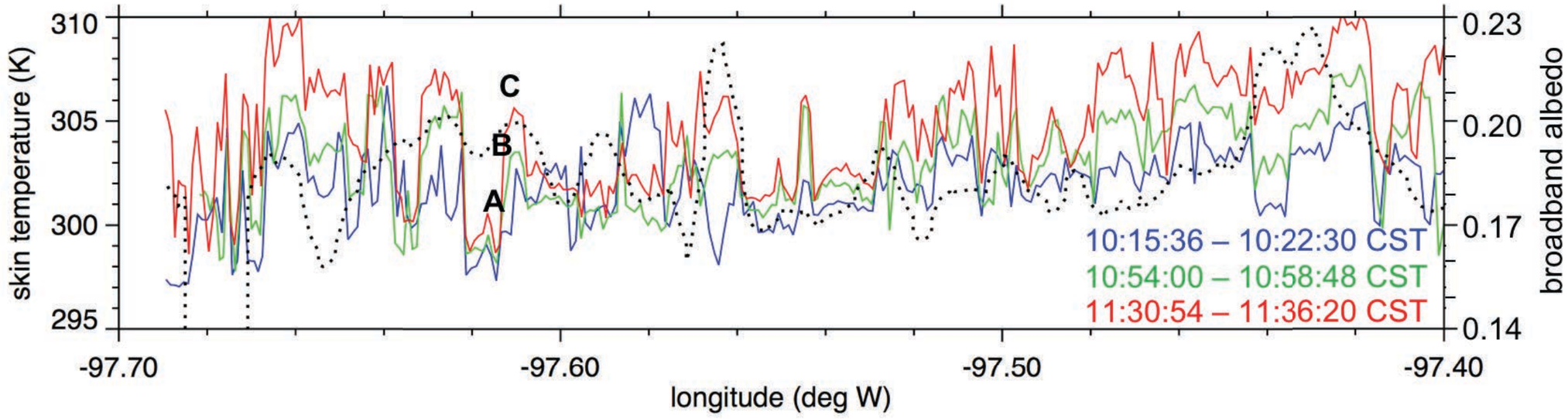
Land-Atmosphere Coupling: Cloud Shading





Land-Atmosphere Coupling: Variable Land

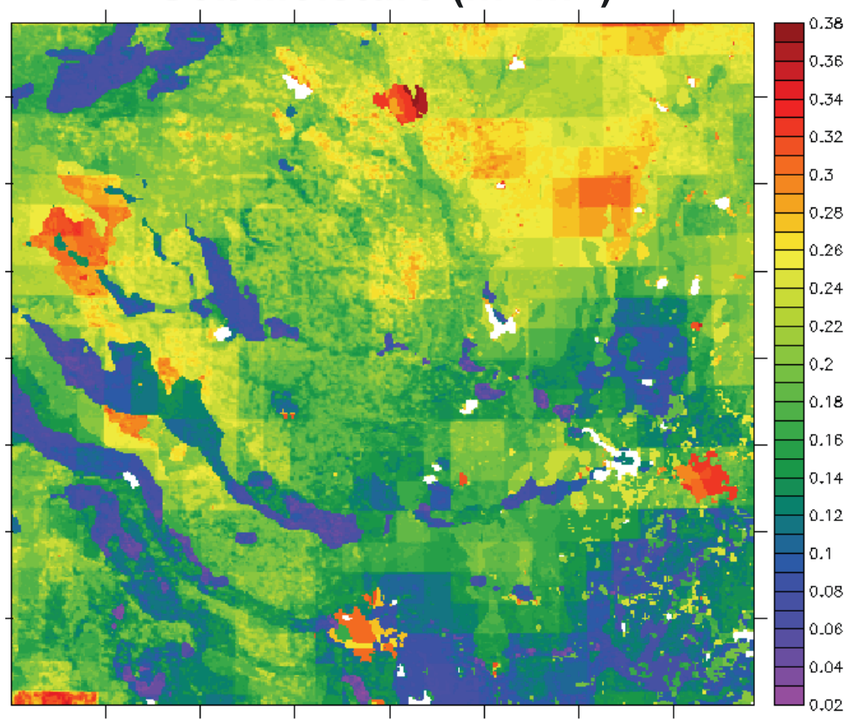




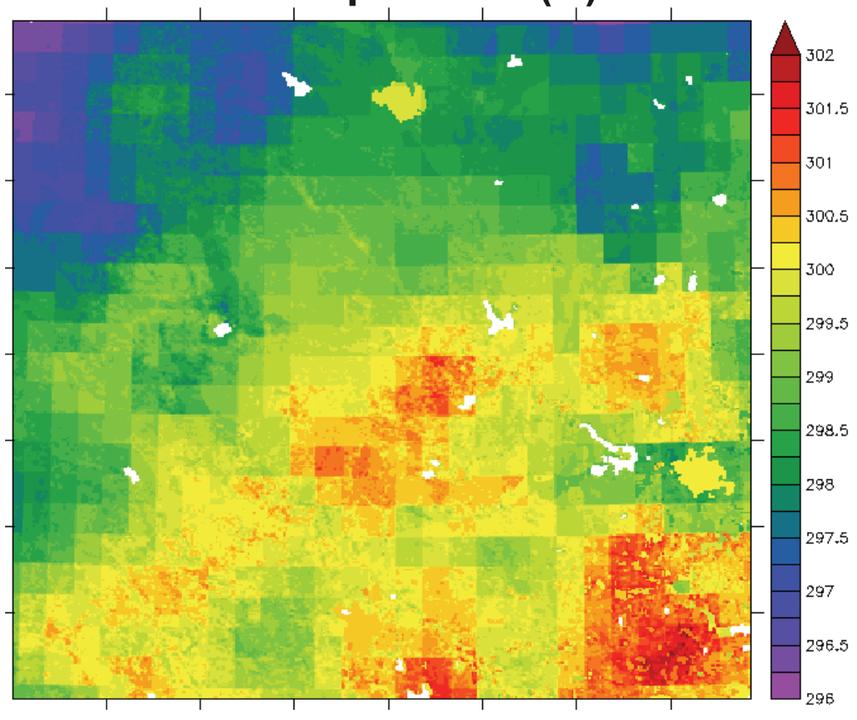
Land-Atmosphere Coupling: Variable Land

- What is the best way to represent the state of the soil and vegetation properties over the SGP site and the surrounding region? Is high spatial variability important?
- For example, can WRF-Hydro be used to “spin-up” more realtistic soil conditions when constrained with observed meteorology and rainfall? Are additional constraints necessary, such as assimilating ARM and Oklahoma Mesonet data?

Soil Moisture ($m^3\ m^{-3}$)



Skin Temperature (K)

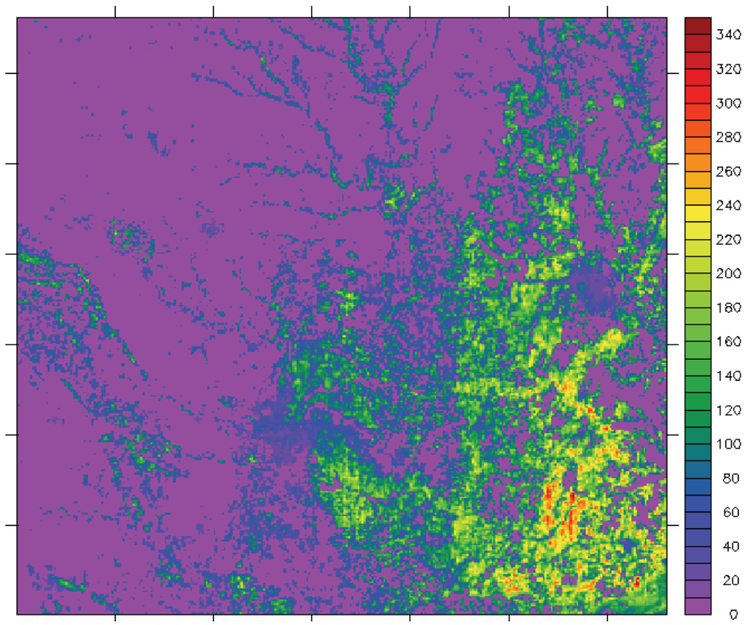


More spatial variability than initial conditions in Fast et al. (JAMES, 2019), but need to evaluate with measurements.

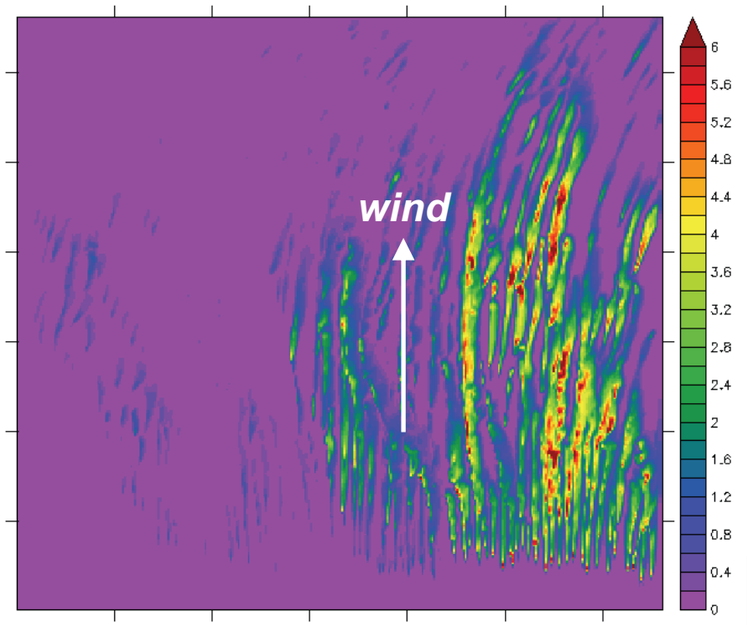
Land-Atmosphere Coupling: Biogenic

- Biogenic emissions of trace gases, that are precursors to secondary organic aerosols, depend on many factors, including temperature and photosynthetically active radiation (PAR)
- Cloud shading will affect both temperature and PAR. Can we use the measurements to determine how these factors affect observed isoprene, isoprene products, monoterpenes?

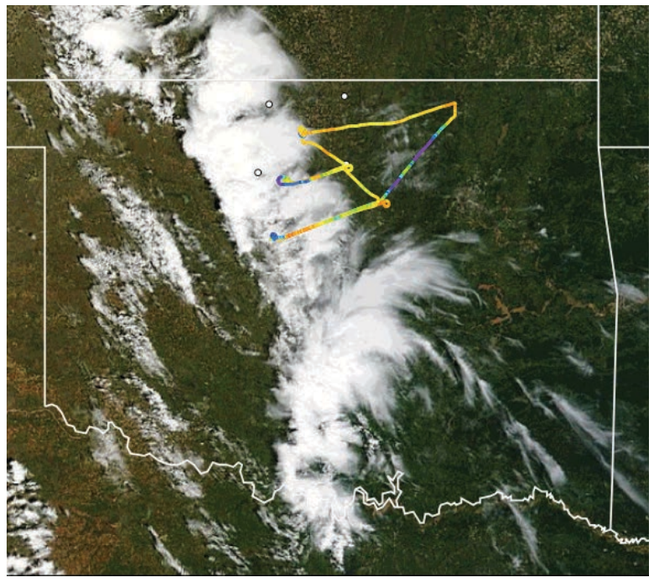
isoprene emission rate (mol km^{-2} hr^{-1})



isoprene ~ 900 m MSL (ppb)

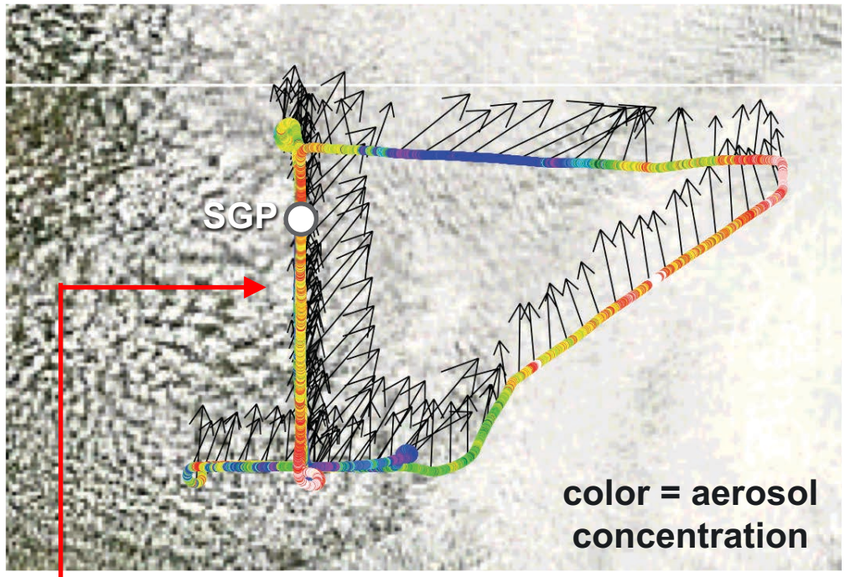


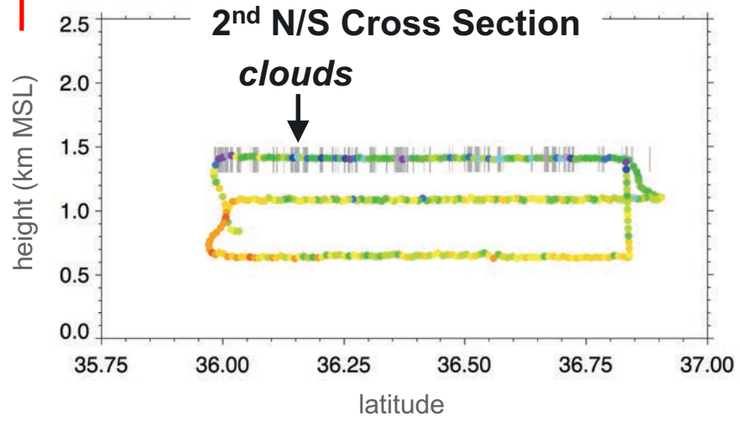
clouds

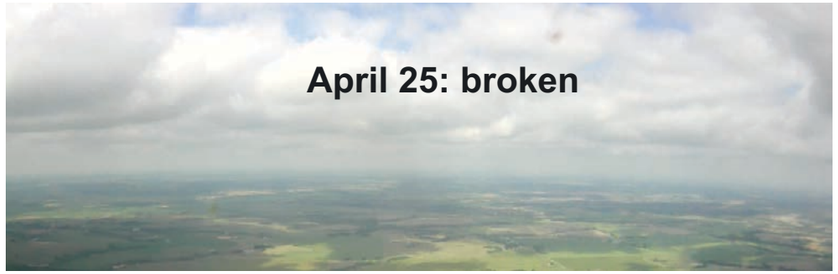


LES Modeling

- LES modeling has focused on a limited number of days during HI-SCALE, primarily August 30
- There are many “more challenging” periods (not just traditional shallow cumulus) to examine processes and evaluate LES models.
- Some days will be strongly coupled to the land, other days will not.
- Lots of G-1 in situ data on meteorology and cloud properties that could be used to evaluate models, in addition to the long-term measurements from SGP instrumentation.



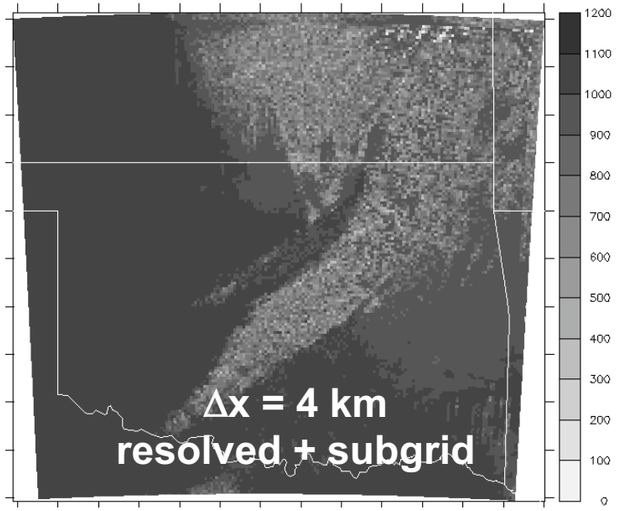




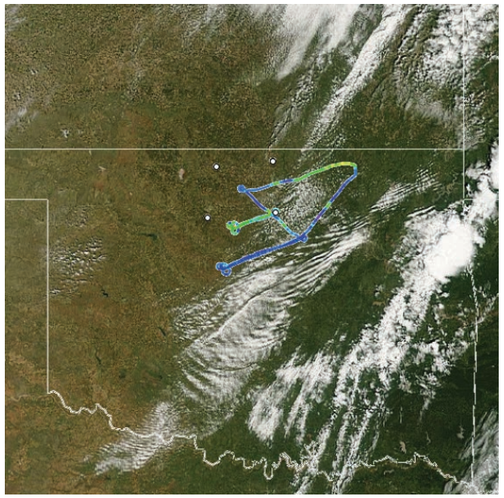
Regional Modeling

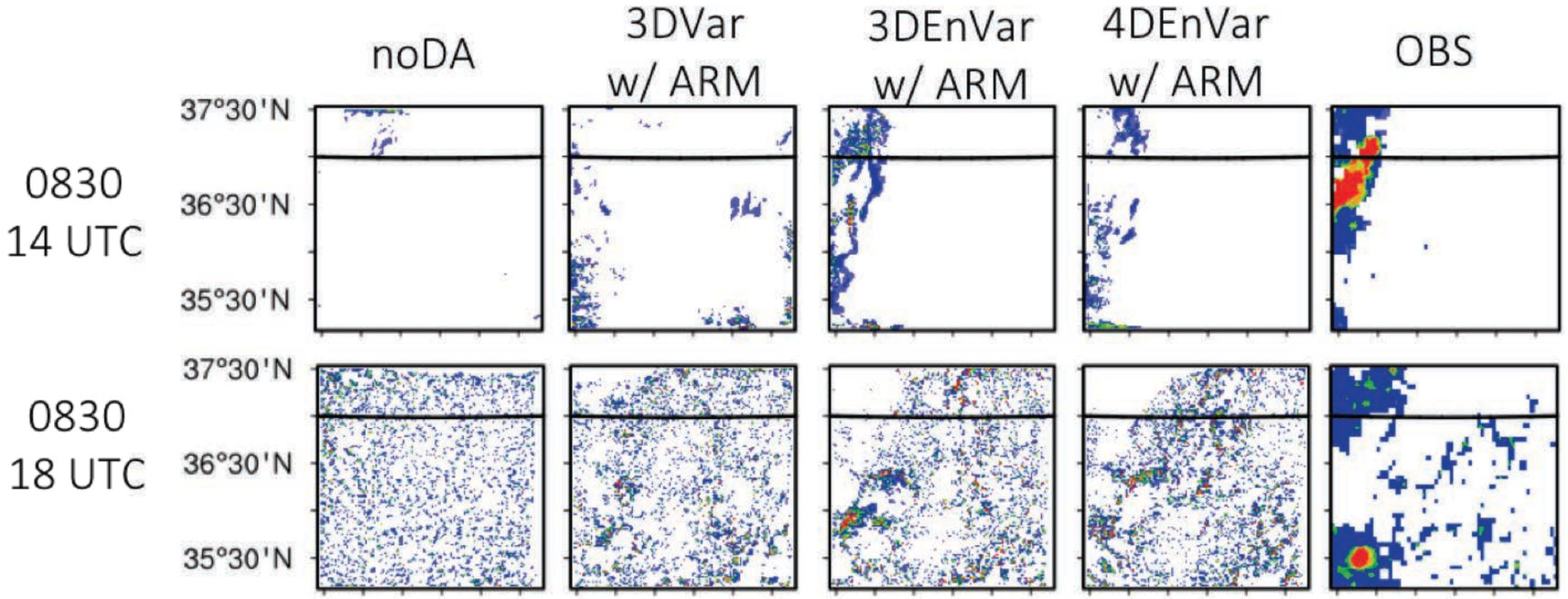
- Use HI-SCALE and SGP long-term measurements to evaluate regional (Δx ~ 1 – 10 km) model predictions of meteorology, clouds, and aerosols
- How adequate are models in representing explicit (resolved) versus parameterized (sub-grid) clouds
- How adequate are models in representing and-atmosphere coupling and boundary layer mixing?

Simulated Clouds, May 11



Observed Clouds, May 11





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Questions?