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Preliminary Findings from the Recent Holistic Interactions of Shallow Clouds, Aerosols, and Land-Ecosystems (HI-SCALE) Field Campaign:

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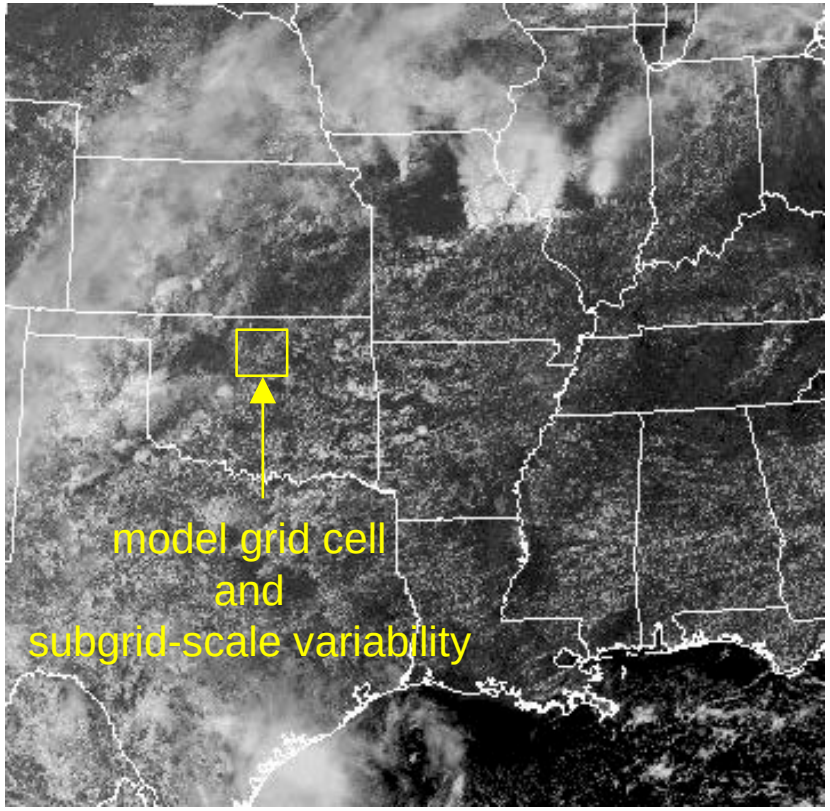
ASR Atmospheric System Research

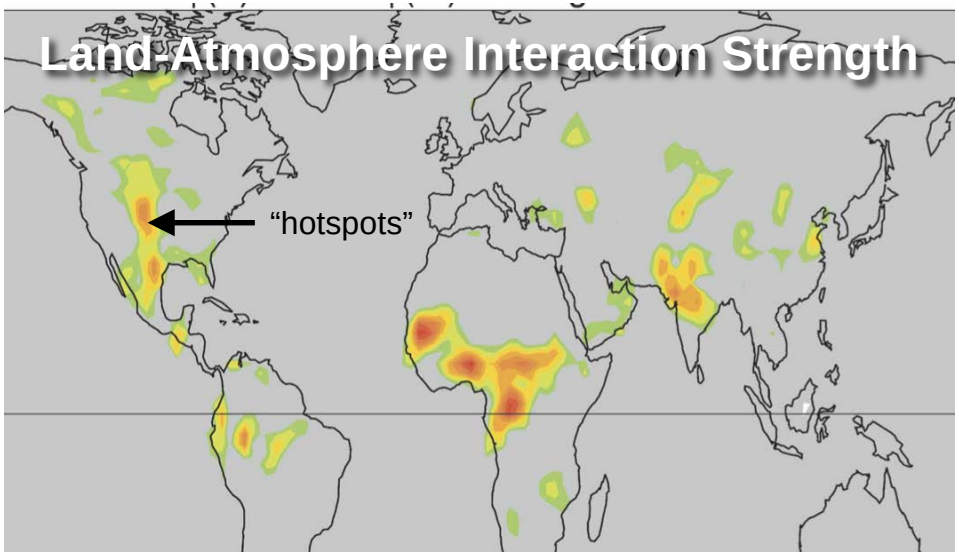
ARM CLIMATE RESEARCH FACILITY

EMSL

Motivation

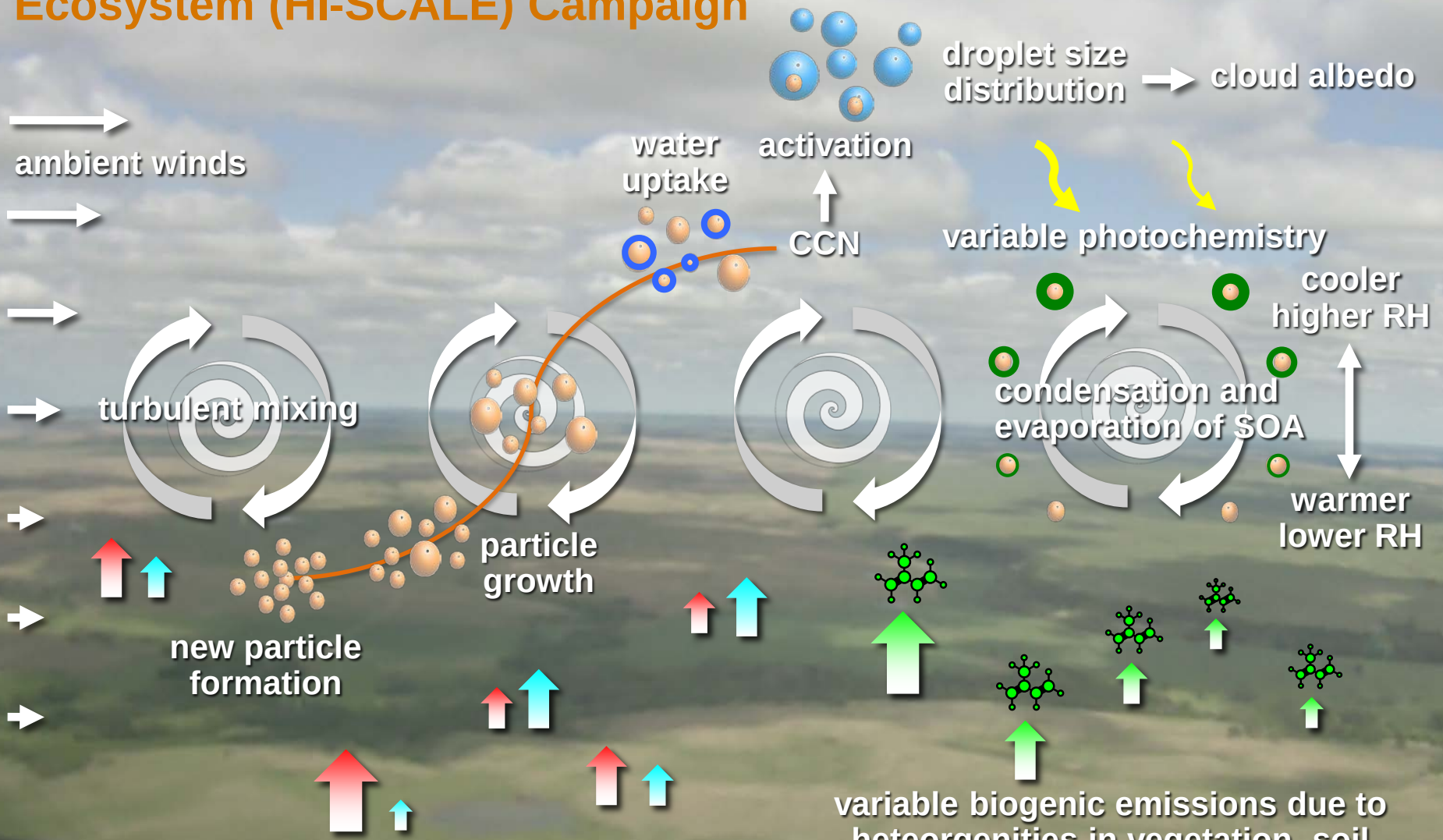
- **Cumulus convection** is an important component of the **radiation budget and hydrologic cycle** over many regions of the world, but …
- Convective **cloud parameterizations contain uncertainties** due partly to insufficient coincident data coupling cloud macro- and microphysical properties to inhomogeneities in boundary layer and aerosols.





Average relative **coupling of land-surface processes to precipitation** for a suite of 12 global climate models (after Koster et al., 2006).

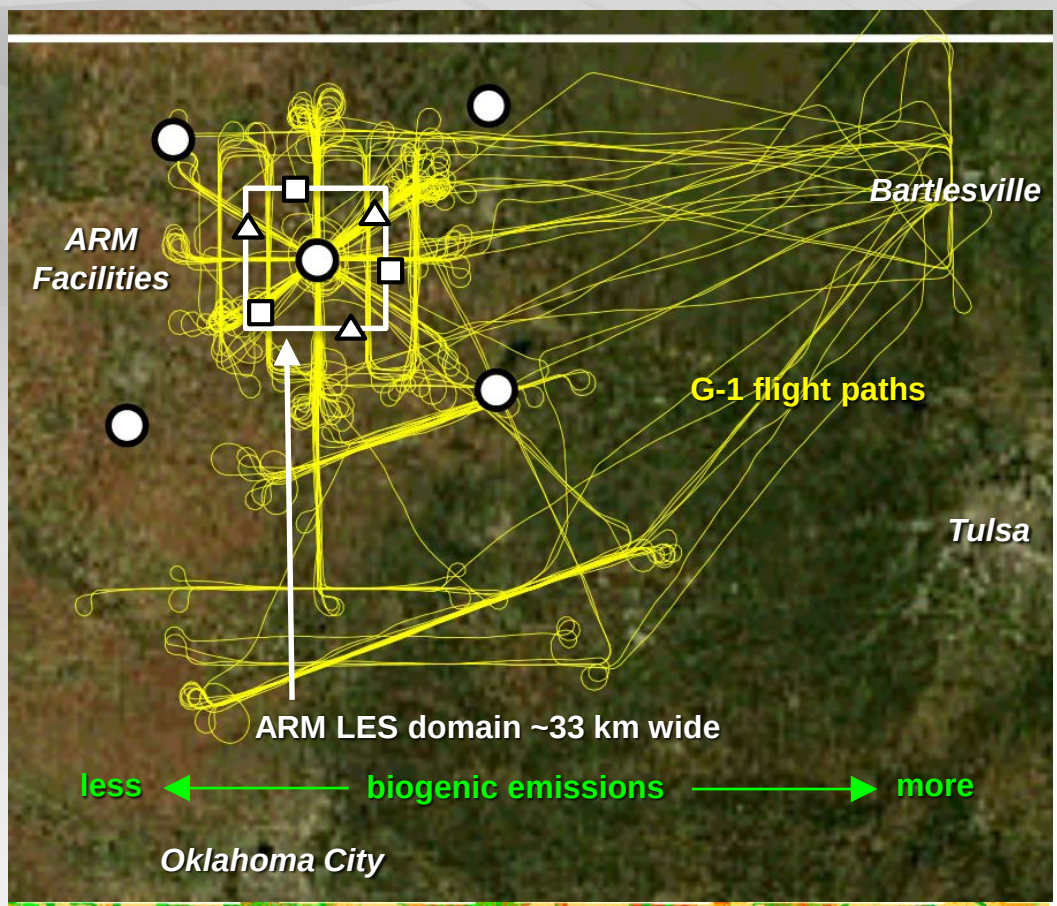
Holistic Interactions of Shallow Clouds, Aerosols, and Land-Ecosystem (HI-SCALE) Campaign

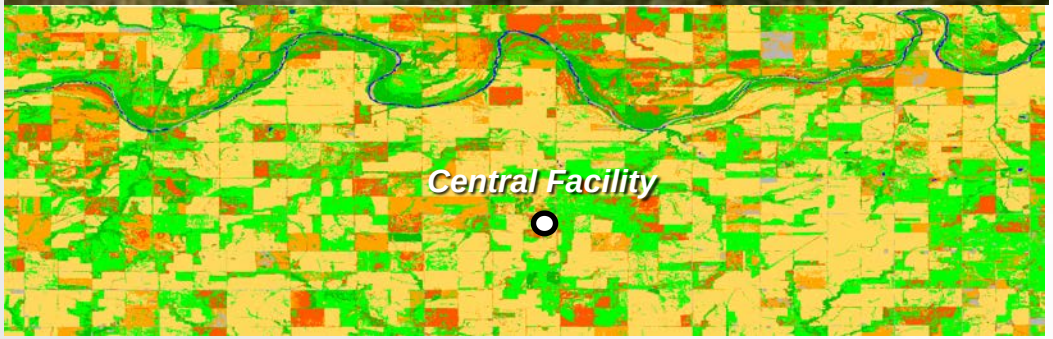


Aircraft Instrumentation

- Meteorology, gust probe, infrared thermometer, video
- Upwelling and downwelling radiation
- Droplet size distribution, CDP (2-50 μm), 2D-S (10 – 3000 μm), HVPS-3 (400 – 50,000 μm)
- Liquid and ice content (WCM-2000, CSI)
- CCN concentrations at various supersaturations
- Trace gases:
  - O_3, SO_2, CO, NO, NO_2
  - CIMS for a range of VOCs, e.g. isoprene, isoprene products
- Aerosols:
  - Number from CPC 3010 and 3025
  - Size from FIMS, PCASP, UHSAS, CAS
  - Composition from HR-ToF-AMS
  - Single particle information from miniSPLAT
  - Isokinetic and CVI (sampling droplet residuals) inlets

Aircraft Operations





from Δx = 1 m land-use dataset (Alice Ciallea, BNL)

Phase 1: April 24 – May 20

- 17 flights, 57.8 hours total
  - 9 in clouds, 6.5 hours total (~11%)
  - 3 < 5 min in cloud
  - 5 clear sky
- 3.4 h average duration

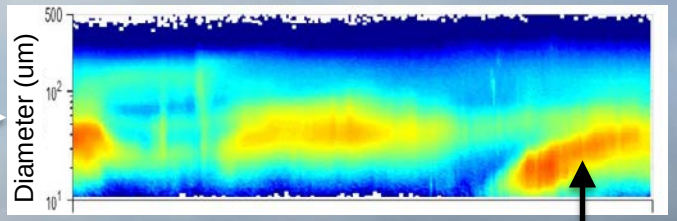
Phase 2: Aug 28 – Sept 23

- 21 flights, 47.8 hours total
  - 9 in clouds, 1.1 hours total (~2.3%)
  - 8 < 1 min in cloud
  - 4 clear sky
- 2 flights / day on 5 days

SGP Site Enhanced Instrumentation during HI-SCALE

Phase 1 and 2

- SMPS, nano-SMPS, size distribution
- PTR-MS, VOCs
- HR-ToF-AMS, bulk particle composition
- SPLAT II, single particle information



new particle formation and growth

Phase 2 only

- TDCIMS & NO_3 CIMS - nanoparticle composition and precursors
- Cluster CIMS, inorganic and organic acids and HOMS
- Amine CIMS & Amp-MS – gas-phase amines
- Api-LTOF – ambient ions
- Sequential Spot Sampler – aerosol bulk chemistry

Harald Stark photo

Overall Conditions

Changes in Vegetation Greenness

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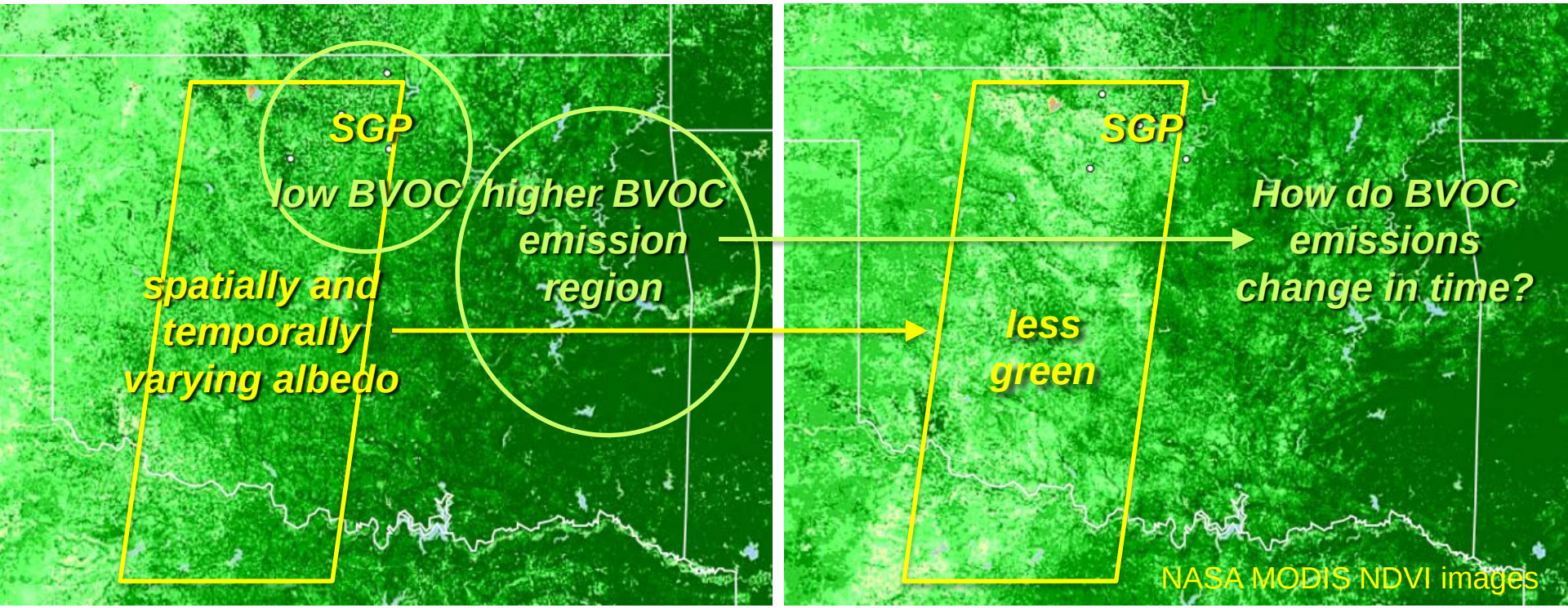
May 4 | **September 11**



spring sampling period

late summer sampling period

- Spatial and temporal variability in albedo affects sensible heat fluxes
- Spatial and temporal variability in vegetation affects biogenic volatile organic compound (BVOC) emissions ➡ SOA ➡ CCN

Changes in Soil Moisture

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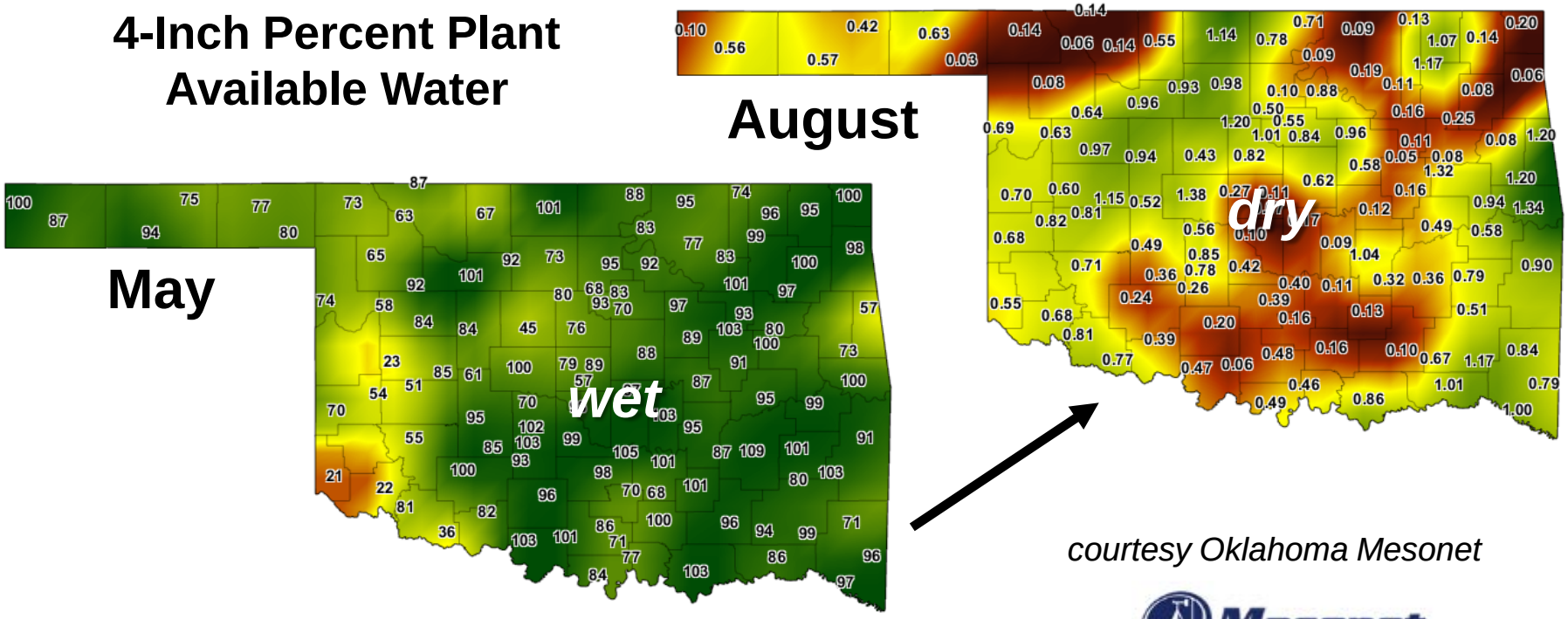
4-Inch Percent Plant Available Water



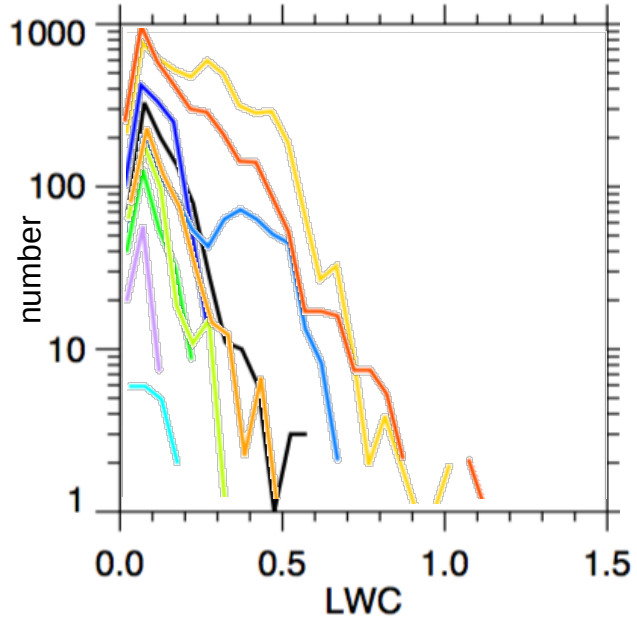
courtesy Oklahoma Mesonet

Mesonet

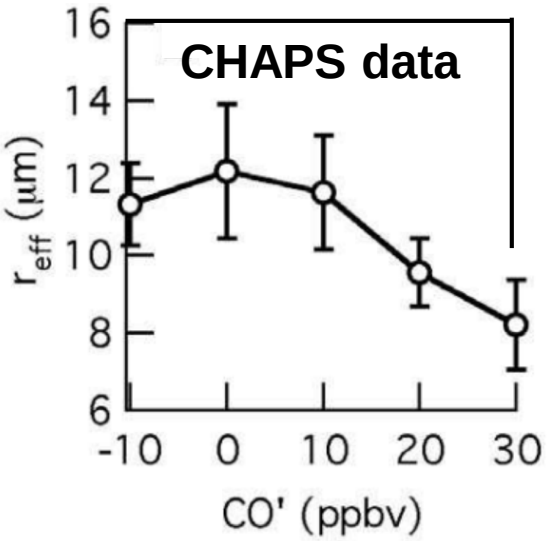
- Spatially and temporally varying soil moisture affects latent heat fluxes
- April - May, wetter and cooler than average ➡ weaker PBL
- August – September, drier and warmer than average ➡ stronger PBL

Cloud Statistics - Phase 1

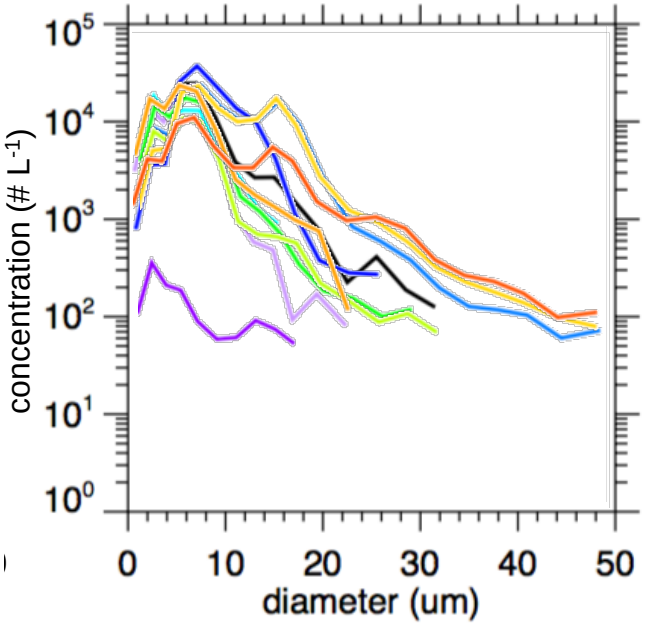
Liquid Water Content Frequency



? for HI-SCALE



Average Droplet Size Distribution



April 25 April 27 April 28 May 1 May 2 May 3 May 8 May 11 May 16 May 18 May 19

- Day-to-day variability reflects range of cloud type and size sampled
- Still need to correlate droplet size distribution to anthropogenic trace gases (e.g. CO) to identify the first indirect effect, as had been shown by previous shallow cloud experiments (Berg et al. 2011)

Specific Example – August 30

Transitions to Deep Convection: August 30 AM

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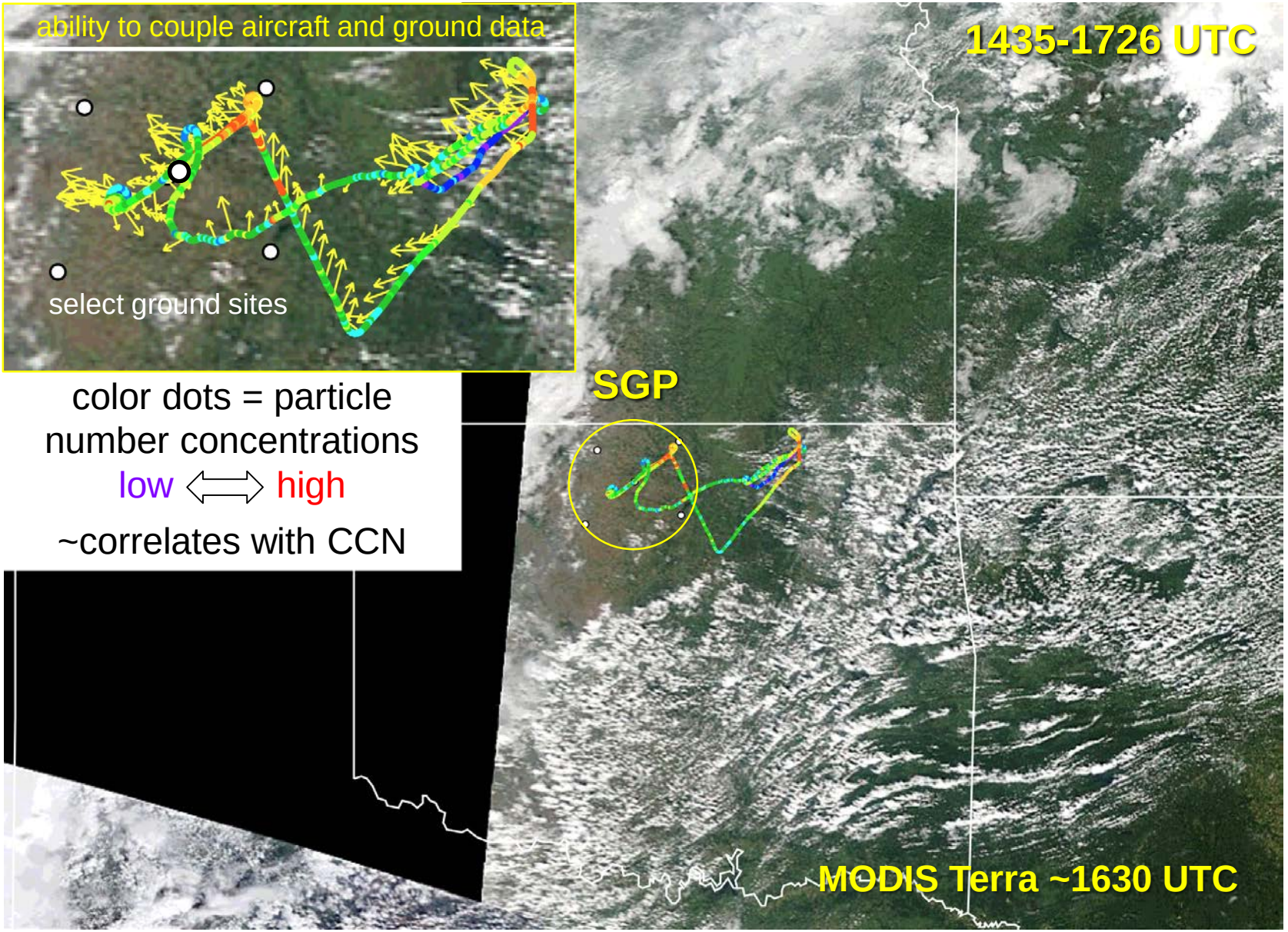

Transitions to Deep Convection: August 30 AM

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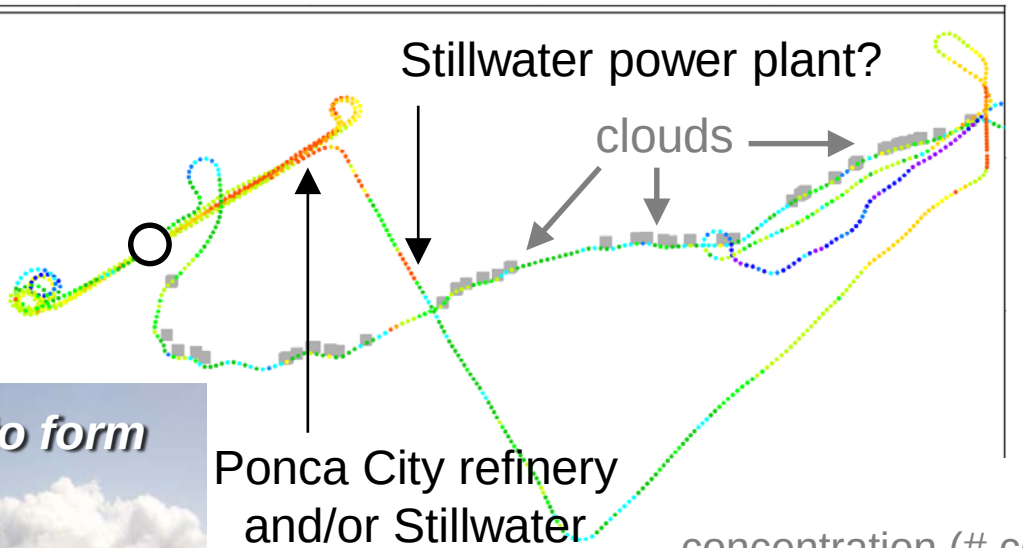
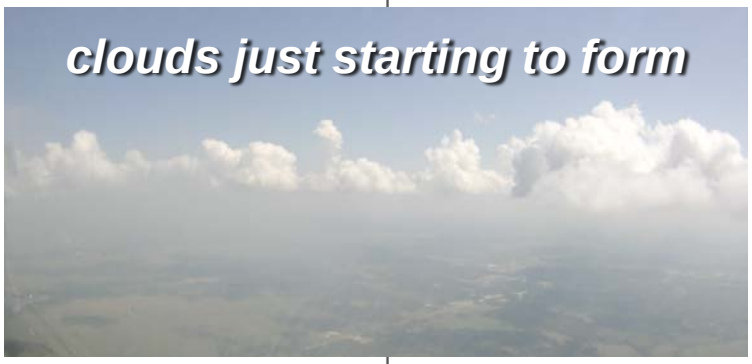
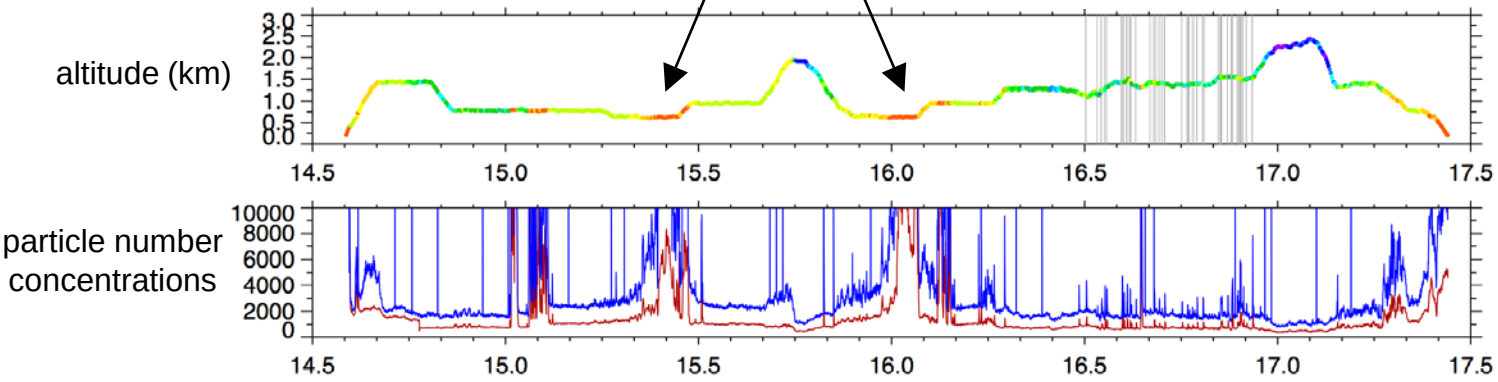
color dots = particle number concentrations
low ⟺ high
~correlates with CCN





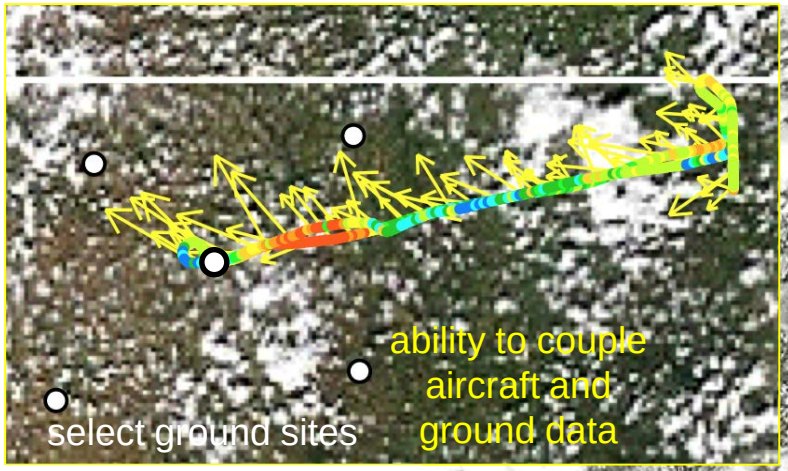
	Ave	Max
concentration (# cc^{-1})	145	392
LWC (mg L^{-1})	0.10	0.36

cloud sampled



CPC 3010
CPC 3025

Transitions to Deep Convection: August 30 PM



1832-1932 UTC

color dots = particle number concentrations

low ⟺ high

~correlates with CCN

SGP

open pockets

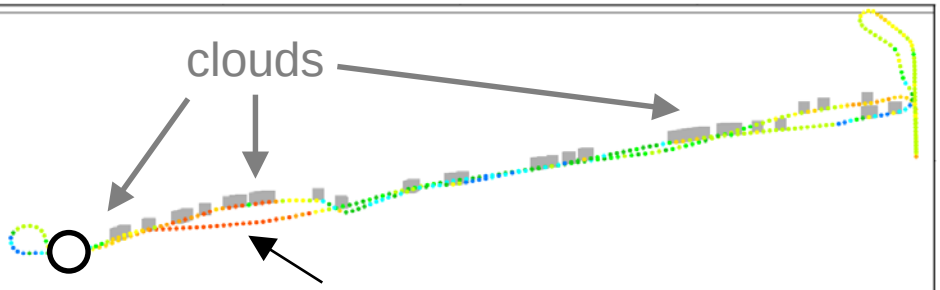
MODIS Aqua ~1950 UTC

Transitions to Deep Convection: August 30 PM

color dots = particle number concentrations

low ⟺ high

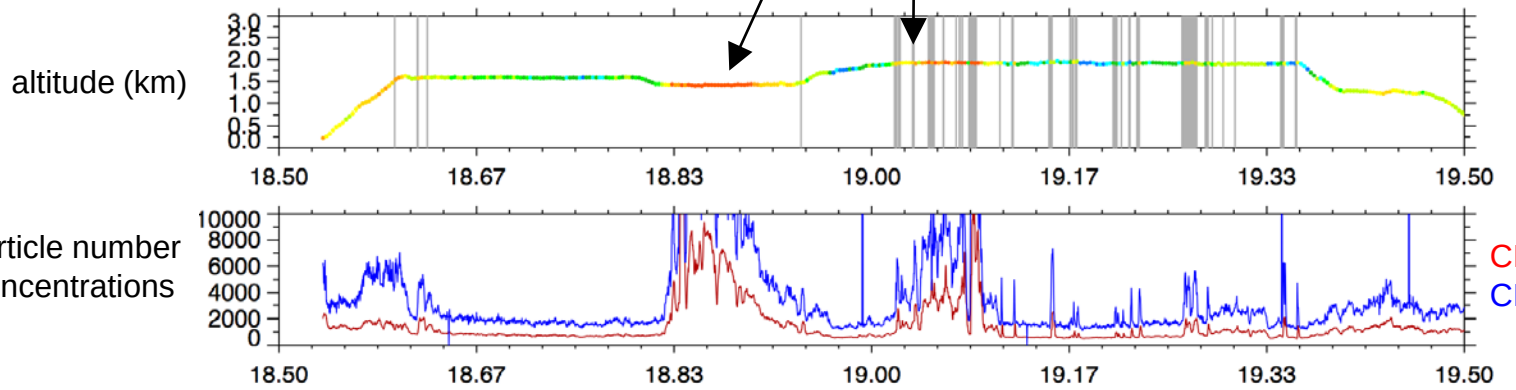
~correlates with CCN



Ponca City refinery and/or Stillwater power plant?

	Ave	Max
concentration (# cc^{-1})	174	493
LWC (mg L^{-1})	0.15	0.98

clouds sampled



Representations of Cloud Populations:
Satellite versus Ground View

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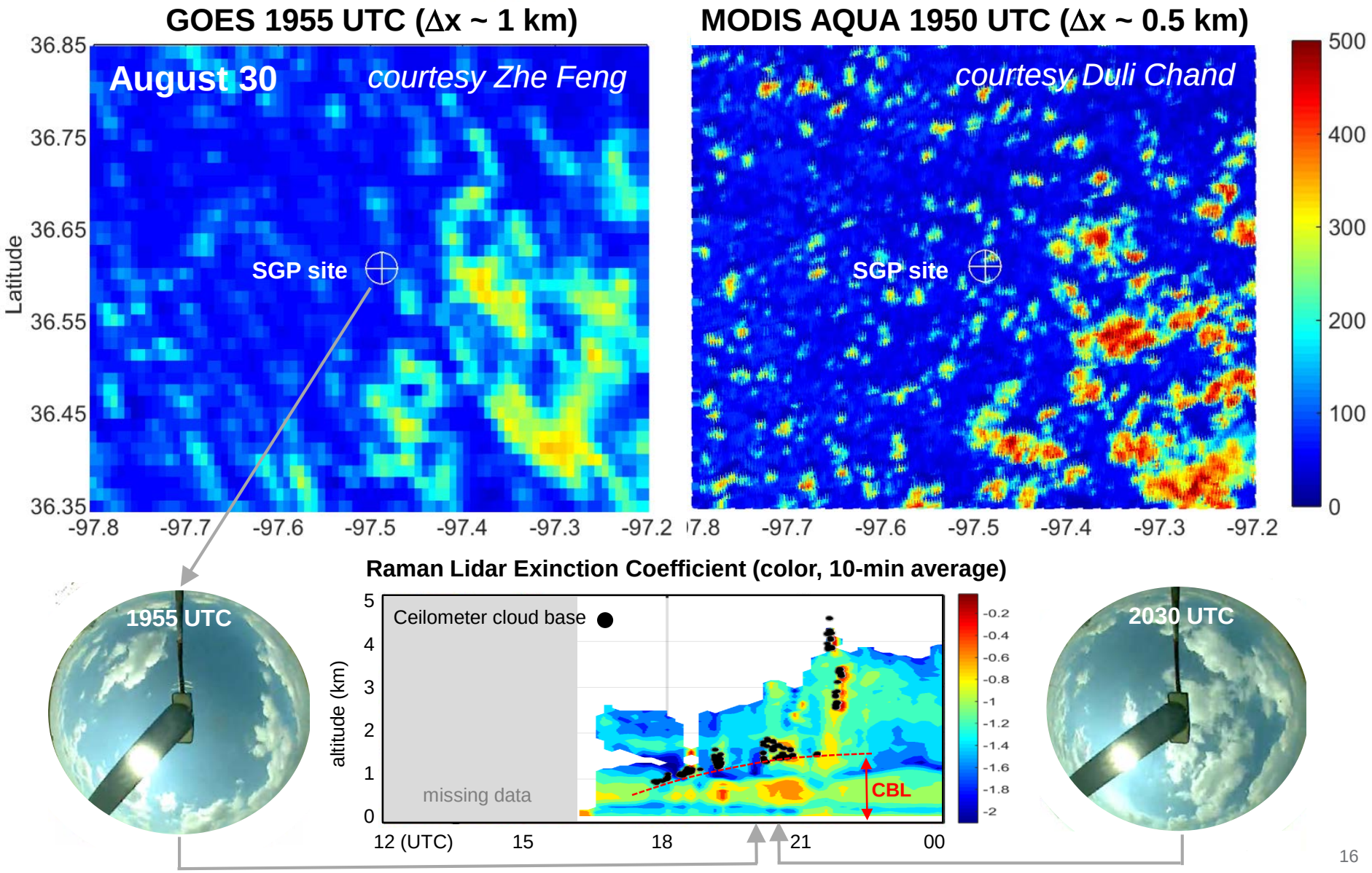

Evaluation of LES Representation of Clouds

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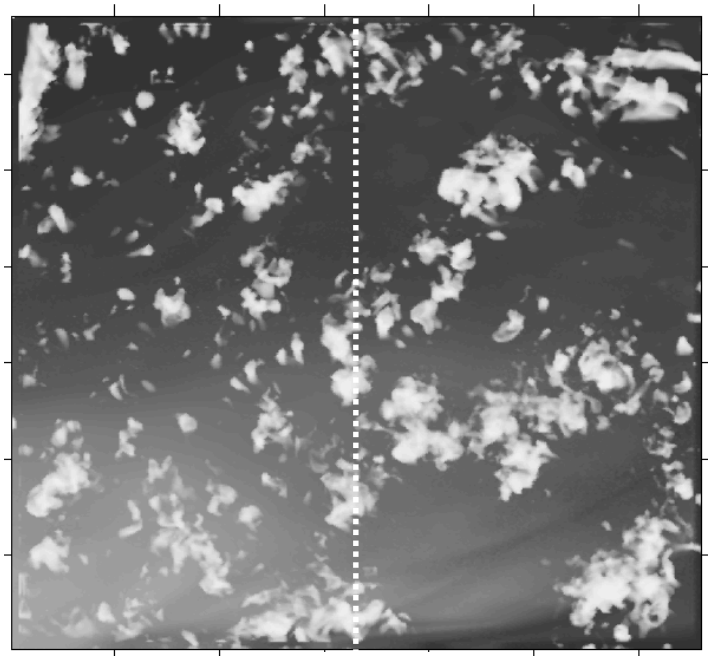
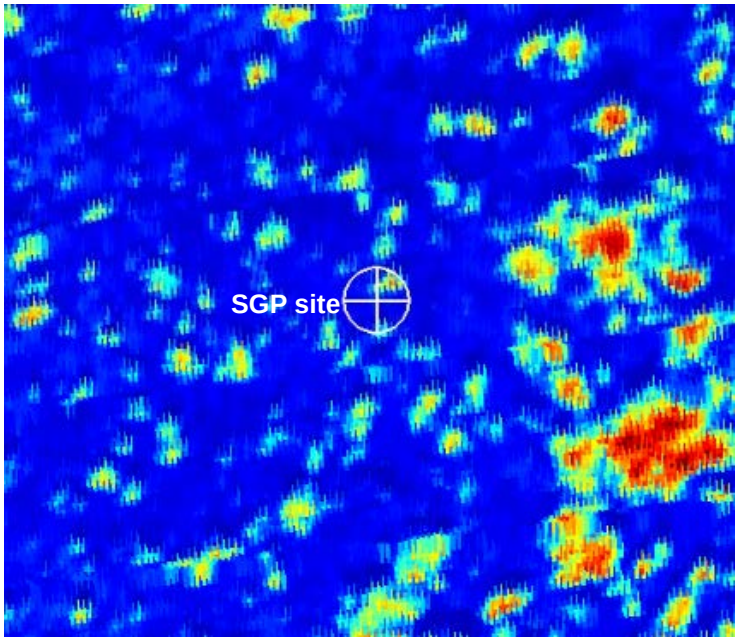
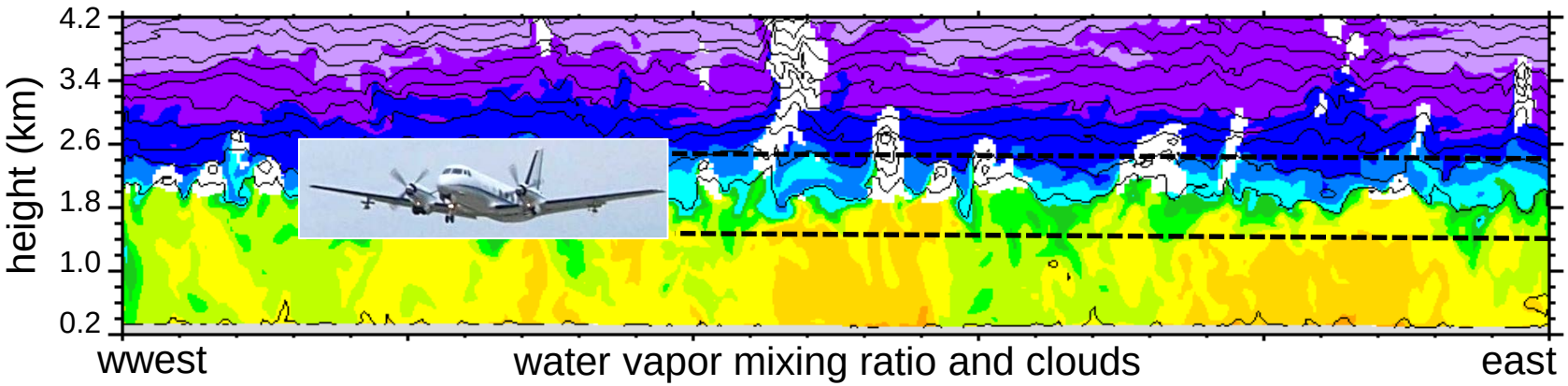
WRF LES 1950 UTC (Δx = 100 m)



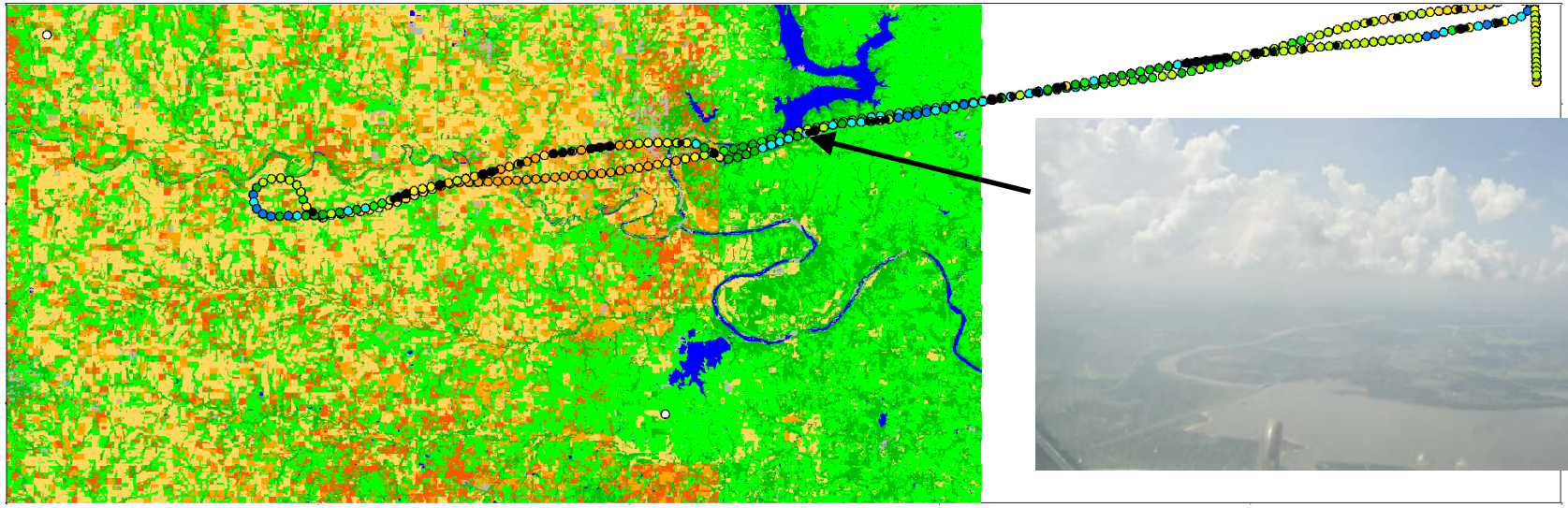
MODIS AQUA 1950 UTC (Δx ~ 1 km)

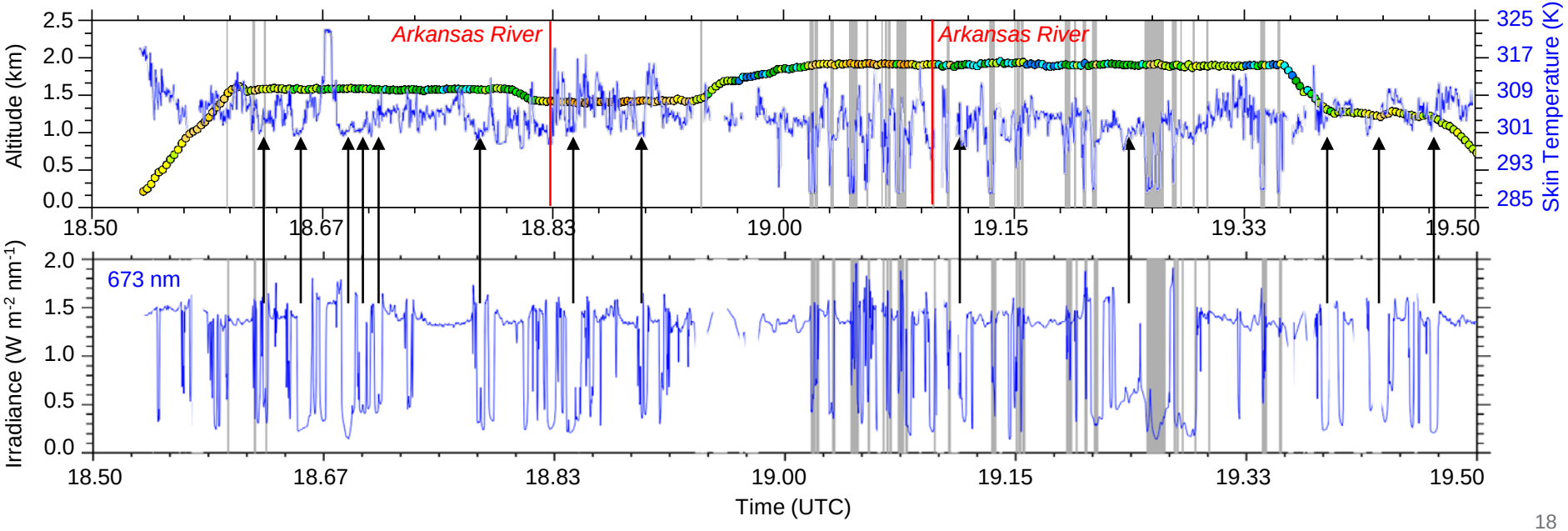


33 km



Coupling Clouds, Radiation, Surface Temperature, and Land Use



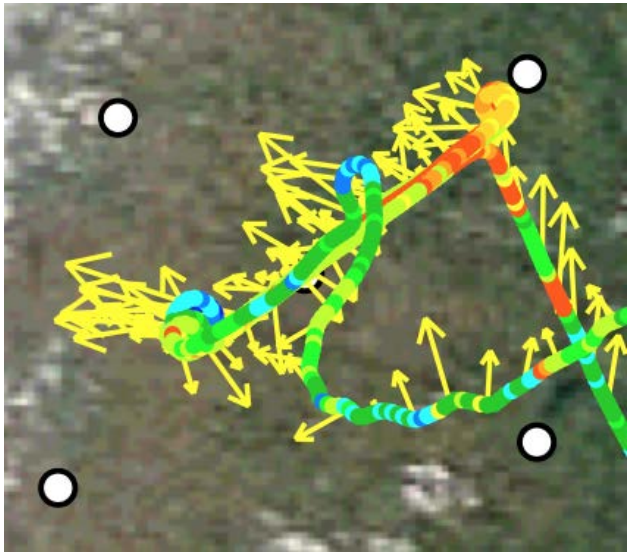


Summary

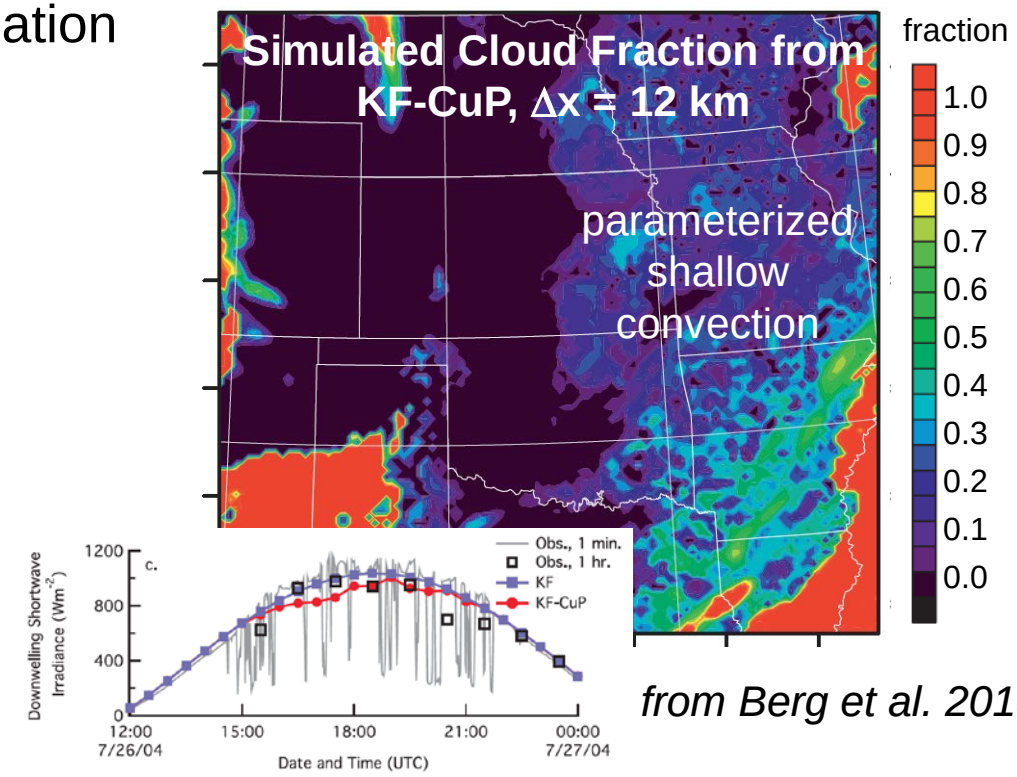
HI-SCALE campaign recently completed this summer with a new dataset:

- **New insights into coupling** of land-atmosphere interactions, turbulent boundary layer mixing, secondary organic aerosols, convective initiation and development, and their interactions
- **Evaluate and improve** LES (explicit) and mesoscale (parameterized) representations of cloud population

Larger LES Domain



100 km



from Berg et al. 2013