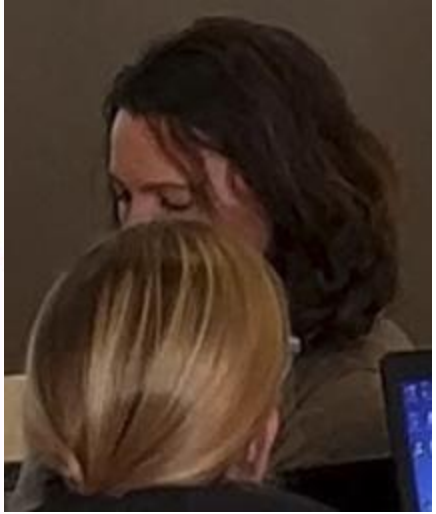
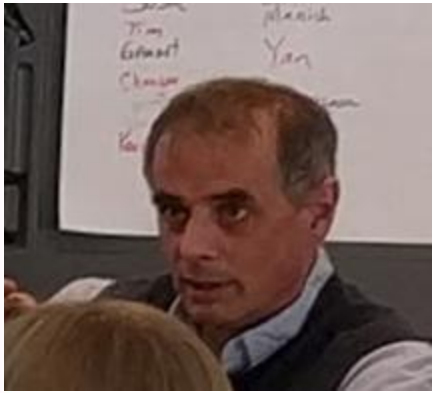
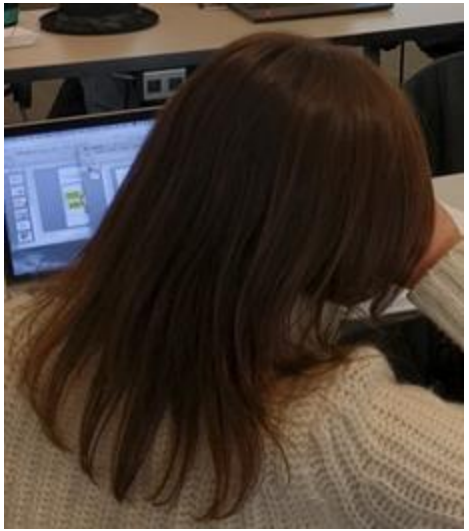
2017 AMSG Workshop







Brookhaven National Laboratory

S3O2 - Large spatial and temporal science studies

Block 1: 15:00 - 15:55, “Setting the Table”

- 15:00 - 15:10 ARM Large-Scale Science (Chongai Kuang)
- 15:10 - 15:15 Multi-scale Temporal Analysis (Jim Smith)
- 15:15 - 15:25 Surface-through-Vertical Observational Analysis (Maria Zawadowicz)
- 15:25 - 15:35 Multi-scale Spatio-Temporal Modeling Analysis (Allison Steiner, virtual)
- 15:35 - 15:45 Aerosol Vertical Profile Data Products (Peng Wu, virtual)
- 15:45 - 15:55 UAS-enabled Aerosol Science (Beat Schmid, virtual)

Block 2: 15:55 - 16:30, Discussion

- creative deployment, modeling, and data-product development strategies
- collaborations with other regional-to-national surface / aerial measurement networks
- opportunities to develop and deploy novel subsets of instruments
- collaborations with satellite programs

ARM Large-Scale Science:

Opportunities with the AMF3-BNF Climate Observatory Targeting Land-Aerosol-Cloud Interactions in the Southeastern US

Chongai Kuang[1], Scott Giangrande[1], Shawn Serbin[2]
with contributions from our site science team and site operations team

[1]Environmental and Climate Sciences Department, BNL
[2]Biospheric Sciences Laboratory, NASA Goddard

AMSG Strategic Workshop, July 9, 2024

Brookhaven National Laboratory

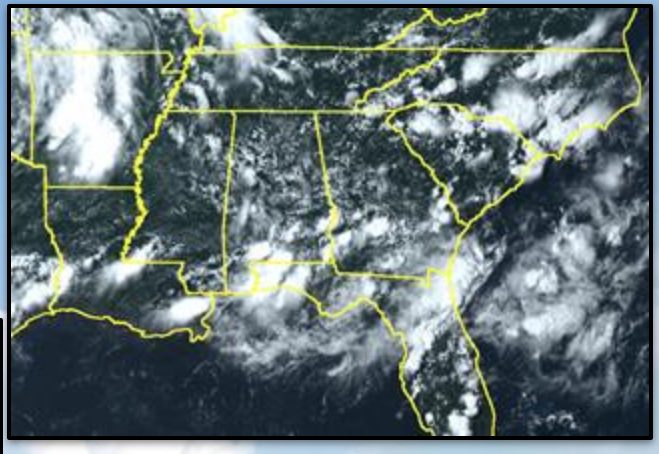
U.S. DEPARTMENT OF ENERGY

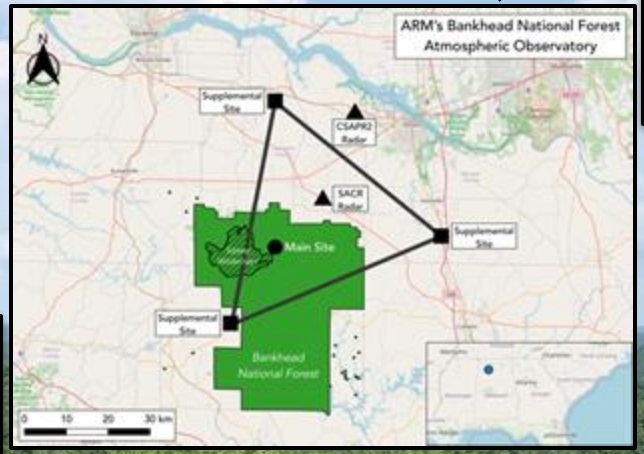
ASR Atmospheric System Research

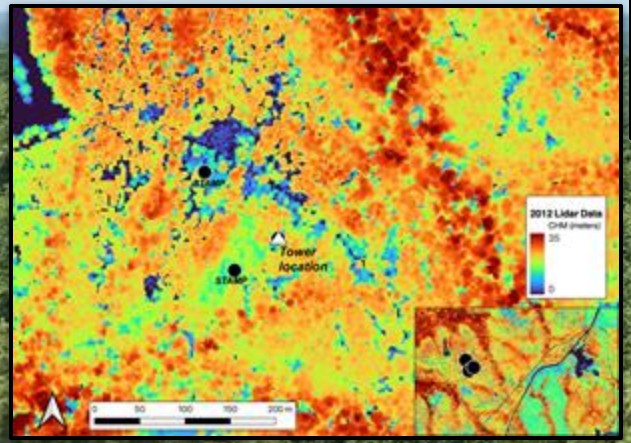
ARM

@BrookhavenLab

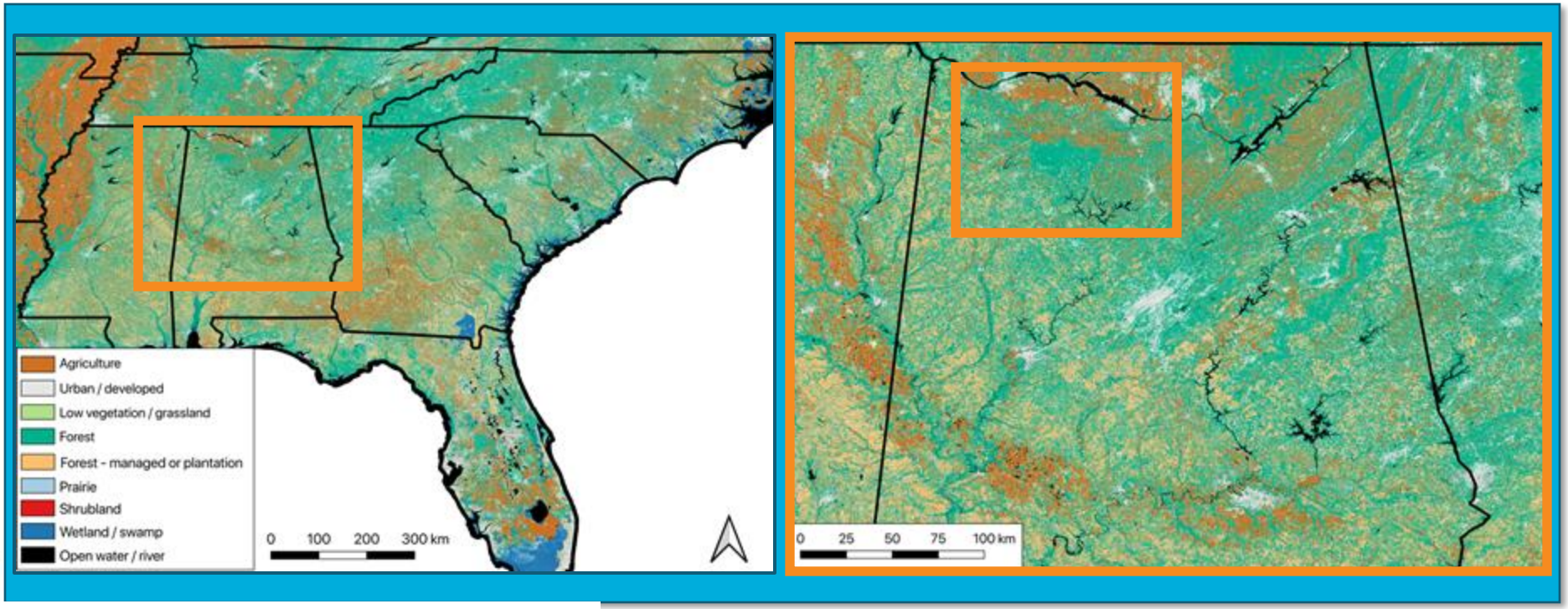
“From the Canopy to the Clouds”





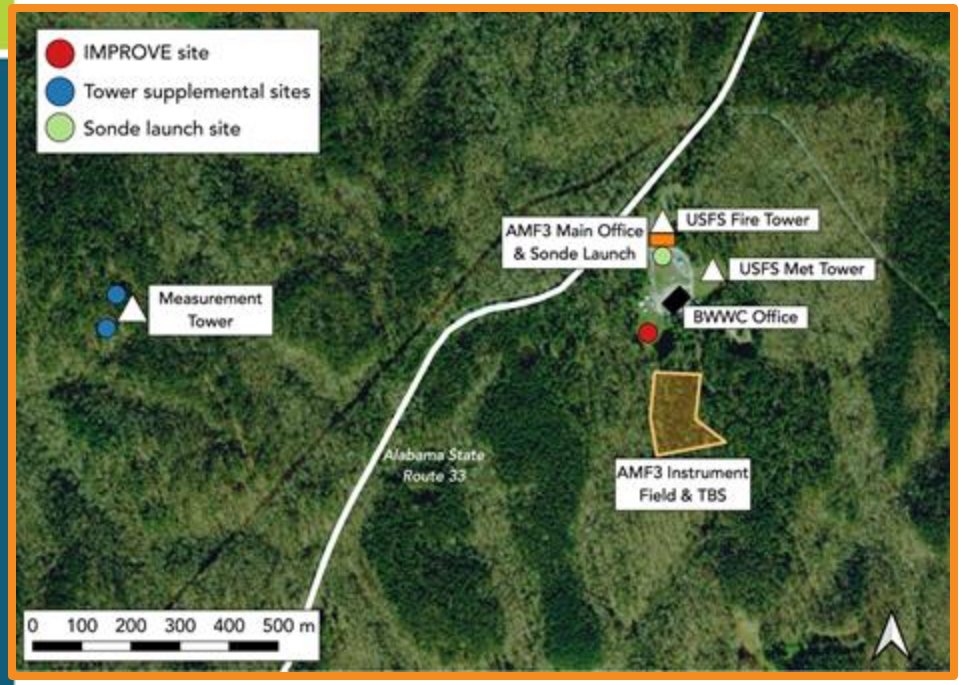


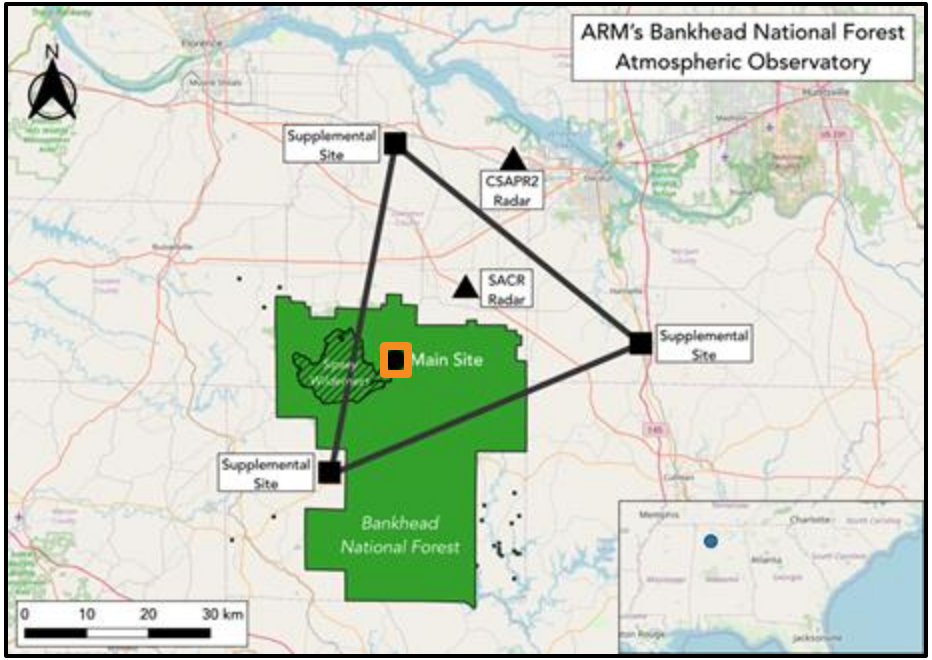
AMF3-BNF: Northern Alabama and the Bankhead National Forest (BNF)



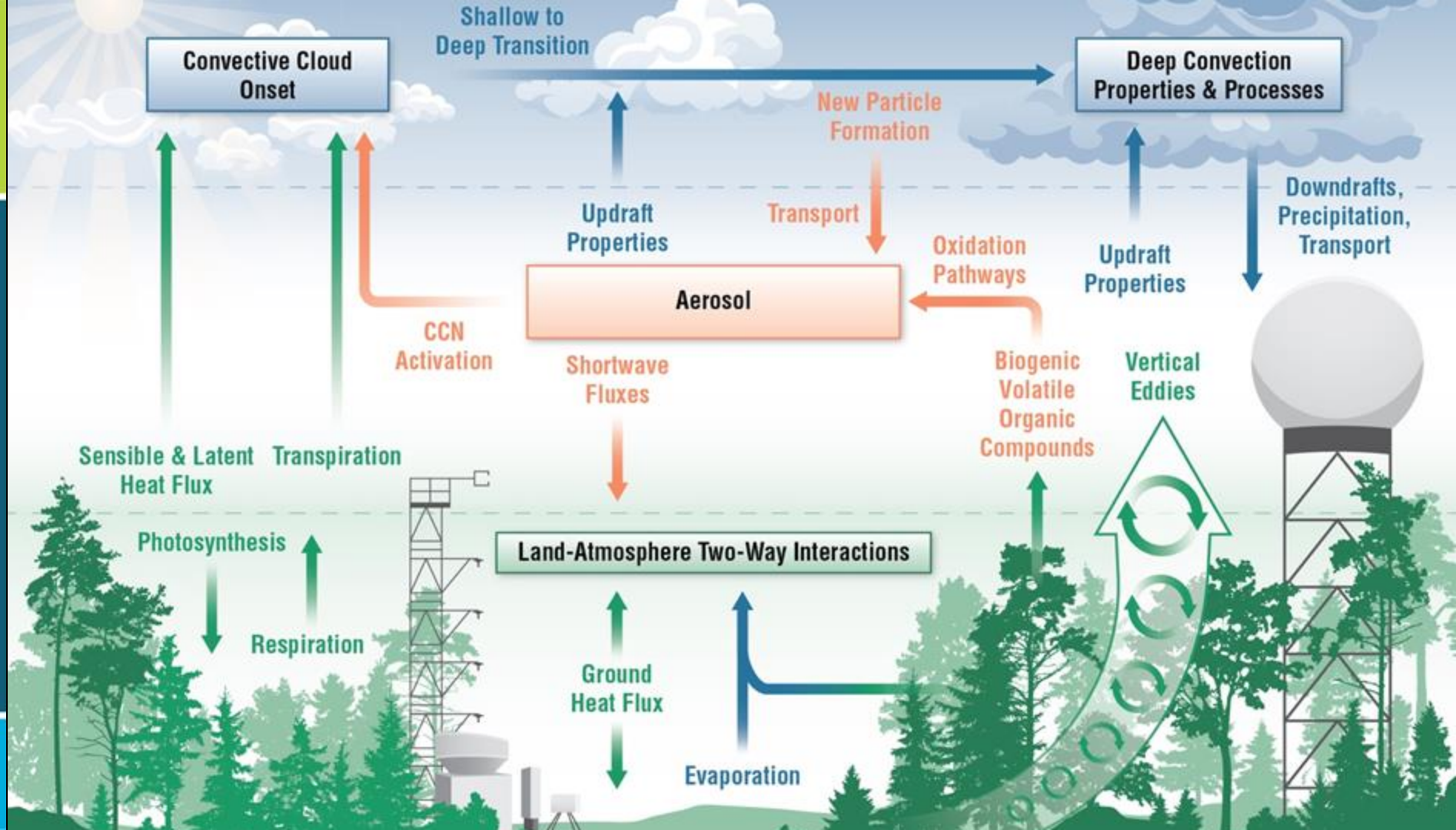
LandFire 30 meter land cover product

AMF3-BNF: Main Site Character and Regional Domain





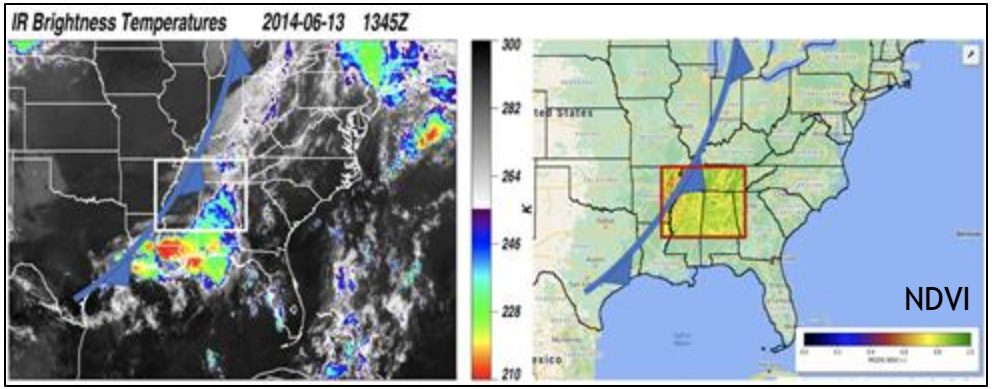
- Bankhead National Forest (BNF): Black Warrior Work Center (BWWC) - Main Site
- Radars and Supplemental Sites


Shallow to
Deep Transition
Convective Cloud
Onset
Deep Convection
Properties & Processes
New Particle
Formation
Updraft
Properties
Transport
Oxidation
Pathways
Updraft
Properties
Downdrafts,
Precipitation,
Transport
Aerosol
CCN
Activation
Shortwave
Fluxes
Biogenic
Volatile
Organic
Compounds
Vertical
Eddies
Sensible & Latent
Heat Flux
Transpiration
Photosynthesis
Land-Atmosphere Two-Way Interactions
Respiration
Ground
Heat Flux
Evaporation

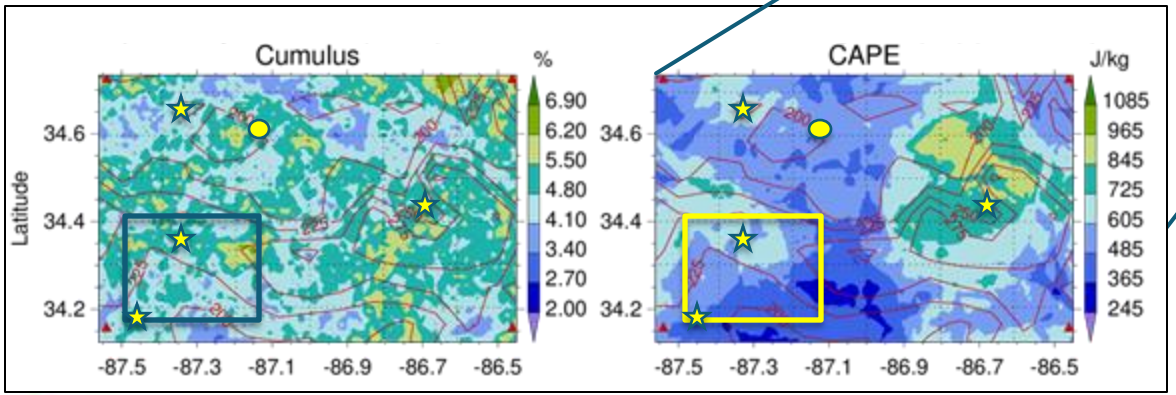
Greg Elsaesser, Columbia University / GISS

Local Controls on Convective Cloud Development

What is the role of mesoscale thermodynamic perturbations in convection onset, and how do surface dynamics shape PBL perturbations?



- Developing new SST-created datasets (with partners).
- Aggregating information including: Fronts, T/Qv profiles, cloud % (soon: soil moisture, vegetation properties).
- Data & Analysis to be done on Cumulus-II.



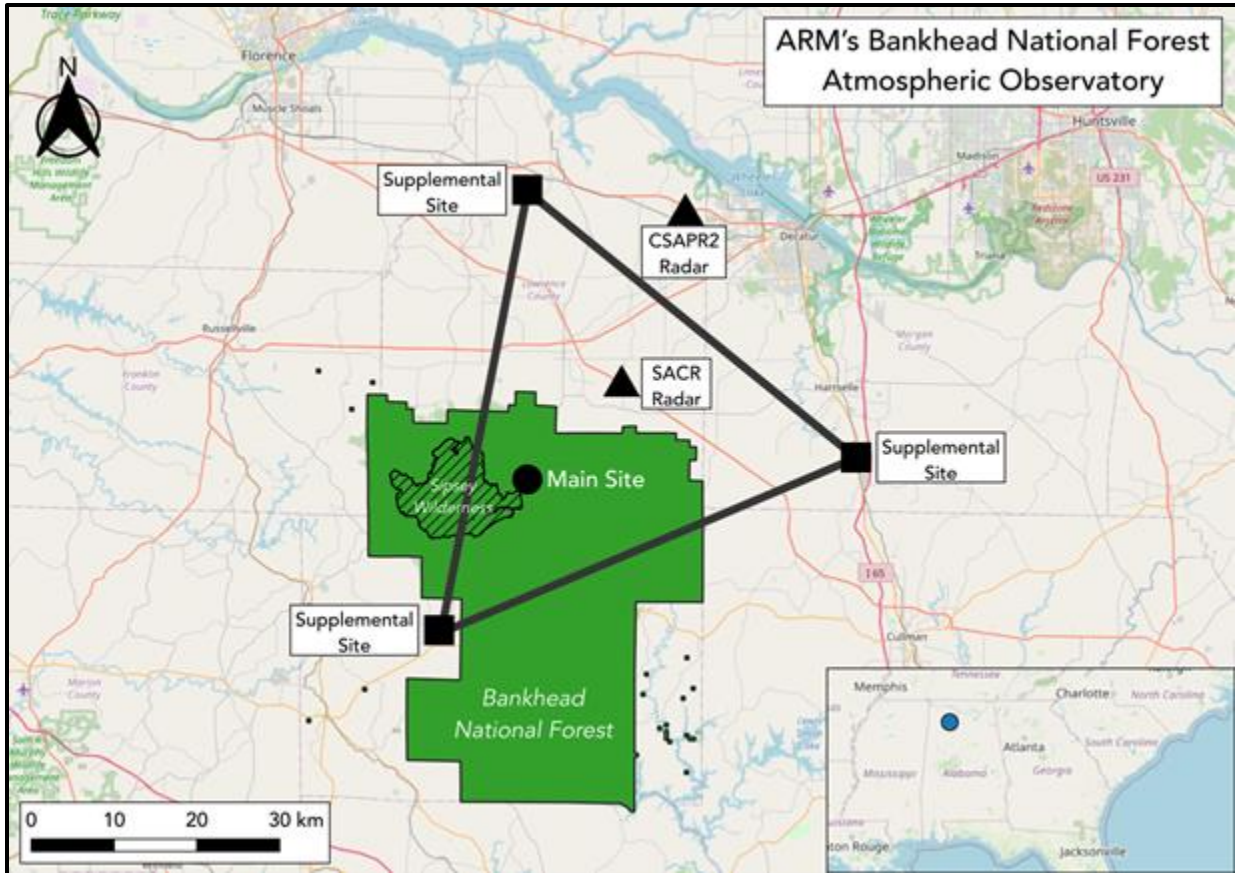
Topography contours (red lines)

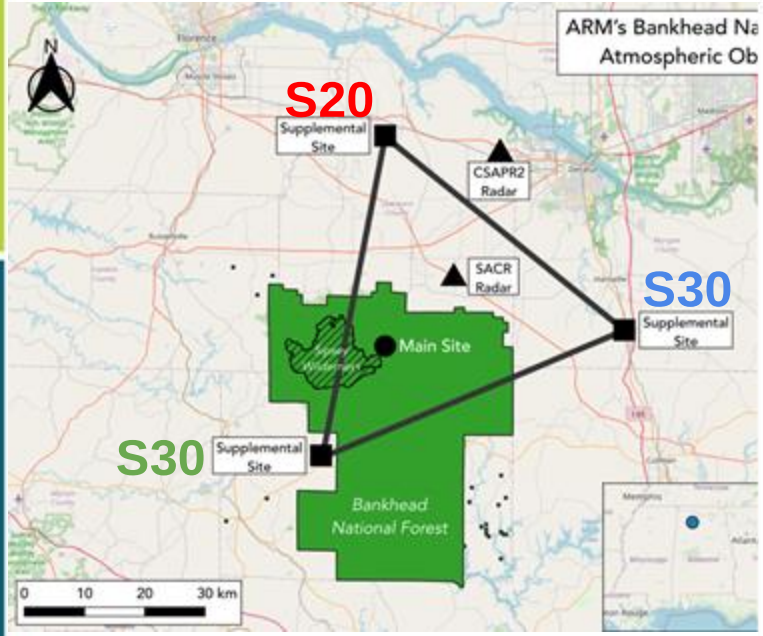
Efforts collaborative with other team efforts:

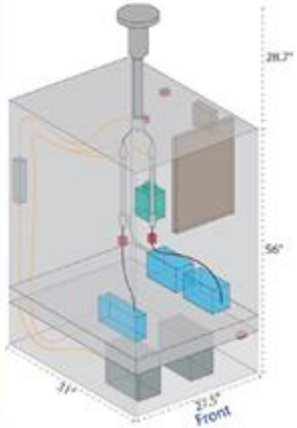
- LES runs will use these efforts to ID quiescent days that result in different dominant cloud types
- Studies on deep convective cloud onset and their properties
- environment (dynamic / thermodynamic) - aerosol interactions

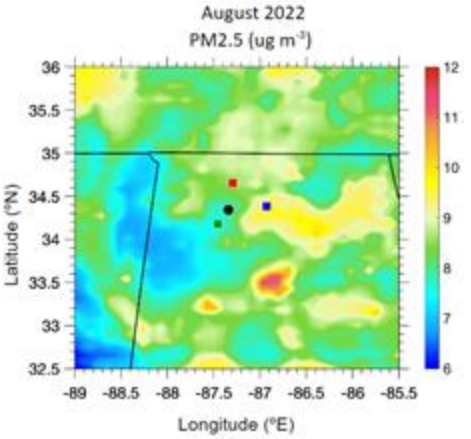
Phase 2: Aerial Platforms, Radar Sites / Partner Facilities, and Supplemental Sites

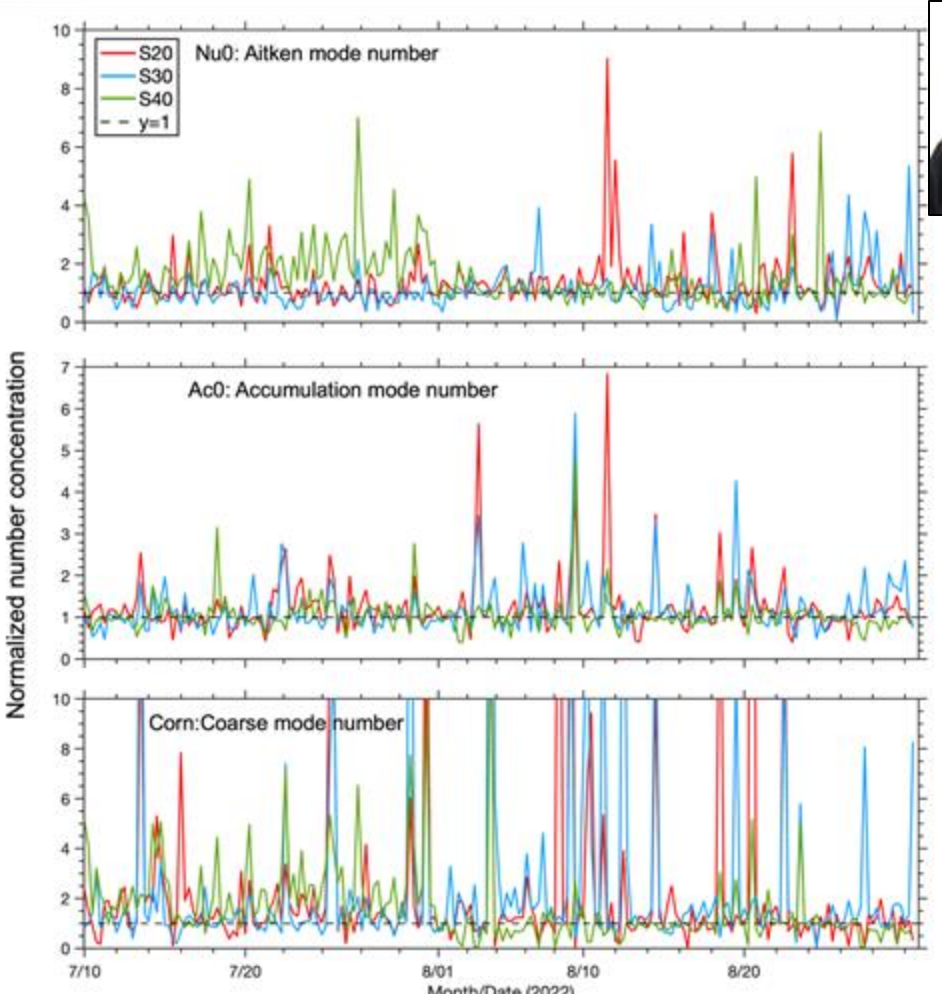
- **Supplemental Sites**:
  - 3 non-collinear sites
  - boundary layer profiles (T, wind, water vapor, LWP)
  - surface fluxes (soil, atmosphere)
  - surface MET / RAD
  - "supplemental" flux towers
- **Potential Partner Facilities**: University of Alabama, Huntsville (ARMOR radar, SWIRLL)
- **Aerosol Distributed Sensor Network**
- **Aerial Measurement Platforms**: Tethered Balloon System, Uncrewed Aerial System
- **ARM Cloud / Precipitation Radars**: CSAPR2, Ka-XSACR







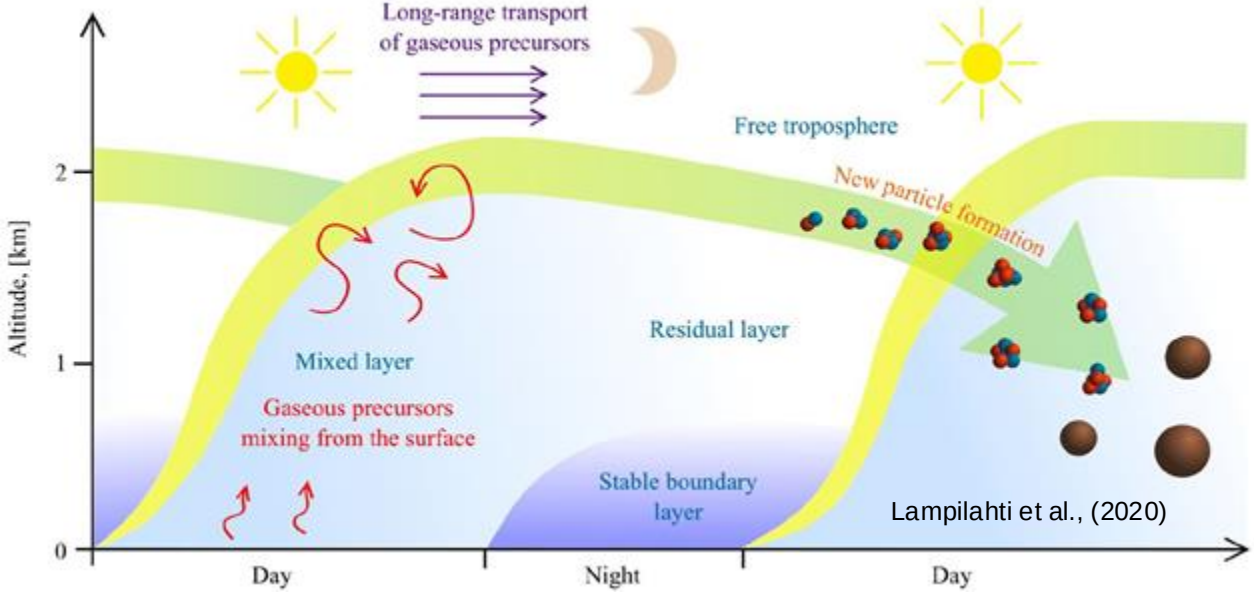




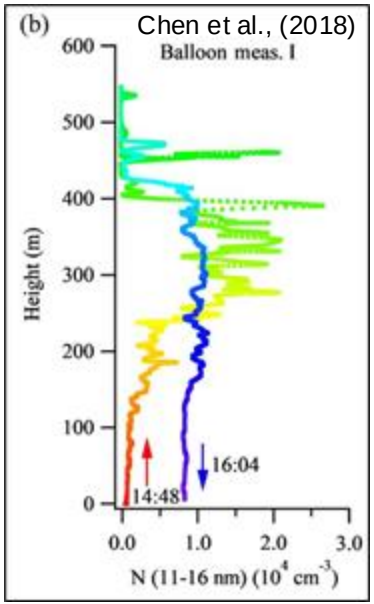
courtesy of Tamanna Subba

Quantifying the Integrated Terrestrial Controls on Aerosol: *Sources, Transformations, and Climate Impacts in the Southeastern US*

- FY25 FICUS proposal call (pending): joint ARM (TBS platform) and EMSL (offline analysis, HPC)
- Team: Shawn Serbin, Tamanna Subba, Maria Zawadowicz
- an objective: resolving the forest / boundary layer controls on new particle formation (NPF)



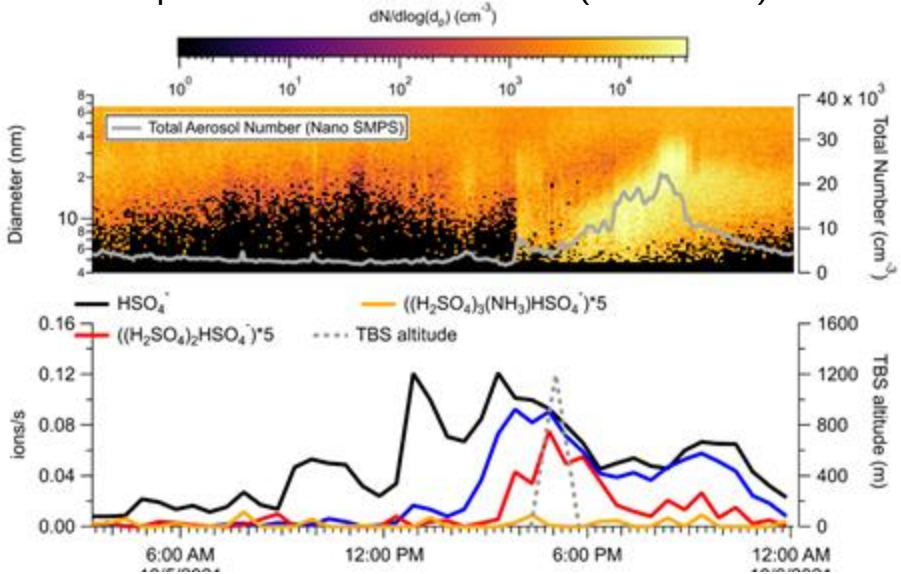
Lampilahti et al., (2020)



Boundary Layer Gradients in NPF: *Target BNF*

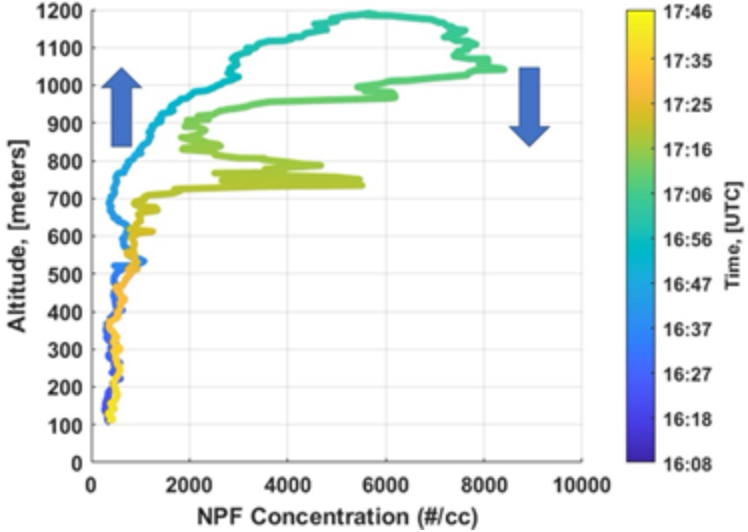
- Current models poorly represent both the **magnitude** and the **vertical initiation** of boundary layer NPF. To address these gaps, a combined TBS-surface measurement campaign was proposed for SGP to:

- Identify any “missing” aerosol precursors responsible for observed NPF (PI: Browne)



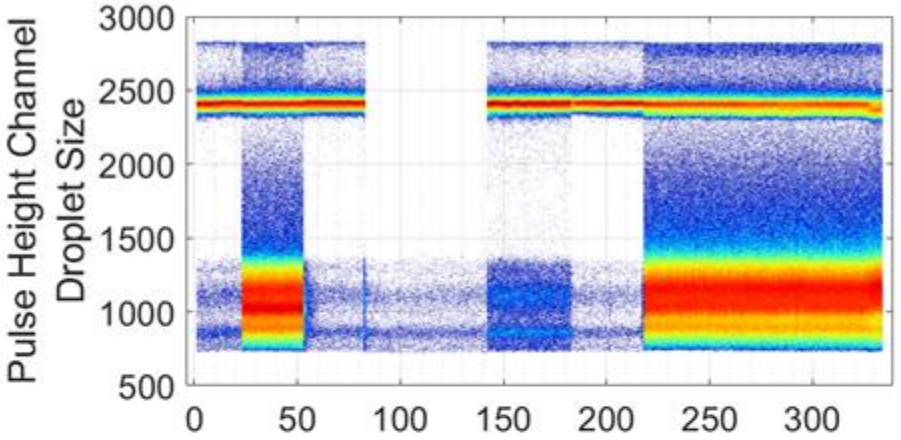
- Higher order sulfuric acid ion clusters (n = 3) were not observed, suggesting **insufficient precursors to initiate surface NPF**.

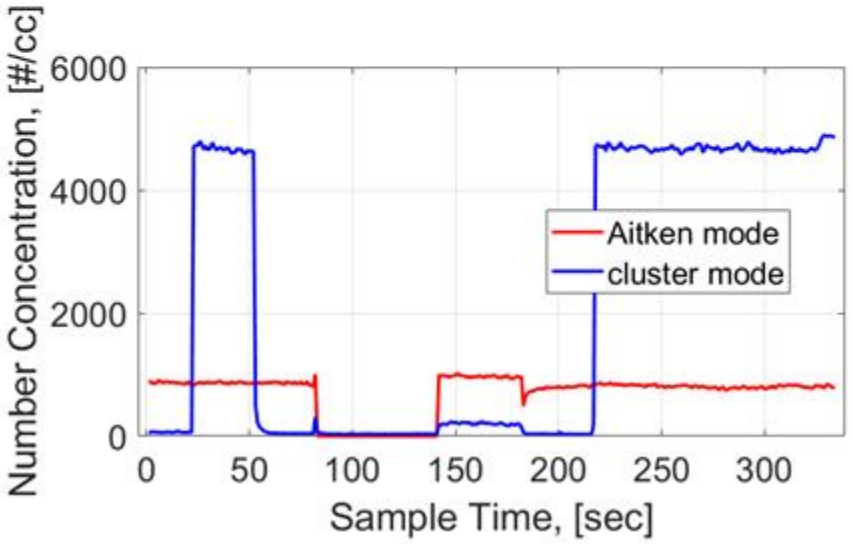
- Identify the vertical locations where observed NPF initiates (PI: Kuang)

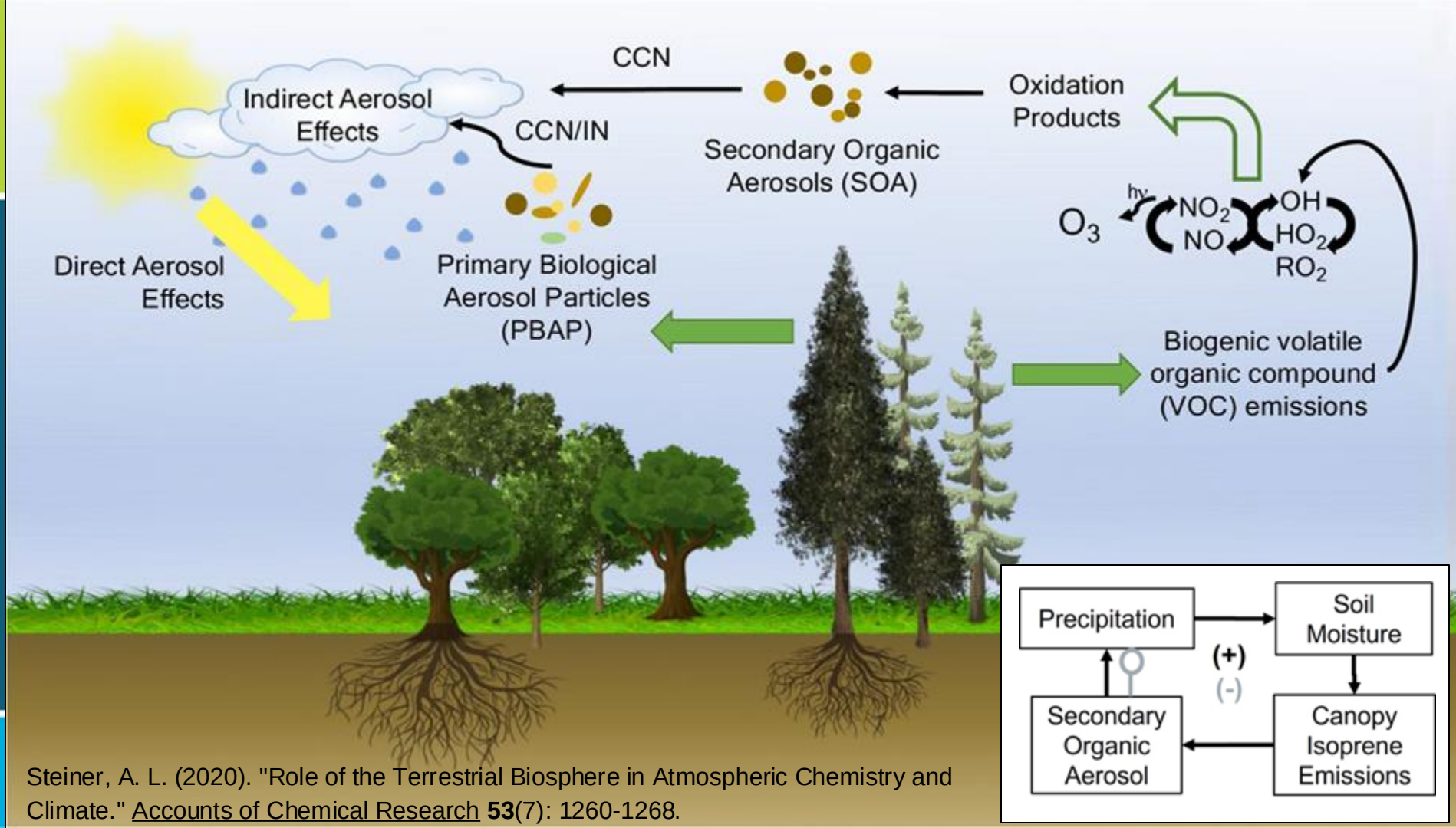


- TBS-based 1 nm CPC (right) provided vertically-resolved aerosol concentrations indicating that **NPF initiates aloft** (> ~1200 m) followed by downward transport to the surface.

(nearly) UAS - ready



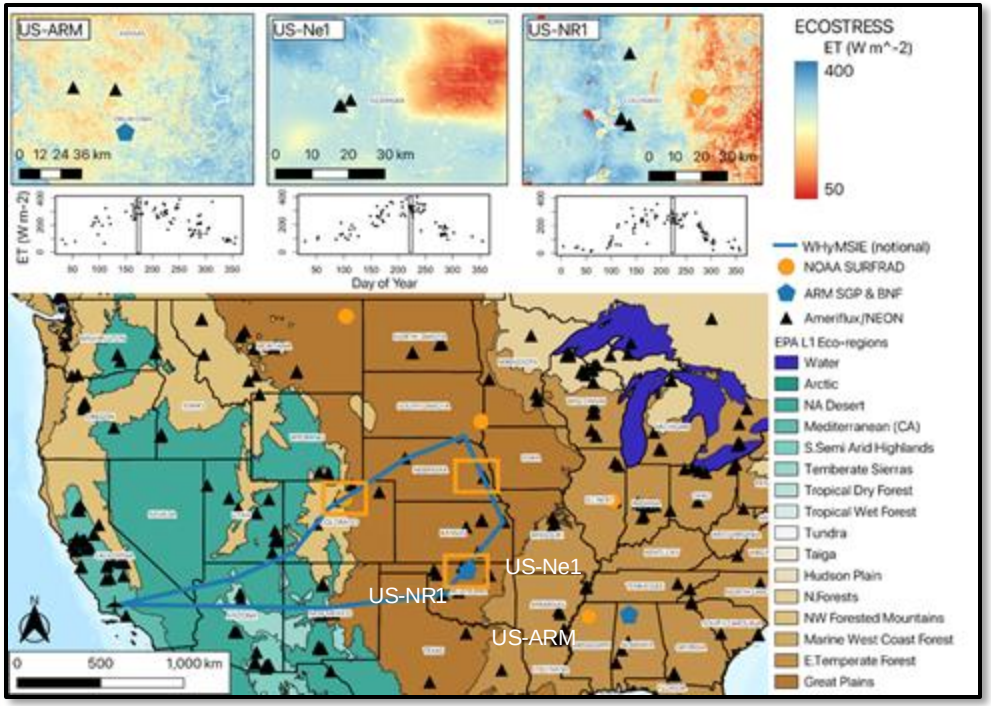




Steiner, A. L. (2020). "Role of the Terrestrial Biosphere in Atmospheric Chemistry and Climate." Accounts of Chemical Research **53**(7): 1260-1268.

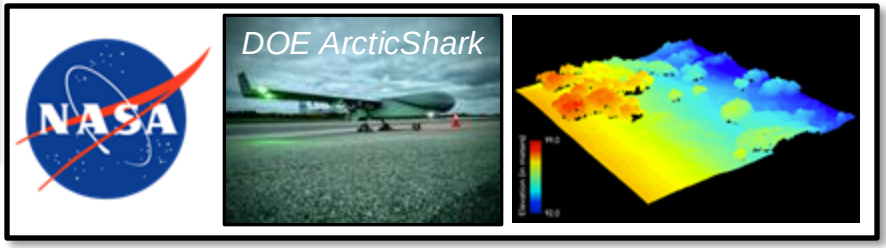
Opportunities to inform PBL priorities

e.g. WHyMSIE; sub-orbital & multiscale campaigns

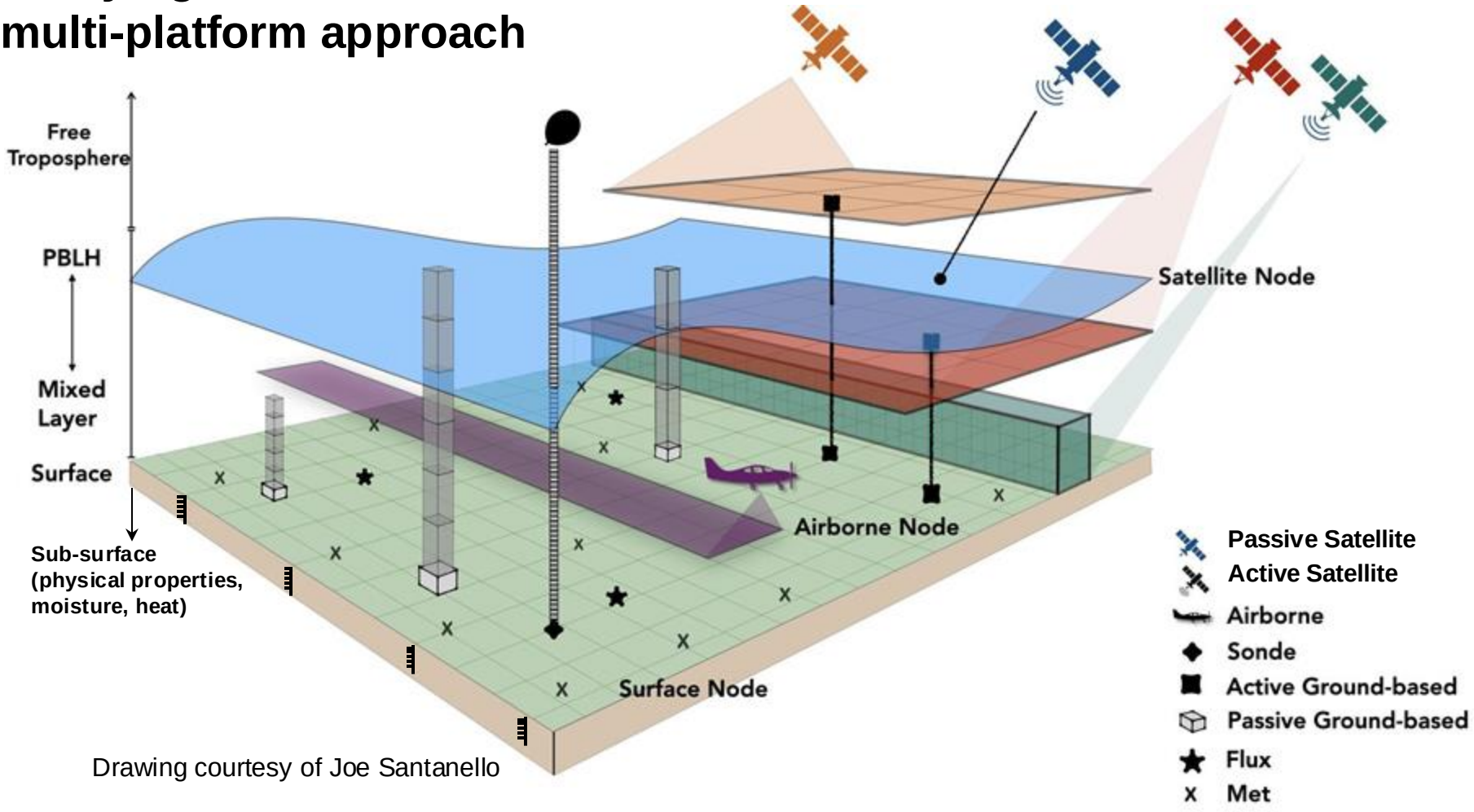


courtesy of Shawn Serbin

- Targeted use of UASs and vertical profiling to study fine-scale surface drivers of aerosols, energy, and water vapor fluxes/profiles in the PBL at high temporal resolution (sub-daily)
- Co-development of coordinated surface and airborne campaigns (e.g. WHyMSIE, APEX, ARCSIX), connected to measurement sites/global networks (e.g. SGP/AMF3, GLAFO, GALION)
- Test-bed for emerging measurement technologies (e.g., distributed sensing) and AI/ML data fusion applications for PBL science; 2D/3D multi-scale products for model evaluation & process studies
- Improve connections between surface and PBL thermodynamics in models; invest in observation operators and satellite simulators for model ingest



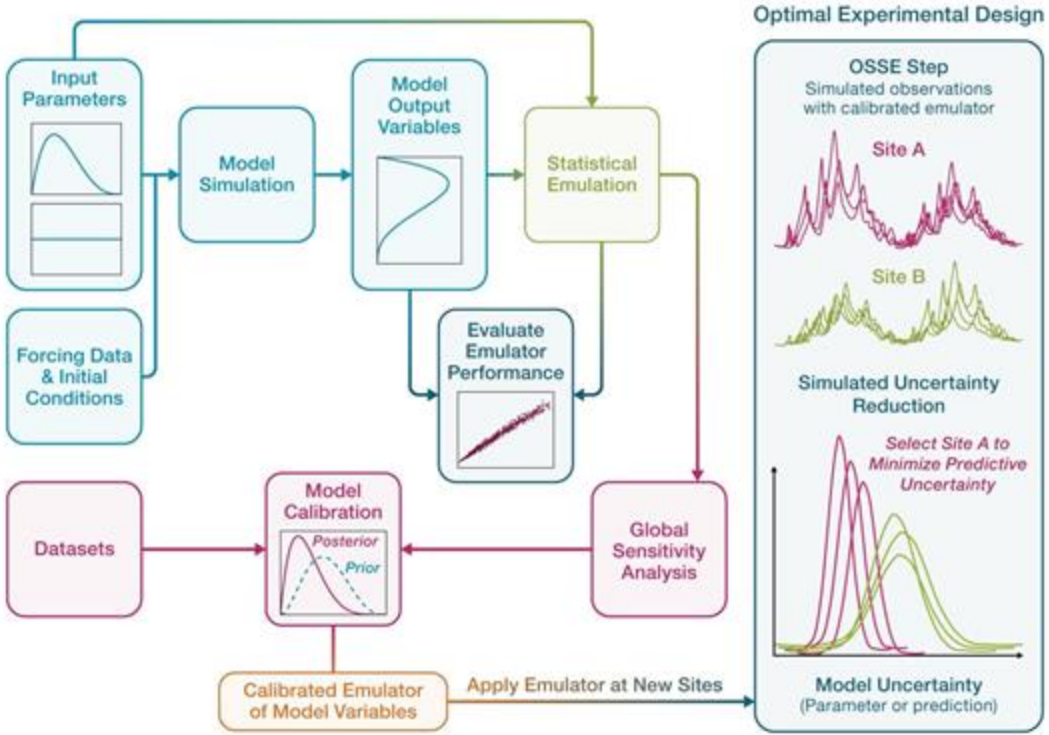
Studying the PBL via a multi-scale, multi-platform approach



Drawing courtesy of Joe Santanello

“Advancing FASSt-Simulation: A Novel Computational Framework for Model-Measurement Integration for Climate Prediction”

Model-Observing System Co-Design

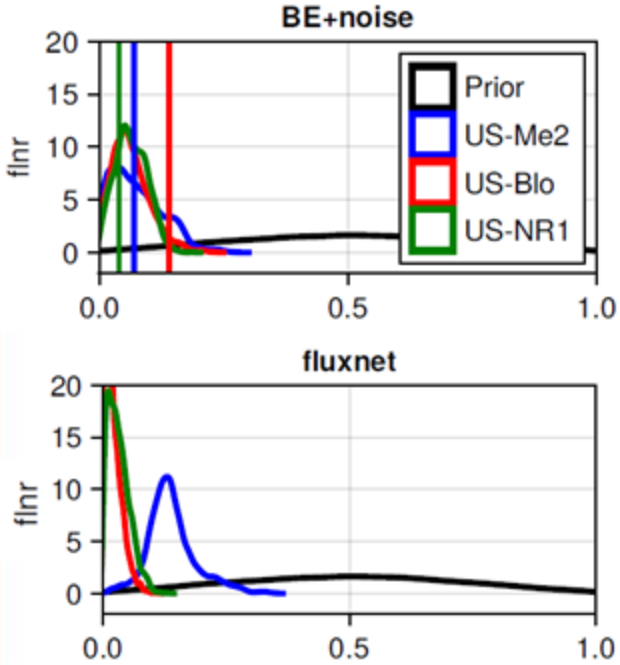


courtesy of Zhongjing Jiang

- **Goal:** Develop a novel, adaptable, and scalable computational framework for rapid model-measurement assimilation.
- **Approach:** Leverage earth system modeling together with computational methods, and the framework sequentially comprises four components:
  - Performing model simulations using an Earth system land model (ELM)
  - Developing statistical emulators for ELM
  - Performing global sensitivity analysis
  - Performing model calibrations (Bayesian inference)
  - Performing optimal experimental design via **observing system simulation experiments (OSSEs)**

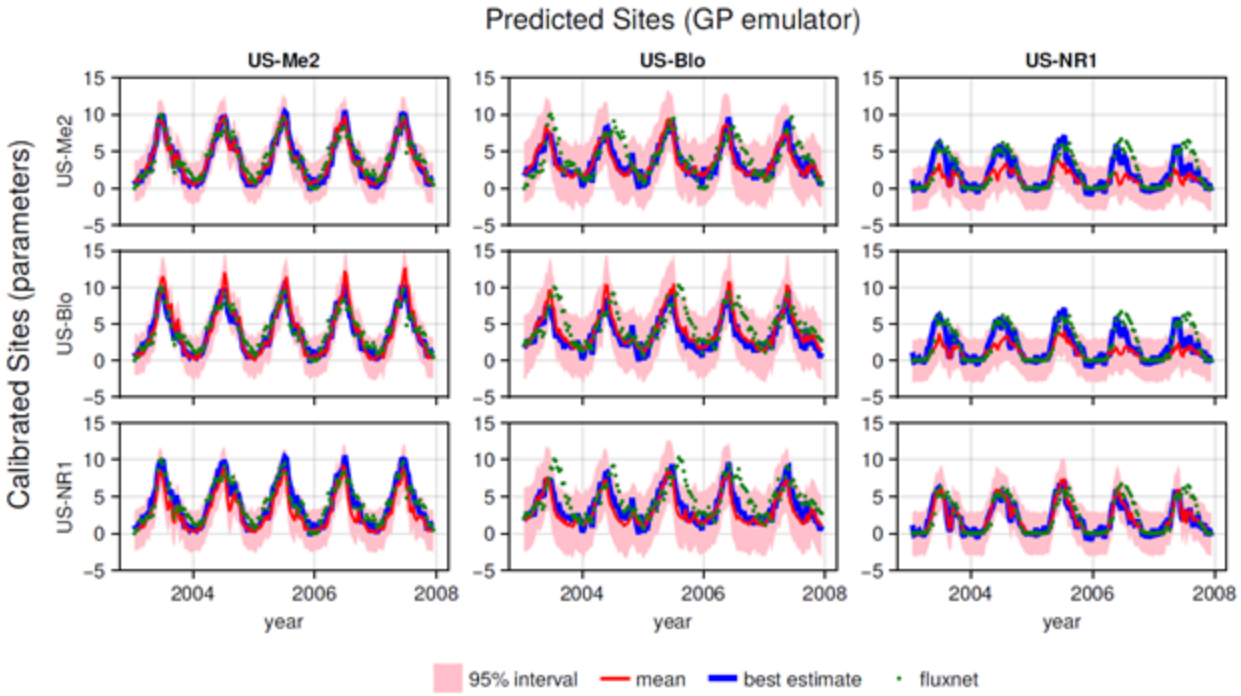
Research Results

Parameter estimation



Posterior vs. Prior

Model Prediction at same site and new sites



courtesy of Zhongjing Jiang

AMF3-BNF Contributors & Partners

- **AMF3-BNF Site Science**: Scott Giangrande, Shawn Serbin, Jim Smith, Allison Steiner, Greg Elsaesser, Mariko Oue, Pierre Gentine, John Peters, Thijs Heus, Allison McComiskey, Mike Jensen, Pavlos Kollias, Art Sedlacek, Andy Vogelmann, Hugh Morrison, Dave Turner, Markus Petters

- **AMF3-BNF Site Operations**: Mike Ritsche, Nicki Hickmon, Patty Campbell, Mark Spychala, Adam Theisen

ARM

ASR
Atmospheric System Research

Some Potential Discussion Considerations…

- creative deployment, modeling, and data-product development strategies to (better) link comprehensive and high-temporal-resolution ARM measurements with spatial information (scales: horizontal ~ 100s km, vertical ~ 10s km) and over longer time periods (scales: seasonal to inter-annual)

- collaborations (and how to build/sustain them) with other regional-to-national surface/aerial measurement networks (e.g., IMPROVE, ASCENT, NEON/AOP, AmeriFlux, NASA) to both contextualize ARM observations (in space and time) as well as provide an important reference for those networks

- opportunities to develop subsets of instruments (e.g., atmospheric thermodynamic profilers, aerosol size spectrometers) and deploy around a main site, to provide greater information about main site representativeness (e.g., local vs. background)

- collaborations with satellite programs for which the joint application of ARM's comprehensive measurements at a single point with satellite-based spatial information would be of particular benefit to the ARM user community

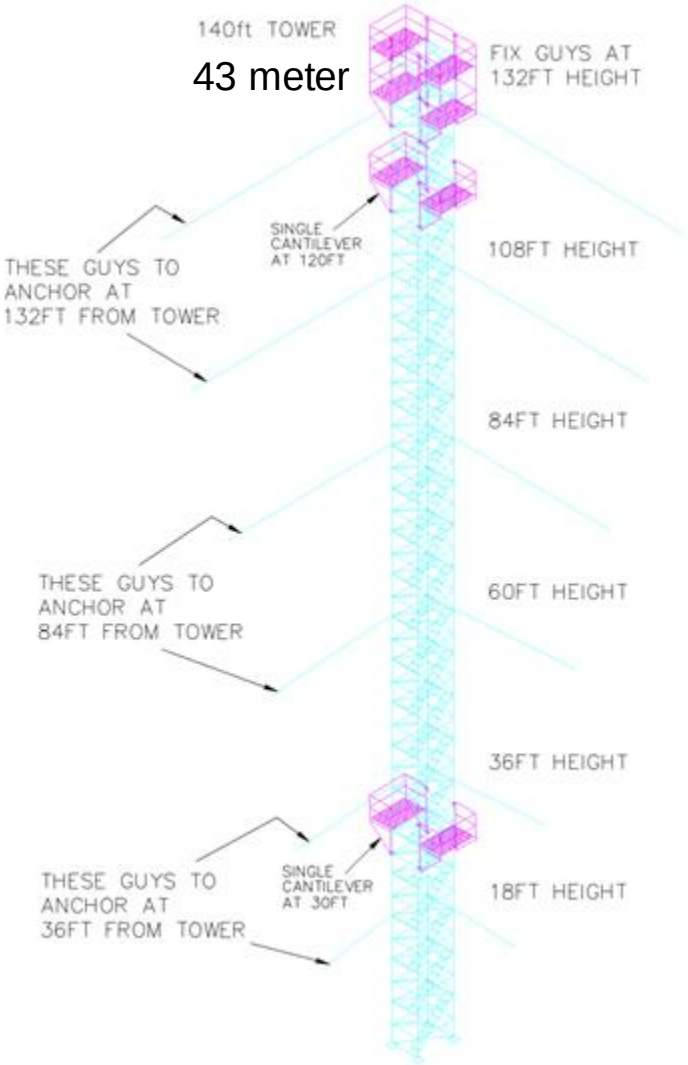
Point to pixel to planet

- The spatiotemporal characteristics of the surface play an important role in regulating land-atmosphere interactions and the PBL.
- ***Challenge:*** Common model representations of LAI are missing key processes and/or spatial/temporal scales (e.g. diel cycles) which drive uncertainties in weather and climate prediction.
- ***Opportunity***: Cross-disciplinary, multi-scale research to help prioritize PBL observational and modeling needs that target the role of surface heterogeneity on LAI and the PBL.
- ***Need:*** Sites/networks that provide ***co-located*** (space+time) surface-atmosphere measurements of key properties and couplings connected to targeted sub-orbital campaigns that enable detailed process and scaling studies.
- ***Need:*** Approaches that can flexibly combine heterogenous data to evaluate multi-platform retrievals and the role of surface drivers.

Space *(e.g. ISS, Satellite)*

Air *(e.g. UAS, WHyMSIE, APEX, ARCSIX)*

Ground *(e.g. ARM, FLUXNET, AERONET)*



S10 Tower Measurements

ARM Instruments:

- CEIL
- LDIS
- T/RH
- 3D WINDS
- IR Radiometers
- Cameras
- MFR
- PGSISO
- PAR
- RADIOMETERS
- STAMP
- SEBS
- TBRG
- Barometer

Partner and new measurements:

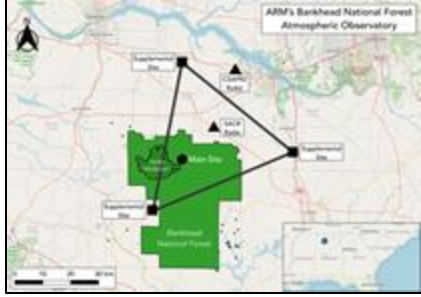
- **AmeriFlux** Eddy Covariance & AP200 CO_2 / H_2O Profiling System
- BVOCs* (**EMSL**)
- Biological aerosol* / WIBS (**EMSL**)
- Distributed temperature sensing
- Phenocameras

Measurements:

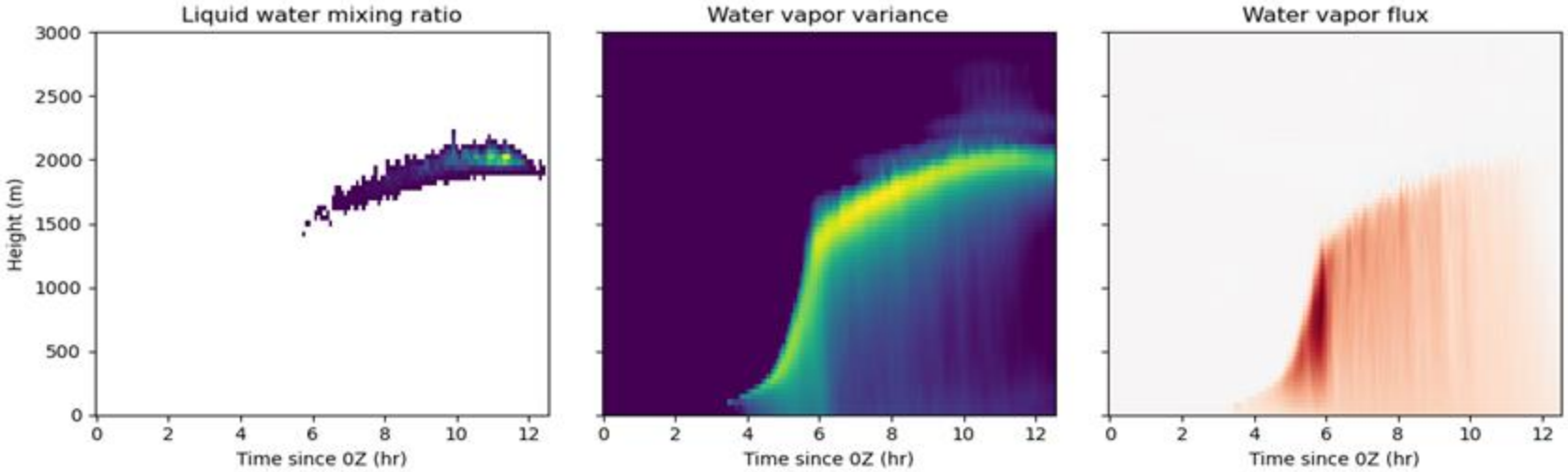
- 3D winds, T/RH, precipitation & throughfall
- Radiation (direct / diffuse), incident / reflected, profiles
- Fluxes of CO_2, H_2O, & energy, aerosols* (CPC)
- Canopy CO_2 / H_2O storage
- Greenhouse gas profiles and mixing ratios, isotopes
- Turbulence profiles
- Vegetation phenology
- Surface temperature
- Soil heat flux, temperature, moisture

Thijs Heus, Cleveland State University

Routine MicroHH LES over the AMF3-BNF



What is the role of surface interactions on the development of the PBL and/or subsequent clouds?



- Prototyping LES runs based on ERA5 and fixed surface fluxes (initial BNF tests above).
- Plan to implement interactive land / dynamics, coordination with S. Serbin & other SST members.
- Initial case selection for these runs will be performed in conjunction with G. Elsaesser (previous slide).
- 25-km sub-real-time simulations to be run on the ARM-Cumulus-II server with a 25 meter grid cell size (resolution).
- Perform boundary layer scalar budget analysis across domain (main + 3 supplemental sites).

AMF3-BNF: Select Opportunities / Goals

- Improve understanding of land-atmosphere two-way interactions and surface controls on aerosol and convective processes.
- Understand impacts of surface heterogeneity and seasonality on the strength and patterns of land-atmosphere coupling.
- Target improvement in model representation of land-surface processes, including energy partitioning, fluxes, turbulence, and contributions to aerosol / convection processes and larger-scale regional variability.
- Develop multi-scale approaches to upscale, extrapolate, and integrate surface observations into models (e.g., LES ⇒ meso-scale ⇒ climate scale).
- Create a regional LAI-network focused on the role of the land-surface on boundary layer dynamics that can address larger Southeast US climate research needs.

DOE Atmospheric Radiation Measurement (ARM) User Facility

MISSION: Provide the climate research community with strategically located atmospheric observatories to improve the understanding and representation in earth system models of clouds and aerosols and their interactions with the Earth's surface.

Comprehensive Measurements Deployed in Diverse Climate Regimes

Background atmospheric state

Surface energy balance

Aerosol and hydrometeor profiles

Near-surface aerosol properties

Aerial measurements

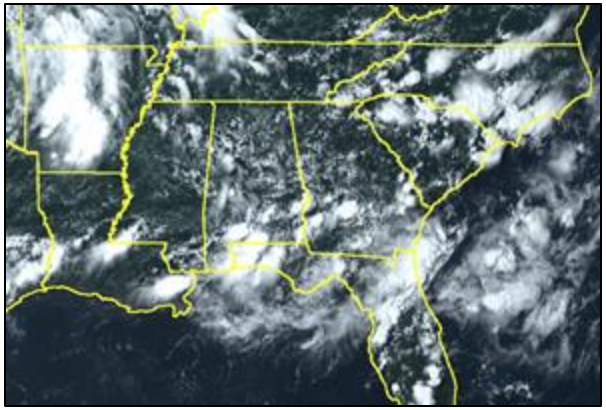
Relocation of the 3rd ARM Mobile Facility (AMF3) to Northern Alabama

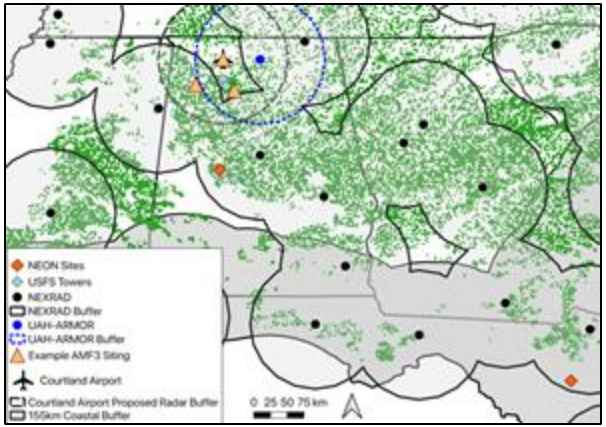
- Motivators for going to Northern Alabama:
  - Abundant locally-forced shallow-to-deep convection
  - Large amount of vegetative-driven biogenic emissions
  - Strong local coupling of the land surface with atmospheric processes

- Expected 5 year deployment, with planned operational start in Fall 2024

- Joint ARM and Atmospheric System Research (ASR)-funded site science project

- Site location, configuration, and instrumentation determined via a joint DOE-supported Site Operations and **Site Science Teams**.





AMF3-BNF Site Science Project: Core Team

- Chongai Kuang: BNL
- Scott Giangrande: BNL
- Shawn Serbin: NASA Goddard
- James Smith: University of California, Irvine
- Allison Steiner: University of Michigan
- Gregory Elsaesser: NASA GISS, Columbia University
- John Peters: The Pennsylvania State University
- Mariko Oue: Stony Brook University, NY
- Thijs Heus: Cleveland State University
- Pierre Gentine: Columbia University

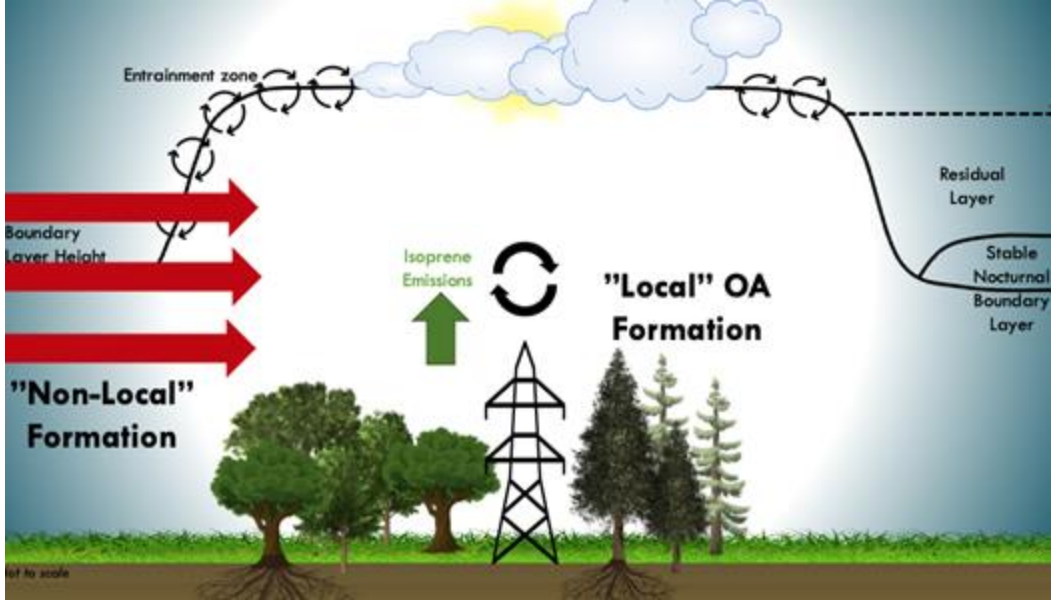
Phase 1: Instrument Field Layout and Measurements

- **Aerosol Observing System**
  - Water-uptake, chemical composition
  - Absorption, extinction, scattering
  - Concentration, size distribution
  - Trace gases
- Radiometry (upwelling / downwelling, short / long-wave radiation)
- Aerosol Profile Retrievals
- Cloud Properties and Microphysics (Profiling Radar)
- Radiosondes
- Surface Carbon, Water, Energy Fluxes
- Soil Moisture and Temperature
- Surface Meteorology
- Thermodynamic Profiles

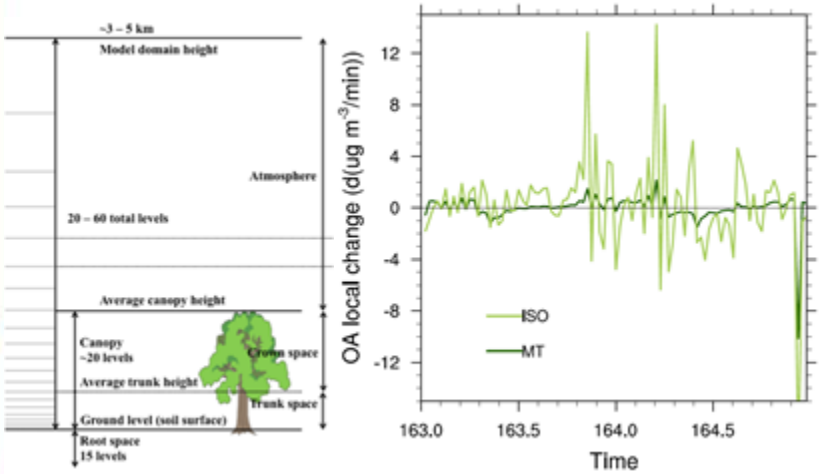
Allison Steiner, University of Michigan

Resolving Local vs. Regional Contributions to Organic Aerosol (OA) formation

Are aerosols observed at a single site representative of local formation or regional contributions?



Calculate local OA formation rates using 1D modeling approach (Wei et al. 2021)



Calculate regional OA contribution using WRF-Chem model simulations and divergence calculation of advective contribution of aerosol