Interim Science Whitepaper for Community Outreach

AMF3 SEUS: Coupled Observational-Modeling Studies of Land-Aerosol-Cloud Interactions in the Southeastern United States

Introduction:

Third ARM Mobile Facility (AMF3) deployment to the Southeastern United States (SEUS) provides new opportunities to improve understanding and model representation of aerosol, cloud, and land-surface processes and their couplings as the deployment will provide long-term observations in an environment strongly driven by local forcings. Resolving the role of local forcing in climate-relevant processes and differentiating them from those driven by larger-scale circulations will promote understanding of how different processes or feedbacks operate to set regions apart in their longer-term patterns of climate variability and trends. We are developing a deployment design and a research plan that leverages these opportunities to understand process interrelationships that drive multiscale weather and climate patterns. Community input plays a vital role in establishing and refining SEUS-relevant science drivers, which would then inform decisions regarding AMF3 siting, deployment, and instrument needs.

An overarching theme for the SEUS Site Science Team (SST) proposal is “scale aggregation” in earth system modeling, specifically following coupled SEUS aerosol-cloud-land surface processes from the canopy to local/cloud to regional/precipitation scales. The DOE Energy Exascale Earth System Model targets a global 3 km grid resolution on a decadal timescale. Observing and representing these coupled processes will necessitate detailed and creative new observational capabilities such as those obtainable from multi-disciplinary DOE ARM instrumentation that similarly scale from detailed column/profiling to regional/scanning of land-surface, atmospheric, aerosol, cloud, and precipitation properties. Proposed research efforts consist of five cross-cutting areas for earth system modeling (Figure 1).

- Convective cloud research topics include the roles of multi-scale thermodynamic perturbations on convective onset, key processes controlling shallow-to-deep convection, and the factors controlling convective updrafts and thermals.
- Aerosol research topics include the chemical processes that control the evolution of organic aerosol, the seasonality and spatial distribution of particulate water, and the role of particulate water on aerosol optical properties.
- Land-atmosphere interaction research topics include the impact of surface processes on aerosols via precursor emission and on clouds via moisture flux and thermal development, as well as the two-way feedbacks between surface contributions to aerosols, clouds, and precipitation and the associated radiative impacts on plant physiology and canopy-scale fluxes.

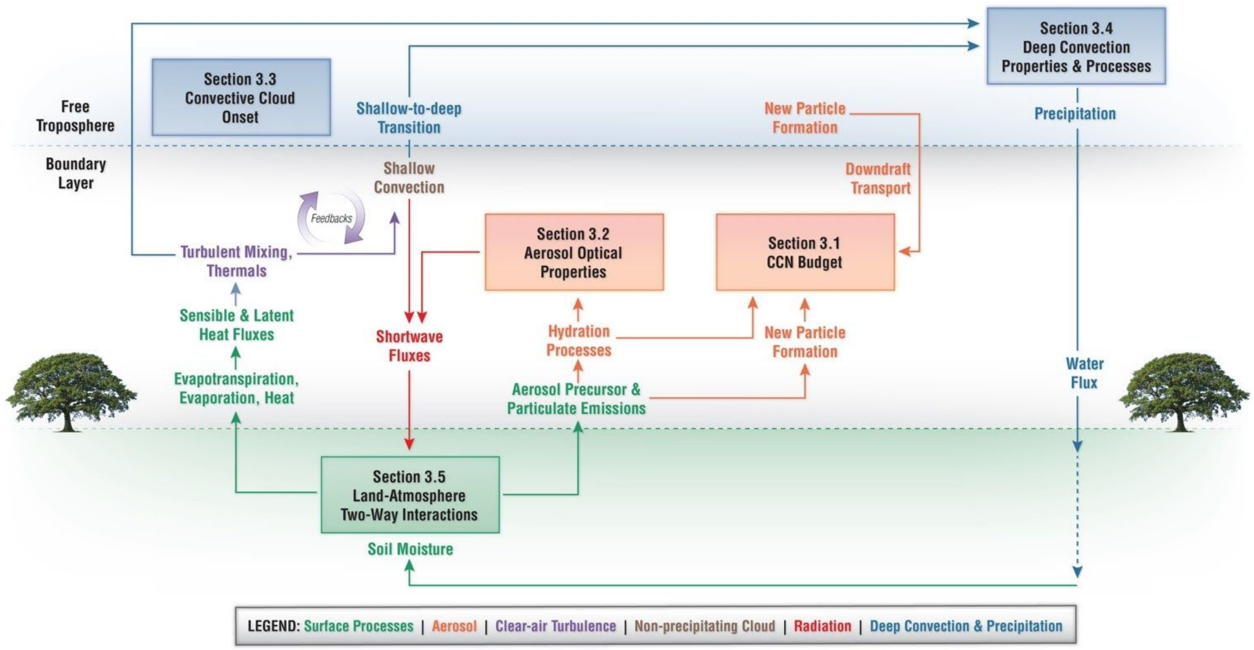

Figure 1: Schematic showing the five main science topics and key cross-cutting processes addressed in this initial science plan: i) CCN budget, ii) aerosol optical properties, iii) convective cloud onset, iv) deep convection properties and processes, and v) land-atmosphere two-way interactions.

Aerosol Science Drivers:

Science questions that target the processes and properties that control the cloud condensation nuclei (CCN) number budget include: the contribution of new particle formation and growth to the boundary layer CCN number budget; the chemical processes that control the role of organic aerosol as potential CCN; and the spatial and temporal distribution of aerosol hygroscopic properties and composition. Science questions that target aerosol optical properties include: the role of particulate water on aerosol optical properties; the role of biomass burning on regional radiative forcing; and the different controls on secondary organic aerosol and brown carbon optical properties that drive regional radiative forcing.

Convective Cloud Science Drivers:

Science questions that target the onset of convective clouds include: the role of large-scale vs. meso-scale thermodynamic perturbations in the onset of shallow convection; the role of the surface and prior convection on subsequent meso-scale perturbations; the key atmospheric processes that regulate the transition from shallow-to-deep convection; and the role of moist thermals and the middle tropospheric relative humidity on the shallow-to-deep convective transition. Science questions that target deep convective cloud processes and properties include: the connection of PBL characteristics (depth, thermodynamics) to the size of thermals, and how the size of thermals influence the fractional coverage of deeper convection; the factors that regulate the nature of convective updrafts and the size of thermals within cumulus updrafts above the PBL; how convective updrafts relate to the nature of stratiform precipitation; and how convective updrafts and downdrafts impact the spatial distribution of boundary layer aerosol.

Land-Atmosphere Interactions (LAI) Science Drivers:
LAI science drivers target key cross-cutting topics including the strong local coupling of the land-surface with atmospheric processes, surface-atmosphere feedbacks, influence of regional heterogeneity on land-surface modeling, and the influence of surface dynamics on regional aerosol formation. Specific science questions include: closure of the surface energy budget in the SEUS region; applicability of turbulence theory for boundary layer modeling; feedback cycles between ecosystems and biogenic atmospheric aerosol; plant physiological responses to cloud and aerosol radiative impacts; and the biotic and abiotic controls on surface energy balance and associated influences on convection. This deployment will enable a wide range of observational, analysis, and modeling studies to characterize the relationships between local and regional weather patterns and surface processes across a patchwork of natural, managed, and anthropogenic landscapes in the SEUS.

Science-driven Siting and Deployment Considerations:
The AMF3 SEUS SST will provide scientific guidance to the ARM user facility on site selection, site layout, and instrumentation needs for the AMF3 to address the articulated science questions. In providing guidance on site selection, we note that there are additional factors that may also be relevant in AMF3 site selection, such as the ability to leverage existing measurement sites through collaborations with other agencies or science activities.

A core set of AMF3 instrumentation has been identified by the ARM facility for initial operations at the new AMF3 location, targeting atmospheric state, surface energy balance, cloud and precipitation profiles, and near-surface aerosol properties (see Appendix 1). Details of advanced instrumentation that are the highest priority for the site and the spatial distribution of instruments beyond the central site will be guided by ongoing scientific input and priorities. Therefore, the SST will also include a plan to prioritize advanced instrumentation and additional measurement sites beyond a central facility, informed by team science drivers and community feedback. The ARM facility will make final decisions on siting and instrumentation to be deployed for AMF3 based on the scientific input from the site science team, available funding, logistical concerns, and other factors. Community feedback will help inform these siting and deployment considerations.

Community Feedback Request:
The AMF3 SEUS SST requests community input regarding [0] key SEUS science drivers and opportunities, [1] corresponding critical properties and measurement needs, and [2] the requisite spatial and temporal observational scales that would support a successful deployment of the AMF3 to the SEUS. Please provide feedback to Chongai Kuang (ckuang@bnl.gov).

Appendix 1 - AMF3 Instrumentation
The following information is subject to change. The intent is to provide some background on the instrumentation currently anticipated to be deployed with the AMF3.

Initial Core Instrumentation:
The following set of core instruments are expected to be deployed at the central facility of the AMF3 for initial operations:

- Radiometry
  - 2- or 3-channel microwave radiometer
  - Upward looking broadband shortwave and longwave radiometers
  - Downward looking broadband shortwave and longwave radiometers
  - Sun photometer and/or multifilter rotating shadowband radiometer (MFRSR)
  - Atmospheric Emitted Radiance Interferometer (AERI)
- Sky imager
- Standard surface meteorological measurements, including bulk precipitation
- Ka-band zenith ARM radar (KAZR)
- Ceilometer
- Micropulse lidar
- Doppler lidar
- Aerosol Observing System (AOS)
  - aerosol chemical speciation monitor (ACSM)
  - cavity attenuated phase shift monitor (CAPS)
  - carbon monoxide/nitrous oxide/water vapor
  - cloud condensation nuclei (CCN)
  - fine condensation particle counter (CPCF)
  - ultra-fine condensation particle counter (CPCU)
  - CO_2, CH_4, O_3
  - humidified tandem differential mobility analyzer (HTDMA)
  - nephelometer
  - particle soot absorption photometer (PSAP)
  - scanning mobility particle sizer (SMPS)
  - ultra high sensitivity aerosol spectrometer (UHSAS)
- Radiosondes and ground station
- Disdrometer

Phase 2 Core Instrumentation:
The following set of instruments are also expect to be deployed as a core part of the AMF3, but will likely be deployed in a phased approach (installed after initial operations begin) and may require input from the site science team on the sampling approach (surface types/spatial distribution/distance from central facility):

- Soil temperature and moisture properties
- Surface fluxes (eddy correlation)
- Scanning precipitation radar

- Radar wind profiler (RWP)

Advanced or Spatially Distributed Instrumentation:
The ARM facility is also considering the possibility of deploying additional advanced instrumentation and/or spatially distributed instrumentation as part of the AMF3 site. Such instrumentation would likely be deployed in a phased approach, after the initial installation of the AMF3 central facility, and details will depend on logistical and budgetary constraints. Information from the site science team on scientific prioritization of such instrumentation through modeling studies, observation simulation system experiments, or other analyses will be valuable to ARM. For example, for deployment of auxiliary sites with spatially distributed measurements, information of interest could include types of measurements, number of sites, and/or distance from the central facility needed to address different science questions.

The following set of instrumentation is potentially available for deployment as part of the AMF3. This list is intended to be illustrative, not comprehensive; it is unlikely that all of the below instrumentation can be deployed as part of the AMF3. The ARM facility will make final decisions on all instrument deployments.

Potential advanced/spatially distributed/other instrumentation:
- Scanning cloud radar
- Advanced lidar (e.g., Raman lidar, differential absorption lidar, high spectral resolution lidar)
- Auxiliary sites with a subset of instruments (e.g., sites similar to the Southern Great Plains extended facilities and/or boundary layer profiling sites or other types of sites to address specific science needs)
- Stereo photogrammetry
- Narrow field of view radiometer
- Additional scanning precipitation radar

ARM also expects that the ARM tethered balloon system (TBS) and unoccupied aerial system (UAS) assets will be available for potential deployments at the AMF3 site.