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Spring and Fall Vertically Resolved New Particle Formation and Transport Field Campaign Report

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Acronyms and Abbreviations

ARM	Atmospheric Radiation Measurement
CCN	cloud condensation nuclei
CPC	condensation particle counter
NPF	new particle formation
SGP	Southern Great Plains
TBS	tethered balloon system

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1.0 Summary

Aerosols are an important contributor to climate forcing on local to global scales due to their direct interactions with incoming solar radiation, both through scattering and absorption, and indirectly via their role as cloud condensation nuclei (CCN; Albrecht 1989, Charlson et al. 1992). Accurate assessment of the relationship between CCN and forcing in global climate models requires an understanding of the sources that control the aerosol number concentration budget, such as new particle formation (NPF) from the photochemical reaction of aerosol precursors (e.g., sulfuric acid, biogenic volatile organic compounds) that result in the formation of ~ 1 nm new particles (C. Kuang et al. 2009, Kerminen et al. 2005, Merikanto et al. 2010, Lihavainen et al. 2003). While there have been an increasing number of atmospheric cluster measurements from surface-based platforms, there have been very few measurements of the vertically resolved ambient cluster size distribution from aerial platforms. Vertically resolved atmospheric cluster measurements are needed because aerosol formation in the upper atmosphere may be a significant source of cloud condensation nuclei (Chen et al. 2018, Wang et al. 2016, Zheng et al. 2021, Lampilahti et al. 2021).

Furthermore, these vertically resolved measurements are needed to: 1) connect the atmospheric conditions that drive atmospheric NPF with large-scale boundary-layer transport processes and meteorology; and 2) evaluate the extent to which surface-based aerosol measurements are representative of the atmospheric aerosol aloft. The goal of the Vertically Resolved NPF Study – Southern Great Plains (SGP) was to develop process-level understanding of the formation and growth of atmospheric aerosol aloft through vertically resolved measurements of the atmospheric cluster number and size distribution. These observations were carried out at the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility's SGP observatory, where frequent NPF is observed at the surface (O'Donnell et al. 2023), and where strong vertical gradients in the aerosol number concentration are observed prior to the start of the aerosol formation and growth event observed at the surface (Chen et al. 2018). Vertically resolved profiles of the atmospheric aerosol cluster concentration and size distribution were obtained via the deployment of a water-based condensation particle counter (CPC) with an aerosol inlet modified for the detection of aerosol down to 1 nm in diameter, on board the ARM tethered balloon system (TBS), as shown in Figure 1.

Figure 1. Image of 1-nm CPC onboard the ARM TBS.

The water CPC, manufactured by Aerosol Devices, Inc. (Hering et al. 2019), was chosen for this proposal due to its responsiveness to the requirements for guest instruments deployed on the TBS (weight, power requirements, and dimensions). The CPC modification and characterization occurred in the principal investigator's laboratory according to established protocols (Kuang et al. 2012). Atmospheric cluster number concentrations in a specified range (e.g., between 1 and 3 nanometers) were obtained by application of the pulse height analysis technique, wherein the sampled aerosol size distribution is inferred from the grown droplet size distribution (Kuang 2018). Measurements took place at the Central Facility of the ARM SGP site during the fall season of 2021 and the spring season of 2022.

2.0 Results

Preliminary measurements indicate that NPF can occur aloft followed by downward transport to the surface where particle growth continues, supported by both TBS-based and surface-based measurements. Figure 2 shows a vertical profile of the TBS-based CPC-measured number concentration of newly formed particles during a TBS ascent (up arrow) up to 1200 meters, followed by a TBS descent (down arrow) back down to the surface. From this profile, NPF is clearly occurring aloft as opposed to at the surface, where long-term NPF observations are routinely made. Further planned research efforts include coordination with surface measurements of NPF precursors, and eventual coordination with TBS-based measurements of vertically resolved NPF precursors.

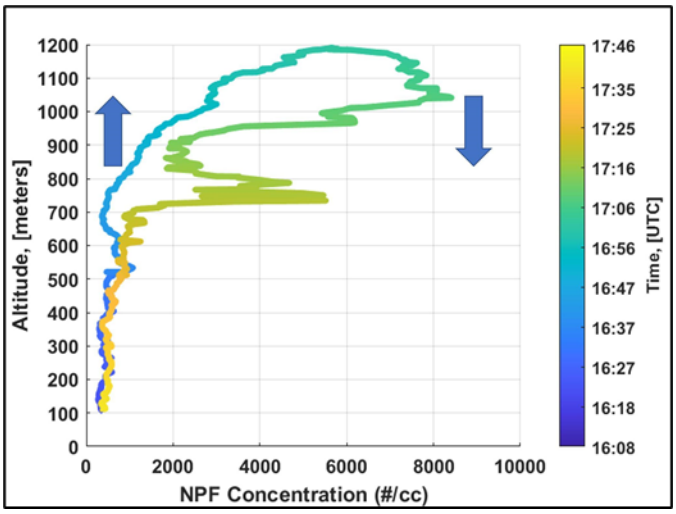

Figure 2. A vertically resolved profile of the concentration of newly formed particles (~ 1 to 3 nm) observed during an NPF event on October 5, 2021.

3.0 Publications and References

3.1 Presentations

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Kuang, C, and T Subba. 2022. "Vertically Resolved Atmospheric Cluster Observations," Joint ARM/ASR Principal Investigatory Meeting.

Kuang, C, S Serbin, S Giangrande, D Dexheimer, G Lewis, T Subba, N Urban, and Z Jiang. 2023. "Deployment of the DOE 3rd ARM Mobile Facility (AMF3) to the Southeastern United States: A Vision for Integrated Model-Observing System Design for Targeting Land-Aerosol-Cloud Interactions," University of Miami.

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