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Vertically Resolved New Particle Formation Study – Southern Great Plains Field Campaign Report

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ARM

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Acronyms and Abbreviations

ARM	Atmospheric Radiation Measurement
CPC	condensation particle counter
MCA	multichannel analyzer
NPF	new particle formation
SGP	Southern Great Plains
TBS	tethered balloon system

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1.0 Summary

The formation of 1 nm-sized atmospheric clusters is an important environmental nanoscale process, with field measurements and modeling studies indicating that freshly nucleated particles can contribute significantly to the global population of aerosol and cloud condensation nuclei (Kerminen et al. 2005, Kuang et al. 2009, Lihavainen et al. 2003, Merikanto et al. 2010). 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 troposphere may be a significant source of cloud condensation nuclei (Chen et al. 2018, Wang et al. 2016). Furthermore, these vertically resolved measurements are needed to:

- connect the atmospheric conditions that drive atmospheric new particle formation (NPF) with large-scale boundary-layer transport processes and meteorology
- 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) SGP observatory, where frequent NPF is observed at the surface (Kuang 2018), 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). These vertically resolved atmospheric cluster observations were combined with local observations of meteorology and cloud conditions to contextualize the atmospheric conditions and transport processes that control aerosol formation aloft.

Vertically resolved profiles of the atmospheric aerosol cluster concentration and size distribution were obtained via the deployment of a pair of water-based condensation particle counters (CPCs) on board the ARM tethered balloon system (TBS), as shown in Figure 1. Measurements took place at the Central Facility of the ARM SGP site between 15 and 26 July 2019. The pair of water-based CPCs were modified by the principal investigator to detect aerosol down to 3 nm and below. 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 subtracting number concentration measurements from the two water CPCs set at two different cut sizes. 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).

Figure 1. Water CPCs in their enclosures, attached to the TBS tether.

During the planned measurement period, water CPC flights on the TBS occurred on 7/17, 7/21, 7/22, 7/23, 7/25, and 7/26. Observations of atmospheric aerosol processes included new particle formation and biomass burning. Instrument operational issues included: overheating inside the CPC enclosure, under-voltage issues with the raspberry pi computer responsible for data acquisition, and under-voltage issues on the onboard multichannel analyzer (MCA) responsible for acquiring the raw CPC photodetector output. Enclosure overheating was addressed by adding enclosure fans to improve heat removal and wrapping the enclosure with reflective aluminum tape(Figure 2). Under-voltage issues were resolved by directly powering the MCA from the lithium ion battery as opposed to the raspberry pi computer. TBS flights were limited, on occasion, due to high winds and proximity to severe storms.

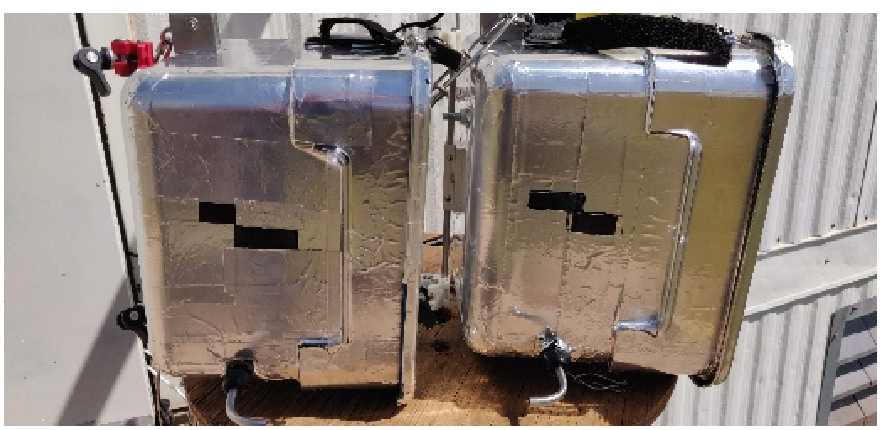

Figure 2. CPC enclosures wrapped in reflective aluminum tape.

2.0 Results

A particularly notable result from this campaign was the observation of a smoke plume on 7/25. Prevailing winds were from the south. Figure 3 presents some observational highlights from that day, showing the number concentration of 1–3-nm aerosol (taken as the difference between the two CPC concentration readings) as a function of time (blue), and the altitude (above ground level) of the CPC measurements as a function of time (orange). This particular example points towards the strong vertical heterogeneity in nanoparticle concentrations that can be associated with biomass burning.

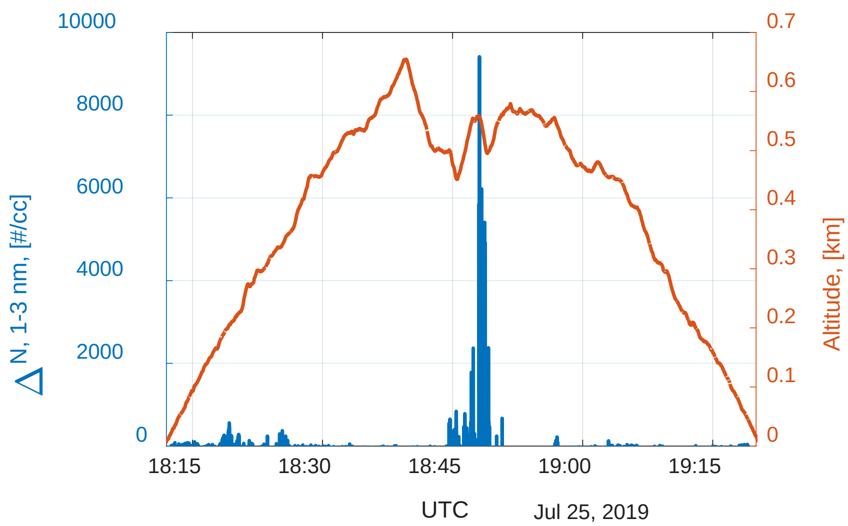

Figure 3. Profiles of 1−3-nm number concentration (blue) and altitude (orange).

3.0 Publications and References

3.1 Presentations

C. Kuang. 2019. "Modification of a Compact, Battery-operated Water CPC to Rapidly Measure Sub-3-nm Atmospheric Clusters." American Association for Aerosol Research Annual Meeting.

C. Kuang. 2019. "Vertically Resolved Nanoparticle Concentrations Observed at the ARM Southern Great Plains Site." American Geophysical Union Annual Meeting.

3.2 References

Chen, H, AL Hodshire, J Ortega, J Greenberg, PH McMurry, AG Carlton, JR Pierce, DR Hanson, and JN Smith. 2018. "Vertically resolved concentration and liquid water content of atmospheric nanoparticles at the US DOE Southern Great Plains site." *Atmospheric Chemistry and Physics* 18(1): 311−326, https://doi.org/10.5194/acp-18-311-2018

Hering, SV, GS Lewis, SR Spielman, and A Eiguren-Fernandez. 2019. "A MAGIC concept for self-sustained, water-based, ultrafine particle counting." *Aerosol Science and Technology* 53(1): 63−72, https://doi.org/10.1080/02786826.2018.1538549

Kerminen, VM, H Lihavainen, M Komppula, Y Viisanen, and M Kulmala. 2005. "Direct observational evidence linking atmospheric aerosol formation and cloud droplet activation." *Geophysical Research Letters* 32(14) :L14803, https://doi.org/10.1029/2005GL023130

Kuang, C. 2018. The Impact of Agricultural Activity on Aerosol Formation and Growth: Proposal and Reviews. U.S. Department of Energy.

Kuang, C, M Chen, PH McMurry, and J Wang. 2012. "Modification of Laminar Flow Ultrafine Condensation Particle Counters for the Enhanced Detection of 1 nm Condensation Nuclei." *Aerosol Science and Technology* 46(3): 309−315, https://doi.org/10.1080/02786826.2011.626815

Kuang, C, PH McMurry, and AV McCormick. 2009. "Determination of cloud condensation nuclei production from measured new particle formation events." *Geophysical Research Letters* 36(9): L09822, https://doi.org/10.1029/2009GL037584

Lihavainen, H, VM Kerminen, M Komppula, J Hatakka, V Aaltonen, M Kulmala, and Y Viisanen. 2003. "Production of 'potential' cloud condensation nuclei associated with atmospheric new-particle formation in northern Finland." *Journal of Geophysical Research − Atmospheres* 108(D24): 4782, https://doi.org/10.1029/2003JD003887

Merikanto, J, D Spracklen, K Pringle, and K Carslaw. 2010. "Effects of boundary layer particle formation on cloud droplet number and changes in cloud albedo from 1850 to 2000." *Atmospheric Chemistry and Physics* 10(2): 695−705, https://doi.org/10.5194/acp-10-695-2010

Wang, J, R Krejci, S Giangrande, C Kuang, HM Barbosa, J Brito, S Carbone, X Chi, J Comstock, F Ditas, J Lavric, HE Manninen, F Mei, D Moran-Zuloaga, C Pohlker, ML Pohlker, J Saturno, B Schmid, RAF Souza, SR Springston, JM Tomlinson, T Toto, D Walter, D Wimmer, JN Smith, M Kulmala, LAT Machado, P Artaxo, MO Andreae, T Petaja, and ST Martin. 2016. "Amazon boundary layer aerosol concentration sustained by vertical transport during rainfall." *Nature* 539: 416−419, https://doi.org/10.1038/nature19819

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