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Particle Number Concentrations for HI-SCALE Field Campaign Report

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ARM CLIMATE RESEARCH FACILITY

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Acronyms and Abbreviations

ARM	Atmospheric Radiation Measurement Climate Research Facility
BNL	Brookhaven National Laboratory
C	Celsius
DOE	U.S. Department of Energy
HI-SCALE	Holistic Interactions of Shallow Clouds, Aerosols, and Ecosystems
nm	nanometer
QA	quality assurance
SGP	Southern Great Plains
μm	micrometer
UTC	Coordinated Universal Time
vWCPC	versatile water condensation particle counter

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1.0 Summary

In support of the Holistic Interactions of Shallow Clouds, Aerosols, and Ecosystems (HI-SCALE) project to study new particle formation in the atmosphere, a pair of custom water condensation particle counters were provided to the second intensive field campaign, from mid-August through mid-September 2017, at the U.S. Department of Energy Southern Great Plains Atmospheric Radiation Measurement (ARM) Climate Research Facility observatory. These custom instruments were developed by Aerosol Dynamics, Inc. (Hering et al. 2017) to detect particles into the nanometer size range. Referred to as "versatile water condensation particle counter (vWCPC)", they are water-based, laminar-flow condensational growth instruments whose lower particle size threshold can be set based on user-selected operating temperatures. For HI-SCALE, the vWCPCs were configured to measure airborne particle number concentrations in the size range from approximately 2nm to 2μm. Both were installed in the particle sizing system operated by Chongai Kuang of Brookhaven National Laboratory (BNL). One of these was operated in parallel to a TSI Model 3776, upstream of the mobility particle sizing system, to measure total ambient particle concentrations. The airborne particle concentration data from this "total particle number vWCPC" (Ntot-vWCPC) system has been reported to the ARM database. The data are reported with one-second resolution. The second vWCPC was operated in parallel with the BNL diethylene glycol instrument to count particles downstream of a separate differential mobility size analyzer. Data from this "DMA-vWCPC" system was logged by BNL, and will eventually be provided by that laboratory.

2.0 Results

The vWCPC is a newly developed, laminar-flow, water-based condensation particle counter that can be operated to maximize particle detection near 1 nm, or can be tuned to eliminate sensitivity to charger ions. The flexibility, and the small particle threshold of the vWCPC, are achieved through the use of the three-stage growth tube. With this approach, the maximum supersaturation, and hence lower threshold, is determined by the temperatures of the first two stages, as is the transport of water vapor from the heated, wetted walls of the middle section into the colder entering flow that creates the supersaturation for particle activation and growth. The cooled final stage maintains supersaturated conditions that permit continued droplet growth while reducing the temperature and water content of the flow prior to particle counting, and allowing the optical detector to be run at 30-40°C. For HI-SCALE, a new growth tube was mounted in the box from a TSI Model 3787 WCPC, and operated with the TSI optics and mother board.

For the HI-SCALE field study, the vWCPCs were operated with temperatures of 10°, 90°, and ~18-20°C for each of the three successive wet-walled growth tube stages. This configuration provides 50% detection at 1.8nm for metal oxide aerosols, but is insensitive to the molecular ions produced when the air sample passes through a bipolar ion source. The detection threshold is lower for salts such as sodium chloride, sucrose, or sulfate. Calibration data are provided by Hering et al. (2017) and Kangasluoma et al. (2017).

The operating temperatures and pulse height data were recorded with each data record. The values of these parameters during the study are summarized in Table 1, but are not included in the data set reported here. Operating temperatures determine the peak supersaturation, and hence particle detection limit, as described by Hering et al. (2017).

Table 1. vWCPC operation temperatures during HI-SCALE

Parameter	Mean	Std Dev.	Max	Min
Conditioner temperature (°C)	8.0	0.04	7.8	8.2
Initiator temperature (°C)	90.1	0.07	89.5	90.9
Moderator temperature (°C)	19.0	1.95	14.6	23.0
Cabinet temperature (°C)	23.4	1.43	19.7	26.9

Figure 1 shows example data from the reported data set. Number concentration data are reported with UTC time stamp at one-second intervals. The data set is tab-delimited text with a header row. Reported parameters are listed in Table 2. The reported data set includes two quality assurance flags, one for pulse height and one for vacuum level. The *pulse height* can be low if the instrument is not operating correctly, or if the sampled particle number concentration is very high. In the latter case concentration effects, mostly condensational heating, reduces the peak supersaturation and the extent of droplet growth. A low pulse height is indicated in the QA code. The *vacuum level* is important to the sample flow, as the flows are set by a critical orifice. Whenever the vacuum level drops, that is the absolute pressure increases above 0.5 atmospheres, a flag appears in the QA code indicating possible low flow. The QA code is included in the data set, and provides flags for out-of-range values of the temperatures, vacuum level, pulse height, and laser status.

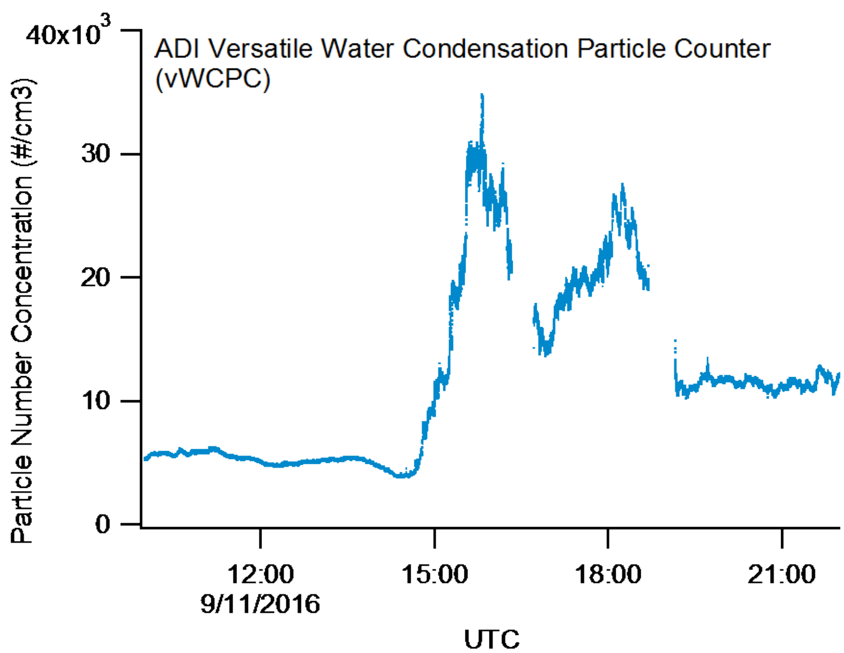

Figure 1. Profile of ambient particle number concentrations recorded by the vWCPC during HI-SCALE.

Table 2. Reported vWCPC parameters

field name	units	description
Datetime	UTC	This is the time stamp in UTC (successor to Greenwich Mean Time).
vWCPC_Ntot	$\#/cm^3$	Atmospheric particle number concentration, with 50% detection at ~2 nm. Units are number of particles per cubic cm.
QAcode	nnnn	Hexadecimal error code, where 0000=no errors 0008=vacuum level low 0100= pulse height low

3.0 Publications and References

Hering, SV, GS Lewis, SR Spielman, A Eiguren-Fernandez, NM Kreisberg, C Kuang, and M Attoui. 2017. "Detection near 1-nm with a laminar-flow, water-based condensation particle counter." *Aerosol Science and Technology 51*(3): 354-362, doi:10.1080/02786826.2016.1262531.

Kangasluoma, J, S Hering, D Picard, G Lewis, J Enroth, F Korhonen, M Kulmala, K Sellegri, M Attoui, and T Petäjä. 2017. "Characterization of three new condensation particle counters for sub-3 nm particle detection: ADI versatile water CPC, TSI 3777 nano enhancer and boosted TSI 3010." *Atmospheric Measurement Techniques,* doi:10.5194/amt-2016-408.

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