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DOE/SC-ARM-18-013

Scanning Mobility Particle Sizer-Portable Optical Particle Spectrometer Intercomparison Field Campaign Report

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March 2018

ARM
CLIMATE RESEARCH FACILITY

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Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Acronyms and Abbreviations

AERONET	Aerosol Robotic Network
AOD	aerosol optical depth
ARM	Atmospheric Radiation Measurement
CLARIFY	Cloud-Aerosol-Radiation Interactions and Forcing
DOE	U.S. Department of Energy
GMD	geometric mean diameter
POPS	portable optical particle spectrometer
PSD	particle size distribution
RI	refractive index
SMPS	scanning mobility particle sizer
UAV	unmanned aerial vehicle
UK Met	United Kingdom Meteorological Office

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1.0 Summary

A portable optical particle spectrometer (POPS) has recently been acquired by the United Kingdom Meteorological (UK Met) Office with the intention of mounting it on an unmanned aerial vehicle (UAV) for atmospheric aerosol research. Before conducting research with the new instrument, an intercomparison has been conducted to test the performance of the POPS against a scanning mobility particle sizer (SMPS) — a veteran and well-characterized particle sizer.

As part of the Cloud-Aerosol-Radiation Interactions and Forcing (CLARIFY) campaign, the POPS was installed at the U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Climate Research Facility mobile site on Ascension Island in the South Atlantic Ocean, alongside an ARM-operated SMPS. Both instruments sampled continuously from 20 August to 9 September, 2017. The SMPS and the POPS were connected to a common aerosol inlet; however, in the case of the SMPS, the sample air was dried before it entered the instrument.

The POPS is a miniaturized optical particle counter designed specifically for use in balloon and UAV applications. The instrument is fully described in Goa et al. (2016) and so is only briefly described here. The POPS samples particles by drawing air through an inlet tube into an optical chamber, where it is illuminated by a 405nm laser. A sheath air flow is used to focus the sample air into the center of the laser beam, and the sample flow is maintained at a near-constant rate by an onboard pump. Side-scattered laser light is reflected into a photomultiplier tube by a hemispherical mirror, and the signal amplitude recorded by a data logger. Individual particle sizes are then inferred by comparing the recorded signal amplitudes to scattering amplitudes calculated using Mie theory.

In common with other optical particle counters, the POPS size distributions are influenced by the refractive index used in the Mie calculations. The POPS is calibrated by the manufacturers (Handix Scientific) using latex spheres, with a refractive index (RI) of 1.615+0.001i. Sampling aerosols with a different refractive index, particularly if they are strongly absorbing, will result in significant uncertainties/errors in the particle size distributions (PSDs). We have therefore used scattering amplitude curves (calculated by Handix) for more absorbing aerosols, with an RI of 1.54+0.027i, which is expected to be more representative of the biomass-burning aerosol particles sampled at the ARM site during the CLARIFY campaign. In contrast to the POPS, the SMPS measures particle size using the differential mobility technique after applying an electrical charge to aerosol particles. The method is independent of the refractive index (Ruzer 2013).

As well as using different techniques to measure particle size, the two instruments cover different parts of the size spectrum. The SMPS measures particles from ~ 0.01μm to ~ 1μm, whereas the POPS measures sizes ranging from ~ 0.12 to ~ 8 μm (for RI = 1.54+0.027i).

2.0 Results

The POPS ran unattended for 20 days and logged data to an internal memory card. The PSDs and total particle concentrations measured by the two instruments show fair agreement, especially considering the difference in the size ranges being sampled by each instrument.

Figure one shows the 20-day mean PSD measured by each instrument. Given the different techniques used by each device, the agreement is fairly good. The variation in the POPS PSD at larger sizes is perhaps due to lower counting statistics at these sizes. The red dashed line in Figure one shows the PSD calculated using an RI for latex spheres, illustrating the considerable impact of the choice of RI used in the data processing.

The upper panel of Figure two shows the particle concentration from the POPS and SMPS for the 20-day period of the intercomparison, and panel 2 shows the ratio of the two concentration measurements (POPS/SMPS). The agreement between the two instruments is good while the geometric mean diameter (GMD) of the size distribution (panel 3) is above 0.12μm, and so in a size region where both instruments are able to measure. As the GMD moves below this value, the POPS is unable to count the very small particles counted by the SMPS. Perhaps surprisingly, there seems to be little correlation with the ambient relative humidity (bottom panel in Figure 1), but this might be due to the rather limited range of relative humidities sampled as the hygroscopic growth will only increase significantly at relative humidities in excess of 90% (e.g., Haywood et al., 2003).

We would expect biomass-burning aerosols to be associated with an increase in carbon monoxide (CO), and the concentrations measured by both instruments correlate well with the CO mass mixing ratio (as measured by a co-located CO analyzer: panel four). The concentrations also show some correlation with the AODs as measured by a co-located Aerosol Robotic Network (AERONET) Cimel sun photometer (panel five, Figure two), although this AOD is a column measurement rather than a point measurement so the influence of vertical profile will likely be important.

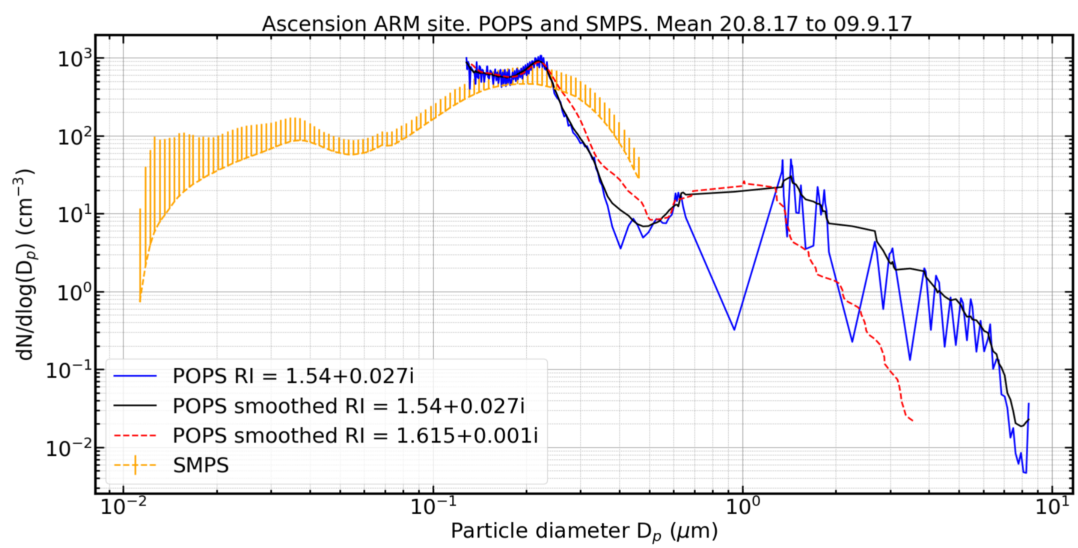

Figure 1. POPS and SMPS size distributions.

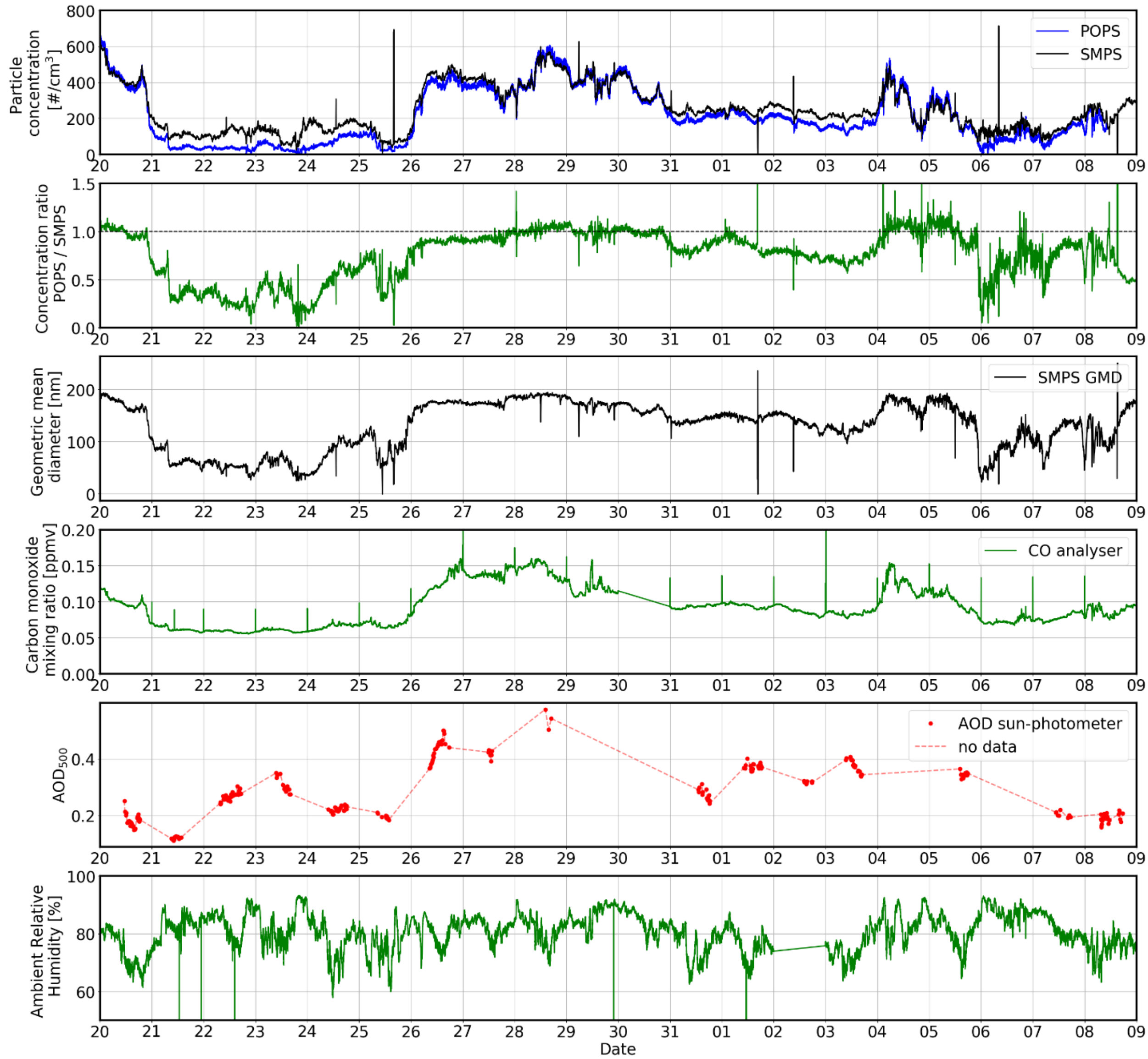

Figure 2. From top to bottom. 1. SMPS and POPS total particle concentrations. 2. Ratio of POPS to SMPS total particle concentrations. 3. Geometric mean diameter from SMPS. 4 Carbon monoxide mixing ratio from CO analyzer. 5. AOD from Cimel sun-photometer and 6. Ambient relative humidity. Data run from 20 August, 2017 to 9 September, 2017.

The POPS has performed well, and has made meaningful measurements of particle concentration and size distributions that are not inconsistent with those made independently by the SMPS when one considers the different sizes that the instruments are sensitive to. Based on these measurements, there is reason to believe that both instruments are behaving adequately.

3.0 Publications and References

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