NCAR GV Scanning Mobility Particle Sizer (SMPS) Instrument

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Instrument Description and Background:

The GV Scanning Mobility Particle Sizer (SMPS) measures the particle size distribution over the mobility diameter range of 3 to 500 nm (pressure-dependent, see discussion below). It consists of two components: an electrostatic classifier (EC) and a condensation particle counter (CPC). The EC samples aerosol-laden ambient air, places a well-defined charge distribution on the particles, and then selects a narrow range of particle "mobility diameter" (approx. equal to cross-sectional area-to-charge ratio) using a differential mobility analyzer (DMA)[1]. The selected diameter can be scanned by a time-varying high voltage applied to the DMA; following this particles are counted by the CPC. The total scan time and the number of counting intervals, the latter of which determines the number of diameter bins in the size distribution, are selected based on ambient particle concentrations and altitude. The raw data (particle counts over each counting interval as a function elapsed time during the linear diameter scan) is mathematically inverted during post-processing to obtain the particle size distribution.

Hardware:

The SMPS system consists of the following equipment:

- Electrostatic Classifier (EC) mounted on a standard HIAPER shelf, using 115 VAC 60 Hz @ ~1 A. This is pictured in Figure 1A.
- Condensation Particle Counter (CPC), a commercial instrument manufactured by TSI, Inc. At the present time we plan to use a model 3010 CPC for DC3 and SEAC4RS, which is the same instrument used during the DC3 test flights in May 2011. This CPC will be mounted next to the CN counter (PI = Dave Rogers/EOL) on a separate HIAPER shelf located in the same rack as the EC.
- Vacuum pump, which is required for both the EC and the CPC. The current plan calls for locating this at the rear of the GV, with a ½" Teflon tube connecting it to the EC and CPC. It will operate on an EOL-provided 28 VDC, which will be provided by a 120 V AC (400 Hz) – 28 VDC transformer.

As mentioned previously, the particle size selection is dependent on altitude (inlet pressure) and DMA voltage. Figure 1B shows how altitude and DMA voltages combine to determine the range of particles that can be detected with this instrument configuration.

Configuration on GV:

The instrument has been certified and was flown on the GV during the DC3 test flights. During DC3 and SEAC4RS, it will occupy a similar position on the aircraft. It will take up one shelf on the rack where the mission coordinator sits. As mentioned above, the CPC will be on the bottom shelf of that rack, which is also shared by the water CN (WCN). The WCN and SMPS will share the same HIML inlet and sampling line, which will be valuable to compare total particle counts to the particle size distribution. The instrument can operate with only minor attention by in-flight personnel (e.g., turning on power), and key parameters can be changed remotely by operators on the ground.

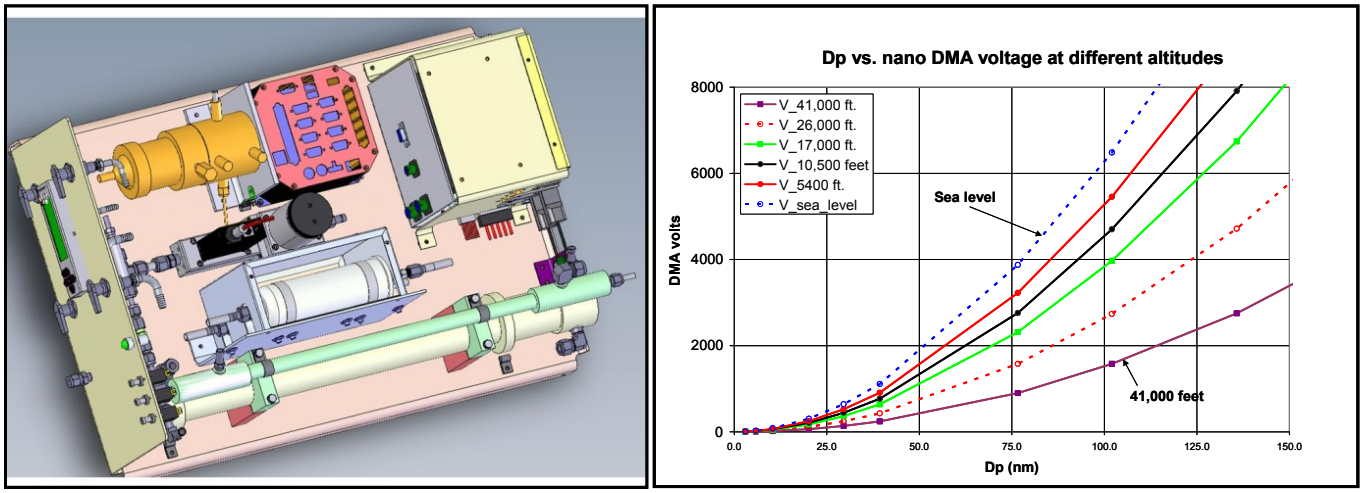

Figure 1 (left): The EC shown on HIAPER shelf (tubing and filter cover removed for clarity); (right) GV SMPS particle size/voltage relationship

Data:

The SMPS raw data are recorded on an on-board (PC/104) computer and critical data are also fed into the aircraft data system (ADS) using UDP so that they can be viewed from the ground using Aeros software. Since these critical data are fed into the ADS, a data back-up is automatically generated for each measurement. Flight parameters including inlet temperature, inlet pressure, relative humidity and altitude are read from the ADS (also using UDP) and are also saved. The combination of these stored parameters (including raw CPC particle counts, DMA voltage, volumetric sheath flow rate, temperature, and pressure) are used to calculate the final particle size distribution for each up/down scan combination. The SMPS control and data acquisition computer's clock is synchronized with the ADS so that particle data accurately reflects the exact conditions of the rest of the measurements.

During DC3 and SEAC4RS, a one-way diameter scan will be performed over 15 size bins every 60 seconds. The diameter corresponding to each bin is highly pressure-dependent (see Figure 1B), and an additional constraint is the need to operate at a DMA voltage that is not susceptible to arcing at the lowest expected pressures. At the highest altitudes expected, we have determined that 3000VDC is a safe maximum DMA voltage. This corresponds to a maximum diameter of 62 nm at sea level, or 140nm in diameter at 41,000 ft (ref: Figure 1B). Instrument conditions can be changed during flight to capture certain particle ranges or achieve faster scan times.

References:

1. Flagan, R.C., *Electrical mobility methods for submicrometer particle characterization*, in *Aerosol measurement: Principles, techniques, and applications*, P. Kulkarni, P.A. Baron, and K. Willeke, Editors. 2011, John Wiley & Sons: Hoboken.