Particle Size Distribution Measurements on the NSF Gulfstream V

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Abstract: A Scanning Mobility Particle Sizer (SMPS) has been developed for airborne measurement of atmospheric aerosol size distributions from 8 to 600 nm at the altitudes relevant to GV aircraft missions. These pressure/altitude regimes include 80kPa (~2000 m) to 15 kPa (~13000 m), the latter of which is high enough to be in the Upper Troposphere - Lower Stratosphere (UTLS) region. This ability to characterize size-resolved aerosols up to the UTLS directly addresses important gaps in our knowledge of the impacts of aerosols on chemistry and climate. We report initial observations of aerosol size distributions from the Deep Convective Clouds and Chemistry (DC3) field campaign (May-June 2012) based in Salina, KS. Three aircraft and extensive ground measurements characterized the influence of convection on the transport, chemistry and evolution of gaseous and particulate species. Of particular interest was the effect of lightning and aging of various species downwind of convective systems and how do these processes affect new particle formation and growth. This SMPS was specifically designed for measurements of 8-150 nm at altitudes over 8000 m and to have overlap with existing GV aerosol instruments (water-based CN counter and UHSAS). Together, these instruments are able to obtain both total aerosol number concentration and a complete size distribution from 8nm to several um. Here, we present the instrument design and operation, performance during the DC3 campaign and some preliminary scientific results.

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Instrument specifications

Diameter Range	7.5- 150 nm (extendable to 600 nm with long column DMA).
Instrument Control	PC104 computer running Labview for instrument control and data storage. Lower Dp set by inlet pressure (~7.5 nm). Sheath/excess flows: 3.1 L/min; aerosol flows: 0.67 L/min for 5:1 ratio. Remote control and data viewing from the ground using UDP communication and satellite link. Time synchronized with Aircraft Data System (ADS).
Particle counting	TSI 3010 run at 0.67 L/min monodispersed aerosol flow. ΔT set to 25 °C; Minimum diameter (Dp min) ~ 7.5 nm. Modifications necessary for low pressure operation (ref 1).
Mobility diameter classification	TSI nano-differential mobility analyzer (DMA). Filtered sheath air provided from total inlet flow. Extendable to use with long DMA. Vmax = 3 kV for 8000 m altitude.
Inlet	Standard NCAR RAF HIMIL (Hiaper Modular Inlet) providing nearly unity transmission efficiency for aerosol within this instrument's range.
Altitude range	1500-12,000 meters.
Other instrument parameters	Sheath air temperature, flow controller pressure, sample relative humidity, pressure difference across 3 orifices (DMA aerosol flow, CPC aerosol flow, DMA excess flow) for verifying all system flows (Figure 1).
Scan time	60 seconds per size distribution (4 seconds per diameter bin).
Data product	Particle concentrations in each diameter of 15 diameter bins providing size distribution (dN/dlogDp vs. Dp) for each scan.
Estimated Uncertainty	Diameter (±10%); Concentration(±20%);

Figure 1 (Left): Instrument layout of expanded 2-DMA configuration. For clarity, tubing is not shown.
Figure 2 (Right): Diagram showing air flow, data, and power connections used during DC3 (single DMA).

Figure 1

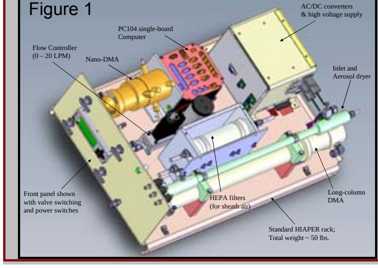
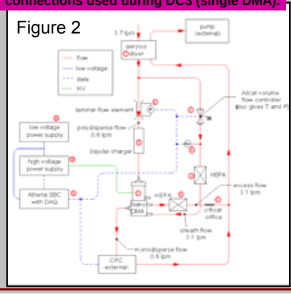


Figure 2



Basic instrument performance

Accurate size-resolved particle measurements require balanced, constant and controlled flow rates into and out of the differential mobility analyzer:
•Sheath and Excess flows balanced at 3.1 L/min
•DMA aerosol flows (mono- and poly-dispersed) balanced at 0.6 L/min.

This is achieved by a wide-orifice Alicat™ flow controller for the sheath flow rate and specifically chosen orifices to balance flows for the other branches (see Figure 2). Three delta P sensors are used to monitor flows in real-time.

Laboratory measurements with regression analysis yields accurate volumetric flow rate measurements for all branches based on inlet pressure (altitude) and delta P across each orifice.

Figure 3:

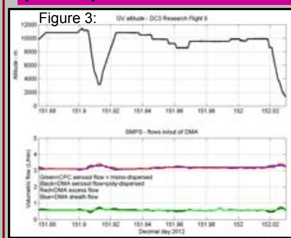
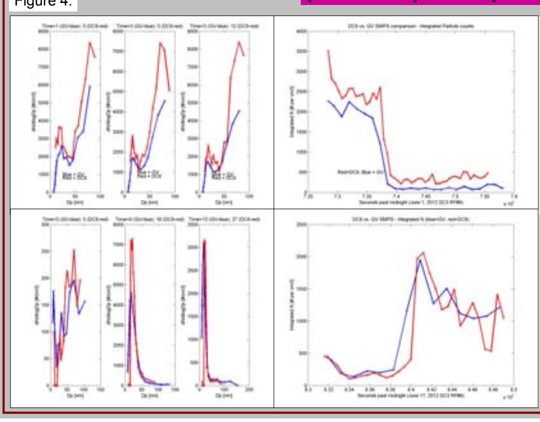


Figure 3 (left) shows sheath, excess, DMA aerosol flow and CPC aerosol flow during research flight indicating that flows are controlled and balanced up to 12,000 m altitude.

Inter-comparison results:
Figure 4 (below) shows the size distributions and integrated particle count comparison between the GV SMPS and the DC8 SMPS on two different flights. Integrated particle counts (right panes) are limited to ~90 nm to ensure that only the particle sizes sampled by both platforms (DC8 and GV) are compared.

Figure 4:



DC3 selected results

Figure 5

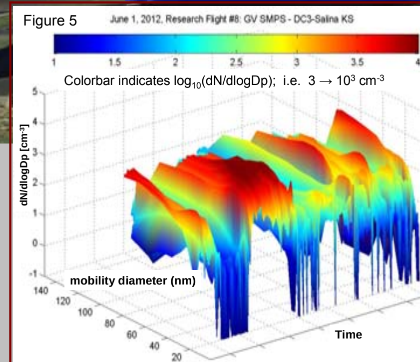


Figure 5 (left): Example of GV SMPS data showing size distributions during the entire June 1 flight (RF#8). A mixture of different air masses were observed. The smallest measured particles (Dp= 8 nm) are evident ~ 1/3 into flight.

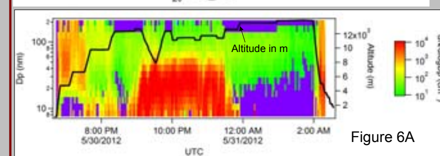


Figure 6A

Figure 6: May 30, and June 21 flights (RF #'s 7, 16). 6A shows the presence of a large number of small particles (~8nm) in the aged outflow of a convective storm. 6B shows the formation and growth of small particles during a mesoscale convective system (MCS). The corresponding flight colored by total particle counts (N) is shown in 6C.

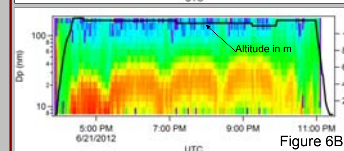


Figure 6B

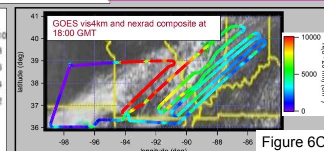
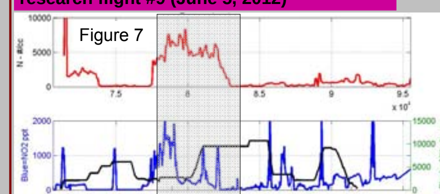


Figure 6C

Figure 7: Total particle counts (integrated N) are correlated with elevated NO2 during research flight #9 (June 5, 2012)

Figure 7



Future work:
•Incorporate multiple charging correction to achieve higher accuracy for Dp>70 nm.
•Study air mass aging, trace gas concentrations, and convection processes to quantify particle formation and growth in UTLS region during DC3.

[1]Hermann, M. and Wiedensohler, A. *J. Aerosol Sci.*, **32**, 975–991, 2001.

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