First Aircraft Measurements with a Fast Mobility Particle Sizer



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Need for High Temporal Atmospheric Aerosol Size Distribution Measurements

- Aerosol indirect affect studies [Conant et al., 2004].
- Scavenging of aerosols by rain events [Chate, 2005].
- Aerosol flux measurements [Vong et al., 2005].
- Aerosol formation measurements [McMurry et al., 2005].
- On-road vehicle emissions [Shah and Cocker, 2005].
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Various Techniques to Measure Particle Number Size Distribution

- Single Detector Electrostatic Classification Methods
- Scanning Mobility Particle Sizer (TSI model 3936)
- Series of Condensation Nucleus Counters
- Electrical Mobility with Multiple Electrometer Detectors (**TSI FMPS model 3091**)

Questions related to the new TSI 3091 Fast Mobility Particle Sizer

- Is the Fast Mobility Particle Sizer (FMPS) a useful tool for atmospheric research?
- Can the FMPS be used for aircraft based atmospheric sampling?
- What are the difficulties of using the FMPS for atmospheric aerosol spectrum measurements?

To address these questions, A FMPS was borrowed from TSI and flown on three Citation research flights.

FMPS Measurement Features



- Particle measurements between 5.6 to 560 nm in 32 channels.
- Particle size distributions with one-second resolution.
- Particle concentration range across more than 4 orders of magnitude.
- Self contained and runs on 120 volts AC power.
- Data collection and analysis software.

FMPS Instrument Properties



- 10 L/min Aerosol Flow Rate.
- Unipolar diffusion charger.
- 22 Electormeter channels.
- 70 lb Weight
- 17x14x28 in. Dimension (LWH)
- 120 Volts AC, 250 Watts Power

Diagram taken from the TSI Model 3091 Fast Mobility Particle Sizer Spectrometer Operation and Service Manual.

Installation of the FMPS in the UND Citation Research Aircraft



Exterior of the Inlet and Outlet use for FSMP on the UND Citation Aircraft.

Interior of the Inlet and Outlet use for FSMP on the UND Citation Aircraft.

The Fast Mobility Particle Sizer in a rear rack on the University of North Dakota's (UND) Citation Research Aircraft.

Filter Sampling: August 30, 2005

Test of the FMPS using a HEPA filter on aircraft inlet. Spectrum shown is a 60 second average taken after the instrument's 10 minute warm-up period. The yellow line denotes the instrument noise level. Total aerosol concentration was 34.7 #/cm^3 . The total aerosol concentration seems high when compared to HEPA filter measurements using a condensation nuclei counter (< 1 #/cm³).

Hanger Sampling: September 8, 2005

Outside Sampling: September 2, 2005

Baltic Sea Region Sampling

Monthly averaged aerosol size distributions near the Baltic Sea region. Data was obtained from Table #1 of Kikas et al., 1996. Note the dip for the 18-32 nm sized channel for December at Rautavaara. Kikas et al., 1996 reported that these double peaked distributions occurred more frequently during rural measurements and lower concentrations.

FMPS Software Averaging Problem

Total Concentration

The 60 second average of FMPS total aerosol concentration during the September 8, 2005 UND Citation aircraft flight produced using TSI's FMPS analysis software. Note that local time is given, not UTC time. The 60 second average of FMPS total aerosol concentration during the September 8, 2005 UND Citation aircraft flight produced using Cplot analysis software. The average results from averaging 60 data points of the 1 second data values.

Aircraft Sampling: Total Concentration

Total aerosol concentration measured with the TSI 3091 FMPS spectrometer during two flights of the University of North Dakota's Citation Research Aircraft. Data presented are 60 second averages.

Measurements at 1 Hz of the ambient pressure (black lines), the Laser Hygrometer chamber pressure (green lines), the aircraft cabin pressure (red lines), and the FMPS sizing column pressure (blue lines) on two flights of the University of North Dakota's Citation Research Aircraft. The correspondents between the FMPS pressure and the aircraft cabin pressure clearly indicates that the FMPS was sampling cabin air during aircraft flights.

FMPS Spectrometer: Flow Schematic

- The complexity of the FMPS flow system leads to many possible leak sources.
- The most efficient method to ensure that the system has no leaks is to establish a baseline of HEPA filter measurements and then use a HEPA filter on the aircraft inlet to test the system before each aircraft flight.
- The possibility of leaks developing during aircraft installation could make frequent instrument removals problematic.

FMPS flow schematic from the TSI Model 3091 FMPS Spectrometer Operation and Service Manual.

Condensation Nuclei Measurements

Total aerosol concentration measured with a TSI 3760 Condensation Nucleus Counter during two flights of the University of North Dakota's Citation Research Aircraft.

August 30, 2005 (3:16:22)

The 1 Hz aerosol spectrum measured with a TSI 3091 FMPS spectrometer during instrument testing on August 30, 2005.

Conclusions: Things to Remember

- It is possible to quickly put an instrument on an aircraft and obtain reasonable data; however, it takes some effort to ensure the usefulness of the measurements.
- It is extremely important to leak check aircraft instruments.
- The noise level of the FMPS instrument is aquatic for airborne sampling of atmospheric aerosols.
- The FMPS is a state-of-art instrument which can conduct high temporal resolution measurements of the atmospheric aerosol spectrum which are very important for aerosol indirect affect studies.

Conclusions: Useful Improvements to the FMPS for Routine Airborne Sampling

- Have the ability to configure the FMPS to start data recording automatically upon power up.
- Have the ability to record and decode the FMPS serial data stream using an aircraft data system instead of using the FMPS data collection software.
- Be able to plot the FMPS pressure and temperature data quickly using the TSI FMPS analysis software.

Outstanding Questions?

- What caused the leak in the FMPS spectrometer system? Was it a result of instrument shipping or installation?
- What causes the "Extraction Flow High" and "Extraction Flow Low" warning during aircraft flights?
- What does it mean to have zero concentration value in an individual channel?
- Why does the TSI software average non-zero concentration values resulting in an exactly zero channel value.

Future Plans

• Obtain funds to purchase a FMPS (\$79,000)

- Charge directly to a research project (OGP Proposal).
- Part of an NFS Major Research Instrumentation
 Program Proposal (Due Date: January 26, 2006).

- Utilize instrument for atmospheric research.
 - Aircraft deployment.
 - Surface Site deployment.
 - Lab deployment.