

Instrumentation for Unmanned Aircraft Systems (UAS)

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OUTLINE: *Intro & Motivation for the development*
Introduction to each UAS instrument
Other aircraft-deployable systems
Power plant plume case study



SBIR

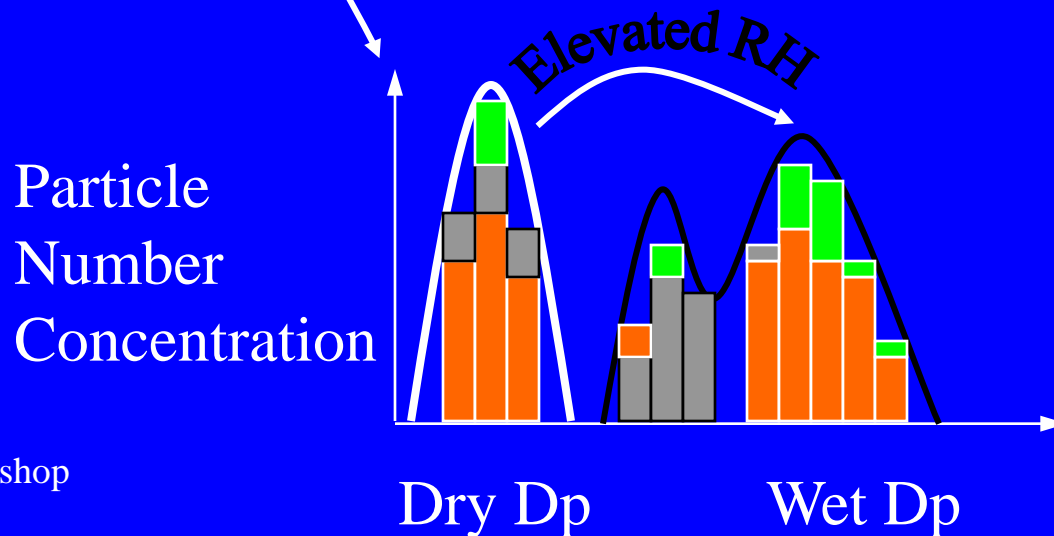
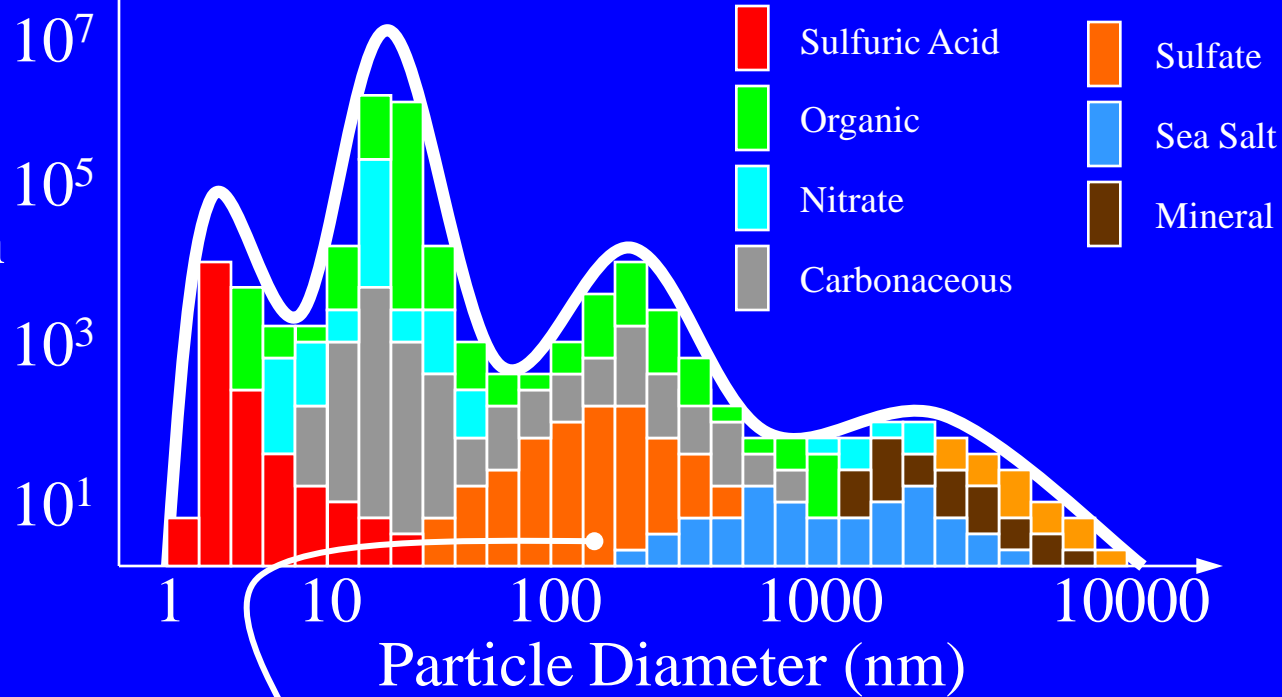


Office of Naval Research

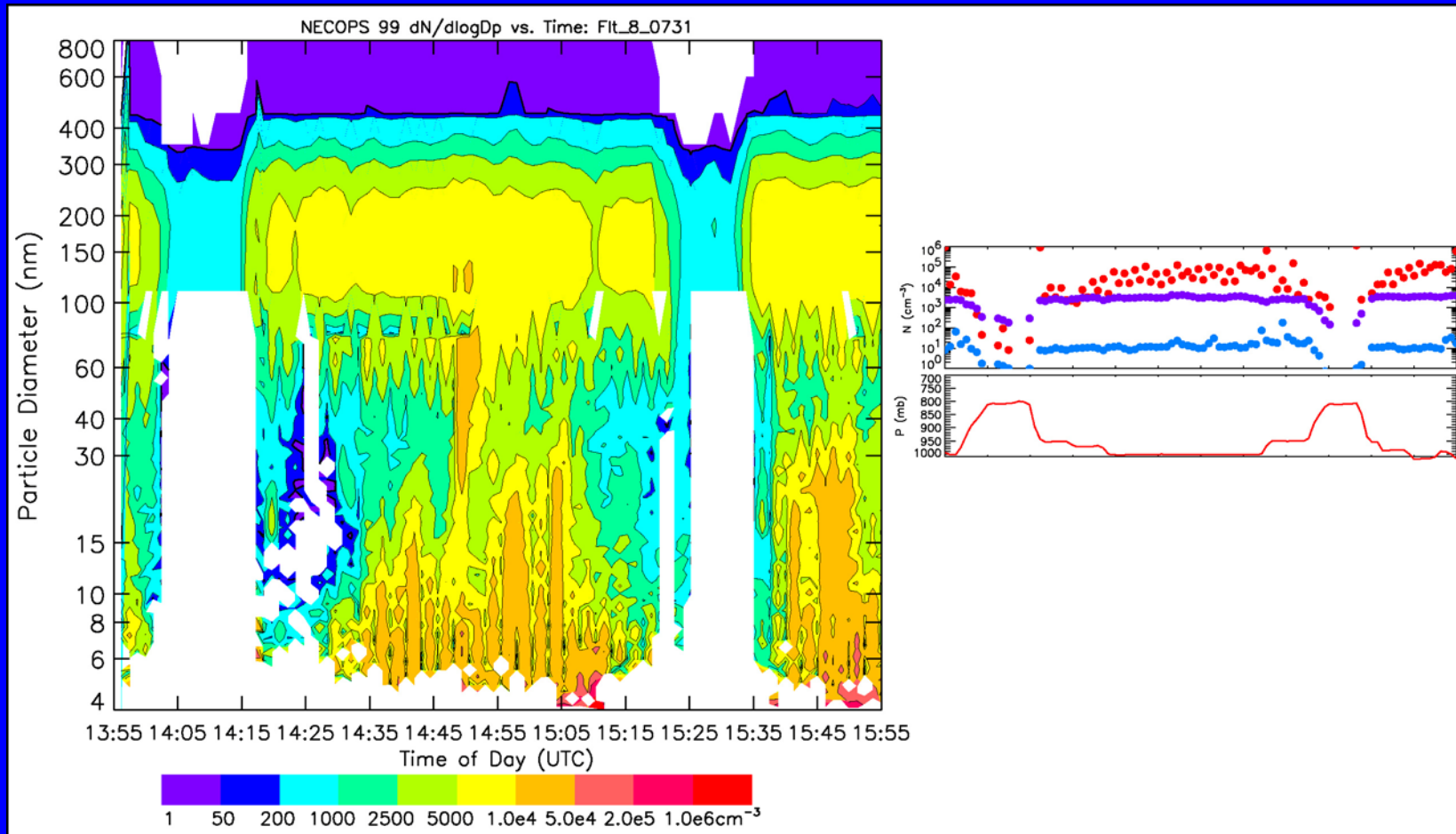
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Ambient Aerosols 101: Part 1

Particle
Number
Concentration
 $1/\text{cm}^3$



Ambient Aerosols 101: Part 2



Motivation for the Measurements

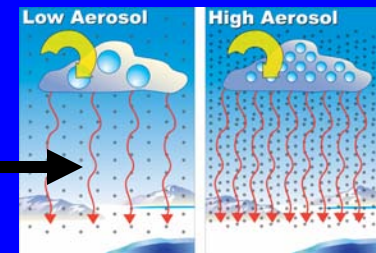


- Shipboard catapult launch
- Net capture landing +/- 1 m precision
- 10,000 ft asl ceiling
- Custom clip system for net capture

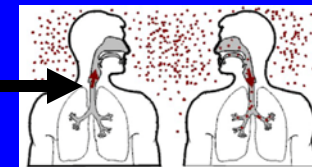
Air Quality Monitoring



Climate Impacts



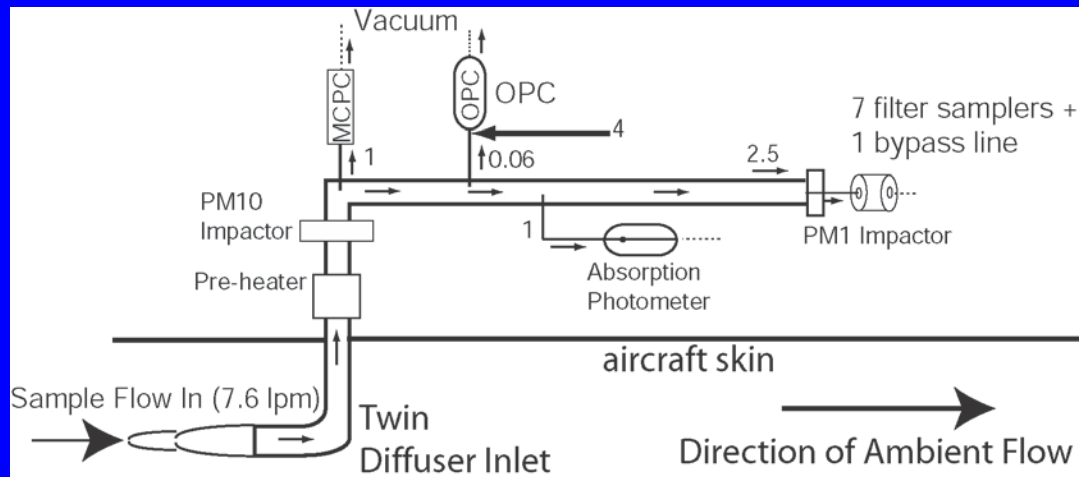
Health Impacts



Source Characterization



Schematic of UAS Instrument Suite



- Condensation Particle Counter
- Eight channel fine-mode particle chemical sampler
- Mini-optical particle counter
- Mini-absorption photometer
- Custom microprocessor DAQ & control software (real-time COM)
- Isokinetic inlet system

Condensation Particle Counter

- Detect total particle concentration $D_p > 10$ nm
- 10 Hz
- BMI Optics Block
- Fast time response
- 1 lpm total flow
- Butanol working fluid
- Other app: SEMS detector

Multi-channel Chemical Sampler v1

- Collect $D_p > 1000$ nm & $D_p < 1000$ nm
- Well impactor for large particles
- Filter collection for fine
- 30 minute sample time
- 1 pump, 8 solenoids
- Too big & heavy
- Delta P too high
- Other applications?



Multi-channel Chemical Sampler v2

- Collect only $D_p < 1000$ nm
- 6 samples / flight (1 bypass)
- 30 minute sample time minimum
- Custom magnetic valves
- Radio control of sampling
- Weight < 1 lb
- Cut & extract 47 mm filter after each flight
- 2.25" dia x 1.5" deep
- In design phase

Miniature Optical Particle Counter

- Detect $100 < D_p < 2000$ nm
- 1 Hz $dN/d\log D_p$
- 0.06 lpm sample flow
- Filtered sheath flow
- 1"x1" BMI optics block
- BMI laser driver
- Laser power feedback
- Initial testing: Reduce noise

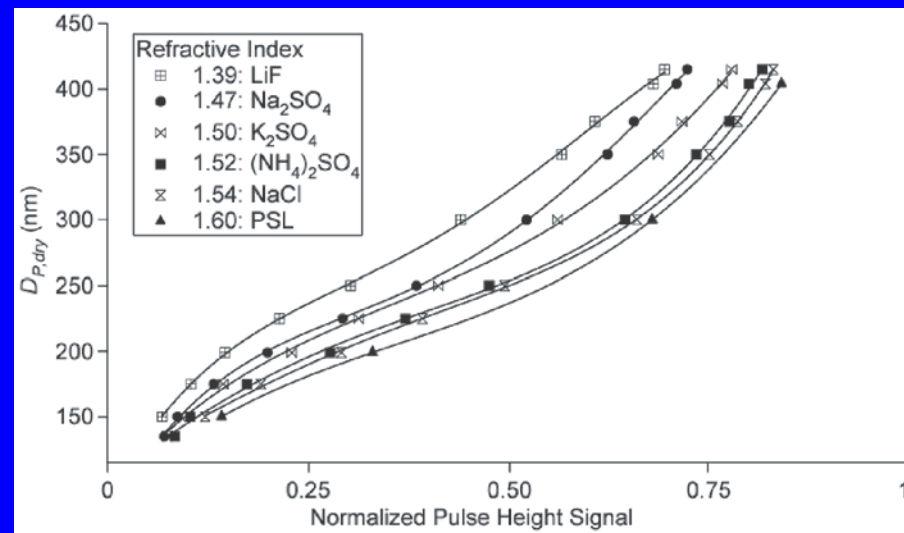
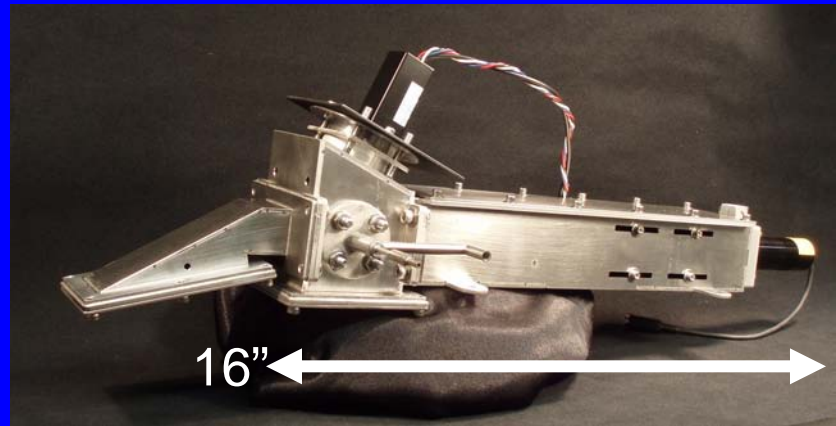
Miniature Absorption Photometer

- Detect Babs $10 < D_p < 1000$ nm
- 10 Hz
- LOD better than 1 Mm^{-1}
- PSAP filters – with reference
- 1 lpm flow, 3" H₂O drop
- Custom electronics

Additional Aircraft Instrumentation offered by BMI

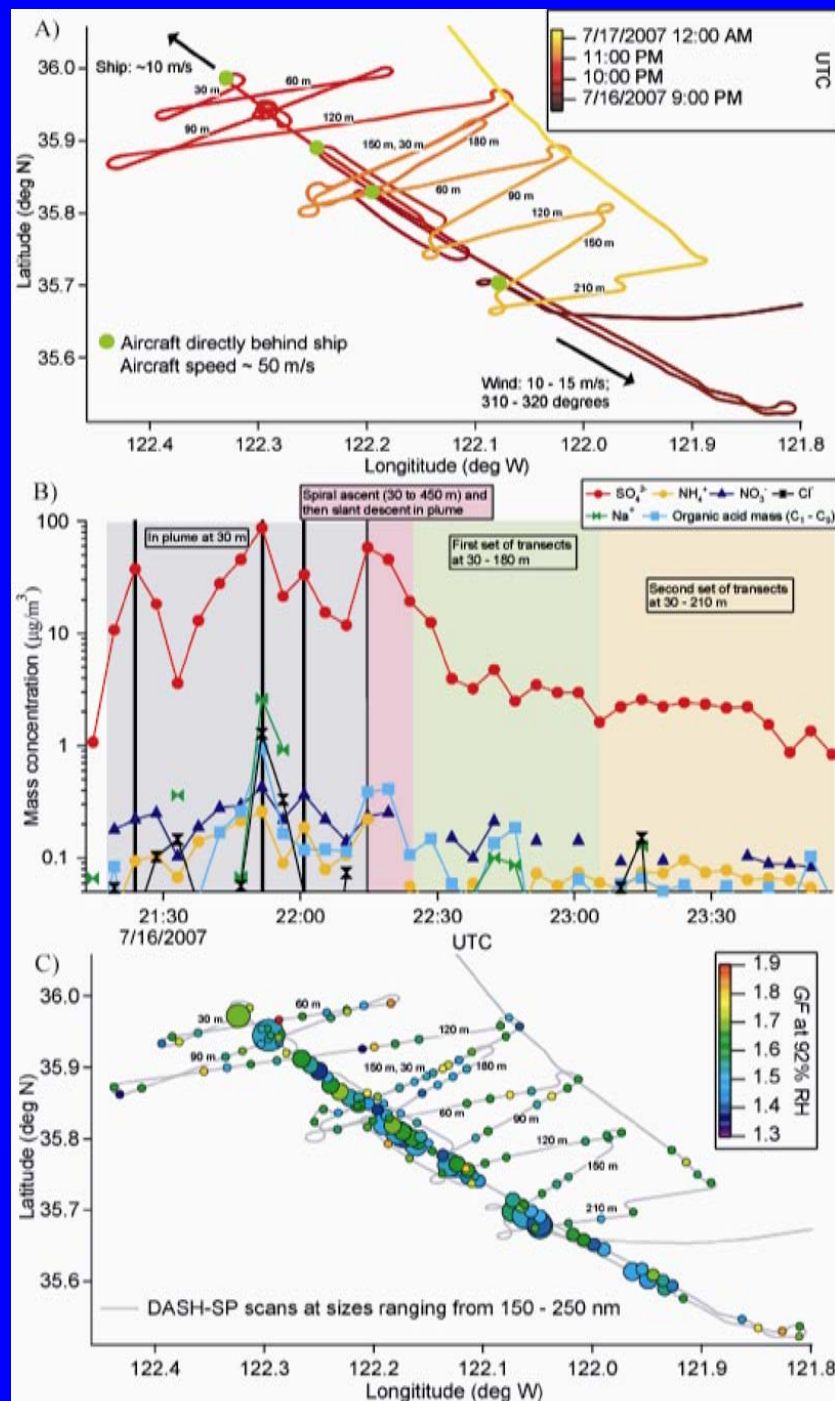
BMI DASH-SP Optical Particle Counter

- Detect $135 < D_p < 2000$ nm
- 1 Hz $dN/d\log D_p$
- 0.06 lpm sample flow
- 4 lpm Filtered sheath flow
- 3"x3" BMI optical cavity
- Green laser diode
- 4 units deployed in DASH on Otter July 2007
- Dry DMA – 4 OPCs
- 1 dry OPC – 3 wet OPCs

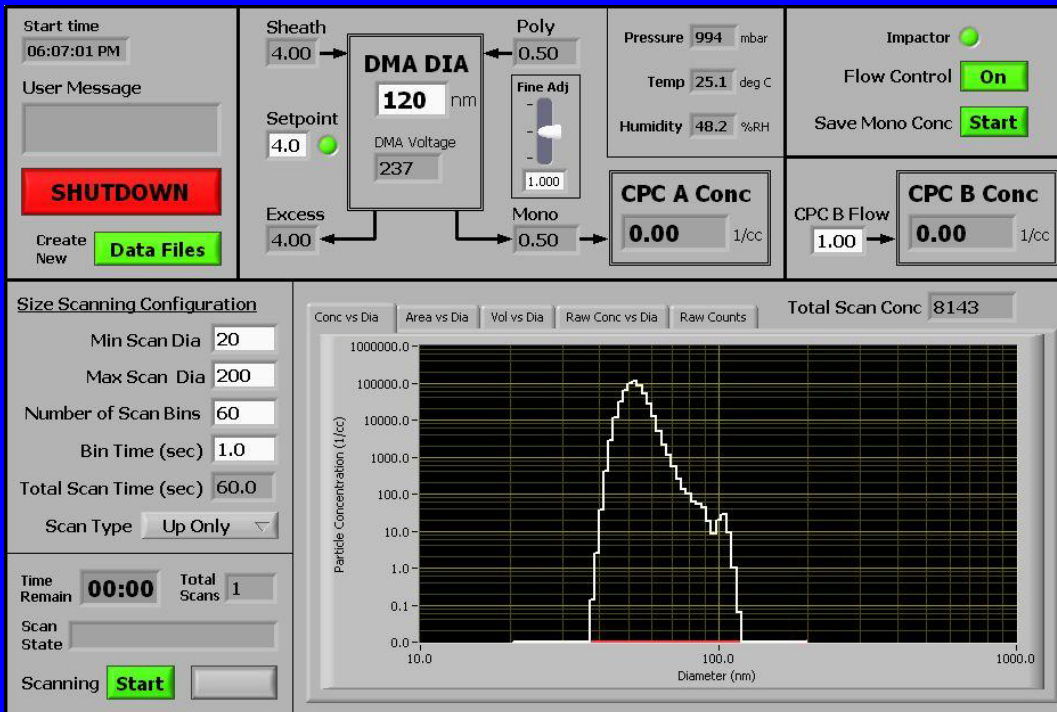


BMI DASH-SP Field Results

(data courtesy Armin Sorooshian)



Scanning Electrical Mobility Spectrometer (SEMS)



- Size Distributions $20 < D_p < 1000$ nm
- 10 to 600 sec scan times
- Real-time data inversion
- Monodisperse aerosol generator
- 0.2-1 lpm sample flow, 6 lpm Sheath flow

Particle-Into-Liquid Sampler (PILS) Technology

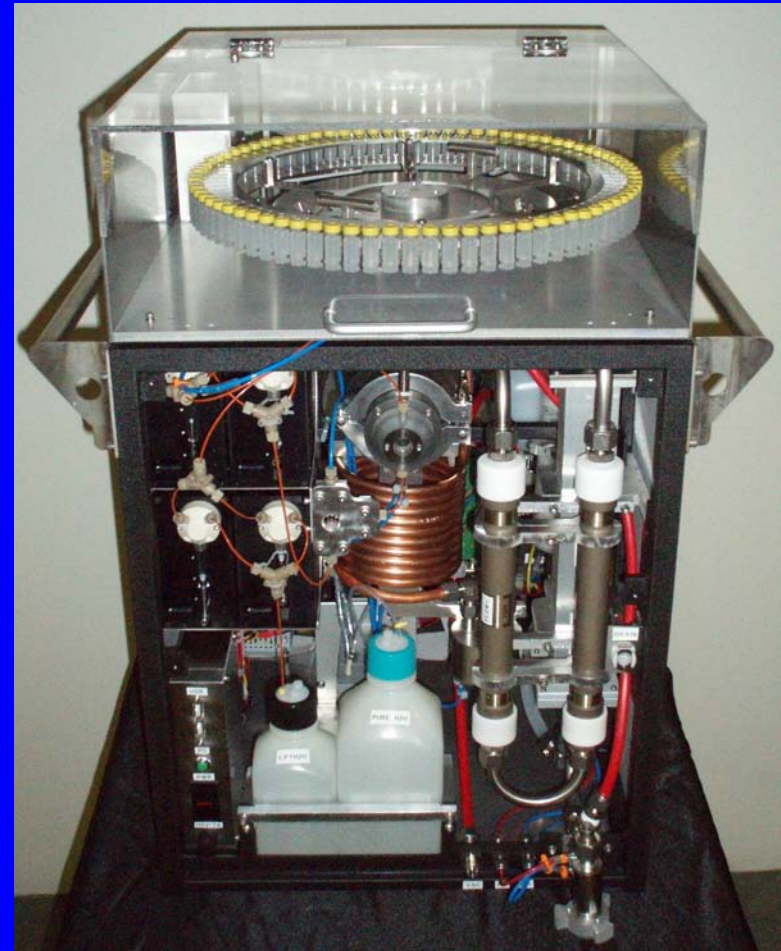
- The PILS collects liquid samples that may be analyzed for multiple water soluble inorganic and organic species, and for total water soluble organic carbon.

Flown on:

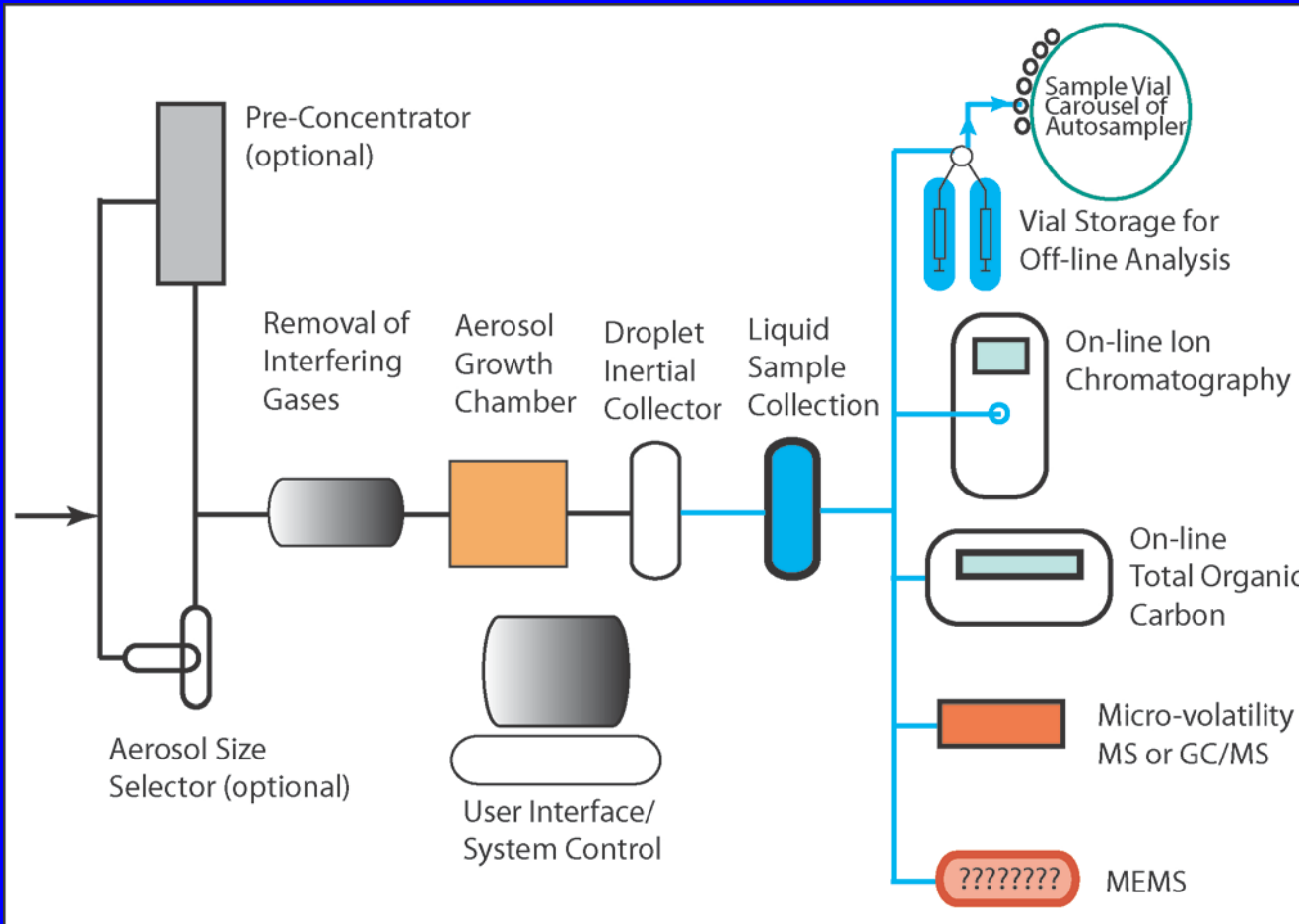
CIRPAS Twin Otter

NOAA P-3

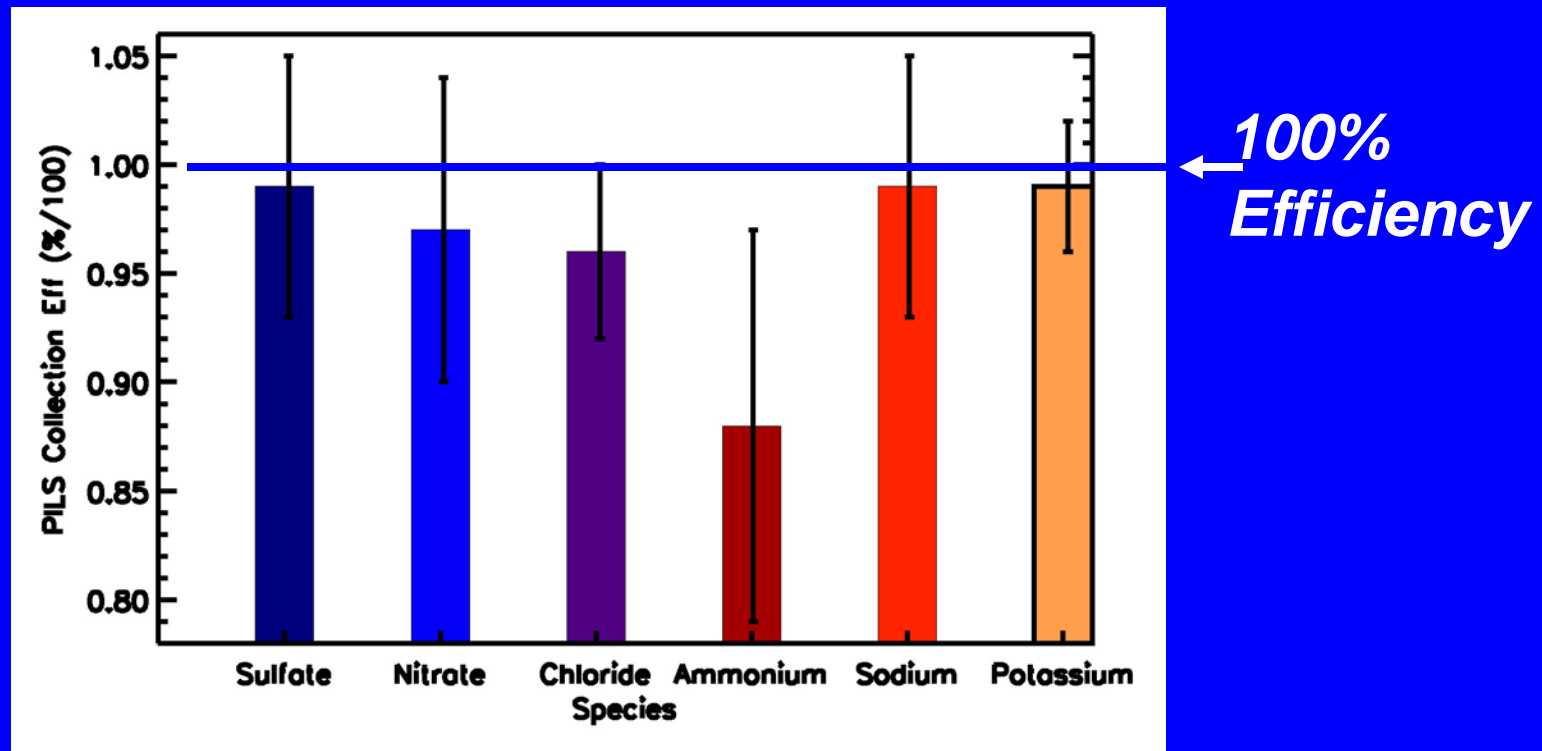
NOAA Cessna 206



Schematic of the PILS:



PILS Sampling Efficiency



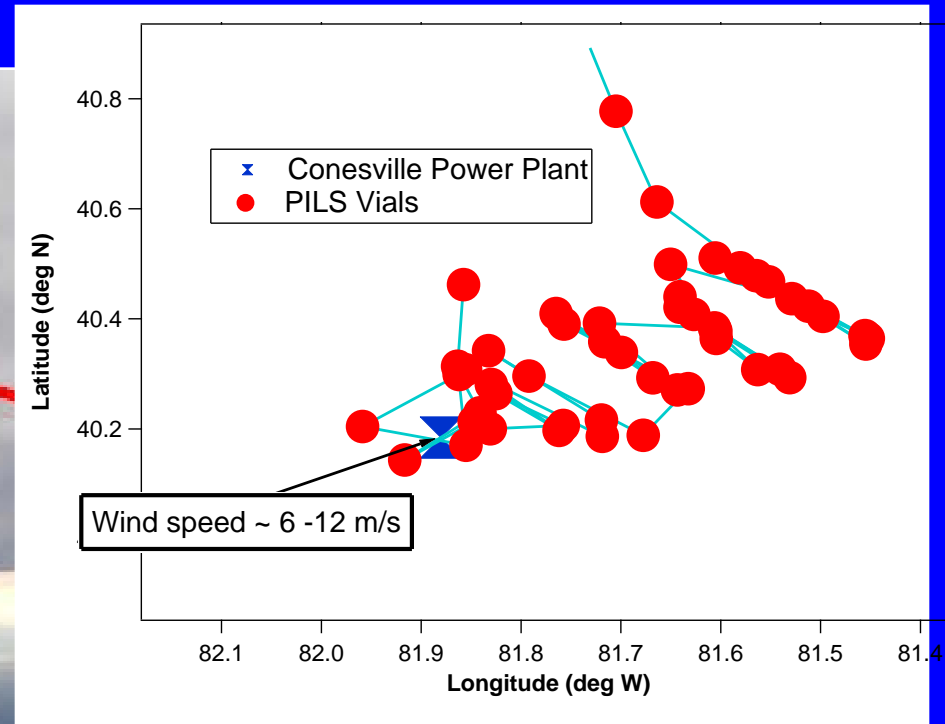
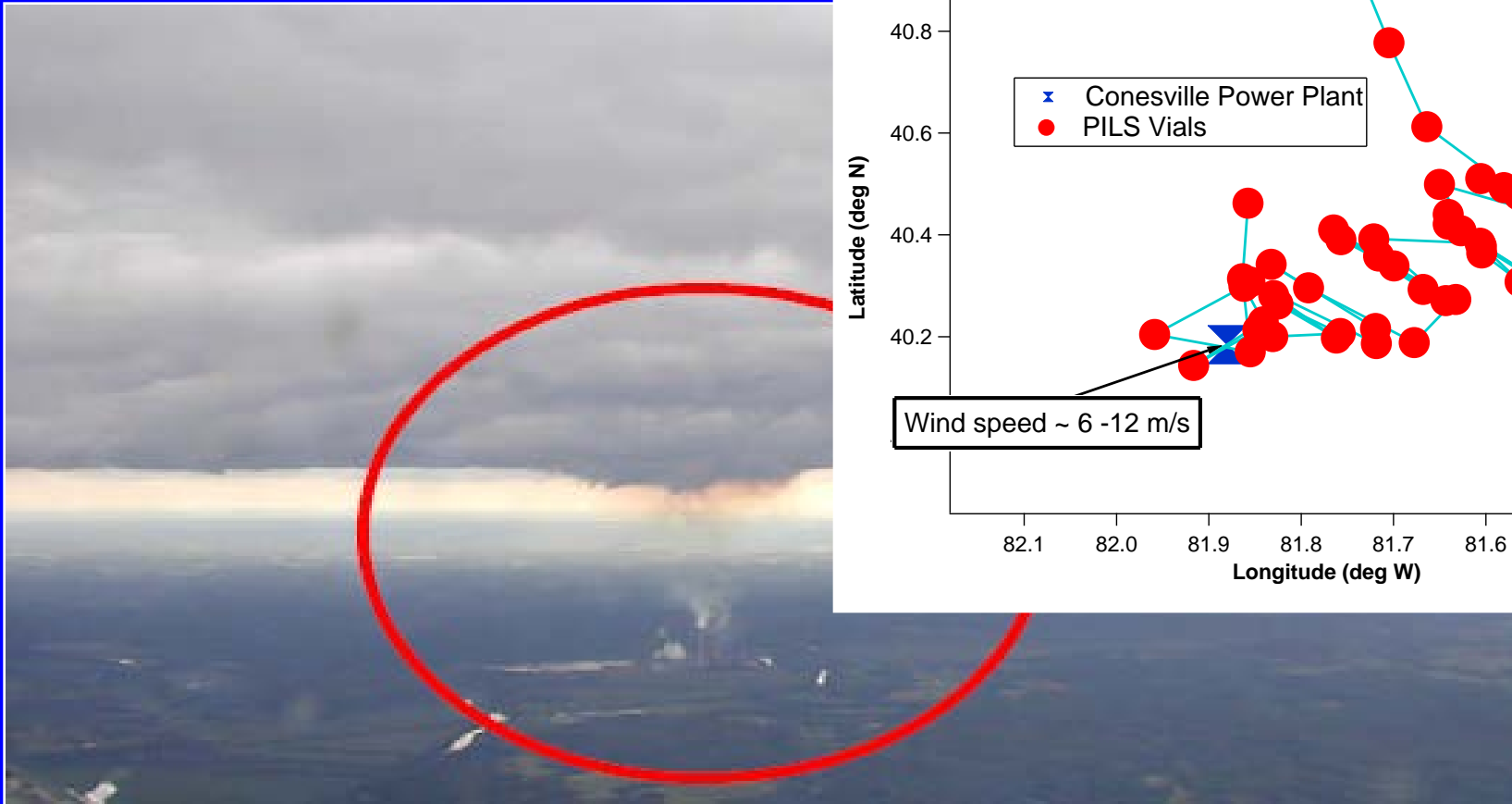
Case Study of the PLS Applied to Chemical Processing in Power Plant Plumes

*Acknowledgement to Seinfeld group at
Caltech.*

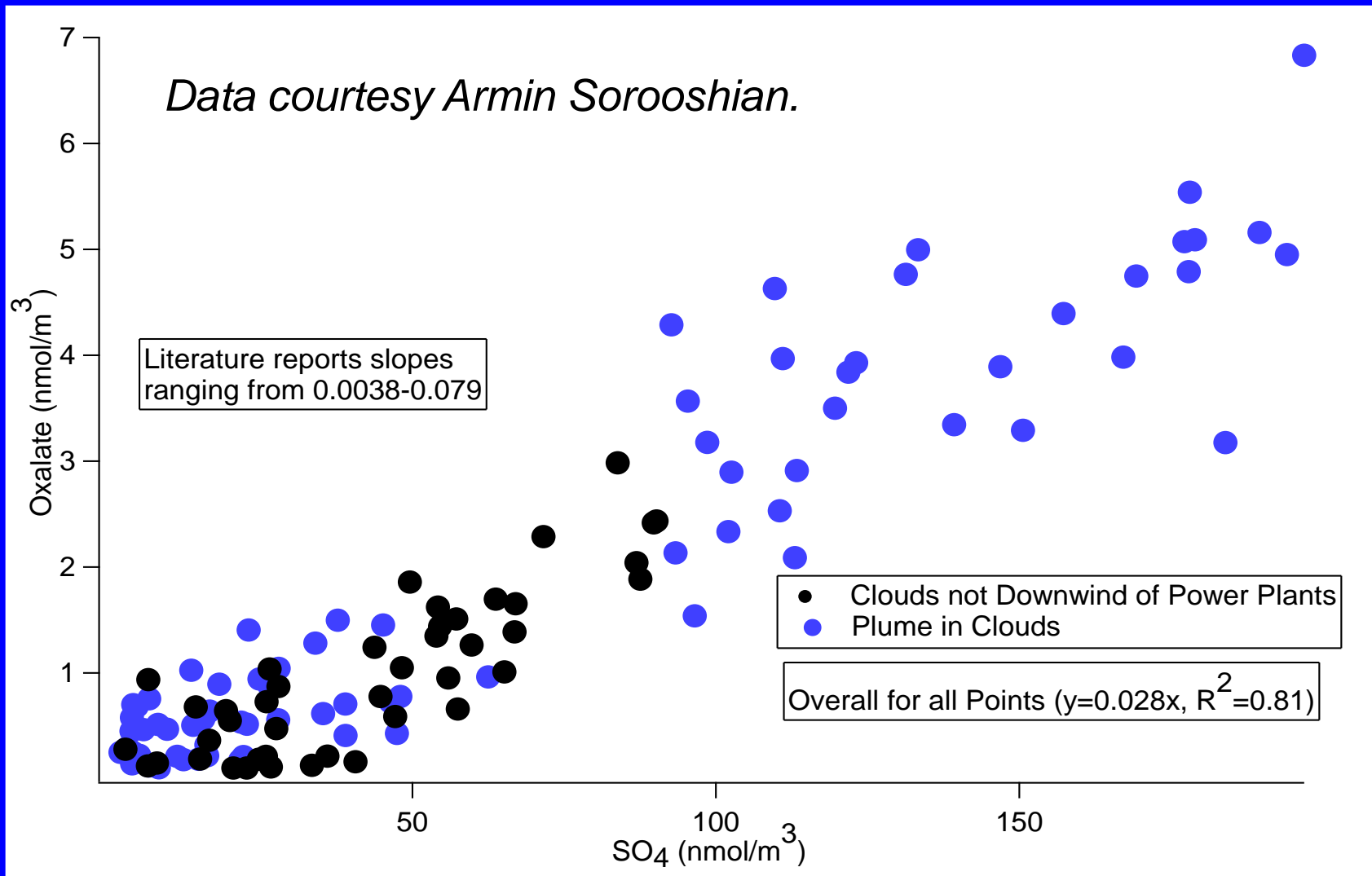
International Consortium for Atmospheric Research on Transport and Transformation



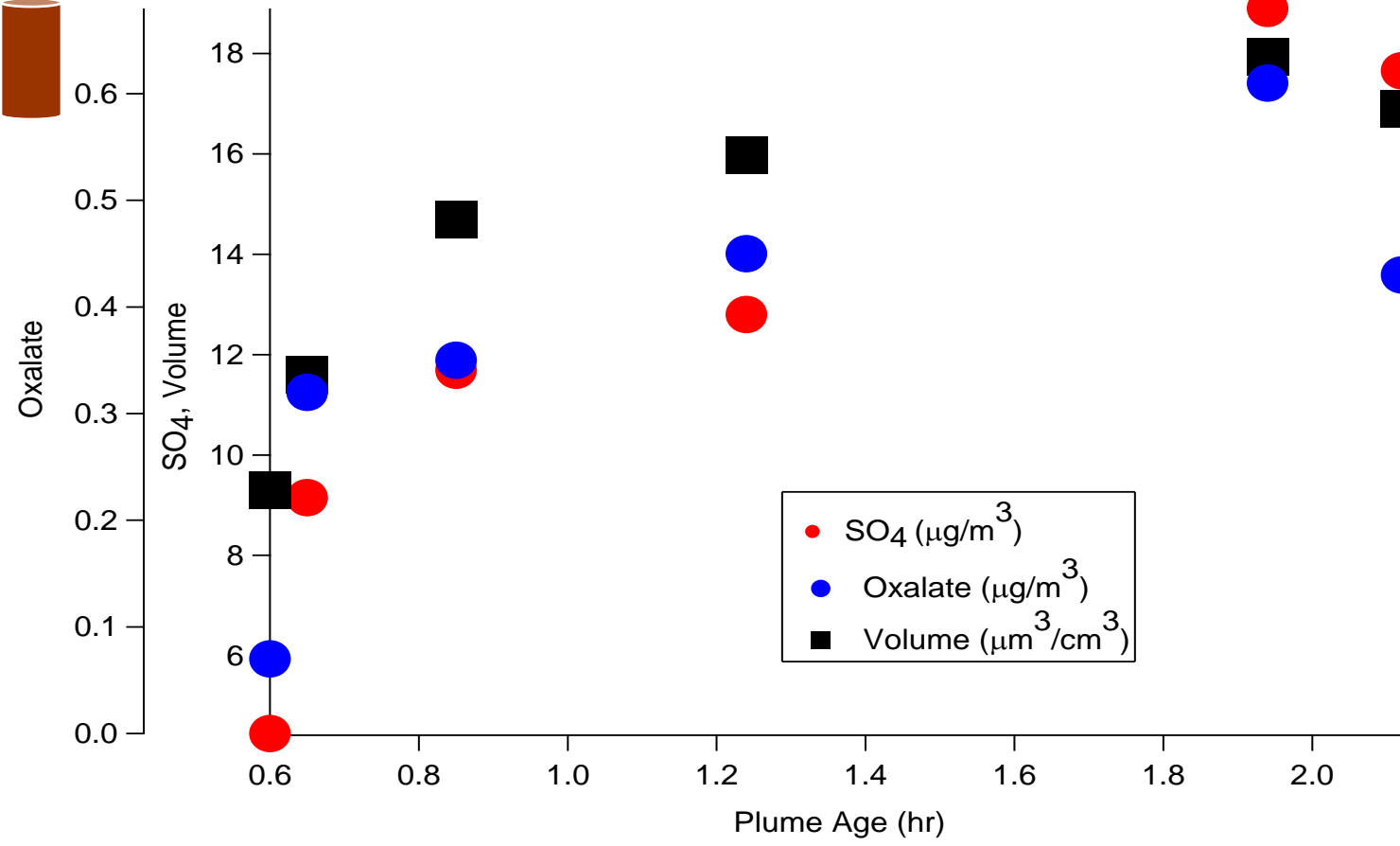
Case Study: Conesville Power Plant Plume Study



Chemical Processing of Power Plant Plumes inside and outside of Clouds



Chemical Processing of Power Plant Plumes inside and outside of Clouds



Thanks for your time.

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BMI PILS Flexible Sampling Features

- **Multiple** sampling options:
 - 1) Autosampler to fill vials for later analysis,
 - 2) On-line IC, TOC, & other analyses
- Autosampler option allows multiple analytical techniques to be applied to a single liquid sample and reduces overall system size and sample acquisition time.

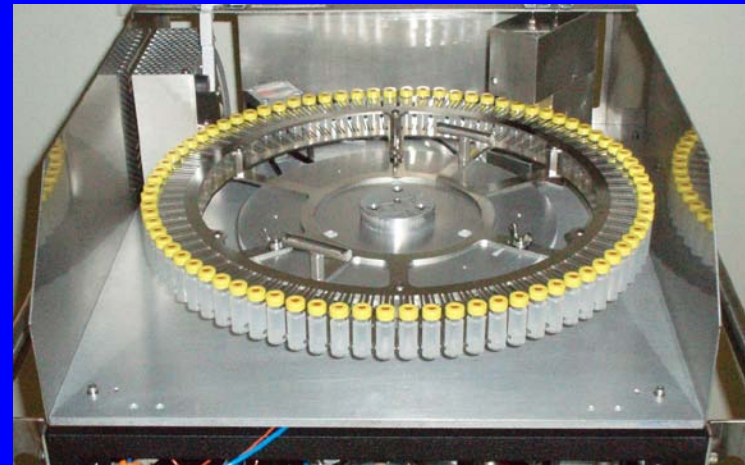


Photo of BMI Autosampler

BMI Autosampler with low-background vials. Septa in vial caps protect collected sample from contaminants.

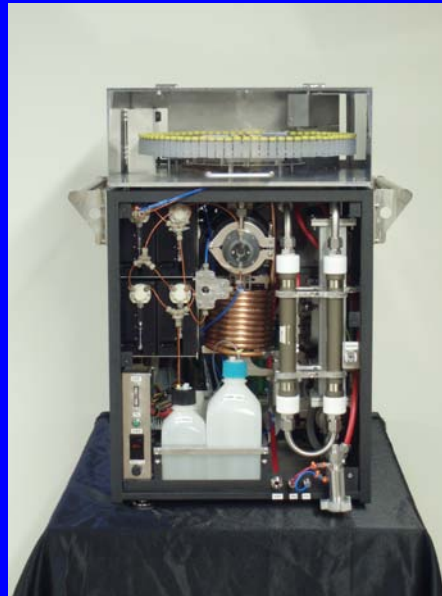
Customer Needs Satisfied:

- *Automation*
- *Reliability*
- *Adaptability*
- *Cost Reduction*
- *Configurability*
- *Traceability*
- *Validation*



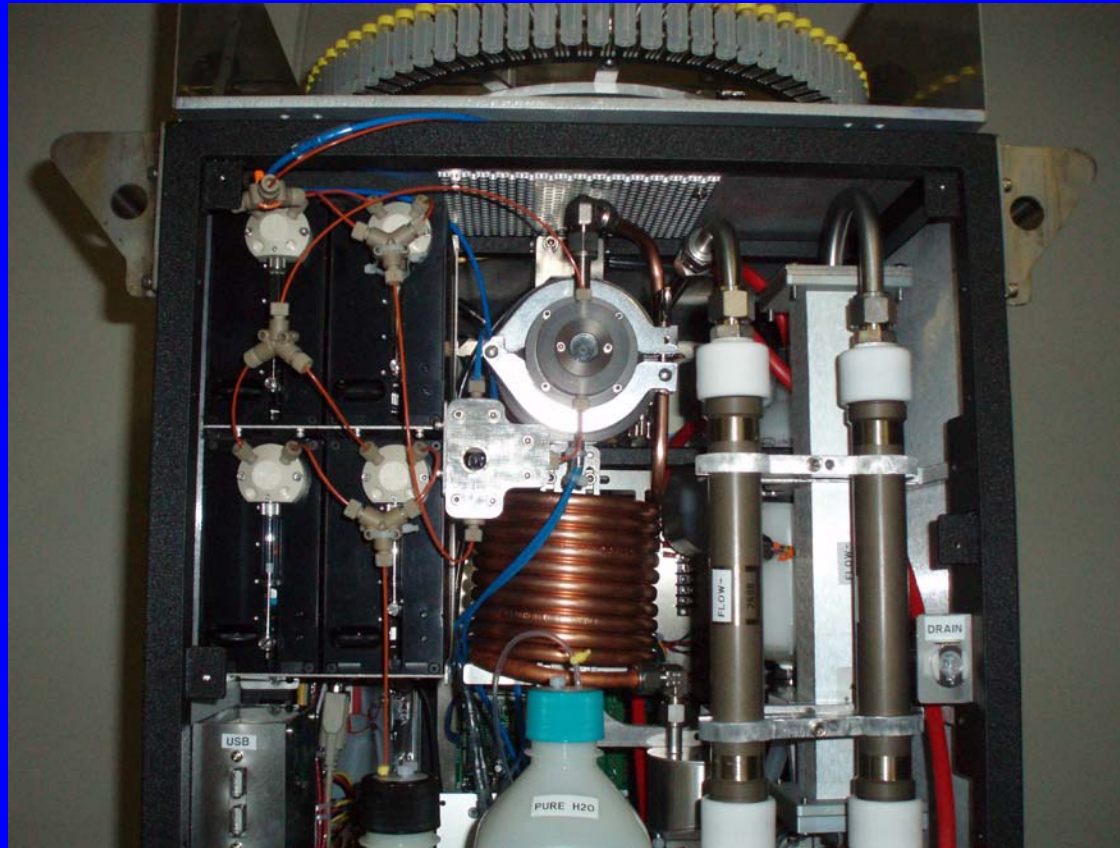
BMI PILS Key Features

- Rapid PM1 or 2.5 μ m composition measurements
- Fully integrated system ready to use
- Ground-based or Airborne sampling capability
- Multiple analytical techniques possible



BMI PILS Key Features

- *Syringe pumps for precise liquid sample flow control*



PILS User Interface

Tip Temp <input type="text" value="99"/> Heater <input checked="" type="checkbox"/> Heater Temp <input type="text" value="225"/>	
Starting Carousel <input type="text" value="1"/>	Starting Vial Num <input type="text" value="19"/>
CAROUSEL POSITION <input type="text" value="0"/>	CURRENT VIAL NUM <input type="text" value="19"/>
Filter Vials Filled <input type="text" value="0"/>	Transition Vials Filled <input type="text" value="0"/>
Sample Vials Filled <input type="text" value="0"/>	AIR FLOW VALVE <input type="text" value="Filter"/>
<input checked="" type="button" value="START PILS"/>	TIME REMAINING <input type="text" value="00:00"/>
User Message <input type="text" value="Enter Settings and Push 'Start PILS' button."/>	
Current Function <input type="text" value="Start Up"/>	
Hardware Status <input type="text"/>	
Manual Control:	
Take <input type="text" value="3"/> Filter Vials Now <input type="button"/>	
End With <input type="text" value="3"/> Filter Vials <input type="button"/>	

Starting Configuration:	
Run Number	<input type="text"/>
Start time	<input type="text" value="11:21:45 AM"/>
Minutes per Vial	<input type="text" value="5.0"/>
Sample Flow Rate	<input type="text" value="130"/> microliters/min
Vial Fill Volume	<input type="text" value="650"/> microliters
Flushing	<input checked="" type="checkbox"/> ON
Flush Time	<input type="text" value="30.0"/> minutes
Start with Filter Vials	<input checked="" type="checkbox"/> ON
Start with	<input type="text" value="3"/> Filter Vials
Num Sample Vials	<input type="text" value="73"/>
Current System Readings	
Impactor Air Flow	<input type="text" value="14.3"/> lpm
System Pressure	<input type="text" value="999"/> millibar
Air Flow Humidity	<input type="text" value="41"/> %RH
Air Flow Temp	<input type="text" value="18"/> deg C
CO Pressure	<input type="text" value="295"/> millibar <input checked="" type="checkbox"/>
Impactor diff Press	<input type="text" value="6.5"/> millibar <input checked="" type="checkbox"/>

BMI PILS Remote Control Feature

- Acquisition times of sample may be controlled by a remote host computer through optional software

Tip Temp 95 Heater Heater Temp 120

Filter Vials Filled 0 Sample Vials Filled 0

CAROUSEL POSITION 1 AIR FLOW VALVE Filter

STOP PILS TIME REMAINING 00:00

User Message Waiting for Remote Command

Current Function Pause

Hardware Status

Starting Configuration:

Start time 12:53:49 PM

Minutes per Vial 5.0

Sample Flow Rate 130 microliters/min

Vial Fill Volume 650 microliters

Auto Startup-Shutdown **OFF**

Current System Readings

LFE Air Flow 16.7 lpm

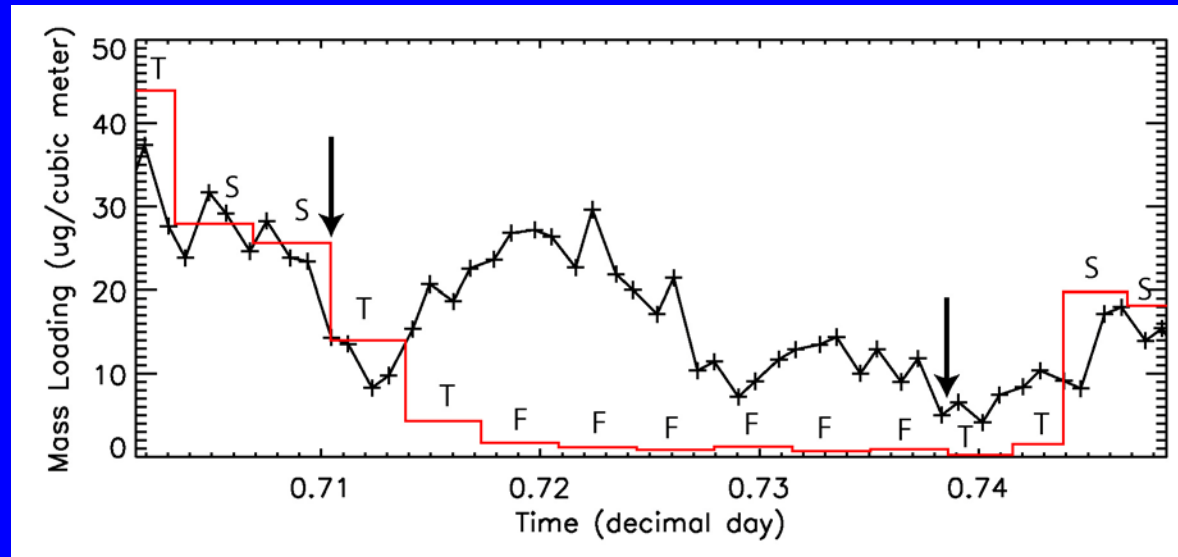
System Pressure 983 millibar

Air Flow Humidity 48 %RH

Air Flow Temp 20 deg C

Impactor Air Flow 16.1 lpm

Intercomparison of PILS & SEMS Measured Ammonium Sulfate Mass



BMI PILS Technical Details

- *12-15 lpm air sample flow rate; 1 μm D50 impactor cutoff*
- *Denuders installed upstream to remove potentially interfering inorganic and organic vapors*
- *0.02-1.0 ml/min liquid sample collection flow rate*
- *30 second to 12 hour sample time provides 0.1-20 ml of collected sample in either poly (1.2 ml) or glass (2, 10 & 20 ml) vials*
- *Power: 230 watts @ 115 VAC (excluding air pump)*
- *Size: 19" rack-mountable frame 19" deep, 26" high.*
- *Weight: 115 lb*