# IN51B-1583: Generating Aerosol Data Products from Airborne In-situ Observations made during the 2011 DISCOVER-AQ Field Campaign

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## Introduction

In July 2011, the first DISCOVER-AQ (Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality) field campaign was completed. The investigation is a broad collaboration between federal and state agencies and academic institutions with the primary goal of improving the interpretation of satellite observations of surface-level trace gas and aerosol parameters by making detailed correlative measurements from aircraft and ground-based instruments in urban regions plagued by air-quality issues. Phase I studied the air-quality of the lower troposphere in and around the Washington, D.C. and Baltimore areas along the I-95 corridor. In-situ airborne data is essential in providing a link between the broad swath satellite measurements and the measurements made by ground based sensors. This is accomplished by examining the relationship between column-integrated values obtained through in-situ sampling and surface measured values, as aircraft can fully characterize atmospheric chemical/aerosol constituents at a given time and location.

To that end, the NASA P-3B was instrumented to record fast-response measurements of various gas-phase tracers and aerosol characteristics of pollution. A flight pattern was created and executed for each of the 14 research flights that had the P-3B performing a series of spiral ascents/descents over six ground sites to perform detailed vertical characterizations of the chemical and aerosol structure. The in-situ aerosol characterization was performed by the NASA Langley Aerosol Research Group Experiment (LARGE) using 15 instruments to measure aerosol microphysical, chemical and optical properties.

In this presentation we illustrate the process in which aerosol science data is generated, from the collection of more than 10 GB of raw data per 8 hour flight, to the initial QA/QC required to produce a preliminary data product within 24 hours of landing, through final data submission to the data archive within 4 months of the end of the field campaign, including post mission calibration and QA/QC. The final data products are estimated to generate about 500 GB total for the deployment and will encompass no less than 10 different archive files per flight at 1s resolution. Examples will be shown such as the correction of nephelometer data for truncation errors and absorption data from filter based instruments due to scattering on the filter media. Interpretative data products are also generated to aid the interpretation and synthesis of the aerosol data with gas-phase in-situ and coincident satellite retrievals, including column integrated dry and ambient aerosol optical depths. Sample data products will also be presented.

## P-3B Aerosol Instruments

| Measured Parameter | Instrument | Size Range (μm) | Response Time (sec) | Precision |
|---|---|---|---|---|
| Hot, Cold, Ultrafine Condensation Nuclei (CN) | TSI-3025, 2 x TSI-3010 Condensation Particle Counters | > 0.003 | 1 | 10% |
| Aerosol Particle Size | Scanning Mobility Particle Sizer (SMPS) | 0.01-0.3 | 60 | 20% |
| | DMT Ultra-High Sensitivity Aerosol Spectrometer (UHSAS) | 0.06-1.0 | 1 | 20% |
| | TSI Aerosol Particle Sizer (APS) 3321 | 0.5-5 | 1 | 20% |
| CCN Spectra | DMT Scanning Flow Cloud Condensation Nuclei (CCN) Counter | | 60 | |
| Total (Dry & Wet) Scattering (450, 550, and 700 nm) | 2 x TSI 3563 Nephelometers | < 5.0 | 1 | 5e-7 $Mm^{-1}$ |
| Submicron Scattering (530 nm) | Radiance Research Nephelometer | < 1.0 | 1 | 20% |
| Total & Submicron Absorption (467, 532, and 660 nm) | 2 x Radiance Research Particle Soot Absorption Photometers (PSAP) | < 5 & <1 | 5 | 5e-7 $Mm^{-1}$ |
| Black Carbon Mass and Size | DMT Single Particle Soot Photometer (SP2) | 0.1 – 0.5 | 1 | 20% |
| Total Organic Carbon (TOC) | Particle Into Liquid Sampler (PILS) / TOC | > 0.01 | 30 | |
| Soluble Ion Composition | PILS/IC + Filters | >0.01 | 240 | Varies by ion |

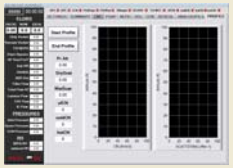
## Summary

- A DAQ system was developed to control a suite of instruments during the summer 2011 DISCOVER-AQ field campaign on the NASA P-3B
  - The system acquired data at 1 Hz from 14 instruments via RS-232 serial interface, with 32 analog inputs and 2 analog outputs
  - The DAQ program was written in C++ with a Lab Windows/CVI interface
  - For one 8 hour flight, the total raw data collected exceeded 10 GB
- The data processing consisted of several steps, including:
  - Automated and manual filtering prior to generating post-flight initial archive files
  - Raw instrument signals are checked for consistency
  - Flows are checked every flight to look for flow-system issues
  - SMPS size distributions are inverted to account for pressure and temperature
  - Scattering coefficients are corrected for truncation errors
  - Absorption coefficients are corrected for scatting on the filter errors
  - Preliminary archive files are submitted within 24 hours of the flight
- Post-Mission Final Data Products and Analysis
  - Interpretive analysis utilizing data from other science team investigators are used as part of the QA/QC analysis to check measurement consistency and aid in data interpretation
  - Final data archive products were submitted on or before 12/01/11
  - Final data products include corrections for instrument offsets and time synchronization which are essential for emission plume analysis
- Final data products can be tailored to individual analysis needs including:
  - Automated graphs for every spiral profile done (avg = 18-20 / flight)
  - Google Earth KML files for flight track maps of CN, extinction, etc.

## Aircraft DAQ

*Screen Shot from the Primary DAQ Software Summary Screen Example*

- The primary LARGE data acquisition (DAQ) system for DISCOVER-AQ consisted of a rack-mount PC and monitor, a National Instruments (NI) PCI-8430 high performance 16-port RS-232 Serial Interface, and 2 National Instruments USB-6218 BNC multifunction DAQ boxes to provide 32 channels of analog input and 2 channels of analog output.
- Secondary computers handled the SMPS, CCN, SP2, and PILS/TOC using manufacturer provided software
- Primary DAQ software written in C++ using a Microsoft Visual C++ and NI Lab Windows/CVI for instrument control and the graphical user interface (GUI)
- The DAQ software records the 1 Hz response from 14 aerosol characterizing instruments and 32 analog input signals as well as providing the data to the GUI, sending 2 signals to the P-3B's central data system for distribution, and recording the data to 2 disk drives.



*Screen Shot from the Primary DAQ Software Profile Screen – Create real time profiles*

- Instrument health status is monitored throughout and displayed graphically via LEDs at the top of the GUI
- The raw binary file from the DAQ is about 10 MB for a 8 hour flight.
- The data is reduced and stored in a comma separated variable (CSV) format and data from all the instruments (those recorded by the primary DAQ computer as well as the others) are combined into an Microsoft Excel file, where the times are synched for the takeoff and landing for further analysis.
- The LARGE DAQ provided real-time raw vertical profiles during flight to aid in layer identification and flight planning
- *For each 1s of flight time, more than 500 parameters are recorded for future processing and analysis.*

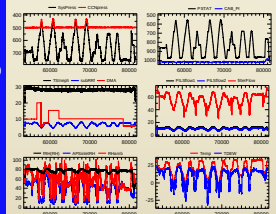
*Screen Shot from the Primary DAQ Software Scattering Screen – Monitor and Zero Nephelometers*

## Preliminary Data Processing

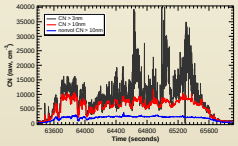
Post-flight analysis, processing, and archive creation is handled by reading in the raw data from the Microsoft Excel spreadsheet into Wavemetric's IGOR Pro software package (Examples herein are from the flight on 29 July 2011)

**Processing Tool**

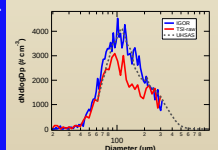
**Post-Flight Processing is controlled by a GUI that allows the user to**
1. Choose the instruments to process
2. Perform some preliminary filtering or data corrections (automated or by-hand)
3. Select times to flag the data
4. Calculate the statistics (average and standard deviation) for post-flight and post-mission offset analysis
5. Compute the average value and average size distributions for a user defined time.



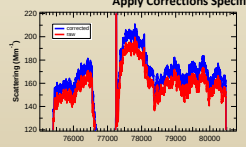
**Prior to creating the preliminary archive files, the raw data is inspected to ensure that all instruments are operating and recording correctly**
1. Analog Inputs and Aircraft Parameter data are checked for measurement issues
2. Raw instrument responses are checked for consistency (i.e. is the raw ultrafine CN > cold CN > hot CN) If not, the problem must be solved prior to the next flight.
3. Flows are checked to make sure the instrument suite flow system is operating as it is designed to do.



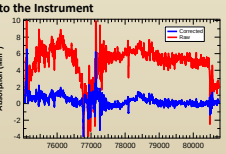
**Apply Corrections Specific to the Instrument**



**SMPS Inversion – Raw SMPS data is corrected for**
1. Multiple charging
2. Diffusion within the SMPS
3. Ambient temperature and pressure



**Scattering Angle Truncation Correction**
TSI Nephelometer data are corrected for truncation errors in the instrument according to Anderson and Ogren (AS&T., 1998)



**Absorption Corrections**
PSAPs are corrected due to the scattering of particles on the filter media and the PSAP instrument geometry according to Virkkula (AS&T, 2010)

**Other Corrections Include**
1. Apply Flow Calibrations
2. Correct TSI-3010 counters for coincident counts at high aerosol concentrations
3. Flag (remove) all APS data above 28,000 ft due to low flow issues
4. Correct all data to ambient temperature and pressure.

*Front page of the D-AQ website*

**Once the corrections are applied the preliminary archive files are created**
1. 10 files are produced at 1s resolution for most parameters and (5s for the sizing instruments).
2. Archive files adhere to the ICARTT format (source) and fulfill the requirements set forth in the Data Management Plan by Chen et al (2011) and archived at http://www-air.larc.nasa.gov/missions/discover-aq/discover-aq.html

*FSCAN, a tool developed by Ali Aknan (SSAI) to check the format of archive files*

## Post Mission Analysis and Final Data Submission

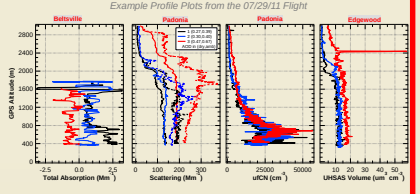
From the **FINAL** data, a variety of special data products are generated to aid in scientific analyses

**Profile Plots**
- During DISCOVER-AQ the P-3B sampled the atmosphere over 6 AERONET sites with a spiraling flight pattern, such as is shown in the KML pictures to the right.
- The data processing software automatically generated profile plots of numerous aerosol parameters, including number concentration, dry and ambient scattering, and absorption.
- In addition, the P-3B made passes over highways such as I-95 between Baltimore and DC

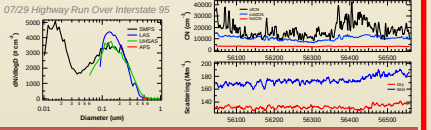
*Example KML file for Aerosol Extinction*

**Google Earth KML files**
For each flight a set of KML files are produced for aerosol number concentration, extinction, and the f(RH)

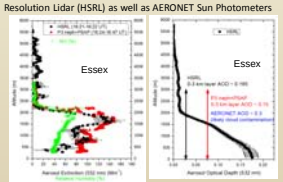
*Example Profile Plots from the 07/29/11 Flight*




*07/29 Highway Run Over Interstate 95*

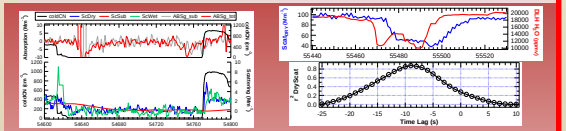



**Final Data QA/QC: Integrated Interpretive Analyses**
As part of the QA/QC process, P-3B aerosol optical data are compared with data from the NASA Langley UC-12 High Spectral Resolution Lidar (HSRL) as well as AERONET Sun Photometers



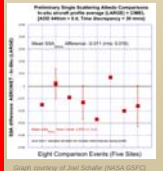

*These graphs show a comparison between LARGE P-3B and UC-12 HSRL aerosol extinction values from a profile over Essex (courtesy of Rich Ferrare (NASA LARC))*

**Post-mission corrections need to be applied to preliminary data to generate the final data archive files suitable for scientific analysis (archived 12/01/11)**



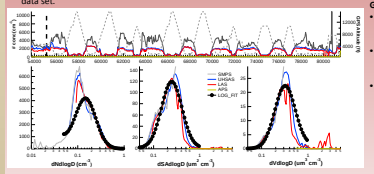
**Instrument Offset Analysis**
- On each flight an in-line filter was used to check for offsets in instrument response for each instrument.
- Mission-long statistics for each instrument were generated and the resulting offset was applied to the data for the final data set.

**Measurement Time Synchronization Analysis**
- Synchronizing the data is essential for emission plume analysis
- The time lag of each instrument was checked post mission by comparing it to the NASA Langley Diode Laser Hygrometer (DLH).
- Lag regression peaks were acquired and applied to the final data set



*Graph courtesy of Joel Schafer (NASA GSFC)*

**Integrated Analysis Examples**
- The two graphs above compare in-situ aerosol extinction data and the Aerosol Optical Depth (AOD) from a spiral to results obtained from the AERONET site and the HSRL. Preliminary results show very good agreement.
- The graph to the left shows a preliminary comparison between the Single Scattering Albedo (SSA) and the CIMEL network. The mean different is -0.011




**Generating Integrated Size Distributions (SDs)**
- An IGOR application was developed to scan through the SMPS, UHSAS, LAS, and APS SDs using the GUI below as a control panel.
- User can select an averaging time of either 1s or an user defined averaging time, or use the SMPS time scale.
- The program will fit the data between user selectable bounds, creating a lognormal fit to either the number, area, or volume distribution.