A23A-0211: Comparison of airborne and ground-based aerosol optical measurements made during DISCOVER-AQ California

Lee Thornhill[1] (Kenneth.L.Thornhill@nasa.gov), G. Chen[2], B.E. Anderson[2], E. L. Winstead[1], L. D. Ziemba[2], A. J. Beyersdorf[2], S. Crumeyrolle[3], R. Moore[2], C. Hudgins[1], M. Shook[1], M. Kleb[2], C. Cappa[4], and X. Zhang[4]

[1] Science Systems and Applications Inc; [2] NASA Langley Research Center ; [3] Laboratoire d'Optique Atmospherique; [4]UC Davis, CA

Introduction and Overview of D-AQ CA

In early 2013 the second phase of the NASA sponsored DISCOVER-AQ (Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality) field campaign examined atmospheric composition over California's Central Valley a location typically characterized by poor air quality and high aerosol optical depths. Like the initial deployment that sampled the DC-Baltimore area, the NASA P-3B systematically conducted vertical profiling over six ground sites. In addition, missed approaches over local airports were made to provide a better connection between the aircraft and ground-based measurements. This additional dataset is especially important due to the shallow boundary layer heights observed in the Central Valley during winter. Preliminary analysis showed sharp gradients in aerosol and trace gases in the early morning runs. In this work, vertical profiles of aerosol extinction are presented along with a comparison between the missed approach data and the ground-based scattering/extinction measurements. While focusing primarily on the comparing the airborne and ground based measurements over Bakersfield and Fresno, additional analysis will be provided to show the ground optical measurements as a function of PM2.5. This relationship can be useful in providing valuable insights into the controlling factors of AODs.

DISCOVER-AQ California Overview

- Primary goal of DISCOVER-AQ: Improve the interpretation of satellite data to better forecast/analyze near-surface air quality
- Second of four planned DISCOVER-AQ field experiments
- Meteorological conditions encountered were normal for this time of year in the San Joaquin Valley (SJV)
- SJV experiences late wintertime buildup of aerosols and other pollutants due to very shallow mixed layers with low altitude inversions and poor ventilation
- Total of 170 spirals (0.3 and ~3 km AGL) were done over six ground sites and about 160 missed approaches were performed at nearby airports to extend the profiles down to less than 0.1 km and ensure that the mixed layer is penetrated
- NASA P-3B was equipped with a complex suite of chemical and aerosol instruments

Composite Flight Track Map showing repeated spirals at each of the six waypoints, highlighting Fresno and Bakersfield, the focus for this study

Example of a missed approach and ground-site overpass at Fresno-Garland on 22 January

NASA Langley Aerosol Research Group (LARGE) Instruments (P-3B and Ground)

Measured Parameter	Instrument	Size Range (µm)	Response (s)	Precision
Condensation Nuclei Counter (CNC)	TSI-3025	> 0.003	1	10%
Aerosol Particle Sizers	TSI Optical Particle Sizer (OPS)	0.3 - 10	1	20%
Total (Dry & Humidified) Scattering (450, 550, and 700 nm)	TSI 3563 Nephelometer	< 5.0	1	5e-7 Mm^{-1}
Total (Dry & Humidified) Scattering (532 nm)	Radiance Research M905 Nephelometer	< 5.0	1	20%

UC Davis Instruments (at Fresno)

Measured Parameter	Instrument	Size Range (µm)
Absorption at 405, 532, and 870 nm	UC Davis Photo-acoustic (PAS)	< 2.5
Extinction at 405, 532, and 870 nm	UC Davis Cavity Ringdown (CRD)	< 2.5

Cappa et al., Science, 2012, DOI: 10.1126/science.1223447

Summary and Future Directions

Initial Summary of Observations

- When the P-3B was able to descend into the mixed layer, the NASA LARGE ground based dry scattering measurements agreed very well with the airborne based optical data
- The scanning humidifier system employed for the first time during DISCOVER-AQ California worked well, but using only one nephelometer at Bakersfield led to an increased number of gaps in the ground based and aircraft derived f(RH) values and could complicate the intercomparison analysis
- Dry scattering, when combined with the preliminary PAS absorption data from UC Davis, showed good closure with their CRD Extinction measurements, within 20%
- The dry scattering showed better agreement between airborne and ground based data than did the f(RH) derived values, which will require some future evaluation

Future Direction

- Pull in the composition data to help explain differences between the optical values observed at Fresno and Bakersfield
- Use the measured OPS size distribution data recorded at Bakersfield to compare the ground based and airborne measurements
- Look more in depth at the f(RH) measurements, including
  - Why discrepancy in f(RH) values exist between the airborne and ground based values?
  - What is the cause of the seemingly diurnal oscillation in f(RH) at Fresno?
  - Derive ambient scattering data from the dry scattering and f(RH) values and compare with overpass/missed approach data from the P-3B

Acknowledgement: This research was funded by NASA's Earth Venture-1 Program through the Earth System Science Pathfinder (ESSP) Program Office. We wish to thank the ESSP Program Office for the support. We also would like to thank the pilots and flight crew of the NASA P-3B and the NASA Wallops Flight Facility for their support and important contributions.

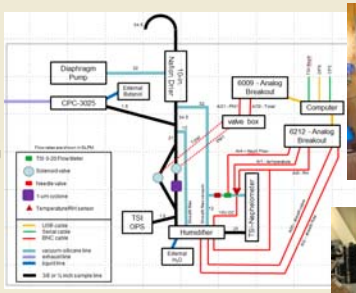
Ground Site Setup and Info

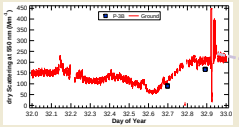
Ground Based Setup (18 Jan – 7 February)

- Co-located with California Air Resources Board (CARB) air monitoring stations at Bakersfield Municipal Airport and Fresno-Garland;
- Collect data underneath the P-3B spirals (or as near as possible)
- Scanning humidifier varies the airmass humidity between dry (<50) and 90% over 120 seconds
- f(RH) is defined as the ratio of aerosol scattering at RH=80% to the scattering when the RH<50%

Bakersfield Municipal Airport Setup:
- Scattering: TSI-3563 Nephelometer
- Size Distribution: TSI OPS
- Number Concentration: TSI-3025 CNC

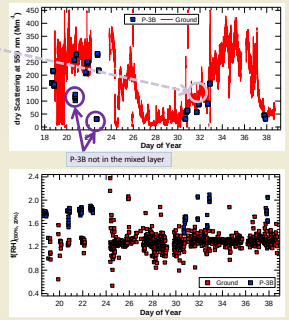
Fresno-Garland Setup:
- Dry Scattering: Radiance Research M905
- Humidified Scattering: Radiance Research M905





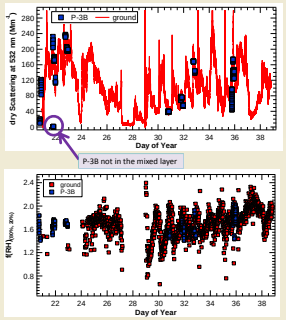
Dry Scattering data at Bakersfield was defined as the scattering with the humidifier RH was less than 50%, leading to gaps in the dataset

Bakersfield



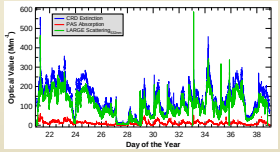
- P-3B overflight data appears to show good agreement for dry scattering in most instances (expanded on below)
- Two distinct aerosol buildup periods were observed at Bakersfield that is less obvious in the Fresno dataset (expanded on below)
- Ground derived f(RH) from Bakersfield is lower than the P-3B data, while better agreement exists for Fresno data
- Fresno f(RH) data appears to exhibit a diurnal behavior (future study area)

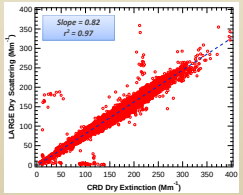
Fresno



Ground and Aircraft Data Comparison

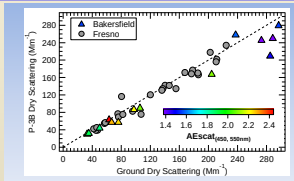
Ground Optical Data Closure – Fresno Garland





- Dry CRD Extinction and LARGE Scattering agree within 20% and track very well
- The regression analysis suggests an absorbing component of extinction of about 20%, which will need to be looked at later
- Future work will look at aerosol absorption and size distribution analysis

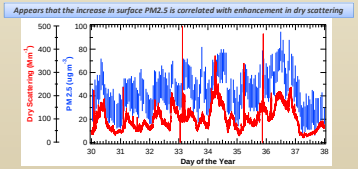
Ground and Aircraft Comparison



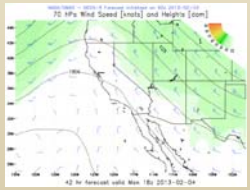
- P-3B data is only used when the aircraft descended into the ML
- Not enough simultaneous f(RH) measurements at Bakersfield to produce any meaningful results
- Initial regression results for the Fresno f(RH) shows that some work needs to be done to investigate differences
- Highest scattering component sampled at the ground showed the presence of dust (AEscat = 1.4-1.6)

Relationship Between Ground Based Optical Data and PM2.5 – Second Buildup Period (30 Jan – 6 Feb)

Appears that the increase in surface PM2.5 is correlated with enhancement in dry scattering



- Period denoted by increasing pollution as a ridge built in over CA
- Widespread fog was common in the morning, burning off by 9-10 AM
- PM 2.5 levels at Fresno were generally elevated at night due to wood smoke and a shallow inversion (SJV APCD forecaster notes)
- Peak in the aerosol build-up was on days 34-36 (4-6 February), with cleaner conditions observed in Fresno due to northerly flow
- A trough and frontal passage on Day 36 cleaned out the SJV

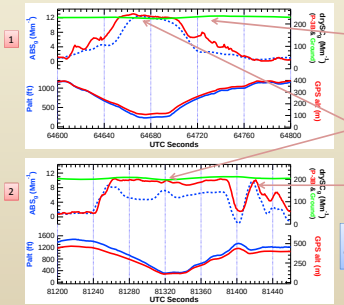


Day to Day Variability – No Clean Diurnal Pattern Emerged

- There is nighttime enhancements in dry scattering over Fresno due to wood smoke
- Influence of northerly flow over Fresno is led to reduced scattering than that observed in Bakersfield
- An increase in scattering is observed as the fog burns off which could be consistent with AM rush hour traffic

Aircraft Profiles & Ground Sites – Effect of ML Height

Fresno – Garland 22 Jan



Ground Site Overpass (bad agreement)

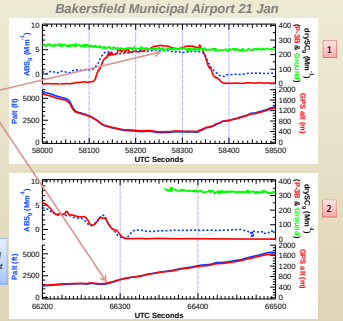
Ground Site Overpass And Missed Approach

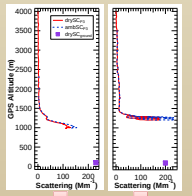
Missed Approach (good agreement)

Ground Site Overpass (good agreement)

The Fresno-Garland ground site was not co-located at the missed approach airport while the one at Bakersfield was

Bakersfield Municipal Airport 21 Jan





- The mixed layer over the SJV in the winter is influenced by meteorological conditions which lead low-level inversions and high PM 2.5 conditions
- When the P-3B was able to descend into the ML (Fresno #2 and Bakersfield #1) the ground and airborne optical measurements were consistent
- When the ML was too shallow to reach, due to either fog or aircraft restrictions, the ground scattering tended to be much larger that the lowest altitude P-3B optical measurements
- The Fresno ground site was not located at the airport (< 3 miles away) and was impacted by the altitude of the overpass, however the missed approach scattering and the ground site scattering matched up well