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Aerosol Composition and Variability in the San Joaquin Valley Measured during DISCOVER-AQ

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Motivation

Measuring surface level particulate concentrations remains a challenge for Earth-observing satellites due to:
1) variability in aerosol vertical distribution, and
2) the effects of aerosol composition and hygroscopicity on optical properties.

DISCOVER-AQ (Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality) is a multi-year project aimed at understanding the variables that affect remote sensing measurements in U.S. urban areas. This poster details airborne measurements of aerosol in the San Joaquin Valley of California, specifically:
1) variation in aerosol properties during two periods of increasing aerosol loadings, &
2) the effects of aerosol humidification, ammonium nitrate & dust on local air quality.

DISCOVER-AQ - California

During January & February 2013, aerosol properties were measured:
1) throughout the period at six locations in the valley, most significantly at Fresno & Bakersfield,
2) during ten flights on the NASA P-3B flying spirals over the ground locations from as low as 100 ft to 10,000 ft, and
3) from an airborne high spectral resolution lidar (HSRL).

On the P-3B measurements were made of aerosol concentration, optical properties, hygroscopicity, size and composition including:
1) black carbon by a SP2, and
2) water-soluble inorganic and organics by a tandem PILS.

Conclusions

Two periods of increasing loadings measured. Aerosol properties differences attributed to:
- Vertical distribution of aerosols due to measurement of aged local pollution
- RH (aerosol humidification contributed up to 50% of AODs during the second phase)
- Precursor source strength which was lower during the second phase

Ammonium nitrate was the dominant aerosol species. Ammonia was measured in excess due to agricultural emissions.

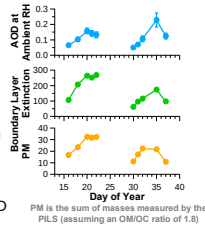
Dust was a minor contributor to aerosol optical depth but was more pronounced between January 20th and 22nd.

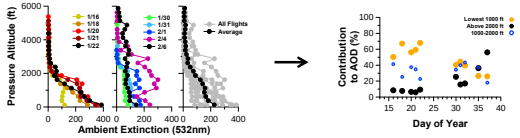
A latitudinal gradient in aerosols were measured with highest concentrations typically in the south (Bakersfield).

Mission Overview

Two sampling periods under the influence of high pressure ridges
- January 16-22: AOD increased from 0.06 to 0.16
- January 30 - February 6: AOD increased from 0.05 to 0.22 and then decreased to 0.13
- Heavy rainfall between the two periods

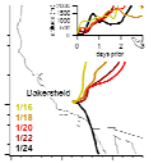
Maximum **AODs** were higher in the second period despite lower boundary layer (BL) particulates (for both **extinction** & **particulate mass – PM**)
- First period – aerosol is confined to the lowest 2000 ft with highest values below 1000 ft
- Second period – contribution of low altitude aerosol to AOD diminishes throughout





First Period:

72-hr NOAA HYSPLIT Back-Trajectory Initiated at 500 ft AGL at noon local time



- Consistent wind direction January 16th-22nd
- As period progresses, air masses spend larger period of the back-trajectory in the boundary layer
  - Leads to larger aerosol loadings
- Back-trajectories initiated at 1500 ft and above had no contact with the boundary layer
- January 24th (black line) – change to a Southerly wind direction and heavy rainfall
  - Aerosol loadings are dramatically reduced

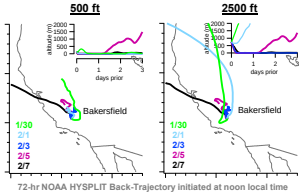
Second Period:

Jan. 30 - Feb. 1
- At 500 ft – sampling aged BL air
- At 2500 ft – no contact with BL
- Corresponds to very shallow haze layer

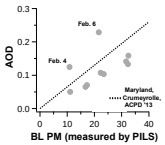
Feb. 3 - Aged BL air masses up to 3000 ft

Feb. 5 - Less polluted but well-mixed throughout column

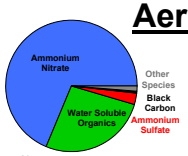
Feb. 7 - Frontal passage; westerly wind and valley continues to clean out

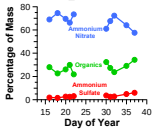


Correlation between AOD and boundary layer PM
- Satellite measurements of AOD must take into account aerosol vertical distribution and humidification of aerosol
- Good correlation for 1/16-2/1 because majority of the aerosol was below 2000 ft
  - Slope is less than measured previously in Maryland (Summer 2011, deeper BL leading to steeper slope)
- AOD/PM ratio higher on Feb. 4 & 6 due to:
  - Aerosol aloft
  - High RH leading to high aerosol humidification



Aerosol Composition





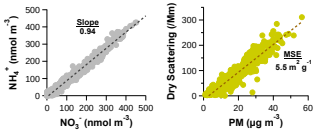
Boundary Layer
69% Ammonium Nitrate
- Ammonia emissions from dairy facilities and vehicular combustion
- Anthropogenic NO_x oxidized to nitric acid

27% Water-Soluble Organic Matter (WSOM)
2.8% Ammonium Sulfate
0.5% Black Carbon
1.3% other species including sea salt and dust

Particulate organics were slightly more prevalent during the second period (in comparison to ammonium nitrate).
Black carbon varied between 0.2% to 0.7% of mass

Ammonium was completely neutralized by nitrate
Average mass scattering efficiency (MSE) of 5.5 m^2 g^{-1}
- Higher than expected – possible presence of water-insoluble organics

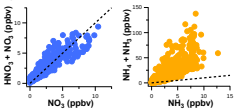
Average aerosol density of 1.8 g cm^{-3}

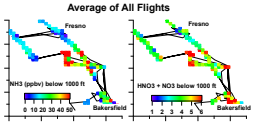


Ammonium Nitrate Formation

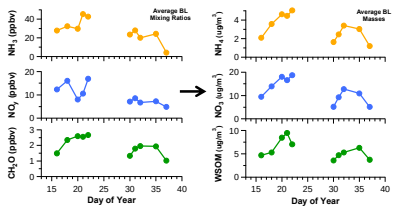
The majority of nitrate was partitioned in the particulate phase
- Particulate nitrate measured by a PILS
- Sum of HNO_3 & NO_3 measured by thermal dissociation laser induced fluorescence
- January 30th – significant portion in gas-phase

The majority (~80%) of NH_x (NH_3 + NH_4) was present in the gas-phase (measured by cavity ring down)



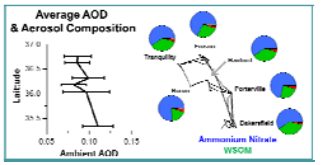


Highest ammonia mixing ratios measured in the center of the study area – correlating with the highest density of dairy farms.
Conversely, the sum of nitric acid and particulate nitrate is more uniform throughout the valley.
However, ammonia levels are always greater than the corresponding nitric acid mixing ratio (even on the western side of the valley).



Second build-up period:
- Lower BL aerosol precursors
- Ammonia
- NO_y
- Hydrocarbons (CH_2O as a proxy)
- Leads to lower aerosol masses and scattering

Variability Analysis



During most flights a gradient was seen in aerosol loading with the largest AOD in the southeast.
- Measurements at the Bakersfield ground site also measured higher aerosol scattering than at Fresno.

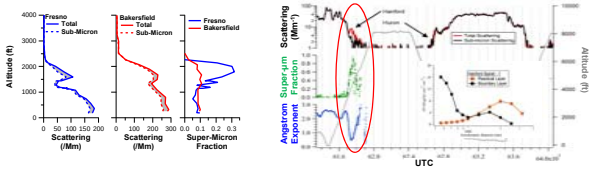
Ammonium nitrate mass was consistent among the sites while organic masses varied amongst them. Highest organic component measured at Bakersfield (37%).

Significance of Dust

Presence of dust is determined by measuring the super-micron fraction of scattering
- Measurement of scattering with & without a 1-micron impactor (super-micron fraction = 1 - submicron/total scattering)

Super-micron scattering (dust) was observed throughout the region between January 20th and 22nd including a lofted layer (January 20th, left figure).

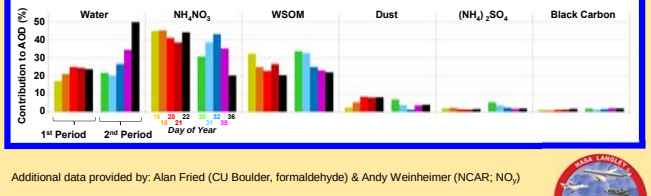
January 30th – dust layer measured aloft over Hanford (center of the valley; right figure)
- Identified by HSRL despite being a very weak layer (10 Mm^{-1})



Relative Component Contribution to AOD

- Contribution is based on aerosol composition (ammonium nitrate, ammonium sulfate & organics), their humidification (water), super-micron scattering fraction (dust) and aerosol absorption (BC).

- **Water** – aerosol humidification contributes 27% of AOD on average but much higher towards the end of the campaign due to high relative humidities.
- **NH_4NO_3** – largest contributor to AOD (39%), decreased in the second period due to higher influence of aerosol humidification
- **WSOM** – 25% of AOD on average, higher MSE than ammonium nitrate
- **Dust** – overall a minor contributor (5%) but greater during Jan. 20-22 when dust is responsible for 10% of aerosol optical depths
- **$(NH_4)_2SO_4$ & Black Carbon** – minor contributors (2% and 1.5%)



Additional data provided by: Alan Fried (CU Boulder, formaldehyde) & Andy Weinheimer (NCAR; NO_y)

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