Overview of Fog Studies during the California Regional $PM_{10}/PM_{2.5}$ Air Quality Study (CRPAQS)

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Background

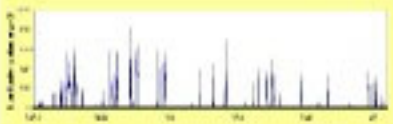
As part of the CRPAQS study, Colorado State University investigated the composition of radiation fogs in the San Joaquin Valley (SJV) and fog impacts on particle concentrations.

The original goal was to:

- Characterize relative of inorganic and organic species in fog droplets
  - Investigations of the spatial variability of fog composition in the SJV
  - Investigations of the vertical profile of fog chemistry and composition
- Study size-dependence of concentrations
  - Impact of fogs on particle concentrations: production vs. deposition

Measurements

Fog samples were collected during the CRPAQS winter campaigns. This [illegible] was an intensive study site near Angiola (Tulare County), and did not stop below I_0 where 10 fog events were sampled between December 10th 2000 and February 2nd 2001. Instruments at Angiola include several samplers and small scale logistics of sampling, meteorologic measurements for fog deposition measurements, and optical probes for the measurement of fog liquid water content and fog drop size distributions.



Fog samples were also installed at 9 "remote" sites (Tulare, Madera, Merced, and Stanislaus counties) selected by blue dots on the map.

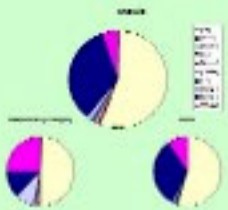
Each remote site was equipped with an optical fog detector (FSDS), a plant or [illegible] collector, and a [illegible] fog gage.

Measurements of vertical gradients

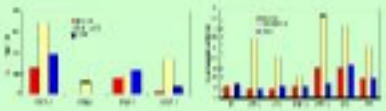
Fog samples were also collected at Angiola at four vertical heights (Aug, May, 24 m, and 91 m).

Tower level was equipped with an optical fog detector (FSDS), aluminum CASCC1 collector, automated sample removal, and data logging/control system.

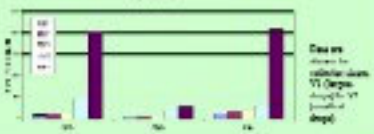
Observations



- Fog pH was high at all sampling sites (typically ~ pH 6)
- Ammonium was the dominant inorganic ion at all 3 sites.
- At the rural Tulare and Angiola sites, nitrate was the second most abundant ion with smaller contributions from sulfate
- Sulfate, nitrate, and chloride were all important anions at the urban Bakersfield site.

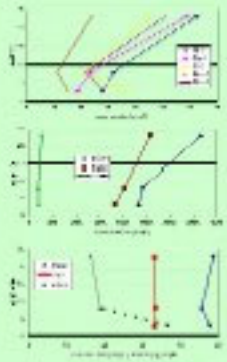


- Observations of fog size-dependent compositions revealed that many species (sulfate, nitrate, ammonium, total organic carbon, (TOC)) were concentrated in small drops while nitrate was slightly concentrated in large drops



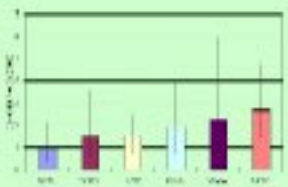
Observations of vertical profiles and fog deposition

- Fog was horizontally homogeneous for relatively large fogs (> 10 m) above the ground
- Pollutant sample concentrations were highest at ground level suggesting that fog tops of radiation cooled (LWR) shallow cold air drainage
- Fog pH increased little with height
- NH_4^+, NO_3^-, Na^+ and Cl^- concentrations increased with height, probably reflecting stronger LWR (less dilution)
- Mg^{2+}, Ca^{2+} and K^+ showed higher concentrations closer to the ground (less) than of Na^+. This might reflect a contribution of these compounds
- NH_4^+ and NO_3^- show little variability with altitude, similar to pH



Average concentrations for January 10

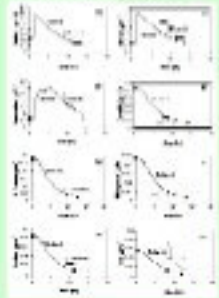
- Deposition velocities for fog droplets were much higher than typically observed for aerosol dry deposition under canopy conditions, indicating the importance of the LWR fog drop as "aerosol" of fine deposition. This is true for both inorganic and organic components. Species associated in small (large) fog drops had larger (higher) deposition velocities than fog water. Aerosol size distributions were measured in the atmosphere prior to fog (Chang et al.)



Average (±1 range) of fog droplet deposition velocities

Modeling of fog chemistry

A stirred fog cross was modeled with the Carnegie Mellon fog model. The model simulated fog microphysics, composition, nucleation, and deposition. Nucleation is assumed to occur with aerosolization. We were first to the case study measured against [illegible], which fog [illegible] were to remove them from the atmosphere. For sulfate, ammonium and nitrate we see an increase of concentrations during the final hours of the fog since [illegible] of gas-aqueous [illegible], but nitrate, ammonium partitioned [illegible]. Partial [illegible], nitrate [illegible] fog, ground, [illegible] and we see a net depletion due to fog deposition.



Organic matter in fog droplets

- Total Organic Carbon (TOC) concentrations were high (2–10 ppmC), consistent with previous SJV fog studies
- 70% of the organic carbon was dissolved. 30% was associated with suspended material which the fog drops
- Up to 50% of the dissolved Organic Carbon (DOC) had high molecular weight (>500 Da)
- Fog pH is buffered based on all the DOC in aqueous fog (~ 70% on average)
  - major individual species are acetic acid 11% (1–47%), formic acid 7% (1–19%) and formaldehyde 5% (1–11%)
  - small chain dicarboxylic acids typically accounted for less than 5% of the DOC, similar to other aerosol compositions
- We observed significant organic carbon deposition fluxes (up to 1.5 mgC/m² on some fog events)
  - Important sink for organic particles in gases

Related publications

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Acknowledgments

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