Spatial, Temporal, Chemical, and Particle Size Variations

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California Air Resources Board

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Task 2.1

[ARB]

- How does the frequency and location of excessive PM concentrations vary from year to year?
- At what locations and during what seasons are State and federal PM standards exceeded?
- How well did the 1999/2001 CRPAQS field study represent the numbers and locations of PM2.5 and PM10 exceedances found over a longer record?
## PM Standard Exceedances in SJV

### SJV Exceedances of PM10 Standard

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### SJV Exceedances of PM2.5 Standard

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Frequency and location of excessive PM concentrations

PM2.5 FRM Concentrations - 1999-2003

Concentrations (ug/m³)

San Joaquin Valley
San Francisco Bay Area
Sacramento Valley

Mean
CRPAQS v. Routine

PM2.5 Concentrations
CRPAQS Community Monitoring Sites, 12/1/99 - 2/18/01

PM2.5 Concentrations
FRM Routine Monitoring Sites, 12/1/99 - 2/28/01
CRPAQS representative of long term exceedances?

- Exceedances have been decreasing
- More frequent sampling during CRPAQS resulted in higher concentrations.
- Monthly averages were affected, but annual averages were not
Task 2.3

[ARB]

• How much of PM10 is composed of PM2.5 and how does this relationship change by measurement site, time of day, and season?
• What meteorological and source emission characteristics are associated with differences in the ratio?
• How accurately can PM2.5 concentrations be determined from PM10 measurements?
• Where and when is the coarse crustal component found in the PM2.5 size fraction?
Relationship of PM2.5 and PM10

Particulate Matter in SJV - 1998 to 2001
Spatial PM2.5/PM10 Distribution
CRPAQS Period
Coarse/Fine Fraction

- Determination of coarse/fine fraction is dependent on
  - Sampler bias
  - Filter handling
  - Spatial/temporal matching of monitors

- Coarse crustal or geological dust component is minor part of PM2.5
  - Less than 10%
Task 2.5 [STI/ADI]

- How do PM, precursor, and associated pollutant concentrations vary in the vertical dimension?
- To what extent are ground-based measurements at higher elevations influenced by horizontal rather than vertical phenomena?
PM variation in vertical dimension

- Significant stratification between surface measurements and elevated (tower) measurements
  - NO – at night, higher at surface than aloft
    - Local highway emissions
  - Ozone – at night, lower at surface than aloft
    - NO titration and nitrate formation at night
  - Black carbon – uniform vertical distribution
    - Regional distribution
Higher Elevation Influences

- SNFH characteristics indicative more of a surface site than towers at ANGI and WAG
  - Above inversion layer and less influenced by valley air
    - Less transport, more local sources
Task 2.8

What are the particle size distributions and particle number counts?
How do they vary in time and space?
Temporal and Spatial Characteristics

• Ultrafine particles more stable at night
  – Small mode in early morning
  – Larger mode (with larger diameter) at midday

• Diurnal pattern shows rapid rise in morning
  – Consistent with nitrate formation aloft brought to surface during rise of mixing height

• Spatial homogeneity within Valley during winter
Urban v. Rural Characteristics

- Urban site (Fresno)
  - Single mode distribution
  - Max count in evening after peak traffic/commute
  - Maximum diameter greater than shown during traffic/commute

- Rural/Agricultural site (Angiola)
  - Bimodal distribution
  - Max peak in morning, smaller peak in evening
  - Particle diameters smaller than at urban site
Task 2.2

- What are seasonal, day-to-day, and diurnal variations in PM mass, chemical components, and PM precursor species?
- How do they vary spatially and by season?
- What are the relations between PM10 and PM2.5 variations and other pollutants?
PM2.5 Concentrations
Fresno

Concentrations (ug/m³)

Dec 99
Dec 00/Jan 01

12/1/99
1/1/00
2/1/00
3/1/00
4/1/00
5/1/00
6/1/00
7/1/00
8/1/00
9/1/00
10/1/00
11/1/00
12/1/00
1/1/01
2/1/01

0
20
40
60
80
100
120
140
160
Seasonal Patterns - Mass

PM10

PM2.5
Chemical Components – PM2.5
San Joaquin Valley

Graph showing the concentrations of Ammonium Nitrate (■) and Carbonaceous Aerosols (△) over the months 1 to 12, with concentrations in micrograms per cubic meter (μg/m³). The graph indicates variations in concentrations throughout the year, with peak values for Ammonium Nitrate in August and Carbonaceous Aerosols in December.
Chemical Components – PM2.5
Sacramento and Bay Area

Concentrations (ug/m3)

Ammonium Nitrate
Carbonaceous Aerosols

Sacramento Valley
San Francisco Bay Area
PM10 Monthly Average Chemical Components

Month

Concentrations (ug/m3)

PM10 Mass
Amm. Nitrate
Organics
EC
Geological
Amm. Sulfate
Chemical Components
PM10 vs. PM2.5

Ammonium Nitrate
Carbonaceous Aerosols

Concentrations (ug/m³)
Urban Vs. Rural Carbonaceous Aerosols

- Rural OC
- Rural EC
- Urban OC
- Urban EC

Concentrations (µg/m³)

Month

1 3 5 7 9 11
PM2.5 Site-to-Site

- Concentrations lower in the northern SJV than in the central and southern
- The three highest urban sites had similar average of ~30 ug/m³
  - Bakersfield (peak - 155 ug/m³)
  - Fresno (peak – 148 ug/m³)
  - Visalia (peak - 130 ug/m³)
- The highest rural site
  - Pixley (average 28 ug/m³, peak peak 165 ug/m³)
- Rural sites on the outskirts of the Valley had lowest concentrations
- Concentrations much lower in the SFB and SV
  - Average concentration ~ 50% lower than SJV)
# Fresno vs. Bakersfield

## PM2.5 Mass

<table>
<thead>
<tr>
<th></th>
<th>Fresno</th>
<th>Bakersfield</th>
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<tbody>
<tr>
<td>Average</td>
<td>27.1 ug/m³</td>
<td>26.3 ug/m³</td>
</tr>
<tr>
<td>Peak</td>
<td>148 ug/m³</td>
<td>155 ug/m³</td>
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## Chemical Composition

<table>
<thead>
<tr>
<th></th>
<th>Fresno</th>
<th>Bakersfield</th>
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</thead>
<tbody>
<tr>
<td>Average</td>
<td>60% carbonaceous 30% amm. nitrate</td>
<td>40% carbonaceous 40% amm. nitrate</td>
</tr>
<tr>
<td>Peak</td>
<td>50% carbonaceous 40% amm. nitrate</td>
<td>30% carbonaceous 60% amm. nitrate</td>
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Day-to-Day Variations
PM2.5 Mass

- Concentrations become more uniform as the episode progresses

<table>
<thead>
<tr>
<th></th>
<th>Dec 1999</th>
<th>Dec 2000</th>
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<tbody>
<tr>
<td>Most Uniform Day</td>
<td>12/26/99</td>
<td>1/6/01</td>
</tr>
<tr>
<td>Concentration Range</td>
<td>71 ug/m³ to 115 ug/m³</td>
<td>82 ug/m³ to 165 ug/m³</td>
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<tr>
<td>Coefficient of Variation</td>
<td>16%</td>
<td>20%</td>
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</table>
## Day-to-Day Variations
### Chemical Components

<table>
<thead>
<tr>
<th>Spatial Variations</th>
<th>Ammonium Nitrate</th>
<th>Carbonaceous Aerosols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude dependent (increase from north to south)</td>
<td>Character dependent (higher at urban sites than rural)</td>
<td></td>
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<tr>
<td>Subregions with fairly uniform urban and rural concentrations</td>
<td>Significant variations from site to site</td>
<td></td>
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<tr>
<td>Temporal Variations</td>
<td>Decrease with time</td>
<td>Vary from day to day</td>
</tr>
<tr>
<td>Meteorology driven</td>
<td>Emission driven</td>
<td>~ 30% in Dec. 2000</td>
</tr>
<tr>
<td>&gt;60% in Dec. 2000</td>
<td>~ 30% in Dec. 2000</td>
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Temporal Variations

Concentrations (ug/m³)

- PM2.5_BRES
- PM2.5_PIXL
- Amm.Nitrate_BRES
- Amm.Nitrate_PIXL
- Carbonac.Material_BRES
- Carbonac.Material_PIXL
## Diurnal Variations

<table>
<thead>
<tr>
<th></th>
<th>Fresno</th>
<th>Bakersfield</th>
<th>Angiola</th>
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</thead>
<tbody>
<tr>
<td>BC</td>
<td>Small morning peak (7-8 am)</td>
<td>Midmorning peak</td>
<td>Flat</td>
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<tr>
<td></td>
<td>Large evening peak (7 pm to midnight)</td>
<td>Midmorning peak (10 am to noon)</td>
<td>Morning increase (10 am to noon)</td>
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<tr>
<td>Nitrate</td>
<td>Midmorning peak (10-11 am)</td>
<td>More pronounced morning peak</td>
<td>Morning increase with a midday maximum</td>
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<tr>
<td></td>
<td>Evening peak (7 pm to midnight)</td>
<td>Large evening peak</td>
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<tr>
<td>PM2.5 mass</td>
<td>Small morning peak</td>
<td>More pronounced morning peak</td>
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<td></td>
<td>Large evening peak</td>
<td>Large evening peak</td>
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<tr>
<td>Particle count</td>
<td>Very small morning peak</td>
<td>Very pronounced evening peak (9 pm)</td>
<td>Morning peak Smaller evening peak</td>
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<td>Very pronounced evening peak (9 pm)</td>
<td>Large evening peak</td>
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Task 2.4
[STI]

- Highest PM2.5 concentrations
  - On the Valley floor within three to five hundred meter above sea level
- Background PM2.5 concentrations
  - 1.5-3.5 µg/m³ annually
  - 1-2 µg/m³ during winter
- Boundary
  - Elevated sites substantially cleaner (concentrations <1/2 of the Valley floor)
Task 2.6
[DRI/ARB]

- Annual standard controlling
- 50-75% of the annual average can be attributed to a high PM2.5 period from November to January (DRI)
- Based on the most recent years the % is lower (40-50%)
Controlling Standard
Fresno, 2001

Concentrations (ug/m³)

2001 Annual Average

10 Exceedances
No exceedances
Task 2.7-Correlation Between O3 and PM2.5

- **Annual**
  - No correlation
    (O3 – summer, PM2.5 - winter)

- **Seasonal**
  - Rural – some correlation in winter
  - Urban – some correlation in summer
Winter Average Diurnal Profiles

- Peak PM$_{2.5}$ occurs during the day in Angiola (same phase as O$_3$)
- Peak PM$_{2.5}$ occurs at night in Fresno and Bakersfield (out of phase with O$_3$)