Tasks 5.2 and 6.3: The Influence of Winds and Vertical Mixing on PM$_{2.5}$ Concentrations

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Task 5.2: Evaluation of Transport

- **Winds**
  - Transport pathways
  - Flows: nocturnal jet, eddy, terrain
  - Flux planes
  - Advection vs. diffusion

- **Mixing heights**

- **Synoptic weather**
  - Winds
  - Mixing
Task 6.3: Transport and the Regional Nature of Secondary PM

- Causes of the regional nature of PM
  - Transport
  - Diffusion
  - Emission source location
  - Aloft $\text{NO}_x$ emissions
Approach

• CALMET modeling
  – Wind fields
  – Trajectories
  – Dispersion (CALPUFF)

• Data Analysis
  – Profiler winds
  – Mixing heights
  – PM data

• Case Studies
  – November 17 through 26, 2000
  – December 13 through 20, 2000
  – December 24 through 30, 2000
  – January 2 through 9, 2001
CALMET – Background

• What is CALMET?
  – A meteorological model that includes a diagnostic wind field generator containing objective analysis and parameterized treatments of slope flows, kinematic terrain effects, terrain-blocking effects, a divergence minimization procedure, and a micro-meteorological model for overland and overwater boundary layers

• Why use CALMET?
  – To resolve mesoscale and local-scale meteorological phenomena by blending observational data with synoptic-scale model results and analyses
CALMET – Data Sources

- Radar wind profiler wind and RASS virtual temperature data from 24+ sites, quality-controlled to Level 2
- Rawinsonde data from 5 sites
- Surface observations from 359 sites
- Eta Data Assimilation System (EDAS)
  - Regional-scale model data
  - Nudged by observations
- 0.9-km resolution terrain data
- 30-m resolution land use data
CALMET – Data sites

Upper-air

Surface

- Doppler Wind Profilers
- Rawinsonde

- Surface Met Stations
CALMET – Grid Resolution

- 20 vertical layers with interfaces at 0, 20, 50, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800, 2000, 2250, 2500, and 2750 m agl
- Horizontal resolution of 4 km
- Modeling grid 273 x 273 (1092 x 1092 km)
CALMET – Method

Normal
First guess wind at all grid points created using data at only one location and height

\[ \text{Terrain effects} \]
\[ \text{Blend with observations and grid} \]
\[ \text{Smooth (optional)} \]
\[ \text{Final winds} \]

CRPAQS
Blend EDAS and observation using weighting factors

\[ \text{Smooth} \]
\[ \text{Intermediate winds} \]
\[ \text{First guess} \]
\[ \text{Terrain effects} \]
\[ \text{Blend with observations and grid} \]
\[ \text{Smooth (optional)} \]
\[ \text{Final winds} \]
Data Analysis – Case Study: Focus on December 22-31, 2000

- Synoptic Weather
- Mixing Depth
  - Peak
  - Diurnal cycle
  - Spatial distribution
- Winds
  - Eddies
  - Jets
  - Terrain flows
- Transport
  - Distance, direction, speed
Mixing Depth – Definition

- **RL** = Residual Layer
- **CBL** = Convective Boundary Layer
- **NBL** = Nocturnal Boundary Layer
- **MBL** = Marine Boundary Layer

- **Midnight**
- **Sunrise**
- **Sunset**

Subsidence Inversion

- **Height**

- **= Surface-based vertical mixing**

- **RL** = Surface-based mixing depth

- **CBL** = Convective Boundary Layer

- **NBL** = Nocturnal Boundary Layer

- **MBL** = Marine Boundary Layer
Mixing Depth – Time Continuity Analysis

Estimated Mixing
Mixing Depth – December 22-31, 2000

Hourly Mixing Heights
December 22 to 31, 2000

Date and Time (PST)

Mixing Height (m agl)

Angiola
Bakersfield
Chowchilla
Hourly PM$_{2.5}$ Concentration – December 22-31, 2000

Hourly PM$_{2.5}$ Concentrations
December 22 to 31, 2000

Date and Time (PST)

PM$_{2.5}$ (µg/m$^3$)

- Angiola
- Bakersfield
- Bethel Island
- Fresno
- Sierra Nevada Foot Hills
Synoptics – 500-mb Heights

December 24, 2000

December 28, 2000
Hourly Mixing Heights
January 1 to 6, 2001

Mixing Height (m agl)

Date and Time (PST)

Chowchilla
Bakersfield
Angiola
Hourly PM$_{2.5}$ – December 27 and 28, 2000

PM$_{2.5}$ ($\mu$g/m$^3$) by Site

Concentration

Date | Hour
--- | ---

Site
- ANGI
- BAC
- BTI
- FSF
- SNFH

Sum of PM$_{2.5}$

Time (12:00 am to 11:00 pm PST)
Mixing Depth – Average Mixing at Chowchilla

Average Diurnal Mixing Height

- **Episode**
- **Non-Episode**

Time (PST):
- 12:00:00 AM
- 3:00:00 AM
- 6:00:00 AM
- 9:00:00 AM
- 12:00:00 PM
- 3:00:00 PM
- 6:00:00 PM
- 9:00:00 PM

Mixing Height (m agl):
- 0
- 300
- 600
- 900
- 1200
- 1500

**Episode** and **Non-Episode** mixing heights are shown graphically.
Mixing Depth – Average Mixing at Bakersfield

Average Diurnal Mixing Height

- Episode
- Non-Episode

Mixing Height (m agl) vs Time (PST)
Winds – 10 m on December 26 at 1500 PST
Winds – 10 m on December 27 at 1500 PST
Winds – 450 m on December 27 at 1500 PST

450-m Winds: 12/27/2000 15:00 PST
Transport – 48-hr Backward Trajectories at 10 m agl Arriving at Bakersfield and Fresno at 1500 PST on December 25-28, 2000
Transport – 48-hr Backward Trajectories at 450 m agl Arriving at Bakersfield and Fresno at 1500 PST on December 25-28, 2000
Transport – 48-hour Forward Trajectories at 10 m agl Arriving at Bakersfield and Fresno at 1500 PST
Transport: 48-hr Forward Trajectories at 450 m agl Arriving at BAK and FSF at 1500 PST
Transport – Pollution Rose at Altamont Pass

Bsp (inverse Mm)

- >0 - 50
- >50 - 100
- >100 - 200
- >200 - 300
- >300 - 400
- >400

Transport – Pollution Rose at Altamont Pass
Transport – Pollution Rose at Pacheco Pass

Bsp (inverse Mm)
- >0 - 50
- >50 - 100
- >100 - 200
- >200 - 300
- >300 - 400
- >400

Transport

Pollution Rose at Pacheco Pass
Chowchilla – Episode Days
Chowchilla – Non-Episode Days
Winds – Trimmer on December 29, 2000

Nocturnal Jet?
Trimmer – Episode Days
Trimmer – Non-Episode Days
Summary

• **Mixing heights**
  – As expected, upper-level synoptic weather patterns influenced mixing heights
    • Trough = high mixing height
    • Ridge = low mixing height
  – **Distinct diurnal pattern**
    • During episodes, mixing heights ranged from about 30 to 200 m at night to about 400 to 600 m agl during the day
    • During non-episodes, mixing heights ranged from about 30 to 200 m at night to 1000 m + agl during the day
  – PM concentration responded to mixing generally as expected, but the magnitude of variation is not explained by mixing alone
    • Low mixing = higher PM
    • High mixing = lower PM
    • Exception: mixing increased as did PM at Bakersfield on December 28 suggesting mixing down of PM and/or its precursors, or local sources
Summary

- **Winds**
  - Episodes had lighter winds during the day than did non-episodes
  - During episodes
    - Winds were variable in direction and were generally light from the surface to the maximum daytime mixing height of about 500 m agl, and at times much higher.
    - There is no evidence of transport from the San Francisco Bay Area (SFBA) into the San Joaquin Valley (SJV) during episodes
    - There is evidence of transport from the SJV into the SFBA.
    - We have not reached conclusions about transport from the Sacramento Valley into the SJV or visa versa.
Summary

• Trajectories
  – Trajectories on three of four episode days indicate that boundary layer air parcels generally circulated within a radius of 25 to 50 km over 48 hours
  – However, on one episode day, boundary layer air parcels traveled several hundred km in 48 hours
  – On most days, pollution from major SJV cities does not impact other major cities but does impact surrounding rural areas
  – However, occasionally pollution can be transported longer distances
What’s Next

- Complete modeling of other episodes
- Run additional trajectories
- Perform CALPUFF dispersion modeling
- Integrate findings from other episodes into existing results
- Further analyze regional chemical characterization of secondary PM
- Deliver results for integration into other tasks