Inter-regional Response of Central California Fine Particulate Matter (PM2.5) to Emissions Reductions

S. Beaver , S. Tanrikulu, C. Tran

Bay Area Air Quality Management District

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Introduction

Central California is a large domain comprising 3 interconnected regions: the San Francisco Bay Area (SFBA), the San Joaquin Valley (SJV), and the Sacramento Valley (SV). Each has violated the National Ambient Air Quality Standard (NAAQS) for 24-h fine particulate matter ($PM_{2.5}$). Elevated winter-season levels for $PM_{2.5}$ account for a majority of all health impacts associated with currently regulated air pollutants.

The Bay Area Air Quality Management District routinely applies photochemical air quality models to study the sensitivity of $PM_{2.5}$ levels to emission reductions. One challenge for central California air quality planning is that the sensitivity may vary considerably among and even within the regions. The spatial variability for $PM_{2.5}$ sensitivity does not necessarily reflect the political boundaries for cities and counties.

In this preliminary study, **spatially resolved $PM_{2.5}$ sensitivities were estimated throughout central California.** We applied the CMAQ air quality model for simulating $PM_{2.5}$ and its sensitivity to emissions reductions. Cluster analysis of the model outputs identified spatial domains of contiguous grid cells having correlated $PM_{2.5}$ sensitivities. **The model results were averaged for each identified homogeneous spatial domain.**

Air Quality Modeling

- 4-km horizontal grid resolution
- Emissions inventory development (SMOKE)
- Prognostic meteorological modeling (MM5)
- Photochemical $PM_{2.5}$ modeling (CMAQ)
- Performance evaluation for 2006-07 winter simulation
- Brute force sensitivity runs for a 1-week episode occurring within simulation period

Spatial Analysis

Cluster Analysis

- Applied to simulated $PM_{2.5}$ sensitivities
- Grouped surface grid cells from 185×185 domain
- Groupings based on correlated $PM_{2.5}$ sensitivities
- Did not use grid positions or political boundaries

Spatial Averaging

- "Clusters" of contiguous grid cells arise as natural patterns
- These spatial domains share similar sensitivities
- Hierarchically nested regions and sub-regions
- Sensitivities averaged for each spatial domain

$PM_{2.5}$ Sensitivity Analysis

- Systematic 10% reductions up to 60% for:
  - NO_x and VOC (NO_x+VOC) reduced proportionally to reflect historical and projected trends
  - Ammonia reduced independently of NO_x+VOC
- Secondary 24-h $PM_{2.5}$ sensitivity expressed as relative reduction factor (RRF)
- RRF plotted as isopleths of NO_x+VOC vs. ammonia emissions reductions
- Explored 5-day episodic average and day-to-day time series
- Verified linear response of direct $PM_{2.5}$ emissions reductions to control primary $PM_{2.5}$ (RRF = 1)

Results – Spatial Analysis

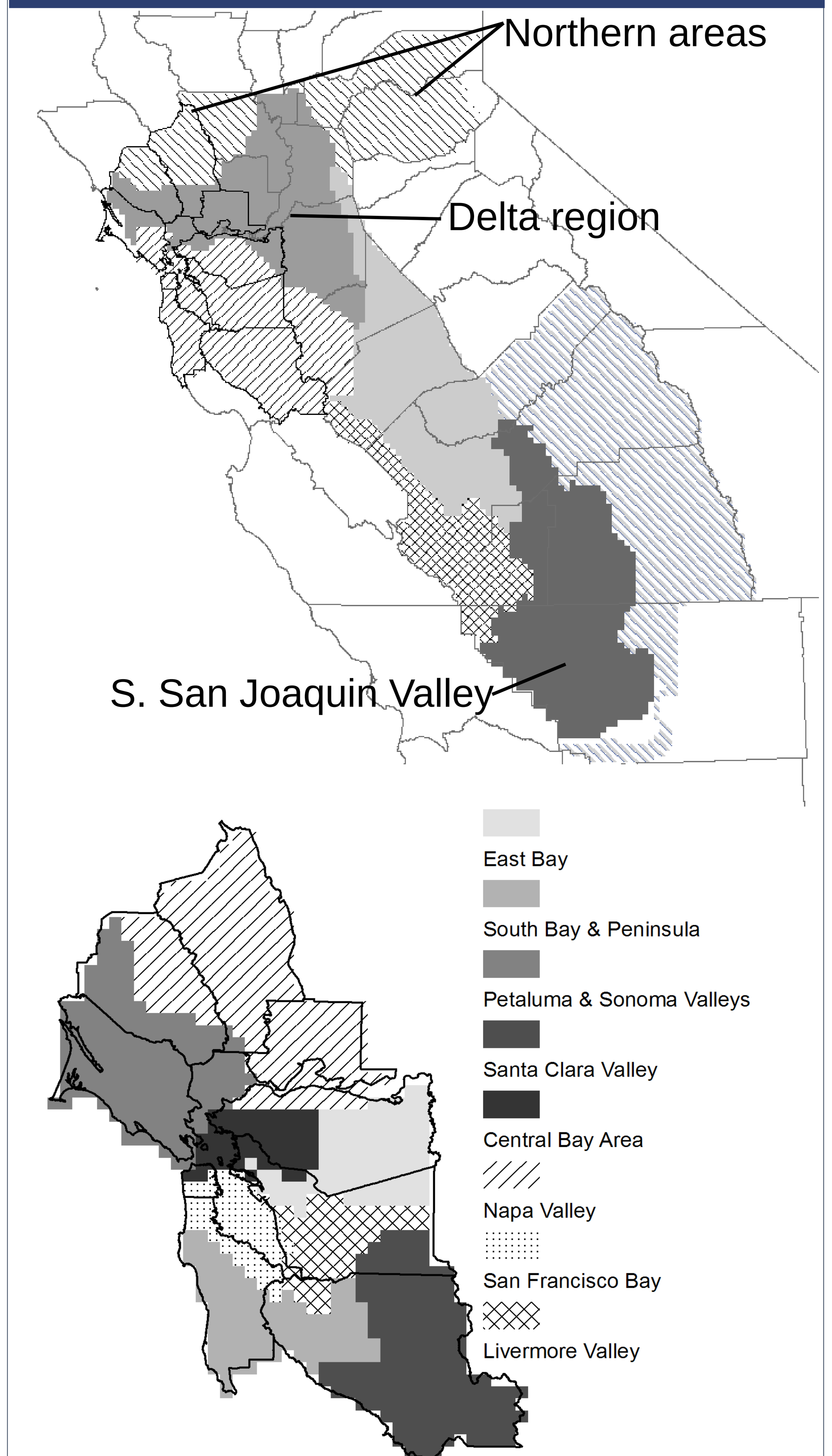

Figure 1. Shading indicates regional (top) and sub-regional (bottom) spatial domains having model grid cells with correlated $PM_{2.5}$ sensitivities. County lines are shown using solid black lines.

Results – Time Averaged

Spatially averaged RRF isopleths were generated for the spatial domains shown in Fig. 1. For each domain, the isopleths were time-averaged across the 5-day episode. Fig. 2. shows results for 3 selected regions that are denoted in Fig. 1.

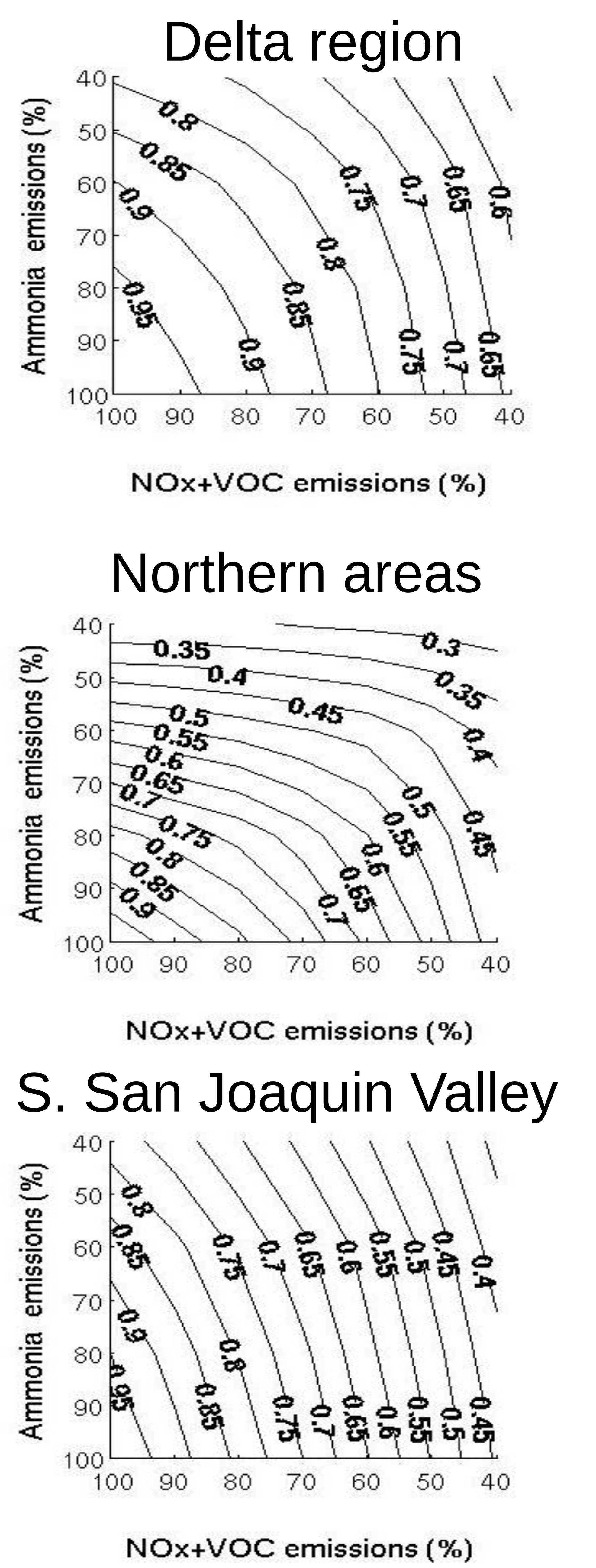

Figure 2. Isopleths time-averaged over the 5-day episodic period, spatially averaged for 3 domains shown in Fig.1. The axes indicate emissions as a percentage of the base case.

Results – Time Series

Spatially averaged RRF isopleths were generated for each day of the episode. Results are shown in Figure 3 for the Delta region (see Fig. 1).

Toward the beginning of the episode, NO_x+VOC reductions were relatively more effective than ammonia reductions. The nearly vertical contours indicated an insensitivity to ammonia reductions.

As the episode progressed, ammonia reductions became increasingly effective.

Toward the end of the episode, the air mass was significantly aged. Reducing the fresh NO_x+VOC emissions became less effective.

A qualitatively similar transition for $PM_{2.5}$ sensitivity occurred for all spatial domains. As the episode progressed, the sensitivity to ammonia and NO_x+VOC reductions increased and decreased, respectively. The 5-day average for each spatial domain resembled the isopleth toward the middle of the episode. For example, the isopleth for 25 January in Fig. 3 resembles the top isopleth in Fig. 2.

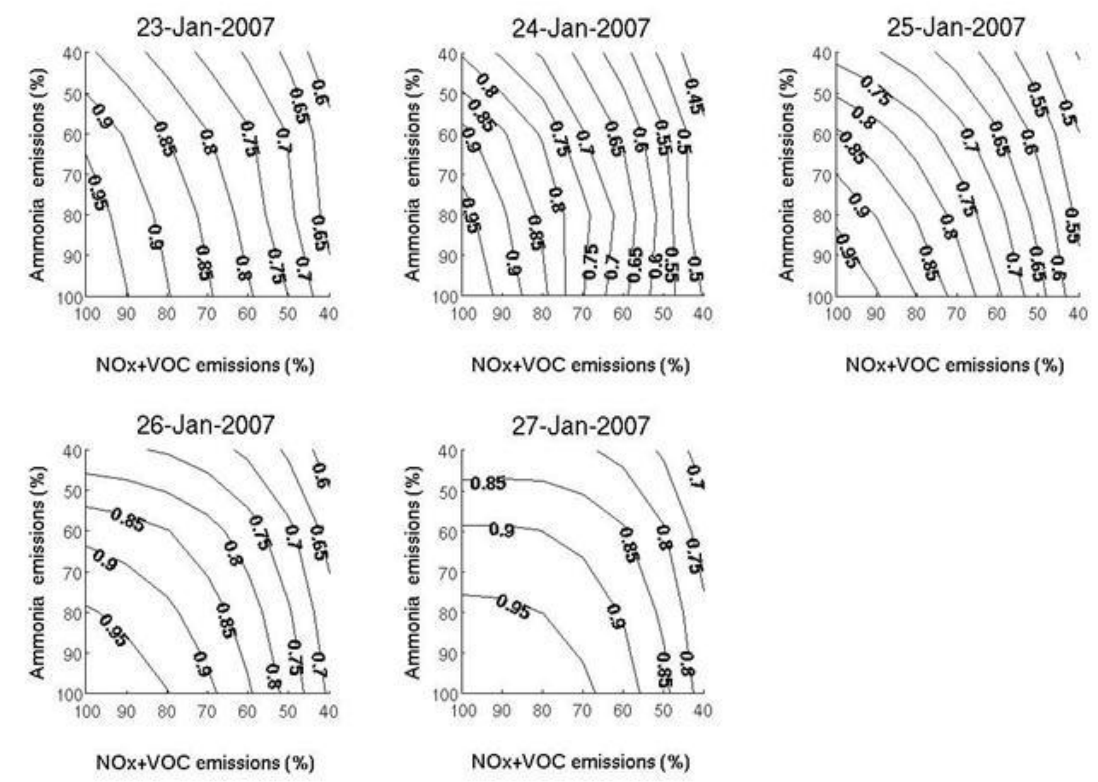

Figure 3. Time series of isopleths for individual days over the course of the 5-day episode for the Delta region. These 5 isopleths were averaged to produce the result shown at the top of Fig. 2.

Summary, Next Steps

- Air quality planning for 24-h $PM_{2.5}$ should account for different behavior depending upon location and episode duration.
- Reducing directly emitted $PM_{2.5}$ is the most efficient means for demonstrating attainment by applying RRF at the monitoring locations. This calculation may, however, not realistically reflect changes in population exposure to primary $PM_{2.5}$.
- Cluster analysis delineated regions of relatively homogeneous secondary $PM_{2.5}$ sensitivity. In many cases, these deviated substantially from political boundaries.