Meteorology-induced Variations in the Spatial Behavior of Summer Ozone Pollution in Central California

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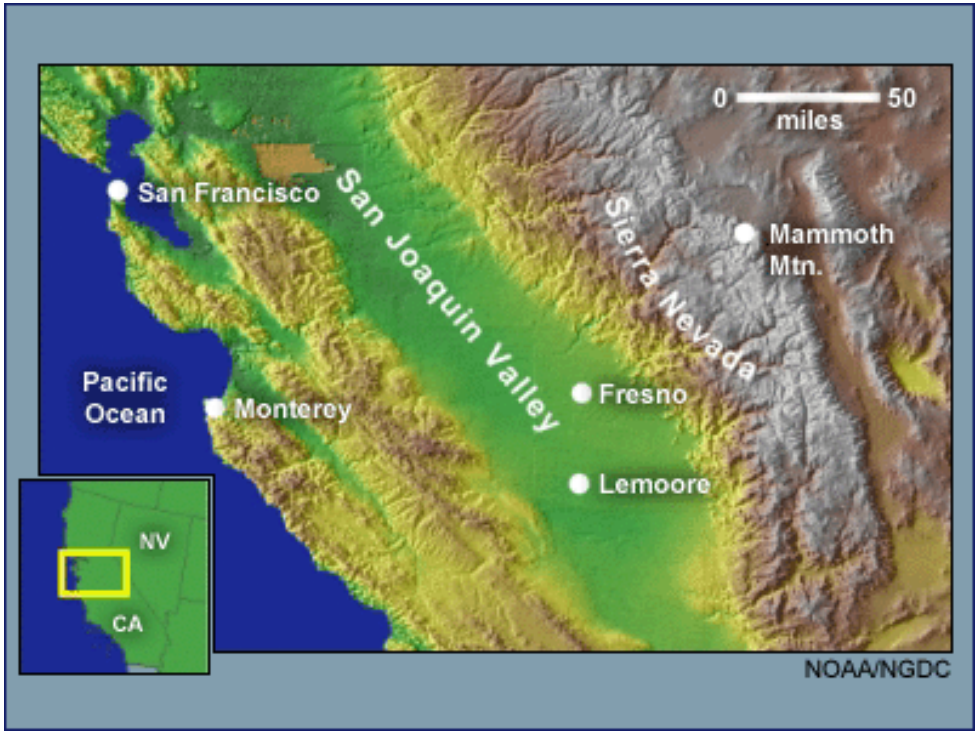
Talk Outline

- Current issues and challenges
- Methodology
- Summary of research and its importance
- Highlights of research
- Summary
- Conclusions and policy relevant findings

Acknowledgments

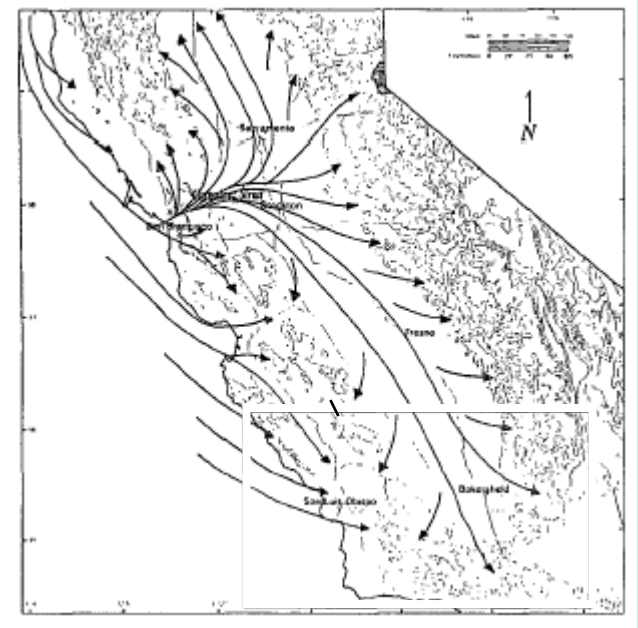
- Ling Jin (LBNL) and Robert A Harley (UCB)
- Shaheen Tonse and Xiaoling Mao (LBNL)
- Jian-Wen Bao, Sara Michelson, Jim Wilczak (NOAA)
- Claire Agnoux, Marie-Anne Serve, Sarah M Sermondadaz, Aurore Loisy, and Nathaniel Seror (Interns from INSA Lyon)
- Cheryl Taylor, Klaus Scott, Neva Lowery, Vernon Hughes (ARB)
- Funding: CEC, DOE, CCOS

Pollution in Central California



Days in exceedance of standards:
1-hour (120 ppb) – 30 days
8-hour (84 ppb) – 100 days

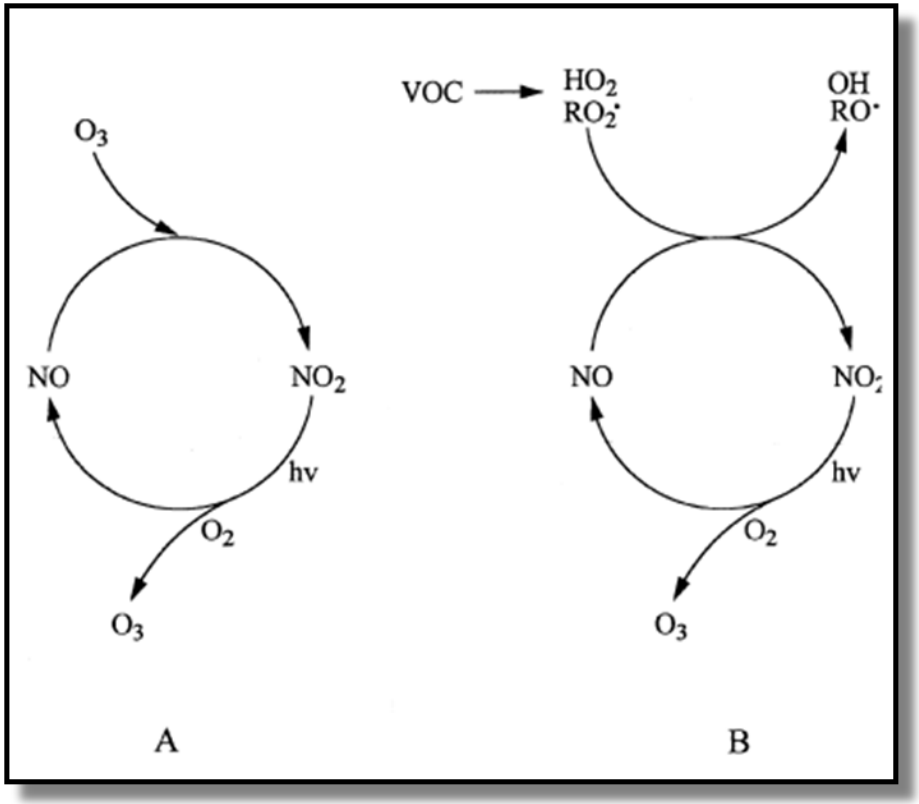
The predominant summer wind flow pattern



Niccum *et al.* 1995

Topography and meteorology give rise to large pollutant loadings. San Francisco Bay forms a gap in the coastal range that allows wind to blow pollutants into the valley from other regions.

Challenges in Ozone Control



(A) NO-NO_2-O_3 system in the absence of VOCs, and

(B) NO-NO_2-O_3 systems in the presence of VOCs.

(Modified from Atkinson 2000)

- Ozone is a secondary pollutant
- Nonlinear response to emissions (NOx and VOCs)
- Spatial and temporal variability of response-limiting reagents
- Unclear source-receptor relationship (Local vs upwind sources for SJV)
- Rely on photochemical modeling

Current issues and challenges in reducing ozone

- Control strategy design
  - Based on a few 3-5days episodes modeling
- Relies on routine inputs (met and emissions)
  - Worst-case weather scenarios
- Controls are expensive, require precursor reductions, complicated because limiting reagents change in space and time

>> Key Issues

- Representativeness and model performance
- Lack of analysis framework for model outputs over longer modeling period

The CMAQ Modeling System

- A 3-D Eulerian photochemical airshed community model.

$$\frac{\partial C_i}{\partial t} = \text{advection} + \text{turbulent diffusion} + \text{reactions} + \text{emissions}$$

- Model consists of meteorology-chemistry interface processor, photolysis rate processor, initial conditions processor, boundary conditions processor and a chemical transport model.

Model an entire summer (ozone) season:
How do potential ozone controls vary?

Research Approach

Modeling and Analysis Sequence:

CMAQ simulations
5-day → 15-day
for smaller domain
(purple)

Diagnostic evaluation, refining input parameters[1]

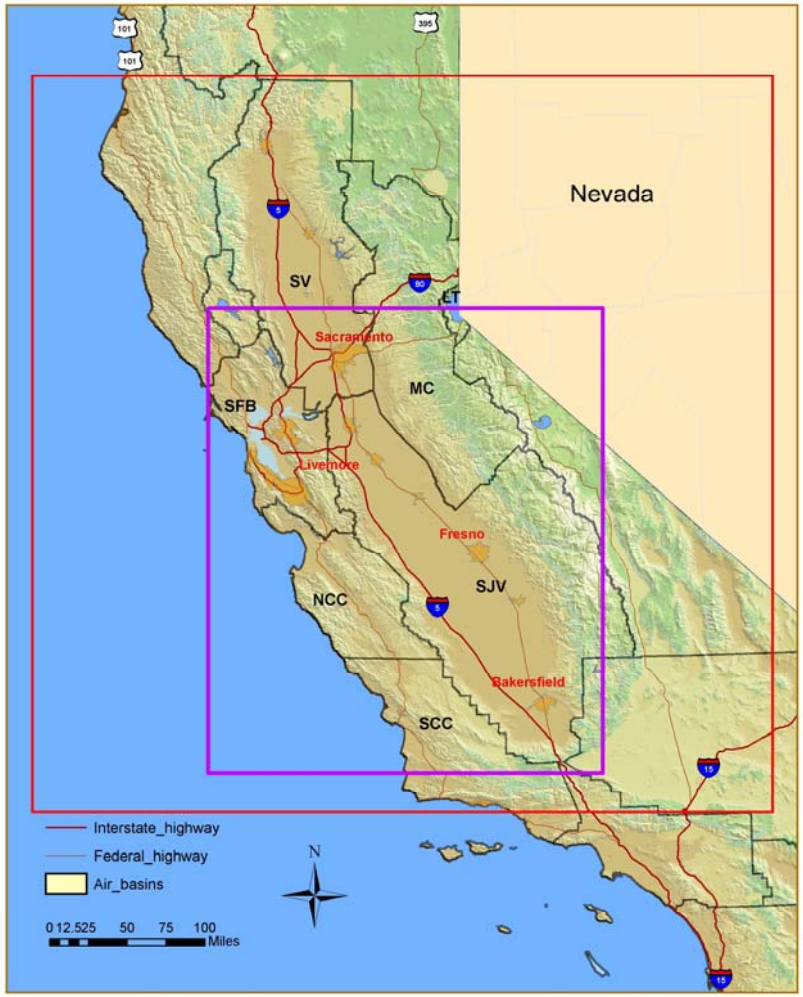
Develop and demonstrate probing tools[2,3]

CMAQ simulations
Whole Summer
(120-day)
for larger domain
(red)

Performance evaluation[1]

Ozone and met regime[4] characterization

Application of probing tools



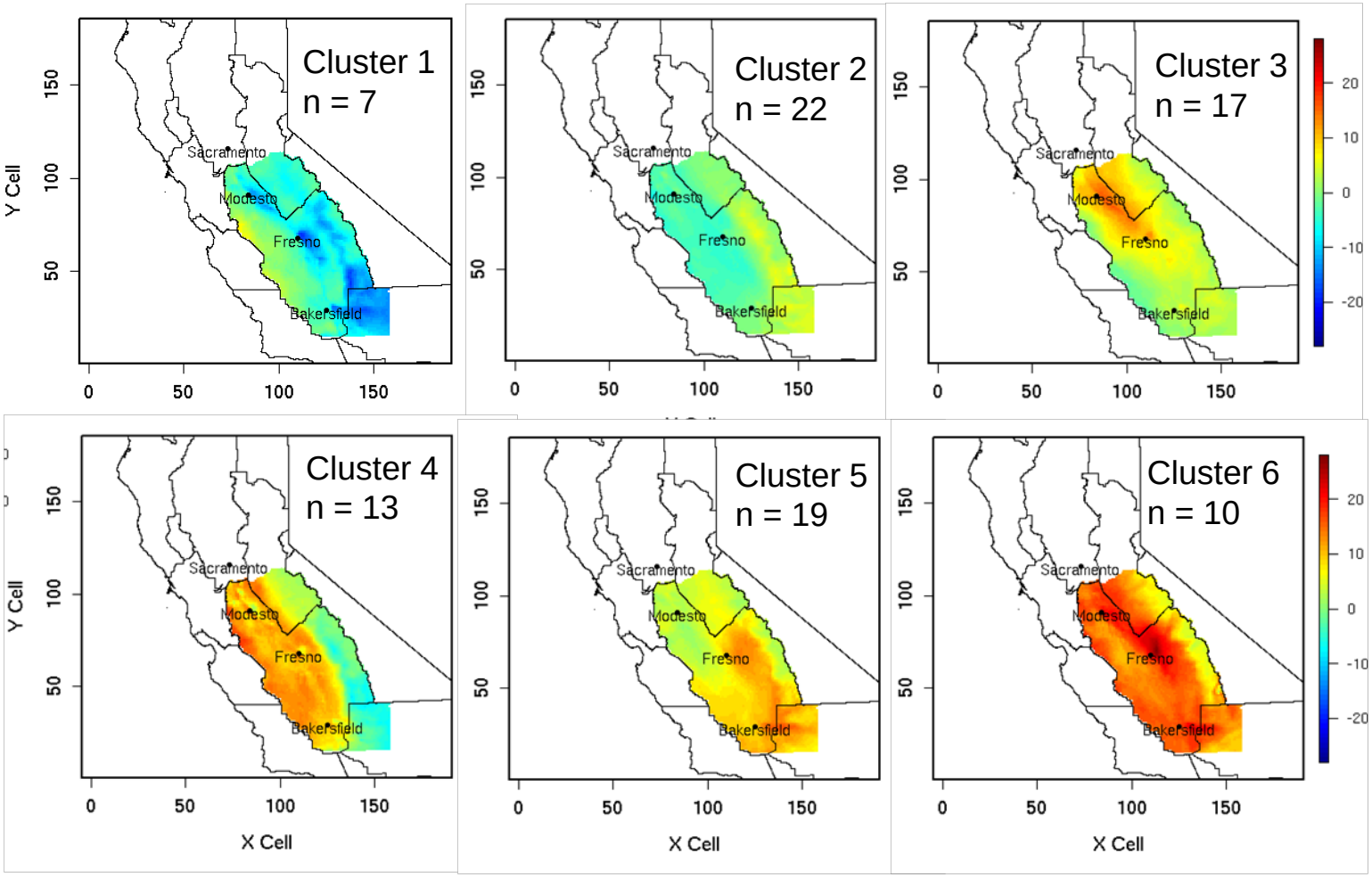
1. L Jin *et al*. (2010) JGR
2. L Jin *et al.* (2008) ES&T
3. Tonse *et al.* (2008) AE
4. L Jin *et al.* (2010) AE, pending revision

Approach: Cluster Ozone → Met Conditions

- Cluster analysis:
  - Statistical method that groups large amounts of data into smaller categories so that each subset shares some common trait (Everitt, 1993)
  - Approach based on Principal component analysis (PCA)
- Ozone regimes → Met conditions
  - Cluster summer days according to their ozone spatial distributions
  - Determine average met conditions for each ozone cluster

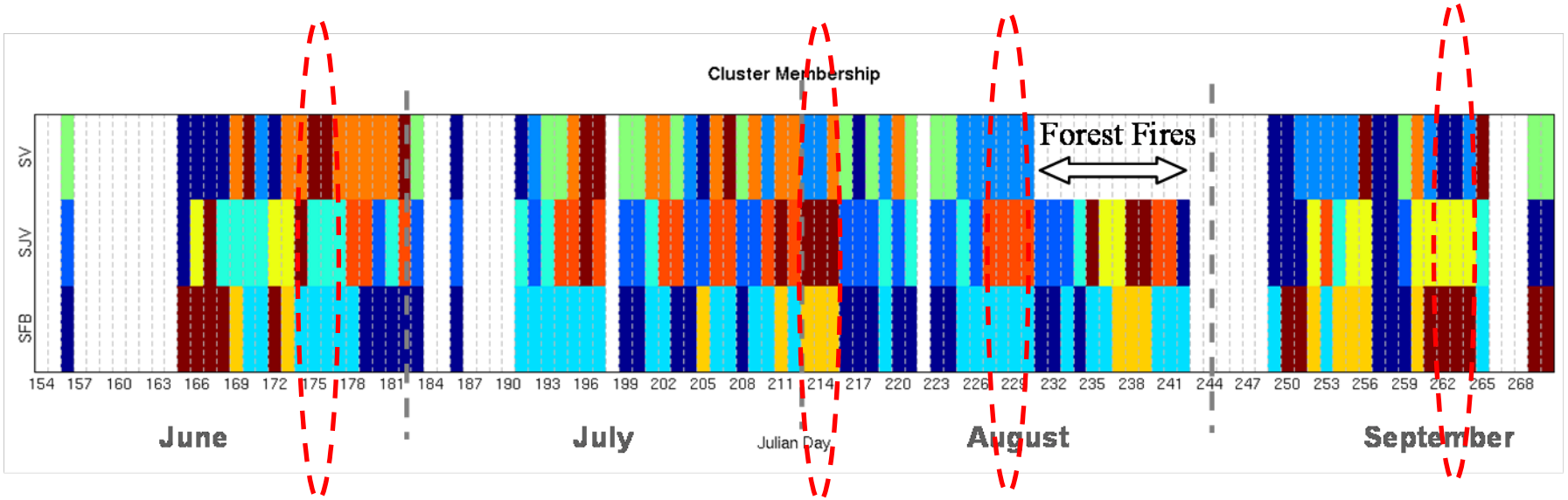
Examined: representativeness*, inter-basin relationships*, weekend effect influence, spatial representativeness of measurements sites, and control issues*

Ozone Clusters: SJV



Ozone anomalies averaged over each cluster (= cluster mean – summer mean)

Ozone Episodes and CCOS IOPs



- Representative ozone episodes:

  Jun 23rd to 25th : Historical Cluster 3 (SJV cluster 3)

  Aug 14th to 17th: Historical Cluster 2 (SJV cluster 5)

  Sep 17th to 20th: Historical Cluster 1 (SJV cluster 4)

  Jul 29th to Aug 2nd: Highest ozone (SJV cluster 6)

Summer Average Behavior

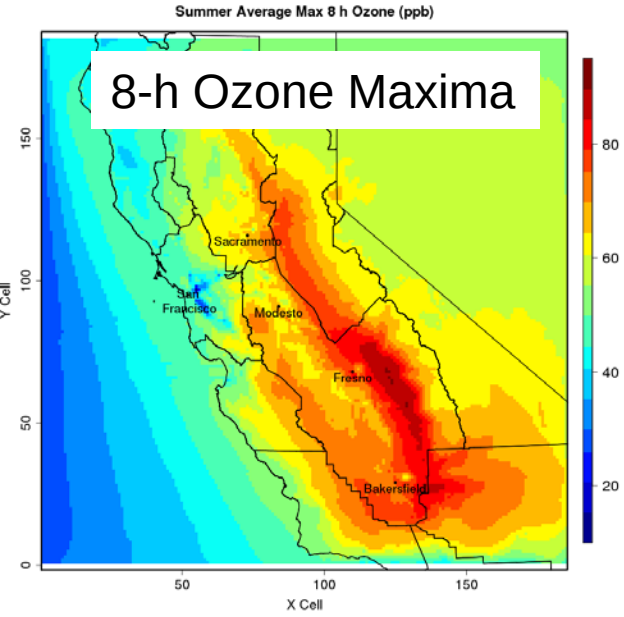
Ozone

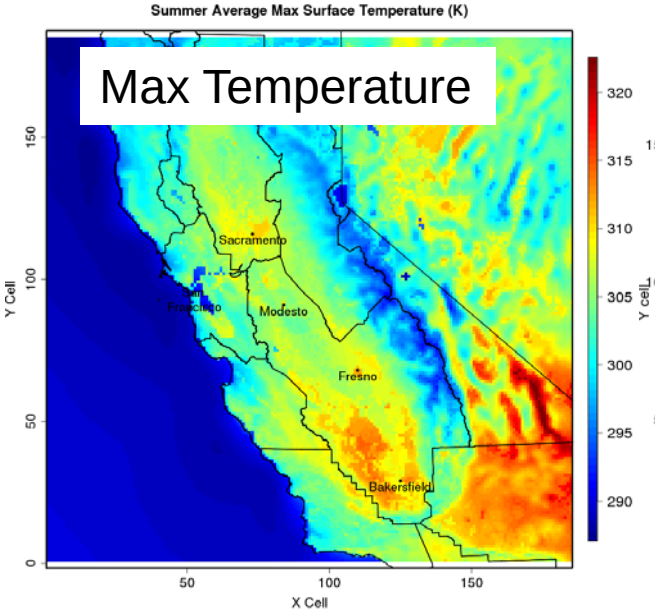
Highest ozone in SJV, lower in coastal

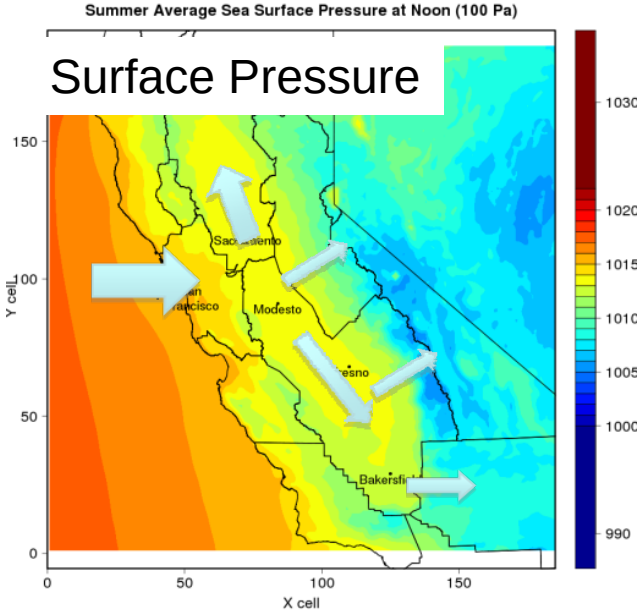
Ozone spreads to Sierras and Mojave D

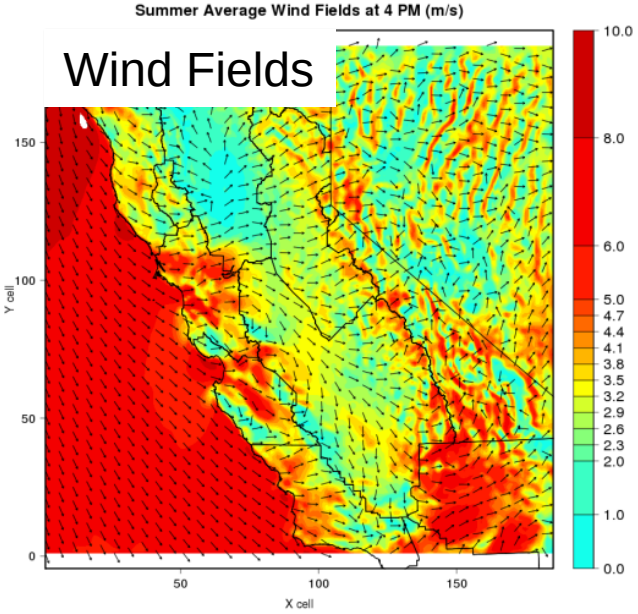
Meteorology

- Higher temperatures in SJV
- Flow directions, mesoscale features







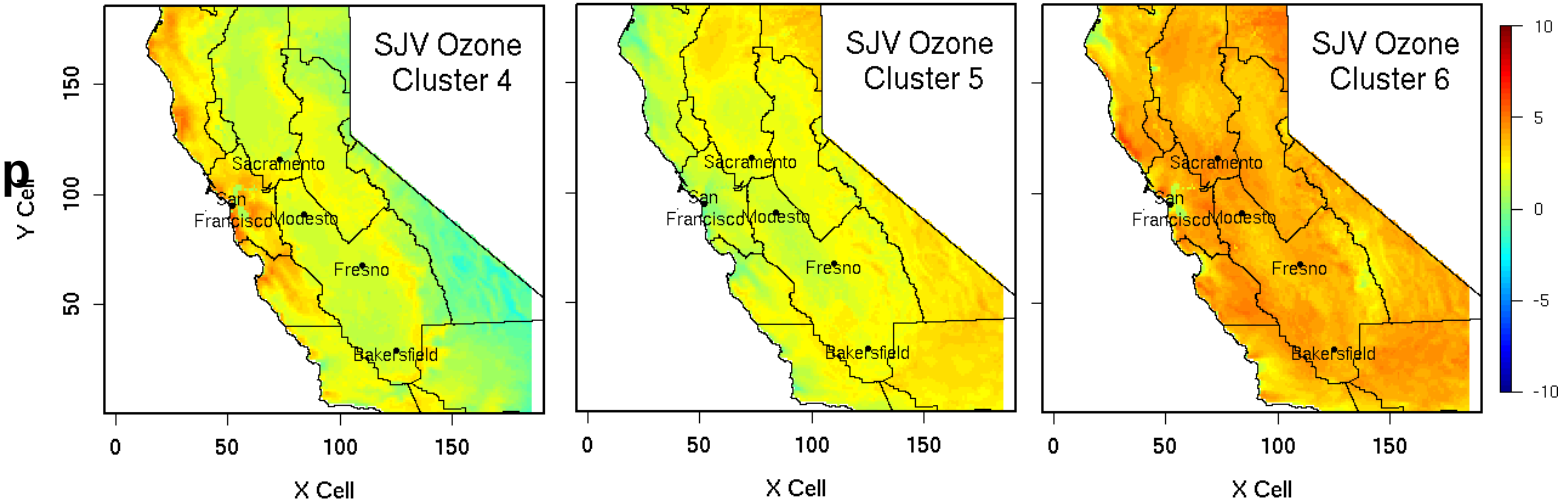


Met Regimes Inferred from Spatial Ozone Behavior by a Cluster Analysis

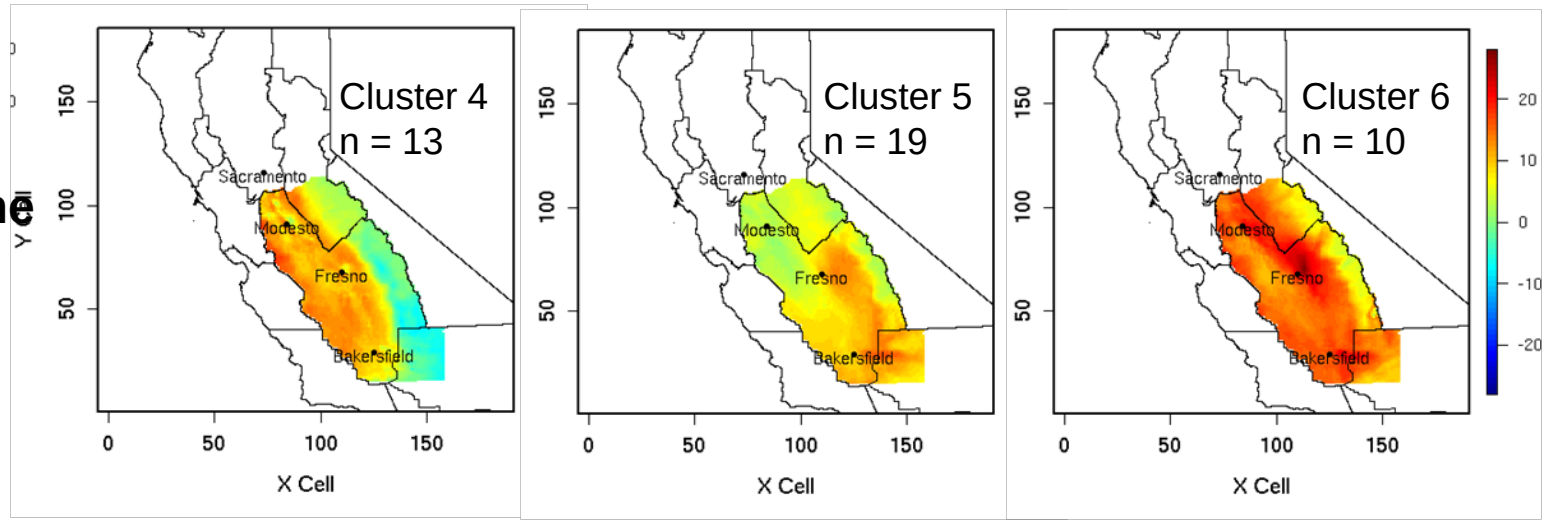
- Met influences on air quality
  - Direct effects: ozone chemistry and transport
  - Indirect effects: light and temperature sensitive emissions
- Observe diverse meteorological conditions by modeling entire summer season
  - Met effects (direct and indirect) are reflected in changes in ozone spatial behavior when anthropogenic changes are relatively small
  - Ozone spatial behaviors allows identification of met regimes

Cluster-averaged Sfc Temperature Anomaly

Temp

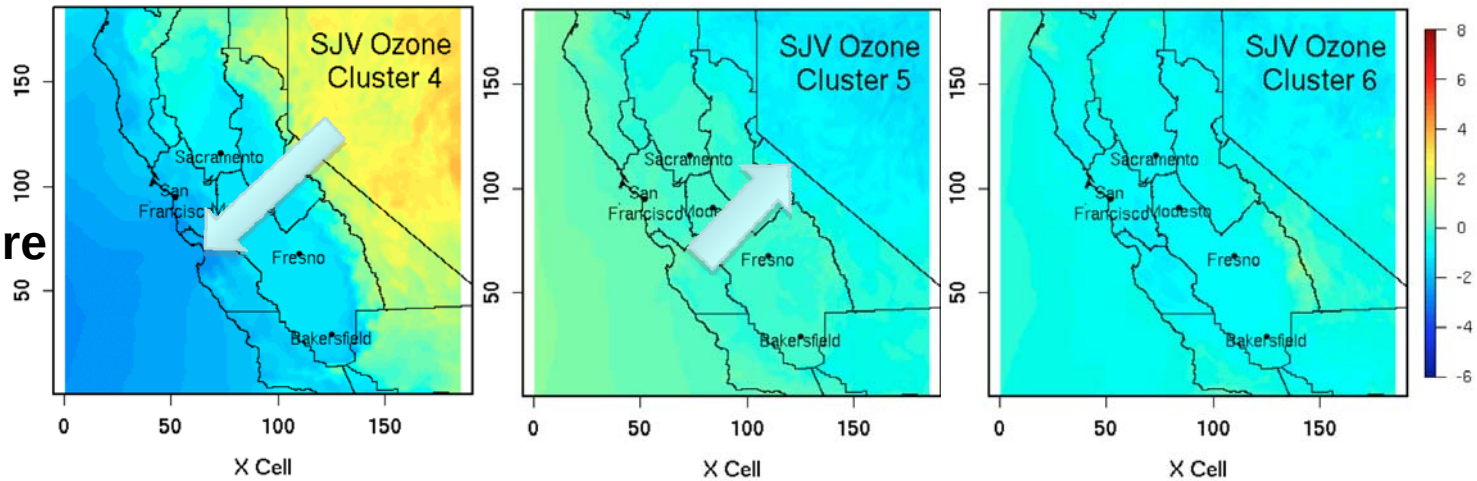


Ozone

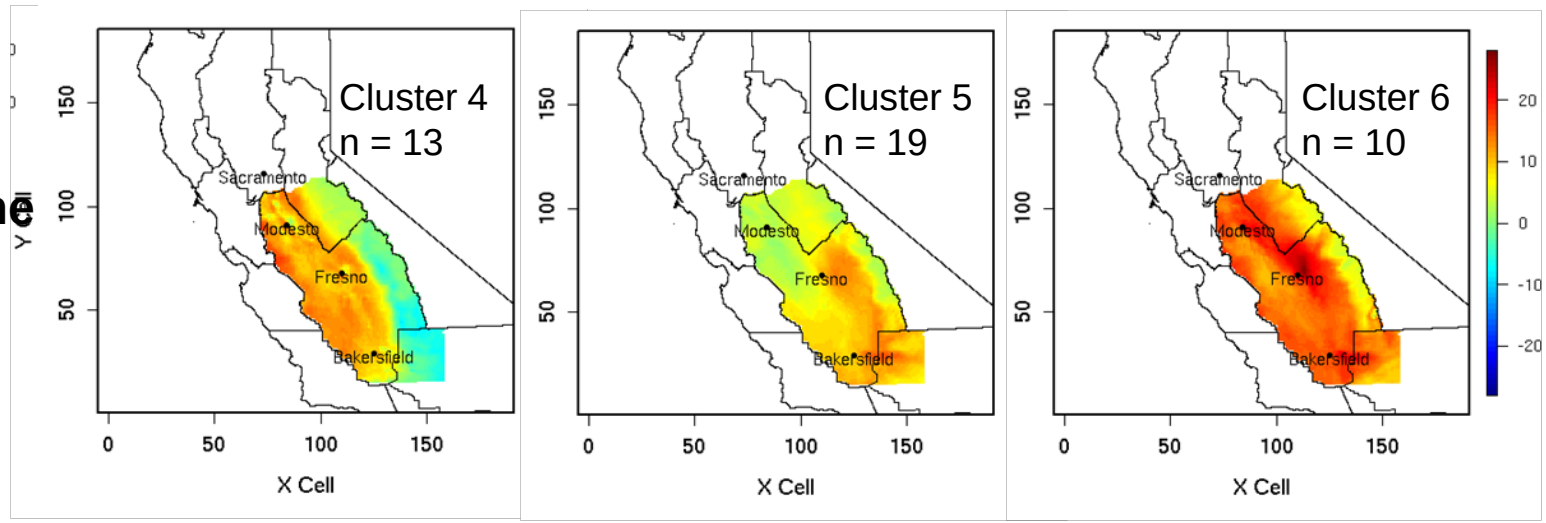


Cluster-averaged Flow Field Anomaly

Sfc Pressure



Ozone



Cluster-averaged Met Features

Most stagnant regime

Moderate temperature

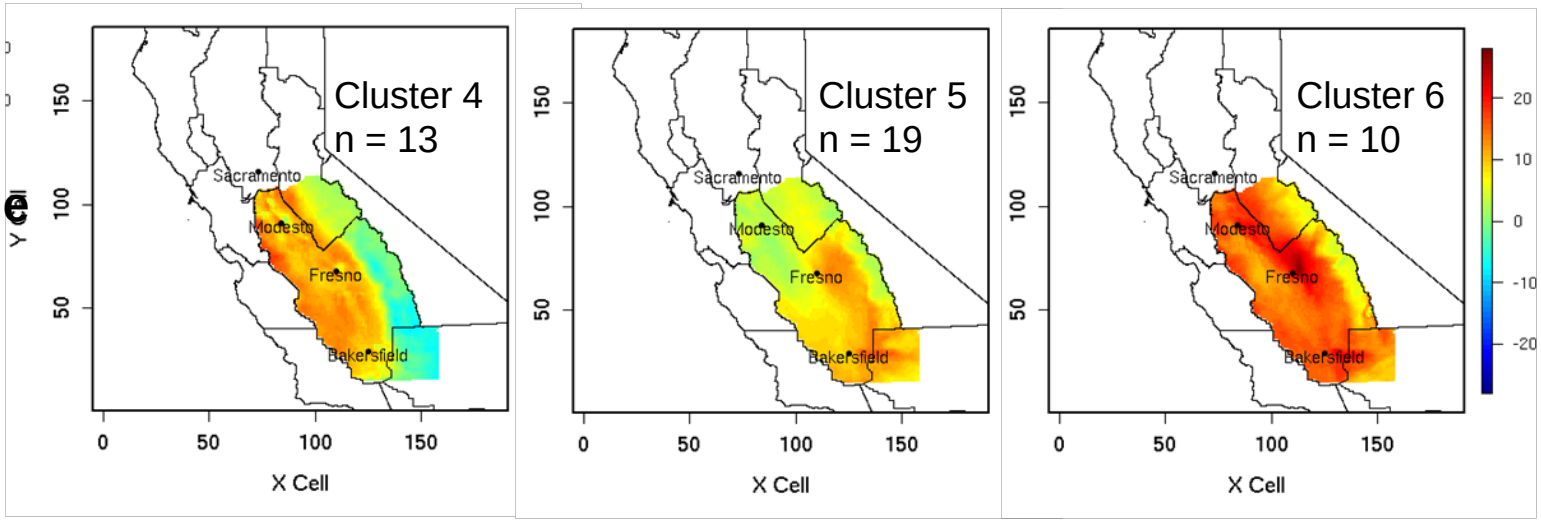
More ventilated regime

Moderate temperature

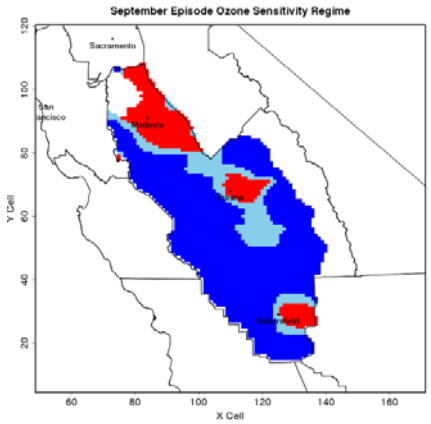
Average flow

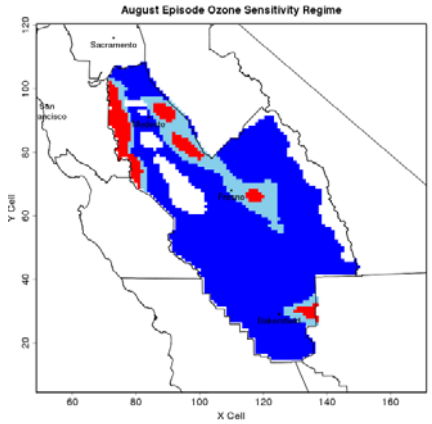
Highest temperature

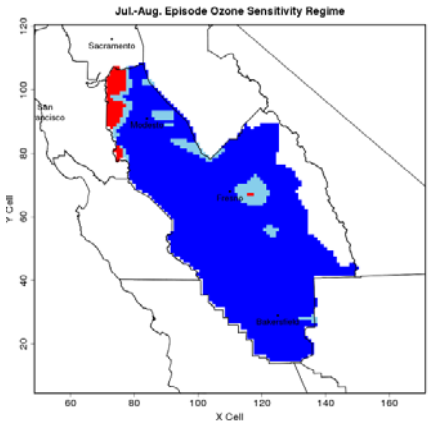
Ozone



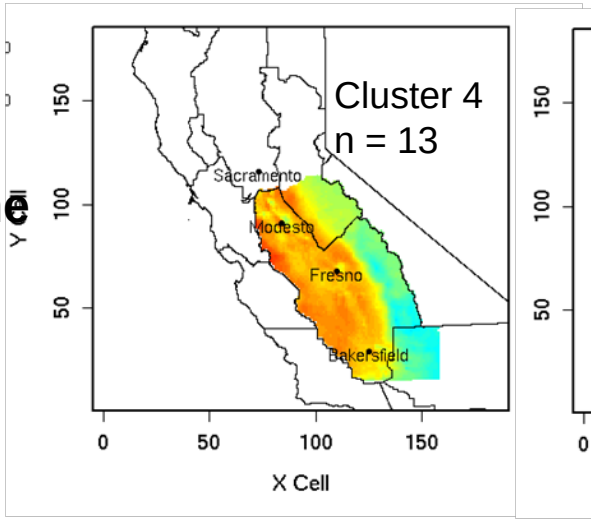
Ozone Control Options Varied by Met Regimes

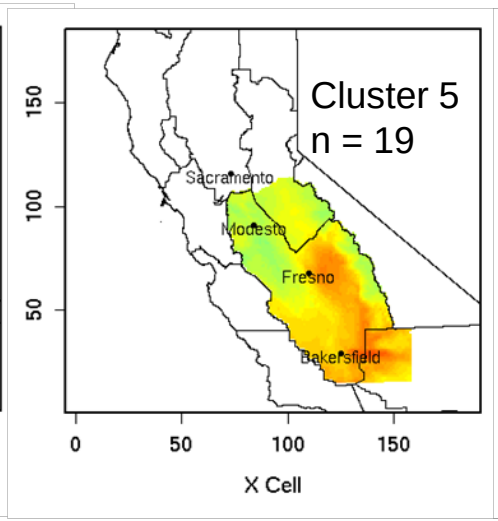


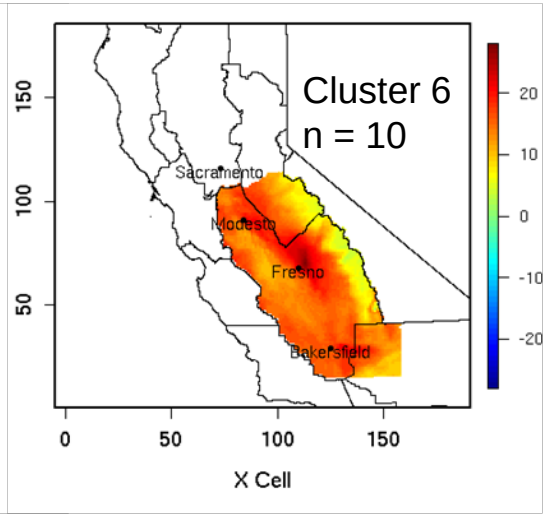




Ozone



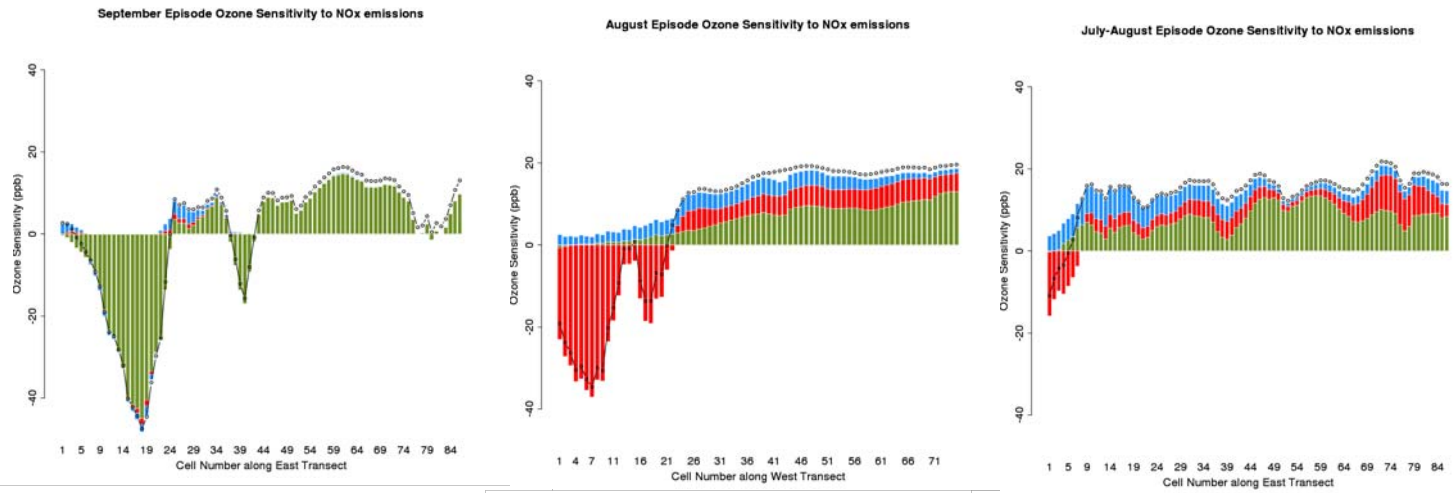




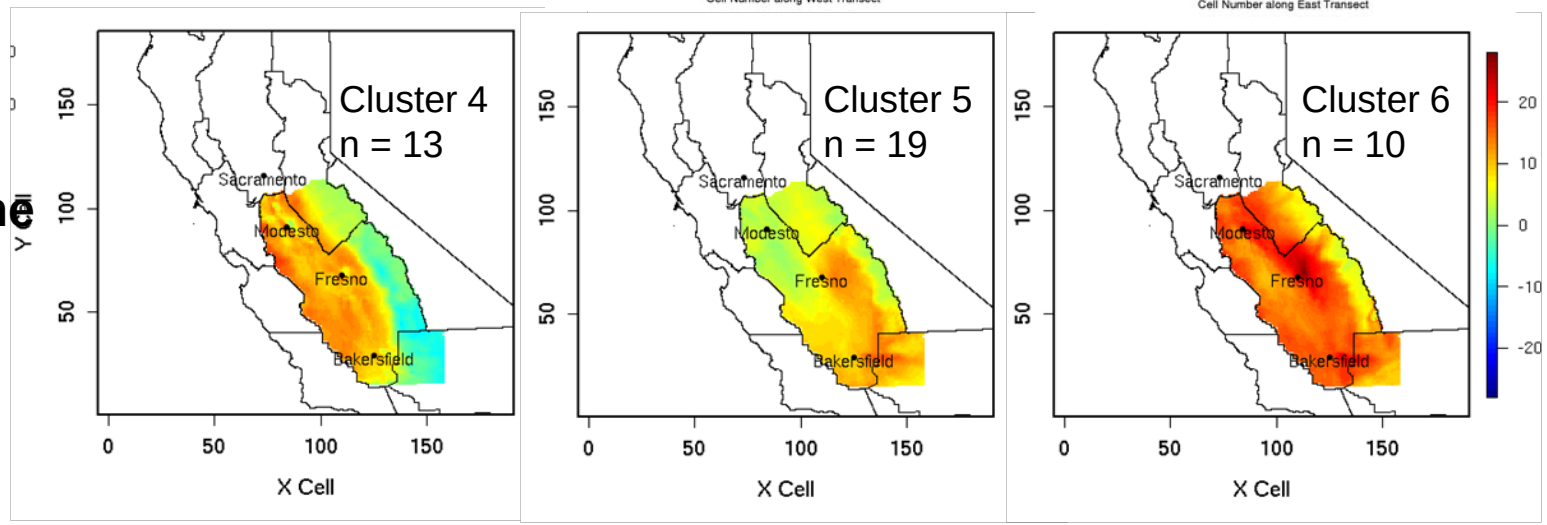
Local vs Upwind Contributions

Sacramento Valley
San Francisco Bay Area
San Joaquin Valley

Eastern Transect
Modesto to Bakersfield



Ozone



Ongoing and Future work

Cluster Analysis

Representative weather conditions in a summer season

Sensitivity Analysis

Various types of ozone responses and source receptor relationships

Policy Design

More integrated ozone control strategies for Central California

On-going

Future work

Summary—what we did

- Conducted air quality modeling for entire summer for year 2000
- Performed comprehensive model performance evaluation
- Developed sensitivity analysis approach
  - Ozone limiting regimes
  - Local vs upwind contributions
- Developed combined cluster analysis/sensitivity framework for variability characterization
  - Met regimes inferred from ozone spatial behavior

Policy relevant conclusions

- Cluster/sensitivity analysis is a powerful technique for understanding the factors responsible for high ozone
- Variations in ozone spatial distributions in the SJV can be explained by associated meteorology
- Limiting reagents in northern SJV and cities change with meteorology
- Importance of inter-basin transport changes with meteorology
- Ozone buildup in the SJV occurs on multiple days.
- Variations in modeled ozone are mostly induced by meteorology; weekend emission changes produce minor effects.
- IOP days largely align with representative ozone episodes.