Air Quality Management in California: Sensitivity to Changing Climate

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  - » Ron Cohen, Allen Goldstein, Andrew Kean, Dylan Millet, Juli Rubin, Allison Steiner, Shaheen Tonse
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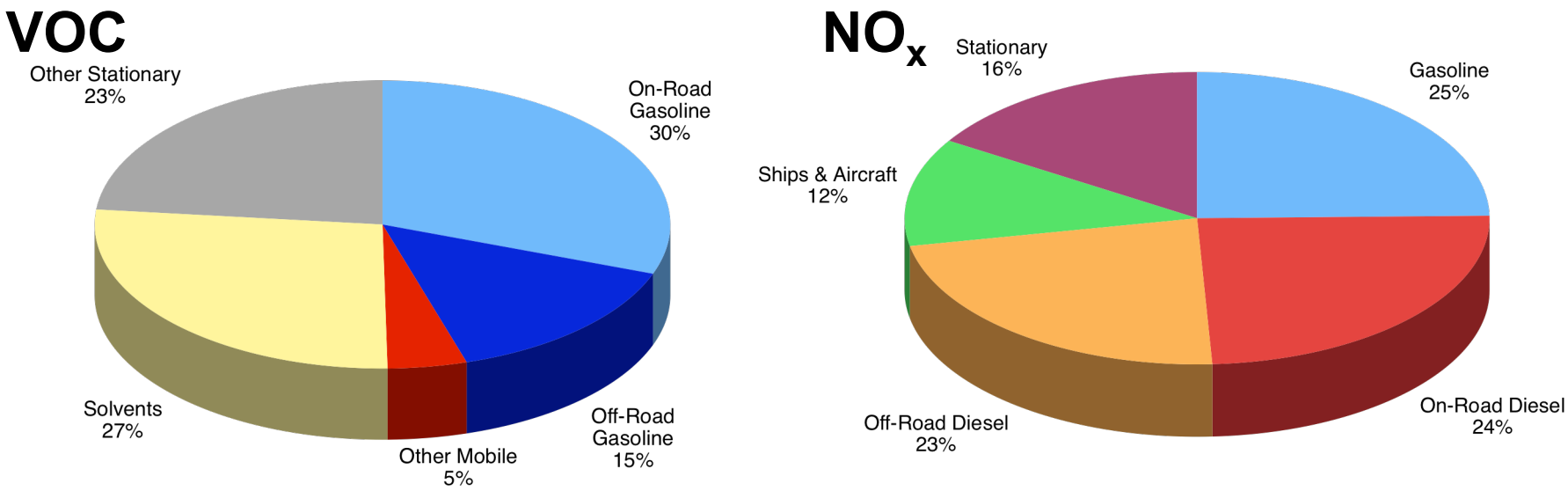
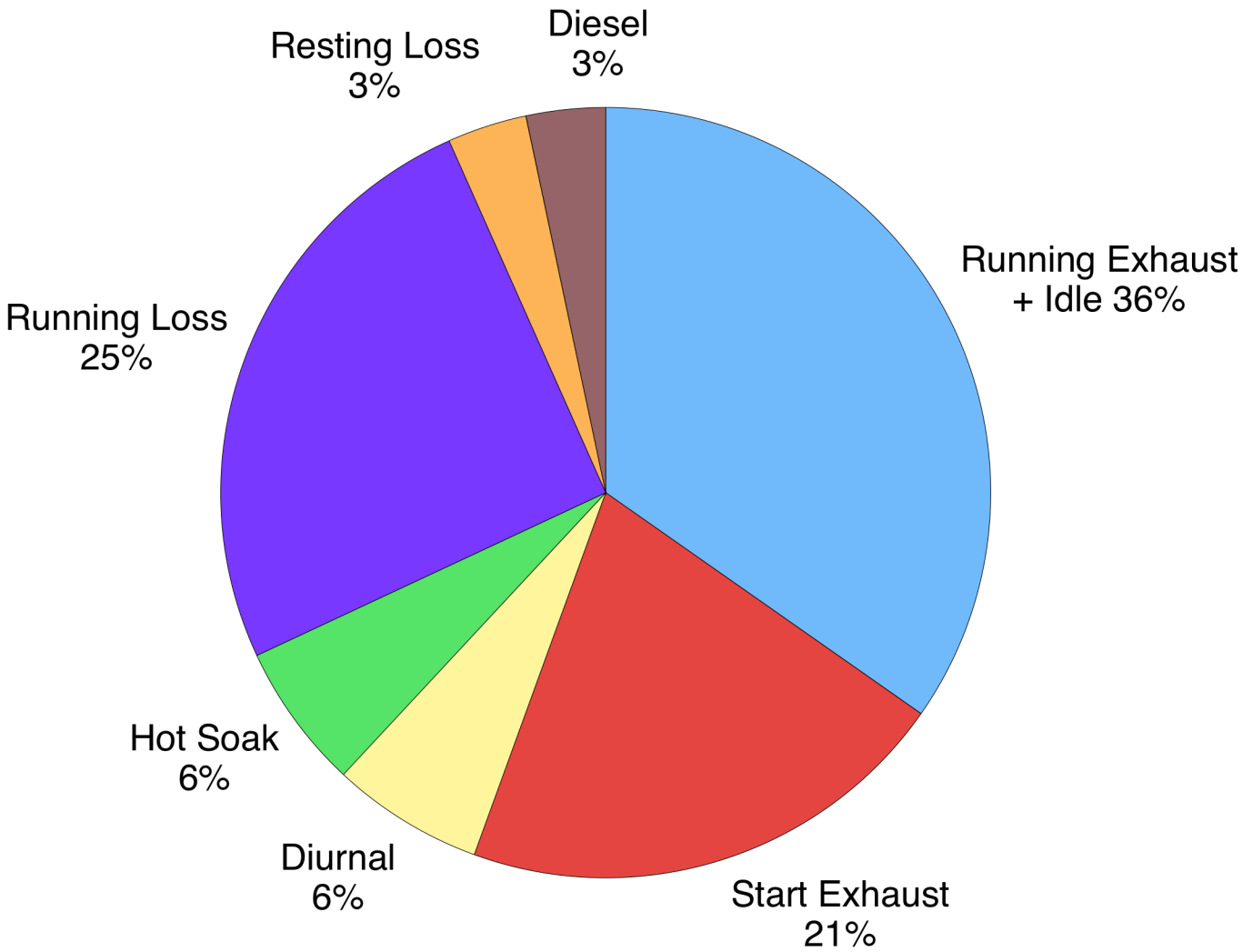
Air Pollution Emissions



- California statewide estimates for 2005 (from CARB)

- Some key questions:
  - → how do emissions vary from day to day?
  - → how will emissions change as a result of changes in population, technology, and climate?

1. On-Road VOC Emissions



California EMFAC model predictions for Sacramento in summer 2001

Exhaust vs. Evaporative VOC

- Emission mechanism affects:
  - » VOC speciation & reactivity
  - » Temperature dependence of emissions
  - » Control strategies

- How do evaporative emissions vary with T and time of day?

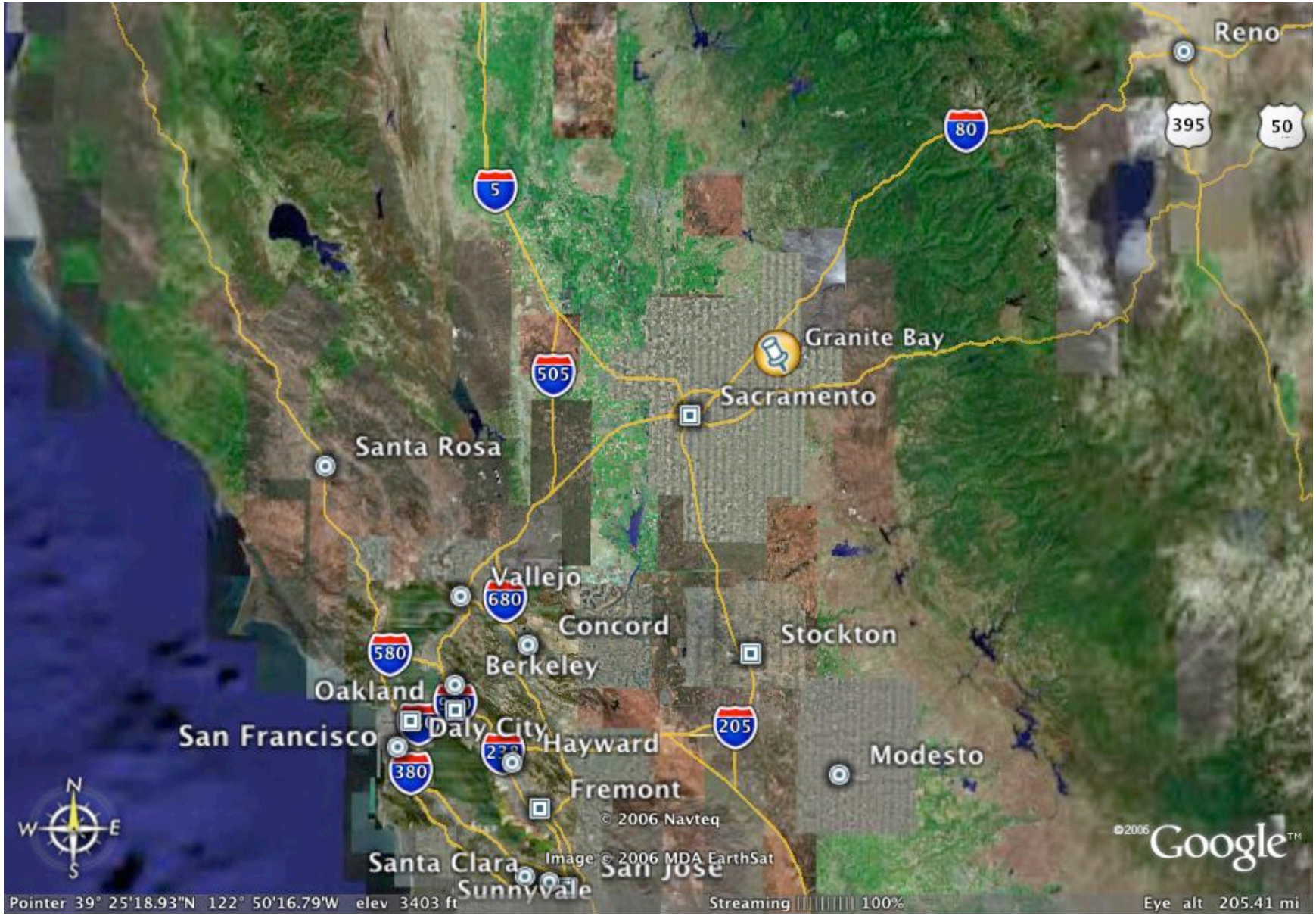
Approach: reconcile ambient VOC with emission source profiles

VOC Measurements

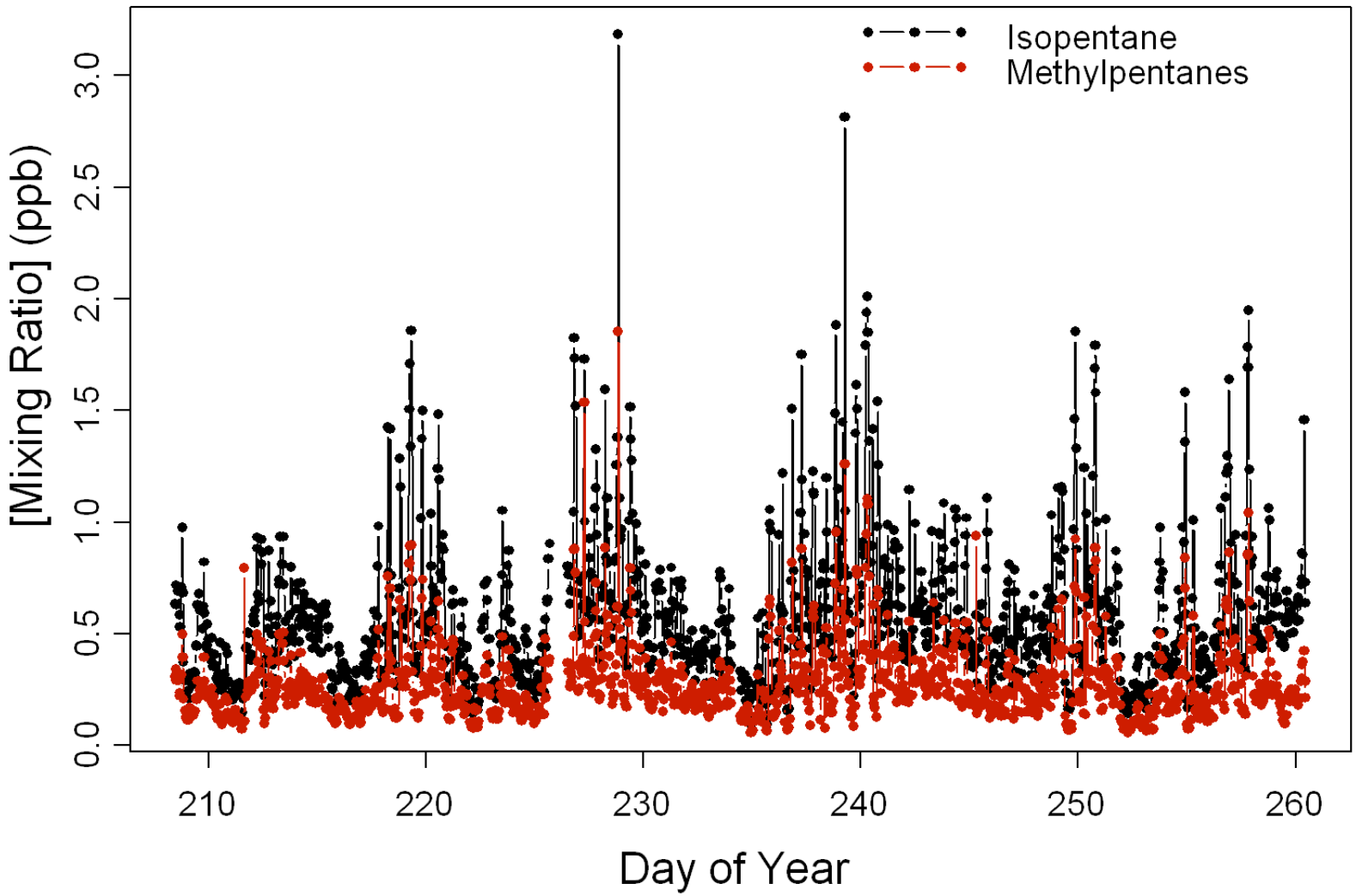
- Millet & Goldstein measured 47 VOC
  - » Granite Bay (near Folsom Lake)
  - » 8 weeks during summer 2001

- Online GC with 45-min time resolution
  1. FID channel: C_3-C_6 alkanes & alkenes
  2. MS channel: BTEX, terpenes, oxygenated & chlorinated organics

Granite Bay, California



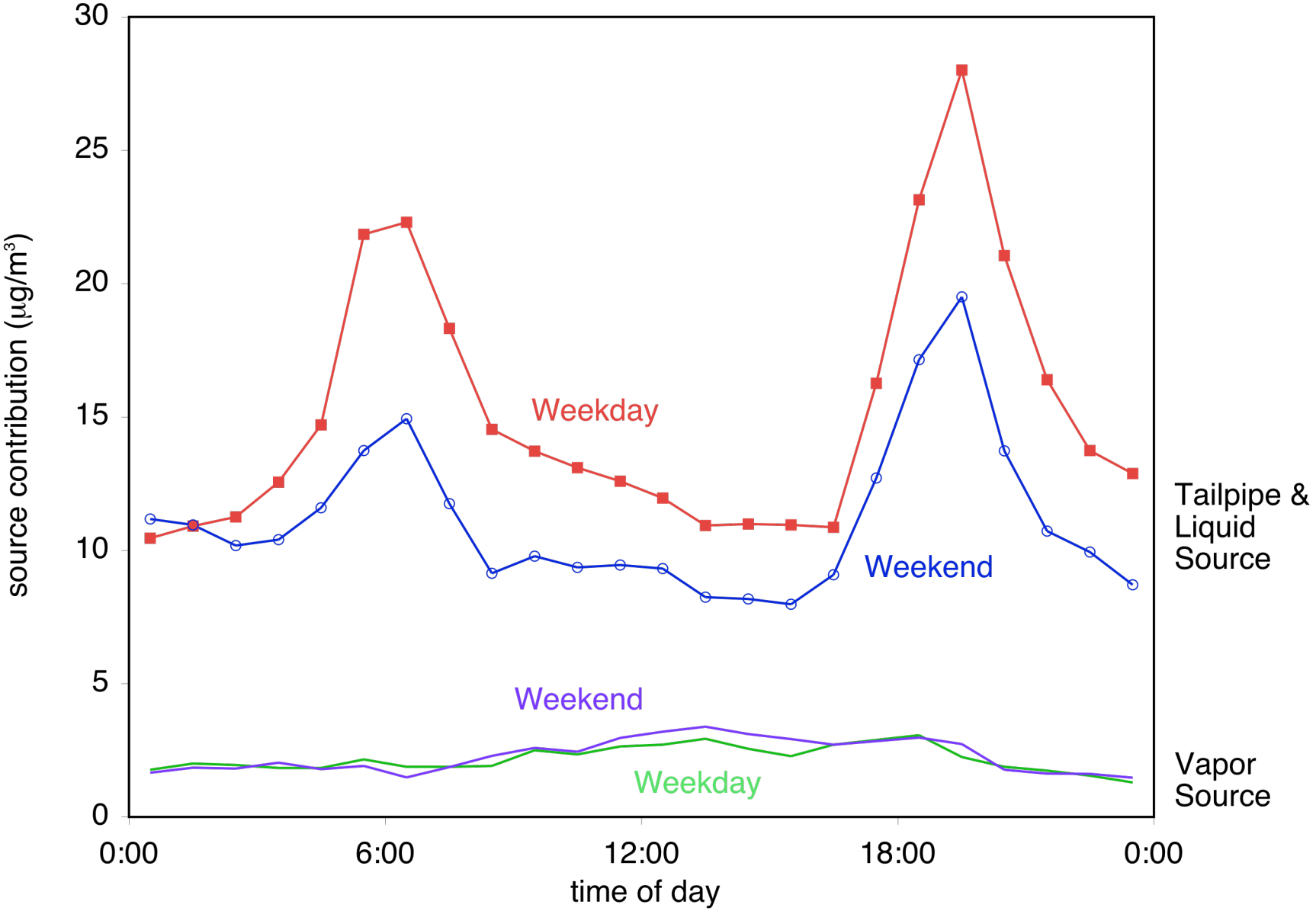
VOC Time Series



Alkanes in Gasoline

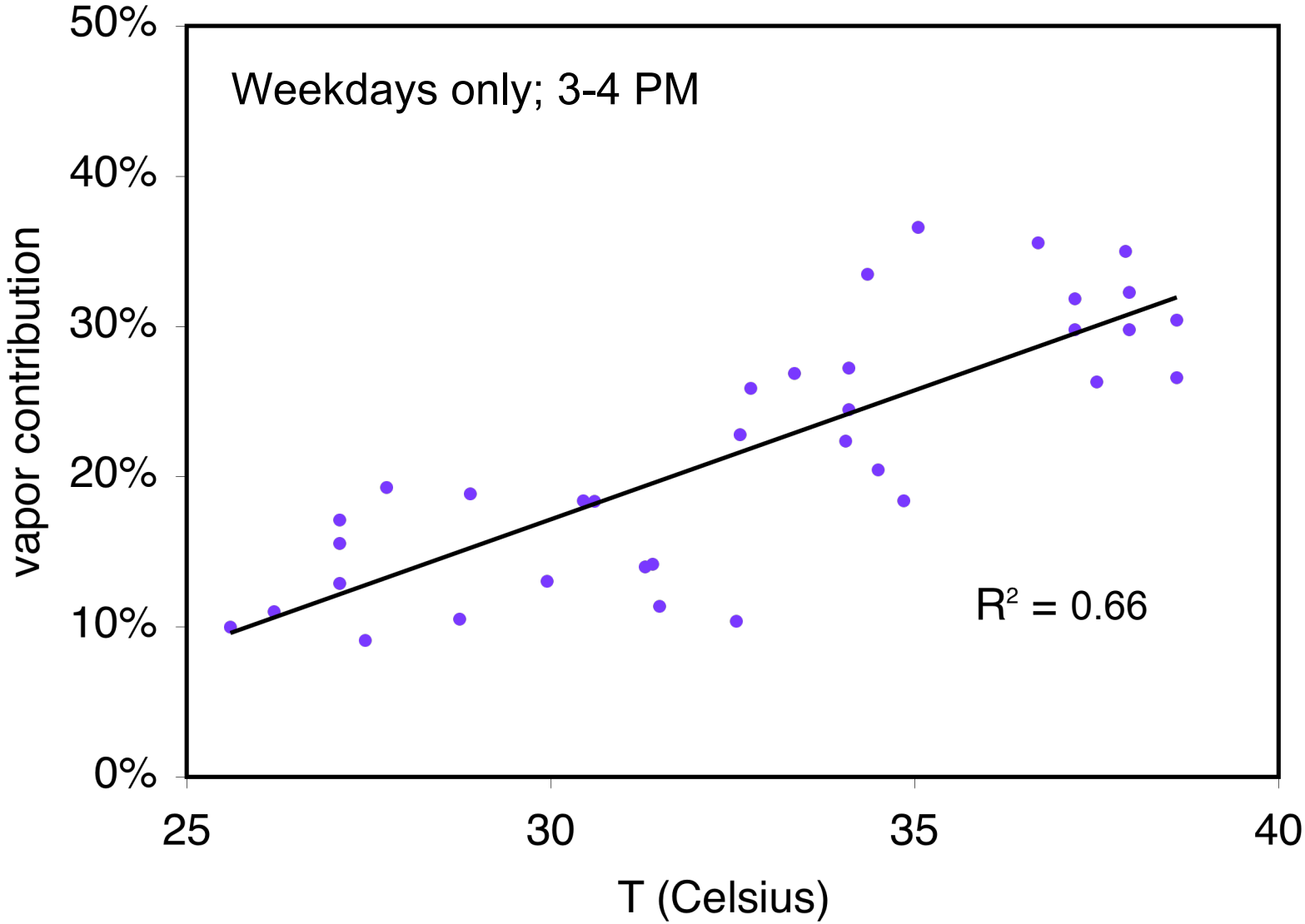
- Oil refiners isomerize C_5-C_6 alkanes:
  - » n-pentane (62) ⇔ isopentane (93)
  - » n-hexane (31) ⇔ methylpentanes (74-76)
- Isopentane & methylpentanes are:
  - » abundant in gasoline (7.5 and 5.8 wt%)
  - » not very reactive in the atmosphere
- Isopentane greatly enriched in vapor emissions relative to methylpentanes
  - » 27 vs. 6.5 wt% in vapors

Chemical Mass Balance Results



Rubin et al., JGR 2006

Vapor Contribution vs. T



Rubin et al., JGR 2006

Main Findings

- Vapor pressure-driven emissions account for 17±1% of vehicular VOC (daytime avg @ Granite Bay in 2001)
- Vapor contribution peaks 2-4 PM
- Vapor contribution correlated with T during afternoon hours

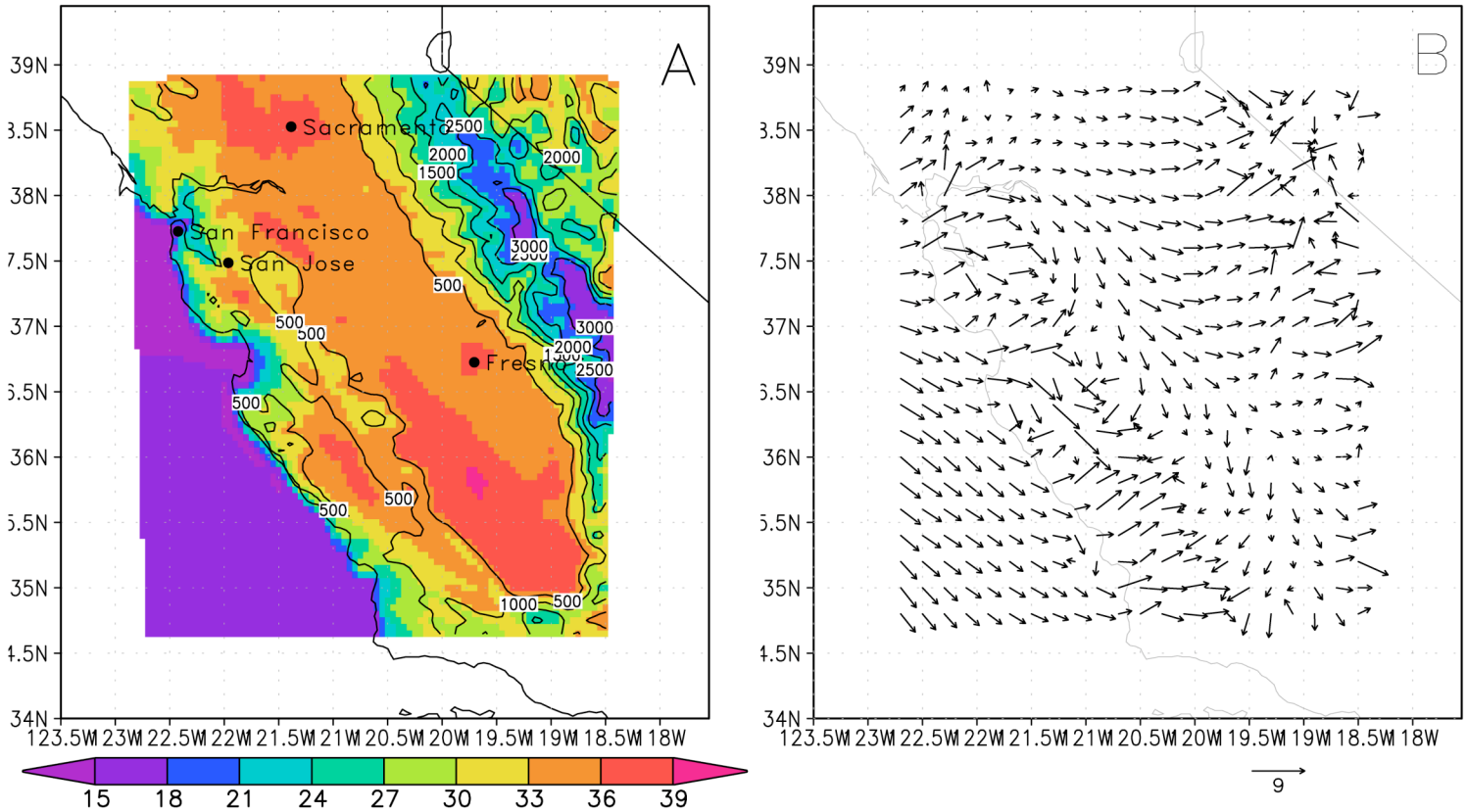
2. Air Quality Modeling

- Use CMAQ model with SAPRC99 chemistry to predict ozone in Central California
- Base case episode from summer 2000
- Consider effects of changes in:
  - » Reaction rates (increased T)
  - » Biogenic emissions (increased T)
  - » Anthropogenic emissions (population growth and technology change)
  - » Inflow boundary conditions (global change)

Modeling Domain

Temperature & Topography

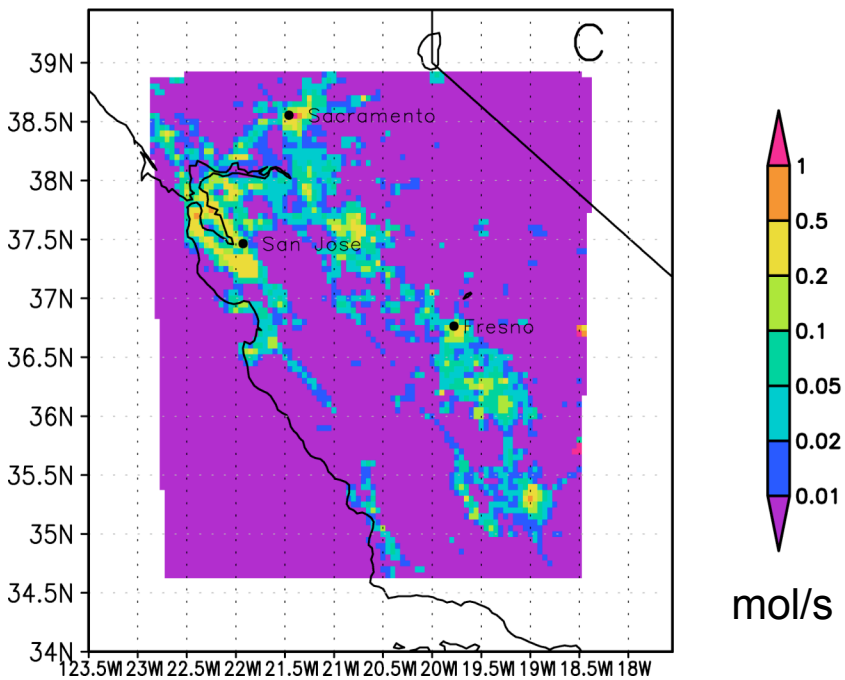
Winds



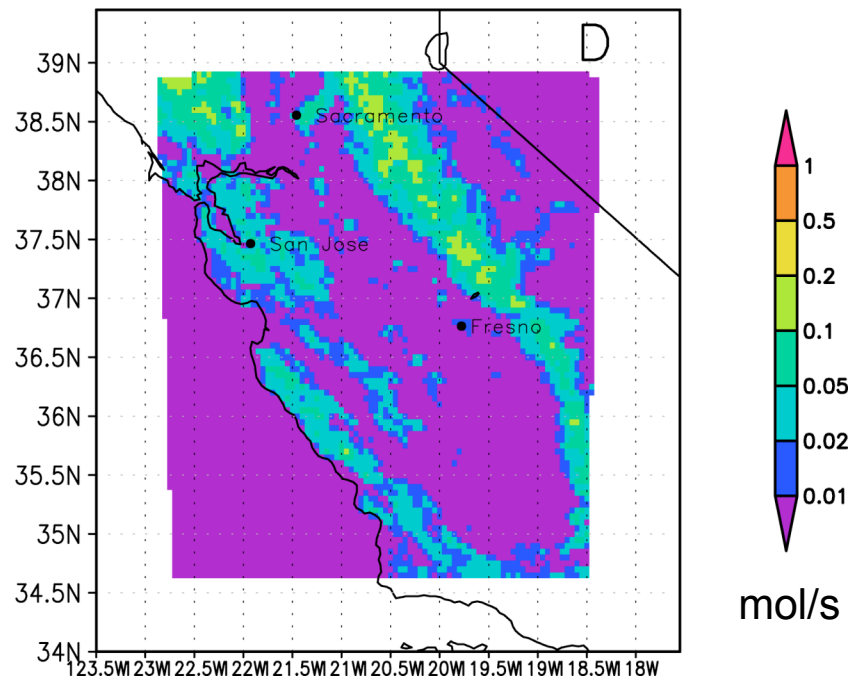
MM5 (Wilczak et al NOAA) for July 29-Aug 2, 2000

VOC Emissions

Anthropogenic



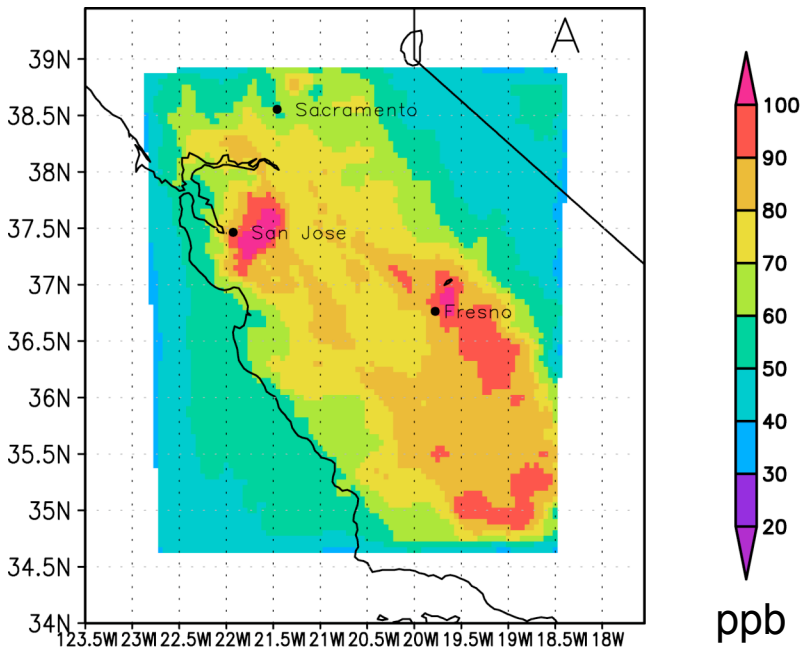
Biogenic



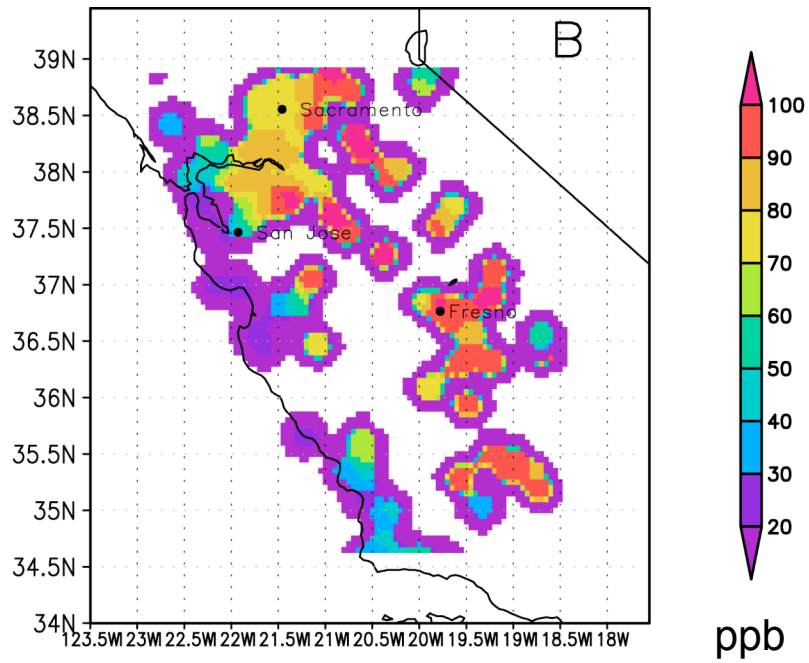
Emission rates shown for 3 PM

Base Case Results

Predicted O_3



Observed O_3

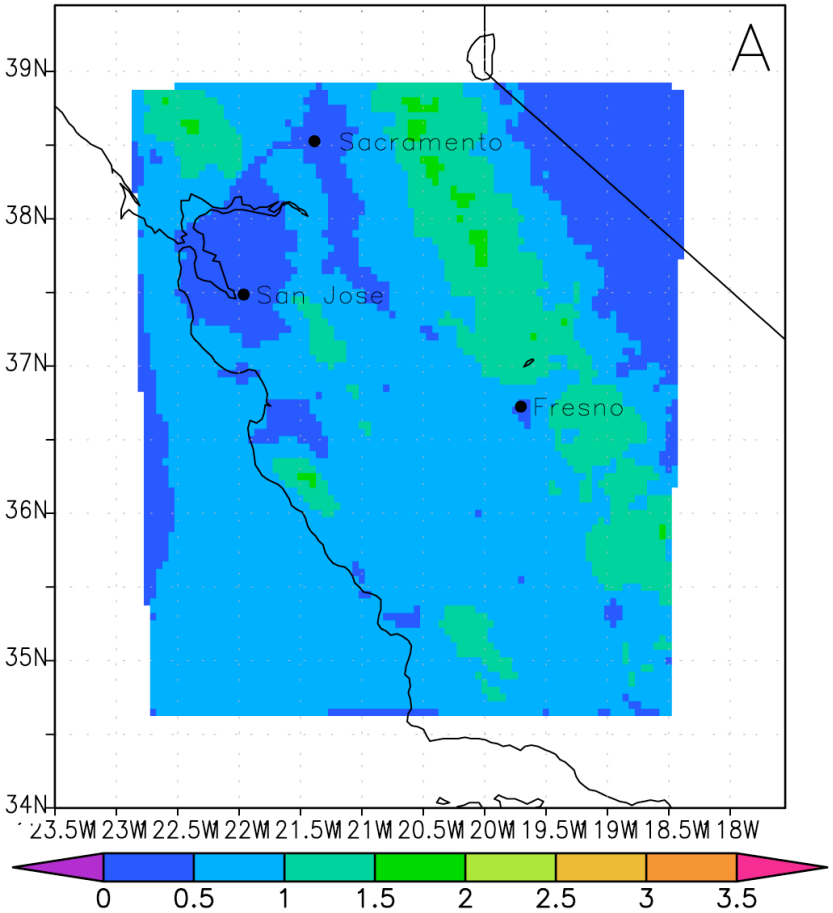


Ozone at 3 PM for 3rd-5th days of Jul 29-Aug 2 episode

Chain Termination Rates

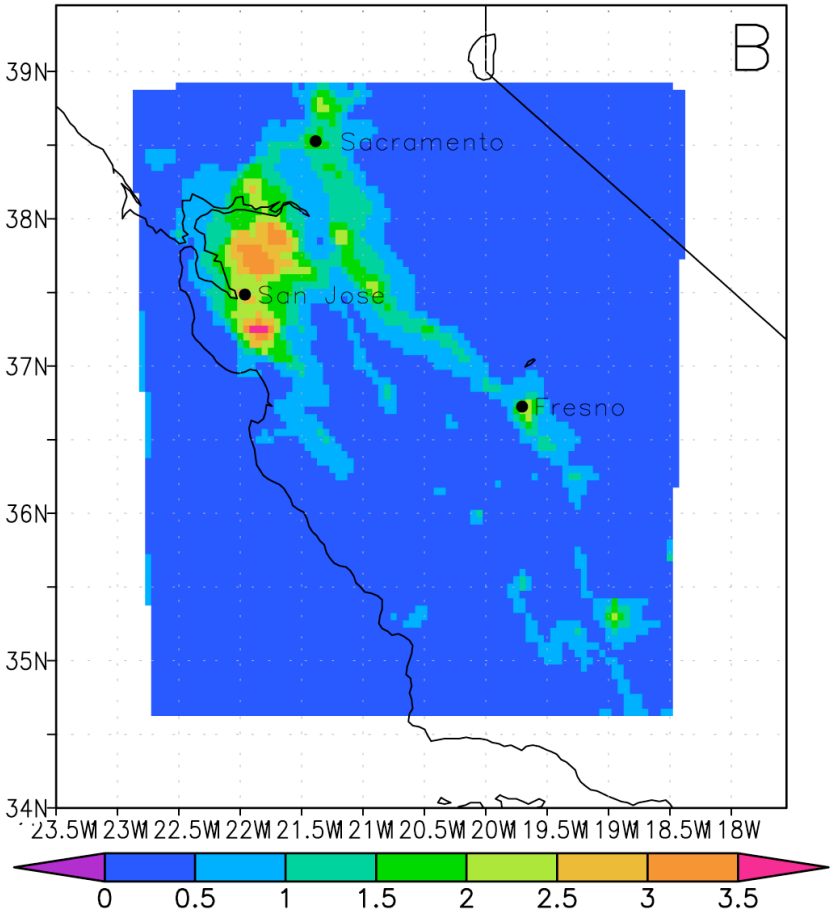
Peroxide Formation

$HO_2 + RO_2 \rightarrow ROOH + O_2$



Nitric Acid Formation

$OH + NO_2 \rightarrow HNO_3$



ppb/hr

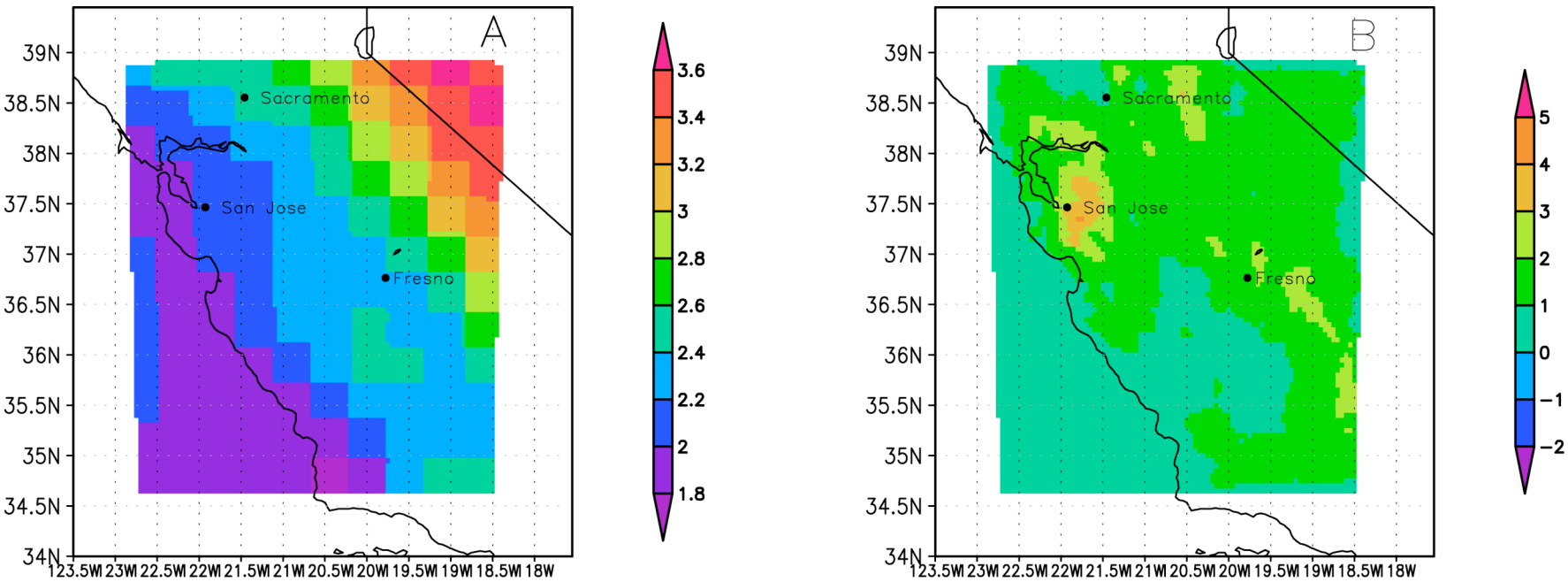
Climate Change

- Consider effects of CO_2 doubling
  - » Pre-industrial = 280 ppm
  - » Future year (~2050) = 560 ppm

- Snyder et al. (*GRL* 2002) used community climate model (CCM3) to drive regional climate simulations for California at 40 km resolution

Effect of ΔT on Chemistry

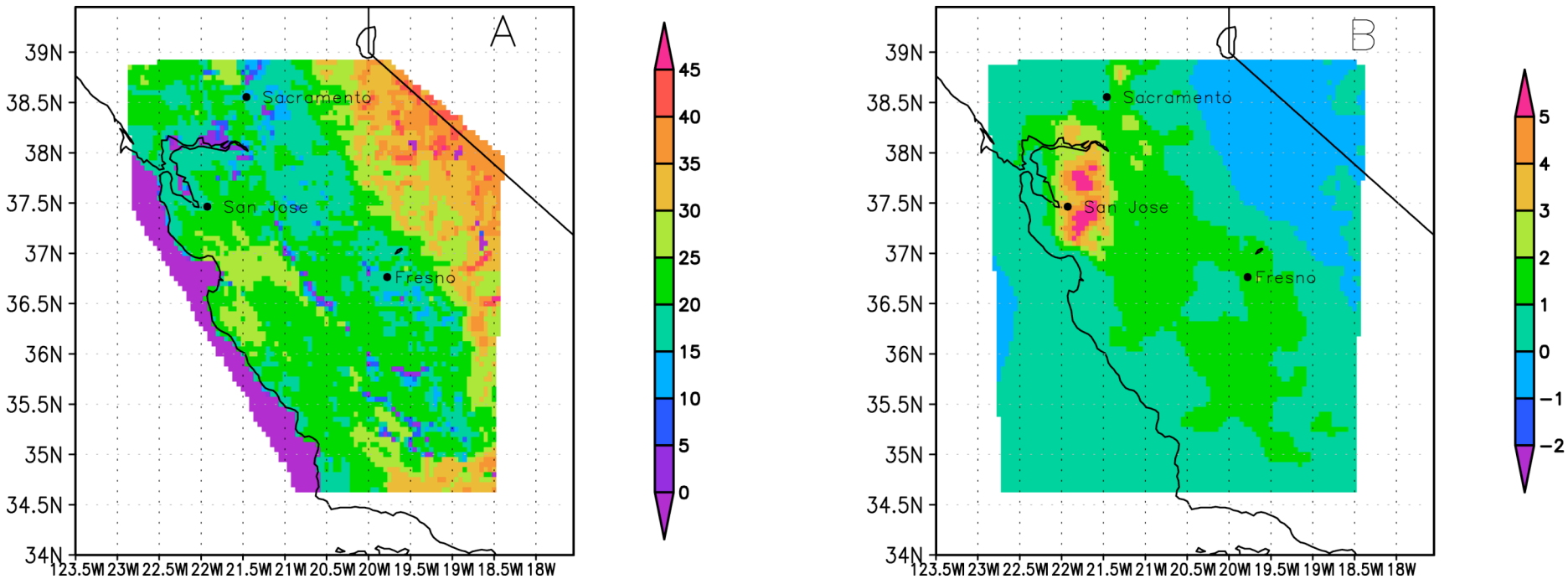
Change in T (°C) → Change in O_3 (ppb)



ΔT for month of August from Snyder et al. (2002)
Other meteorological variables & emissions unchanged

Effect of ΔBVOC on Ozone

% Increase in BVOC → Change in O_3 (ppb)

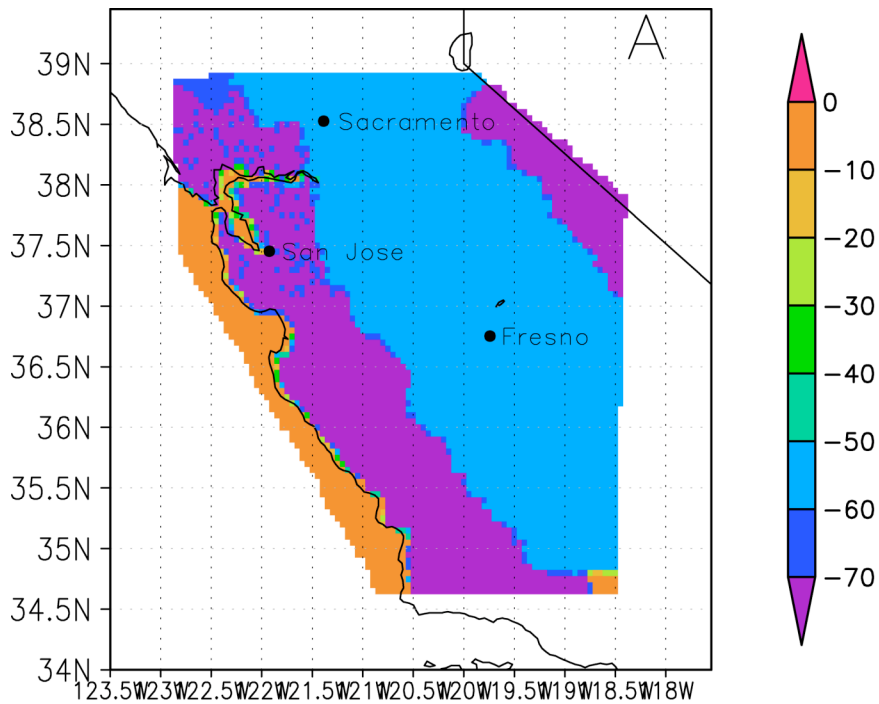


Biogenic emissions of isoprene & MBO peak at 37ºC

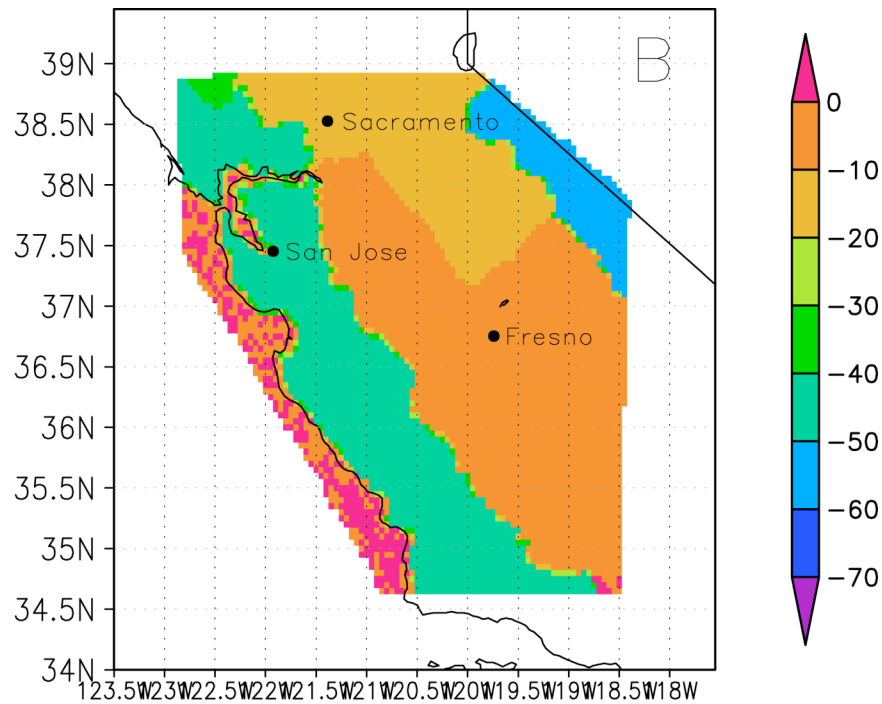
Terpene emissions increase exponentially with T

Anthropogenic Emissions: 2050

% Change in VOC & CO



% Change in NO_x



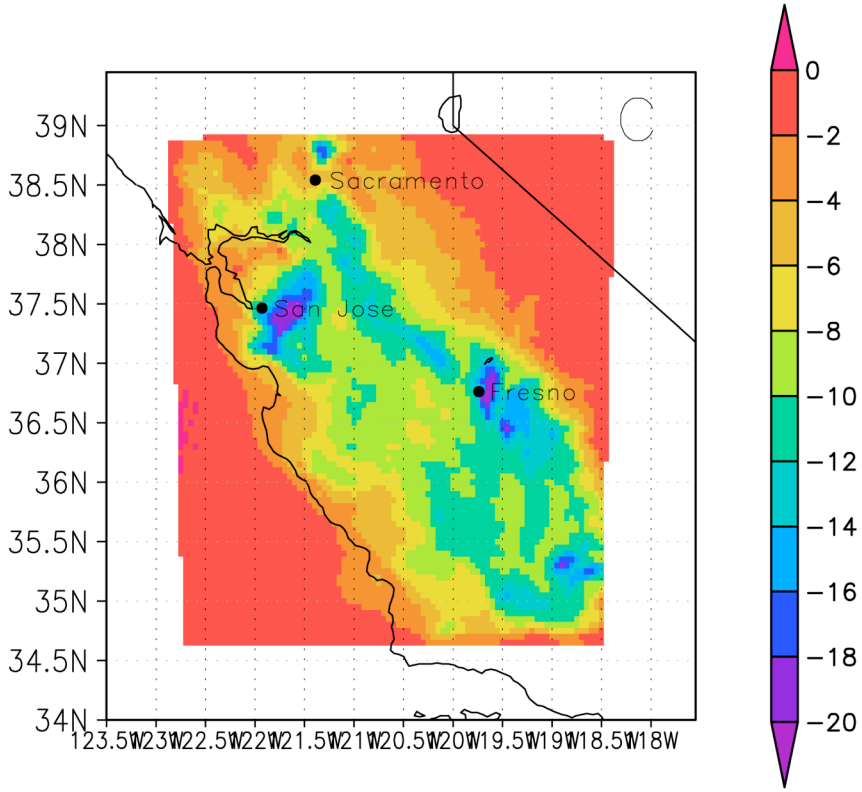
Population forecasts: faster growth in Central Valley

Growth factor for NO_x is 2× that for VOC & CO

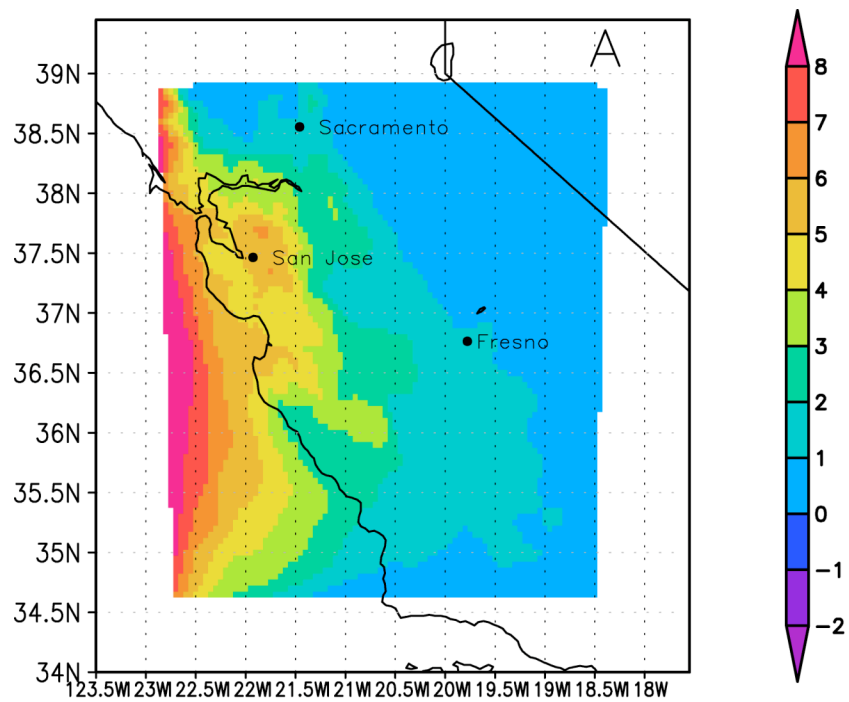
80% reduction in present-day emission factors for CO, VOC & NO_x

Future Emissions & Inflow BCs

ΔO_3 (ppb) with
2050 Emissions



ΔO_3 (ppb) with
2050 Inflow BC

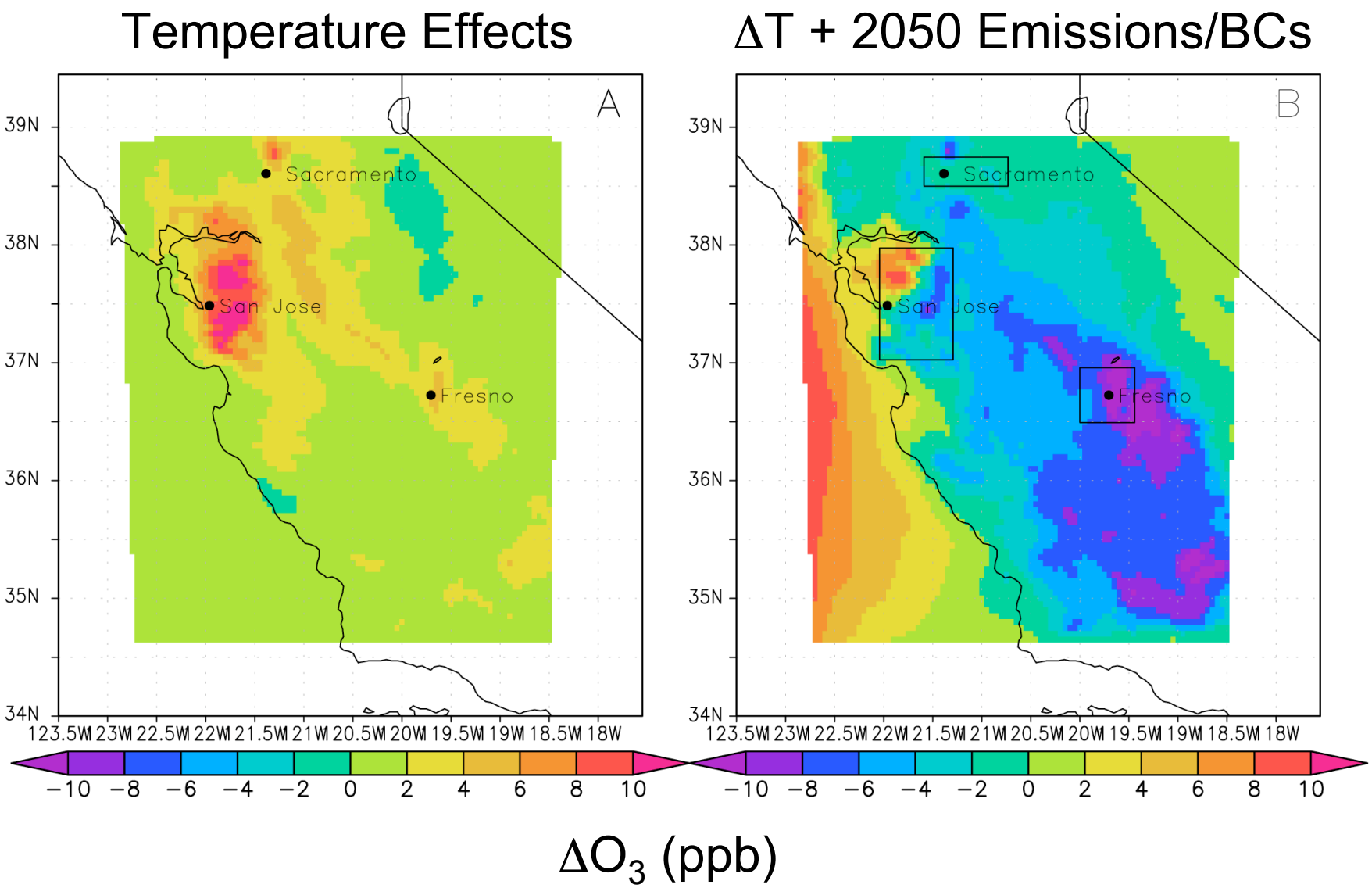


CO: 80 → 104 ppb

CH_4: 1.7 → 2.4 ppm

O_3: 30 → 40 ppb

Combined Simulations

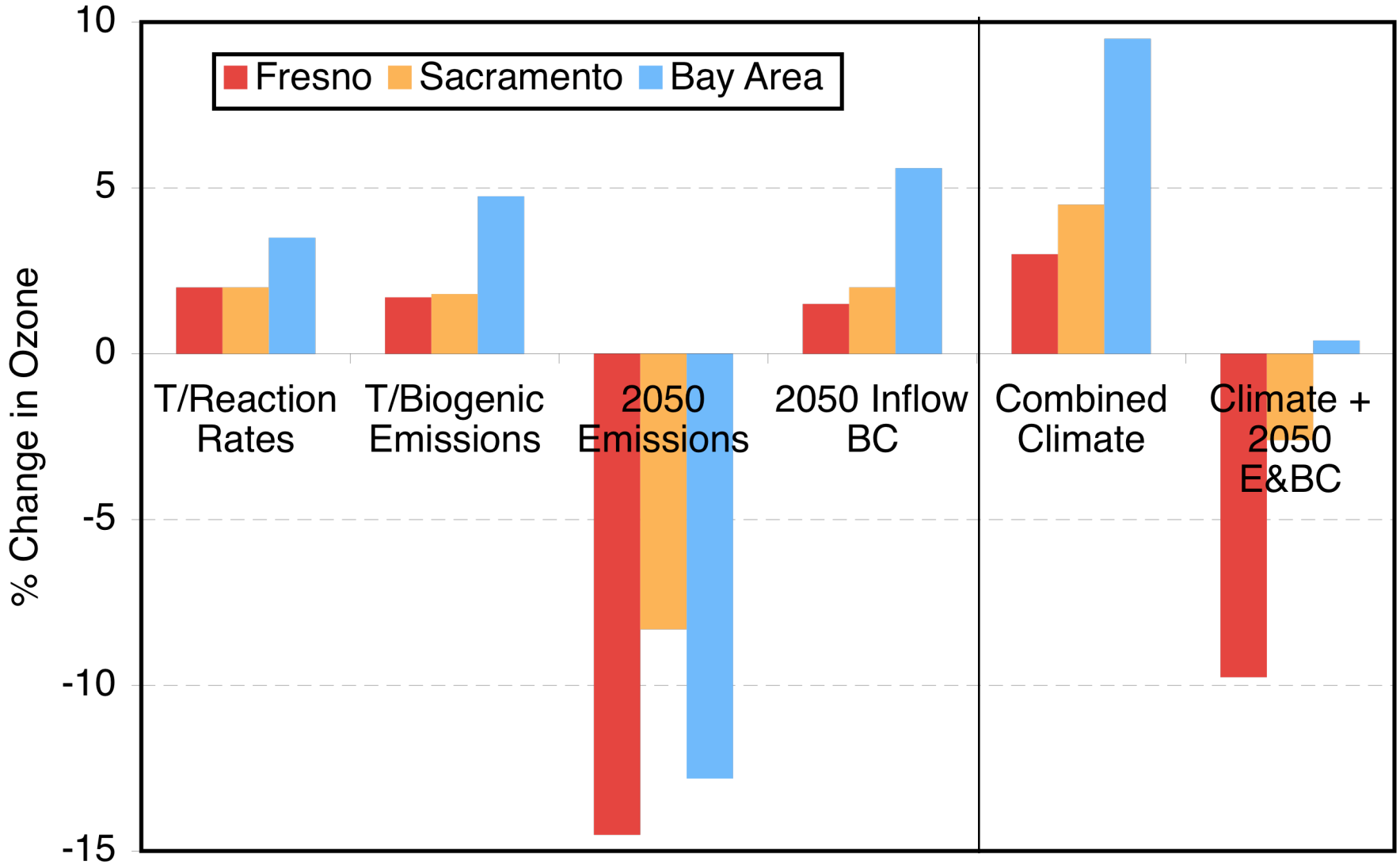


ΔO_3 (ppb)

Other Effects

- Effects on water resources (see Snyder et al.)
  - » rainfall increases up to 20% in northern California
  - » snowpack decreases ~80% by end of Feb
- Sea level rise
- Changes in forest fires
- Changes in $PM_{2.5}$ & winter season air quality
- Ecosystem and land use change
- Health effects of extreme hot weather
- Changes in <u>frequency</u> of O_3-conducive meteorology & <u>length</u> of high-O_3 season

Summary of O_3 Effects



Key References

- Snyder et al. (2002). Climate responses to a doubling of atmospheric CO_2 for a climatically vulnerable region. *GRL*
- Steiner et al. (2006). Influence of future climate and emissions on regional air quality in California. *JGR*
- Rubin et al. (2006). Temperature dependence of VOC evaporative emissions from motor vehicles. *JGR*