Guiding Future Air Quality Management in Central California: Sensitivity to Changing Climate

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  - » Allison Steiner (now at U Michigan)
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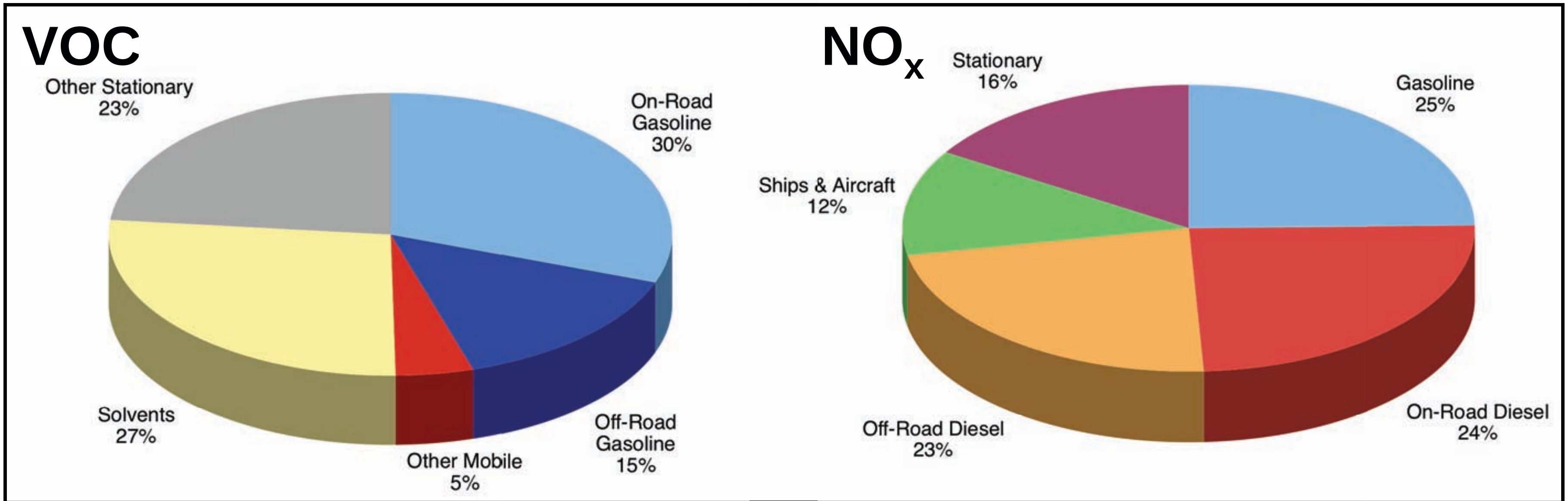
Air Pollution Emissions



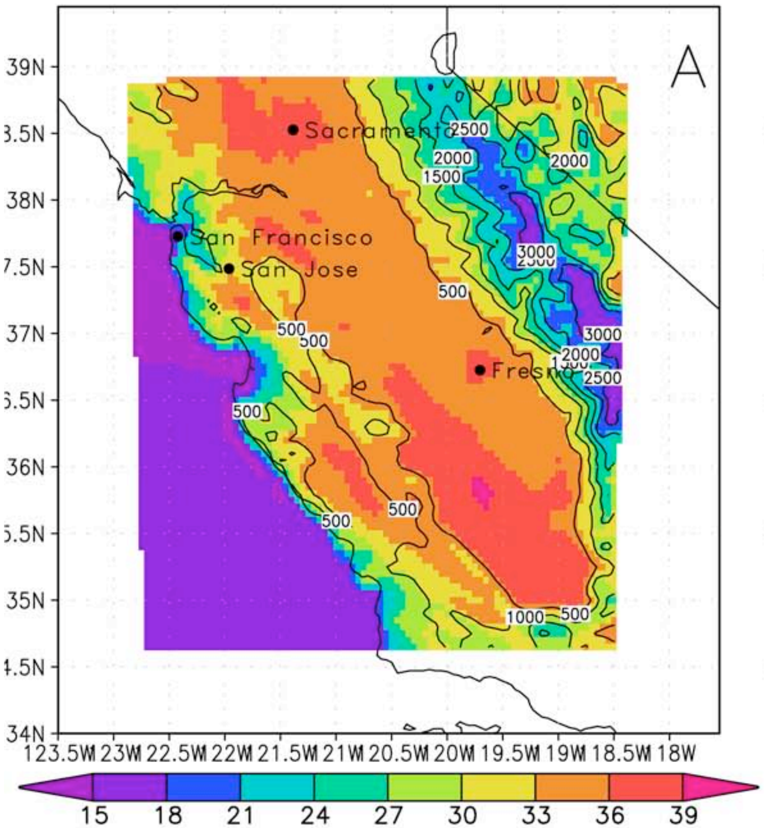
- California statewide emission estimates for 2005
- Some key questions:
  - → are these estimates accurate?
  - → how do emissions vary from day to day?
  - → how will emissions change as a result of changes in population, technology, and climate?

Air Quality Modeling

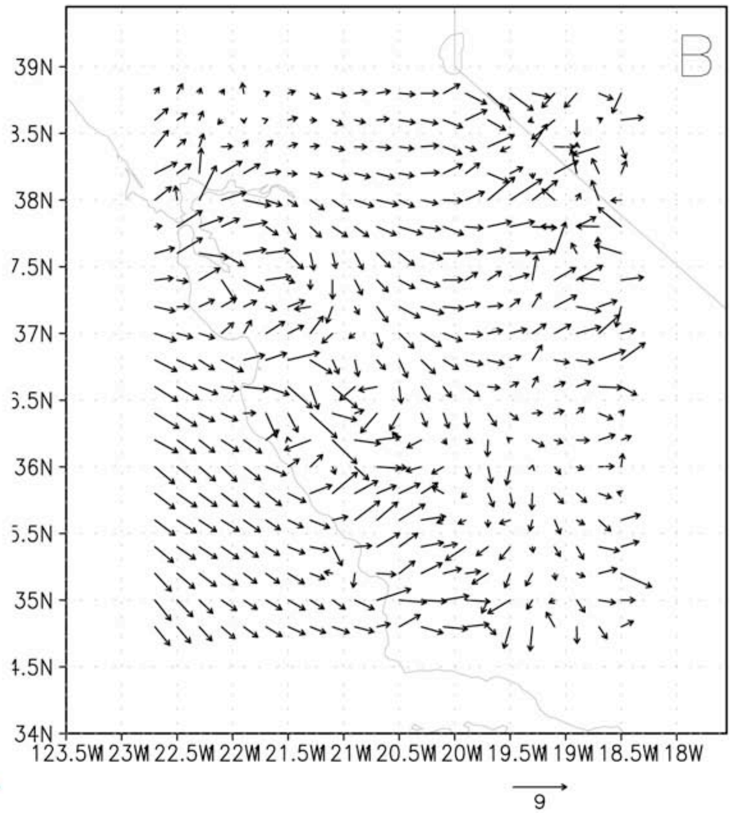
- Use CMAQ model with SAPRC99 chemistry to predict ozone in Central California
- Base case episode from summer 2000
- Consider effects of changes in:
  - » Reaction rates (climate change)
  - » Biogenic emissions (climate change)
  - » Anthropogenic emissions (population growth and technology change)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

Modeling Domain

Temperature & Topography



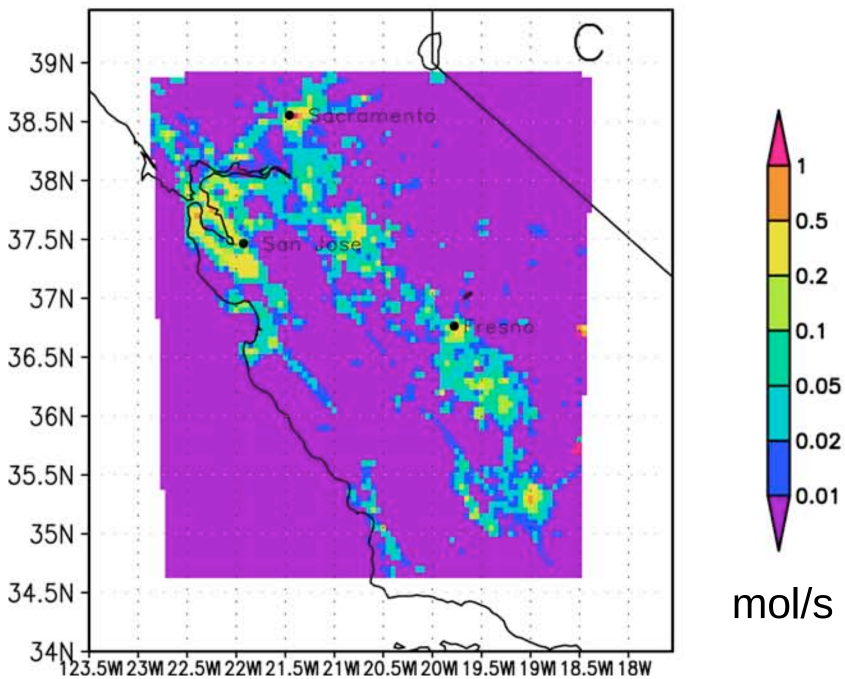
Winds



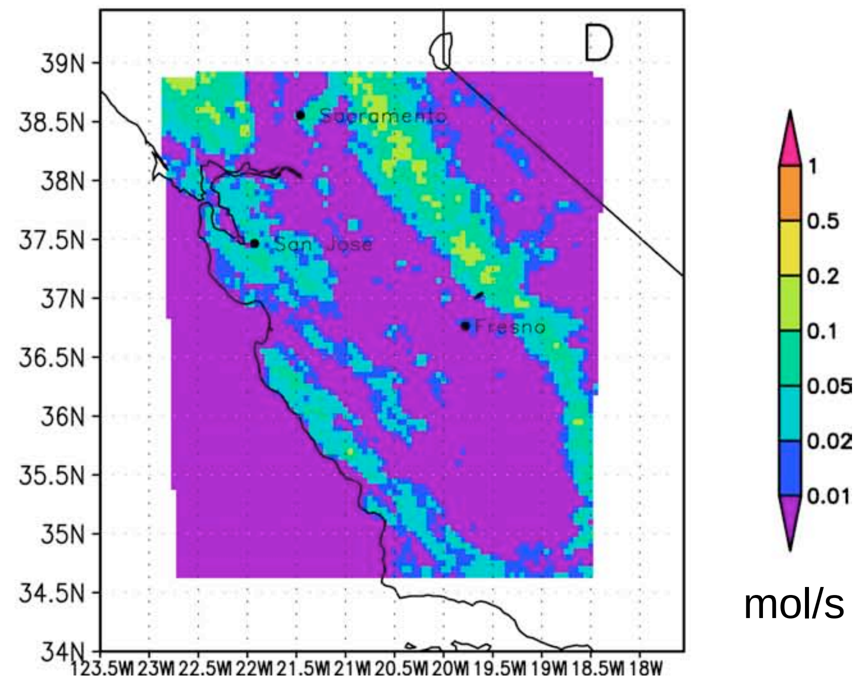
MM5 (Wilczak et al NOAA) for July 29-Aug 2, 2000

VOC Emissions

Anthropogenic



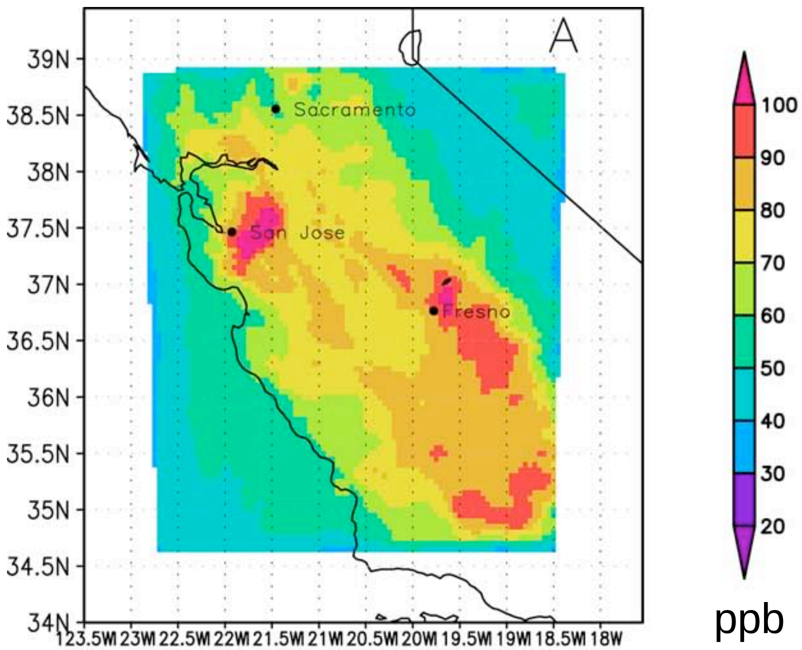
Biogenic



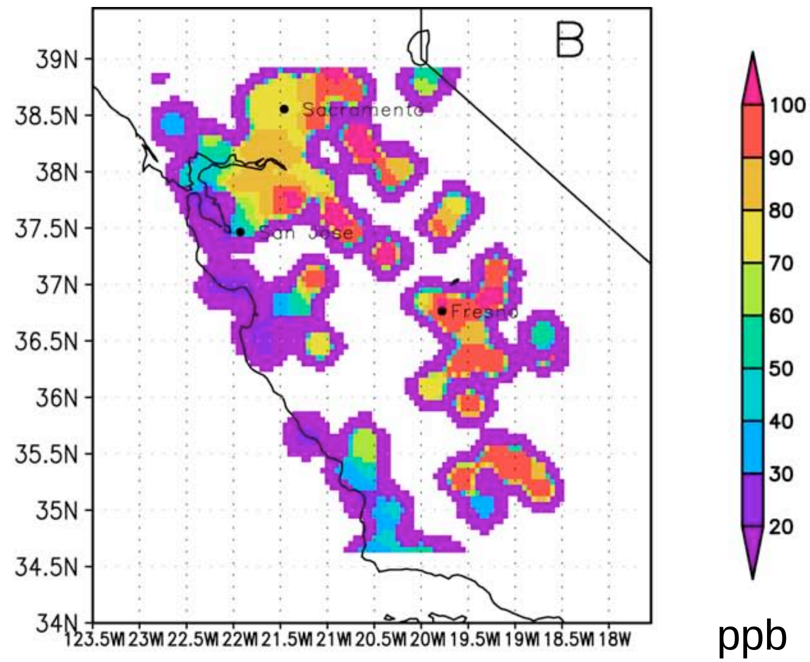
Emission rates shown for 3 PM

Base Case Results

Predicted O_3



Observed O_3



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

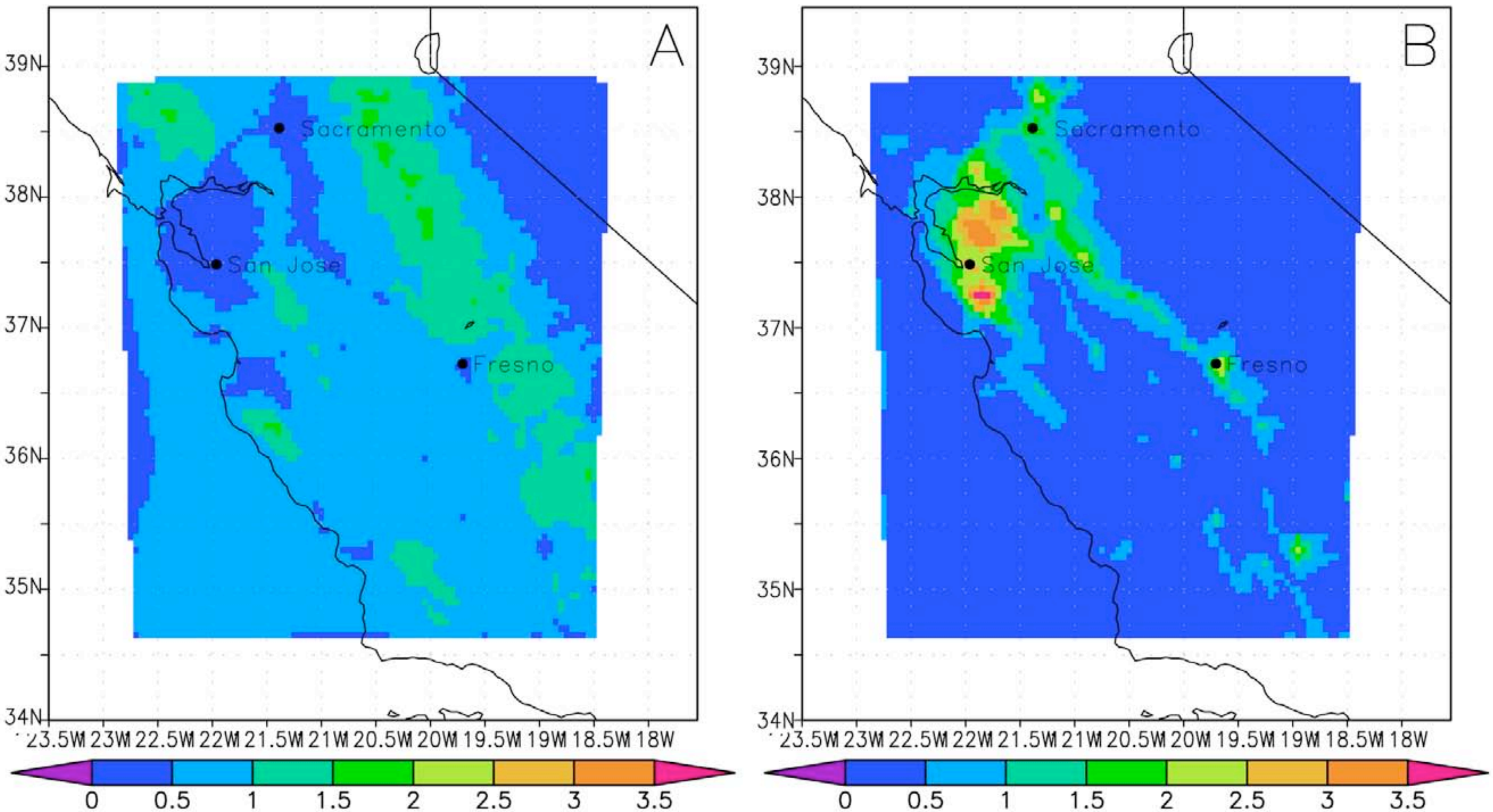
Chain Termination Rates

Peroxide Formation

$HO_2 + RO_2 \rightarrow ROOH + O_2$

Nitric Acid Formation

$OH + NO_2 \rightarrow HNO_3$



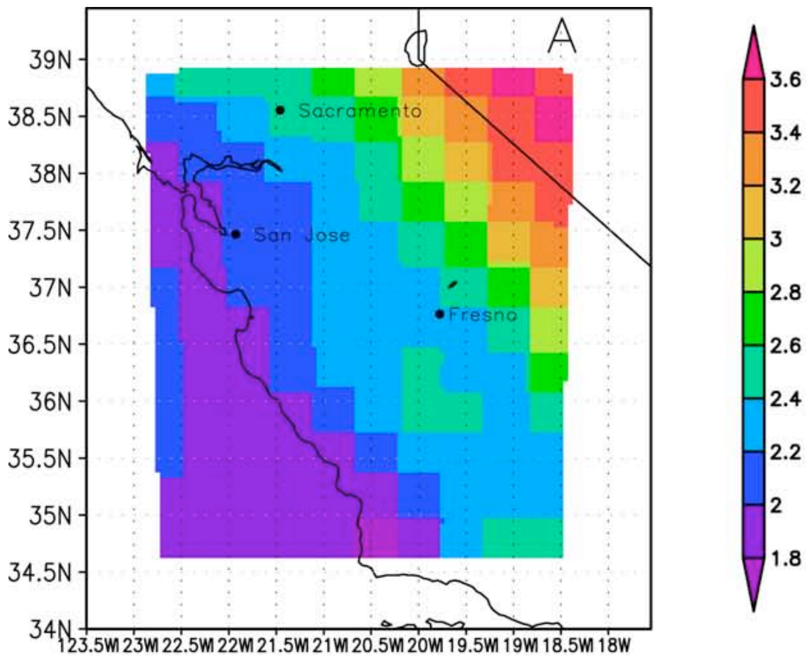
ppb/hr

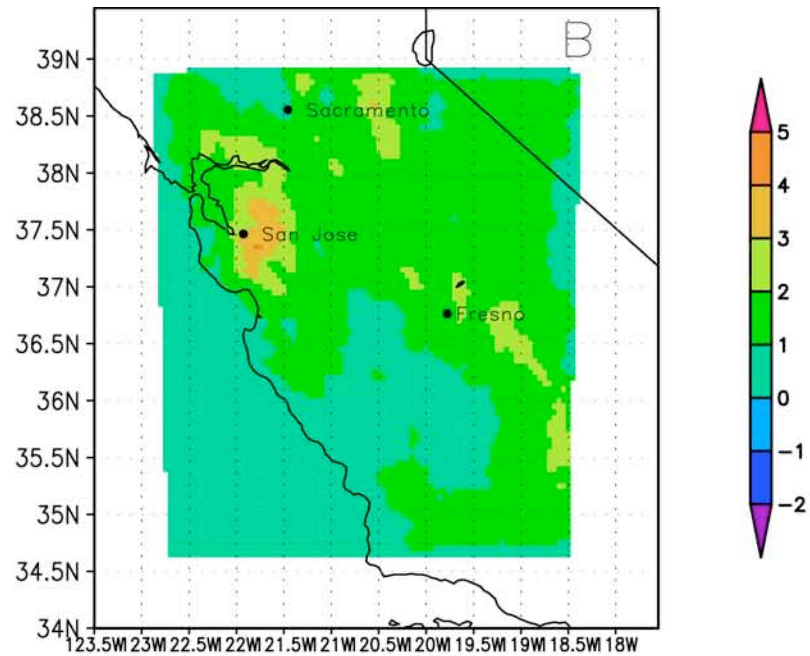
Climate Change

- Consider effects of CO_2 doubling
  - » Pre-industrial = 280 ppm
  - » Future year (~2050) = 560 ppm
- Note ~1/3 of this CO_2 increase had already occurred by 2000
- Snyder et al. (*GRL* 2002) used global climate model to drive regional climate simulations for California at 40 km resolution

Effect of ΔT on Chemistry

Change in T (℃) ⟶ Change in O_3 (ppb)



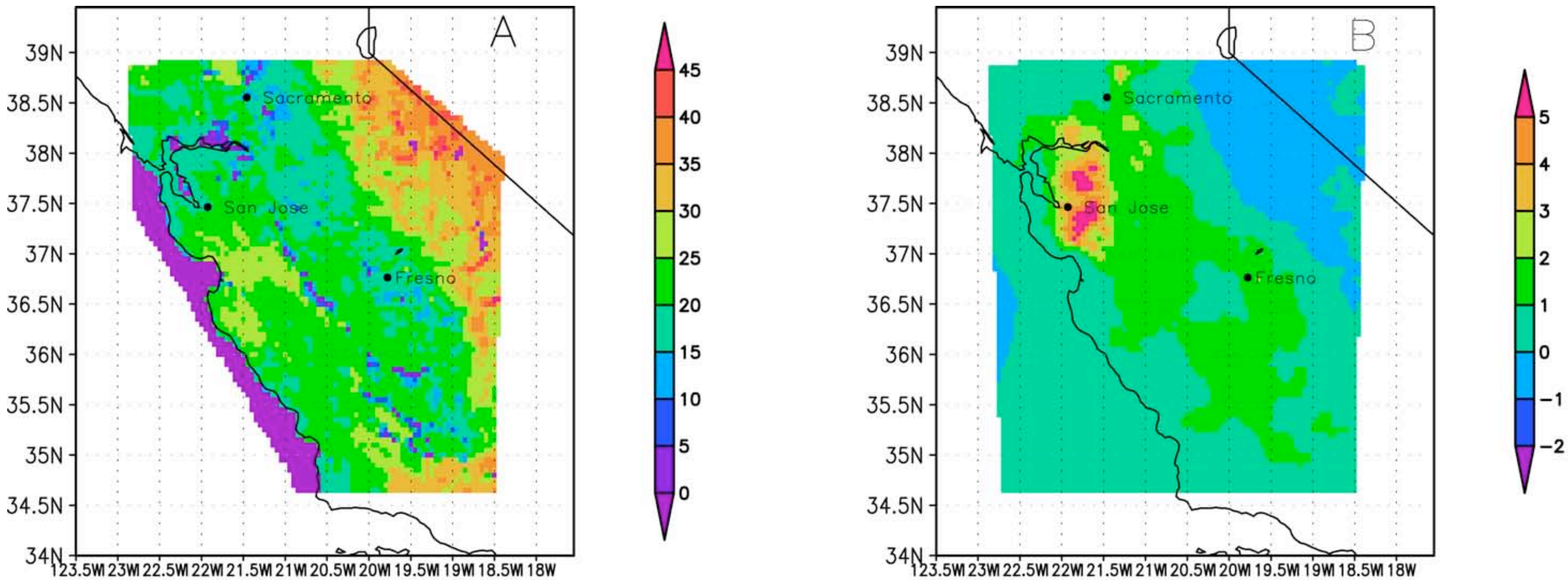


ΔT for month of August from Snyder et al. (2002)

Other meteorological variables & emissions unchanged

Effect of ΔBVOC on Ozone

% Increase in BVOC → Change in O_3 (ppb)

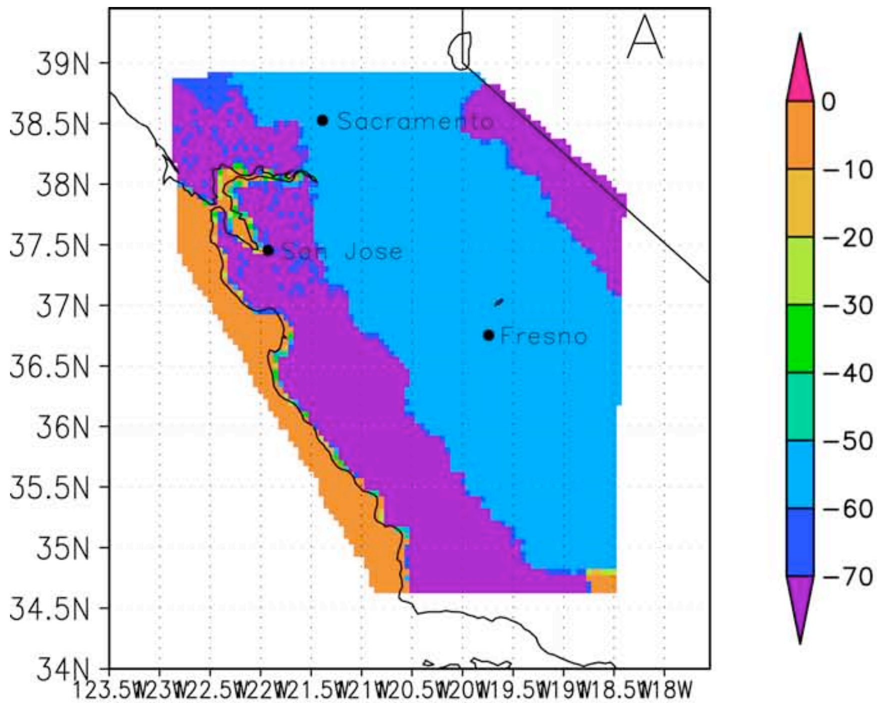


Biogenic emissions of isoprene & MBO peak at 37ºC

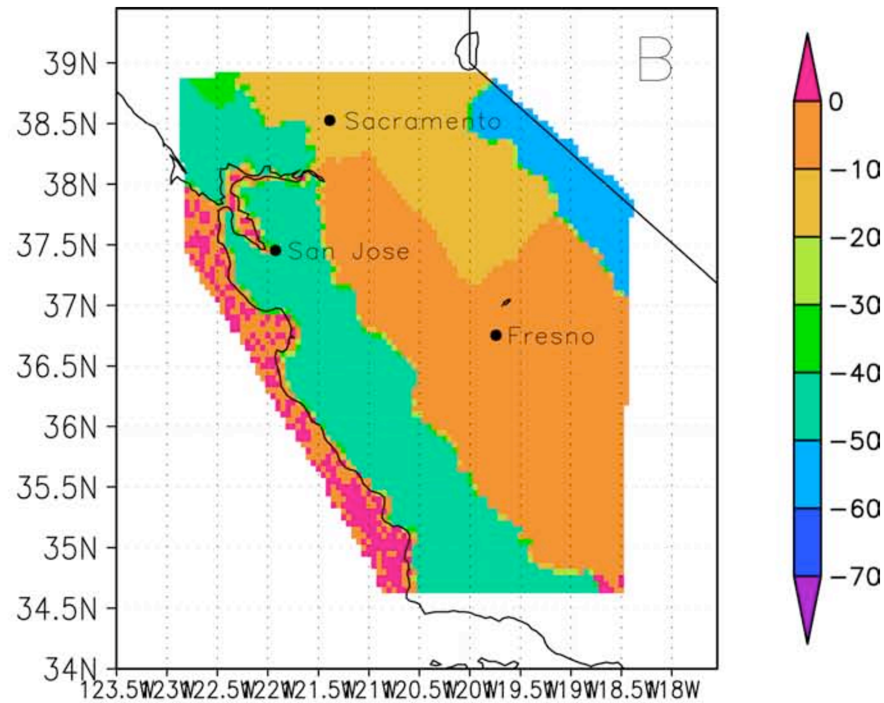
Terpene emissions increase exponentially with T

Anthropogenic Emissions: 2050

% Change in VOC & CO



% Change in NO_x



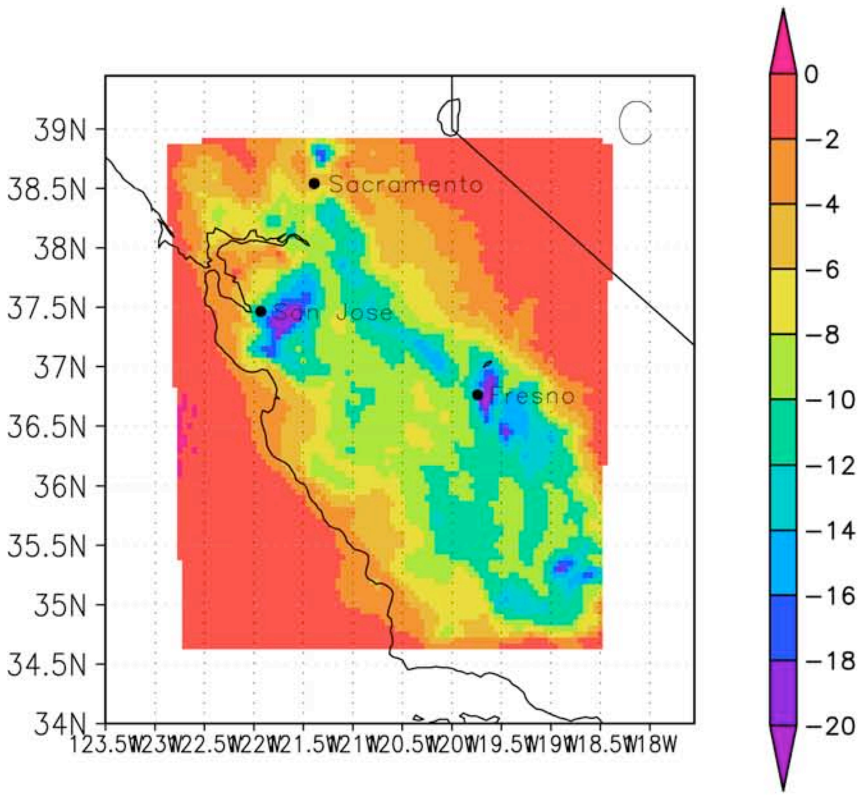
Population forecasts: faster growth in Central Valley

Growth factor for NO_x assumed 2X that for VOC & CO

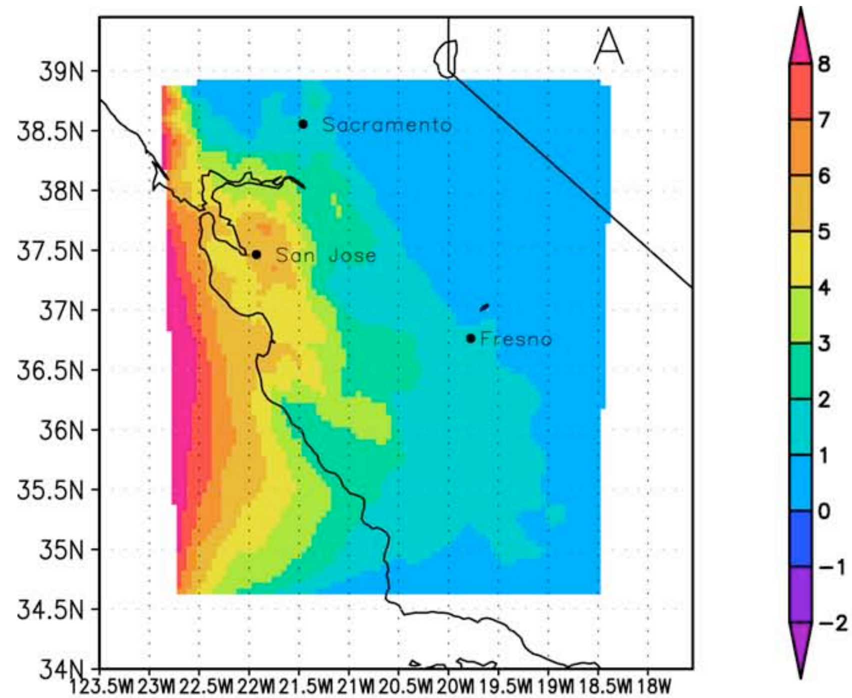
Assume 80% reduction in present-day emission factors for CO, VOC & NO_x

Future Emissions & Inflow BCs

ΔO_3 (ppb) with
2050 Emissions



ΔO_3 (ppb) with
2050 Inflow BC

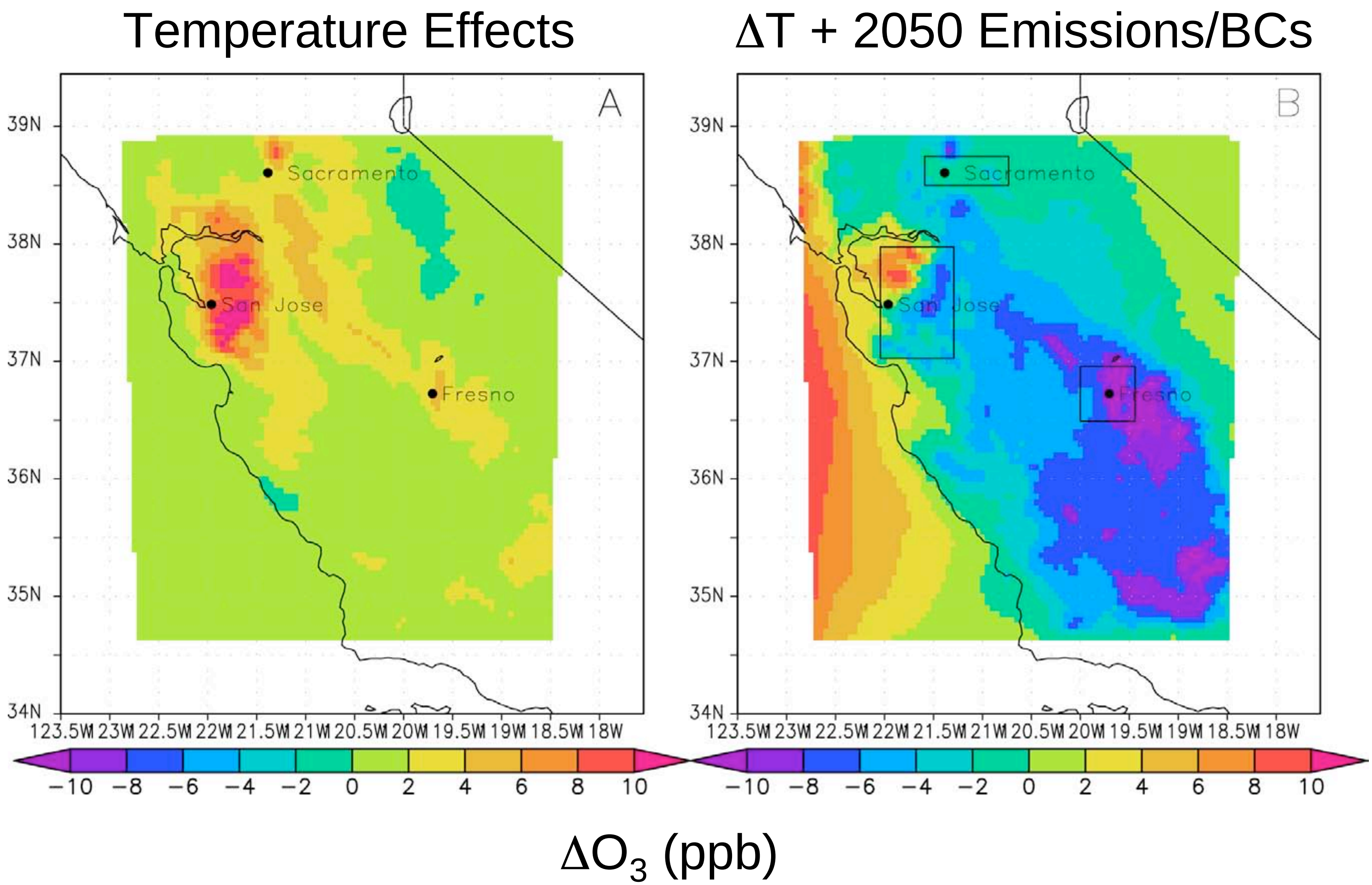


CO: 80 → 104 ppb

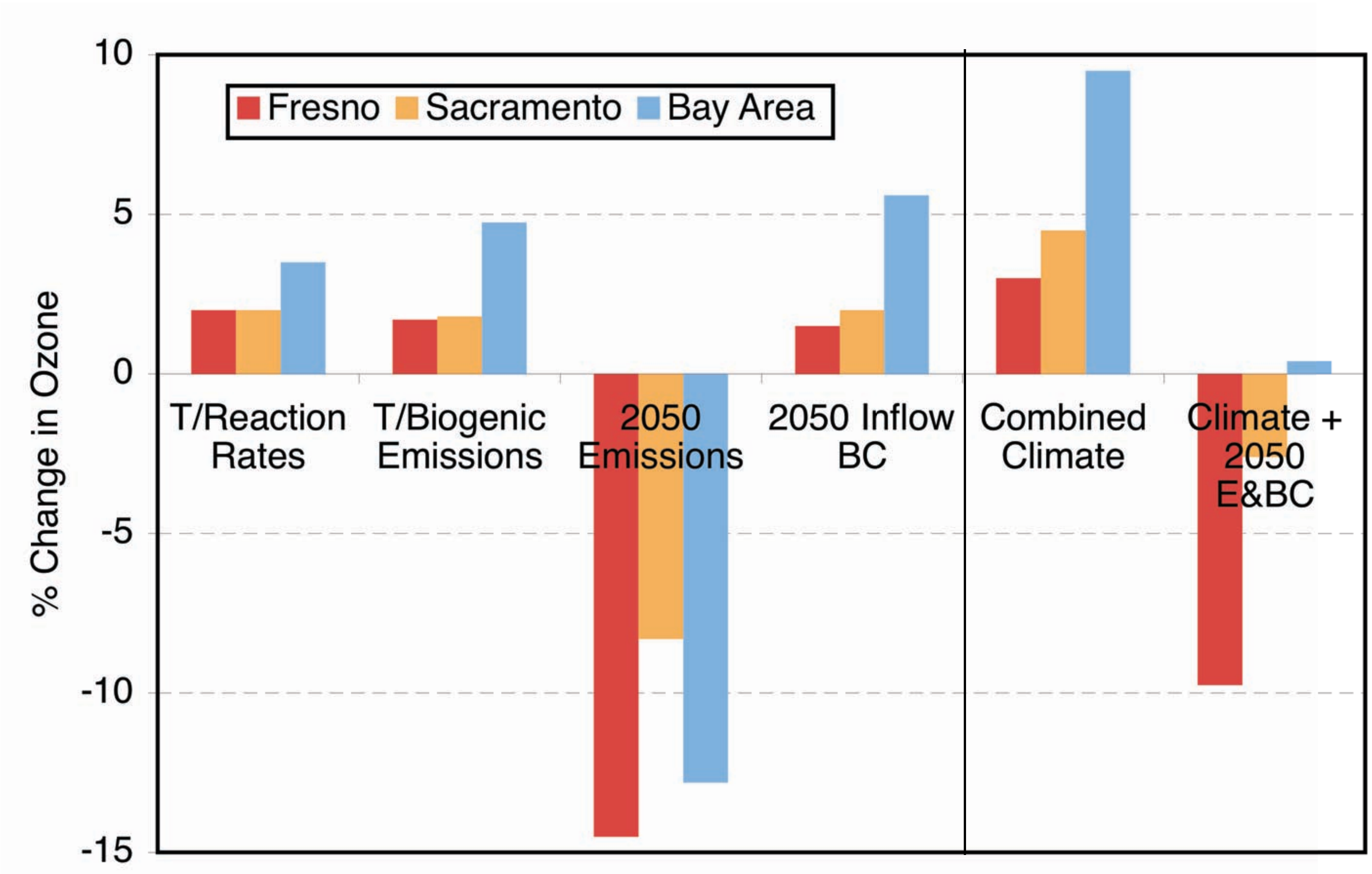
CH_4: 1.7 → 2.4 ppm

O_3: 30 → 40 ppb

Combined Simulations



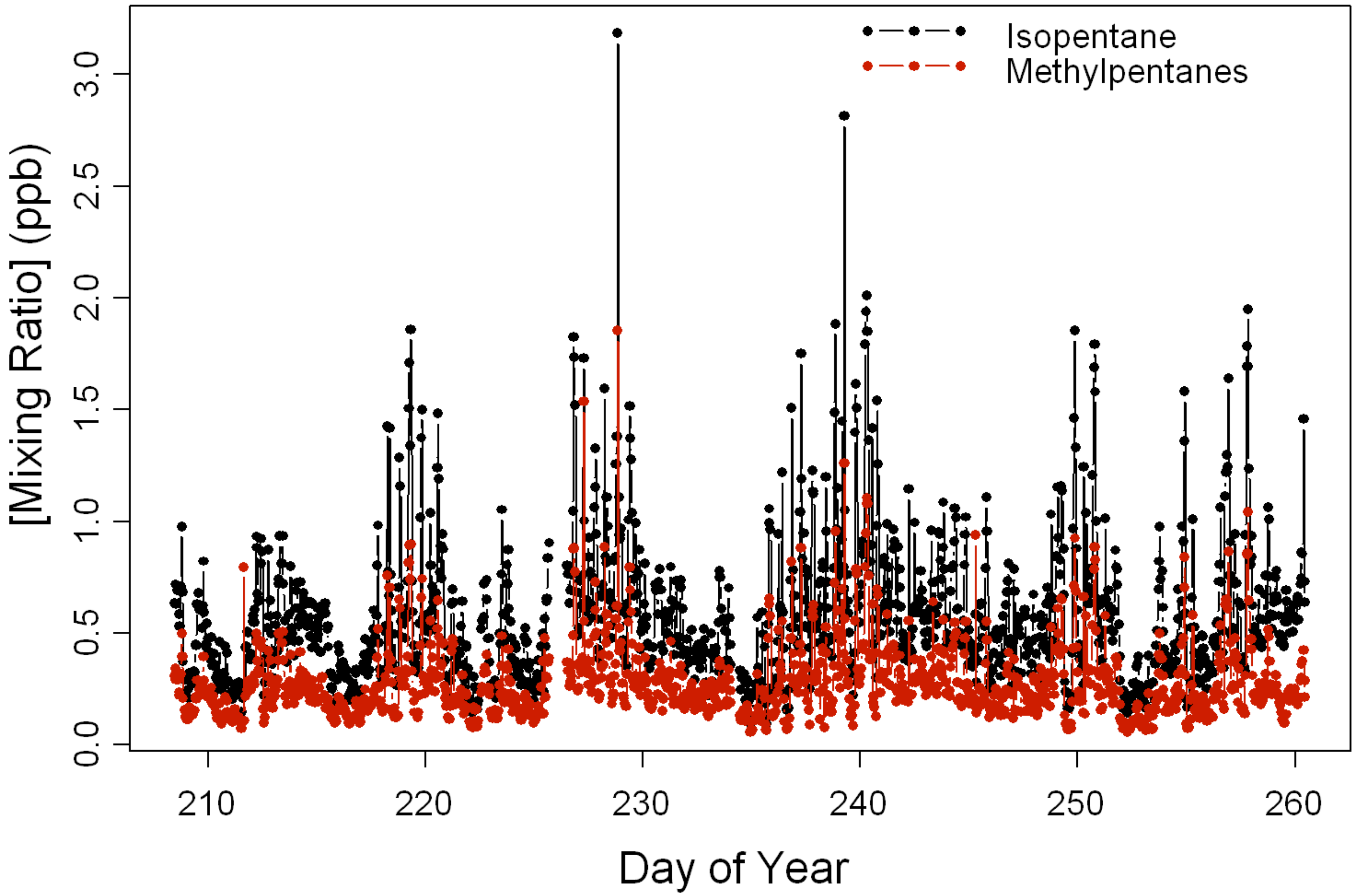
Summary of O_3 Effects



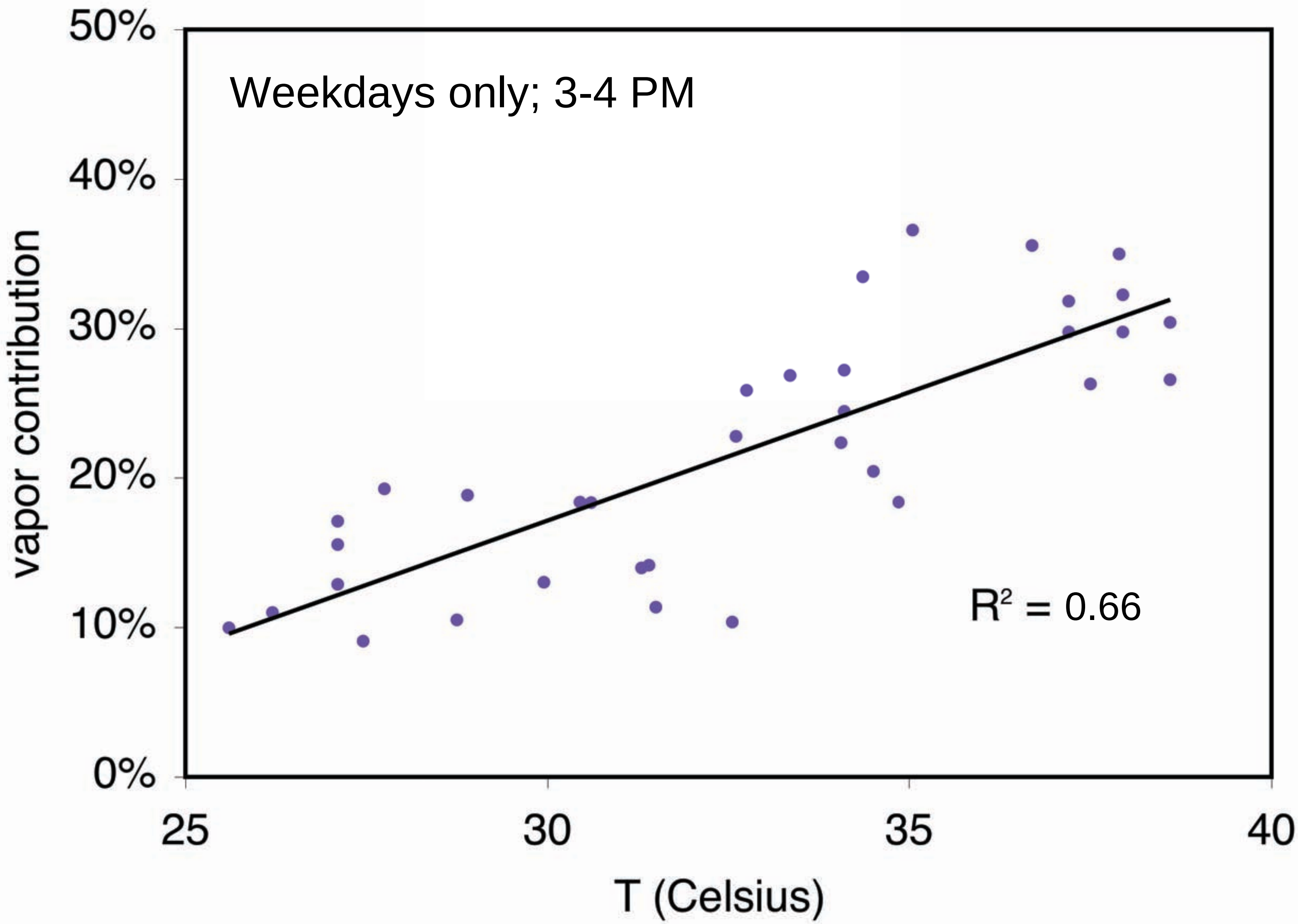
Other Relevant Research

- Steiner et al. poster on effects of biogenic methylbutenol (MBO)
- Variability in anthropogenic VOC:
  - » Millet and Goldstein measured suite of 47 VOC at Granite Bay, CA
  - » 45 min time resolution; Jul-Sep 2001
  - » Chemical mass balance analysis using isopentane and methylpentanes as tracers for vehicle-related emissions

VOC Time Series



Vapor Contribution vs. T



Mean vapor contribution to vehicular VOC = 17±1%

Rubin et al., JGR 2006

Other Relevant Research

- Variability in NO_y speciation with temperature
  - » Cohen group measured NO_y at Blodgett Forest
  - » Speciated NO_y:
    - – NO_x ($NO+NO_2$)
    - – Peroxyacyl nitrates (ΣPN)
    - – Alkyl nitrates (ΣAN)
    - – Nitric acid (HNO_3)
  - » Note SAPRC99 mechanism **missing T-dependence** for alkyl nitrate yields

Figure 3. $NO_x/\Sigma NO_{yi}$ $\Sigma PNs/NO_z$, $\Sigma ANs/NO_z$, and HNO_3/NO_z averaged (median) for single daily values during hours 12-16 vs. daily temperature maximum. Best fit lines shown from top to bottom have parameters: slopes = -0.0042, -0.023, 0.0036, 0.019 and R^2 values = 0.12, 0.52, 0.069, and 0.37, respectively (weekdays only).

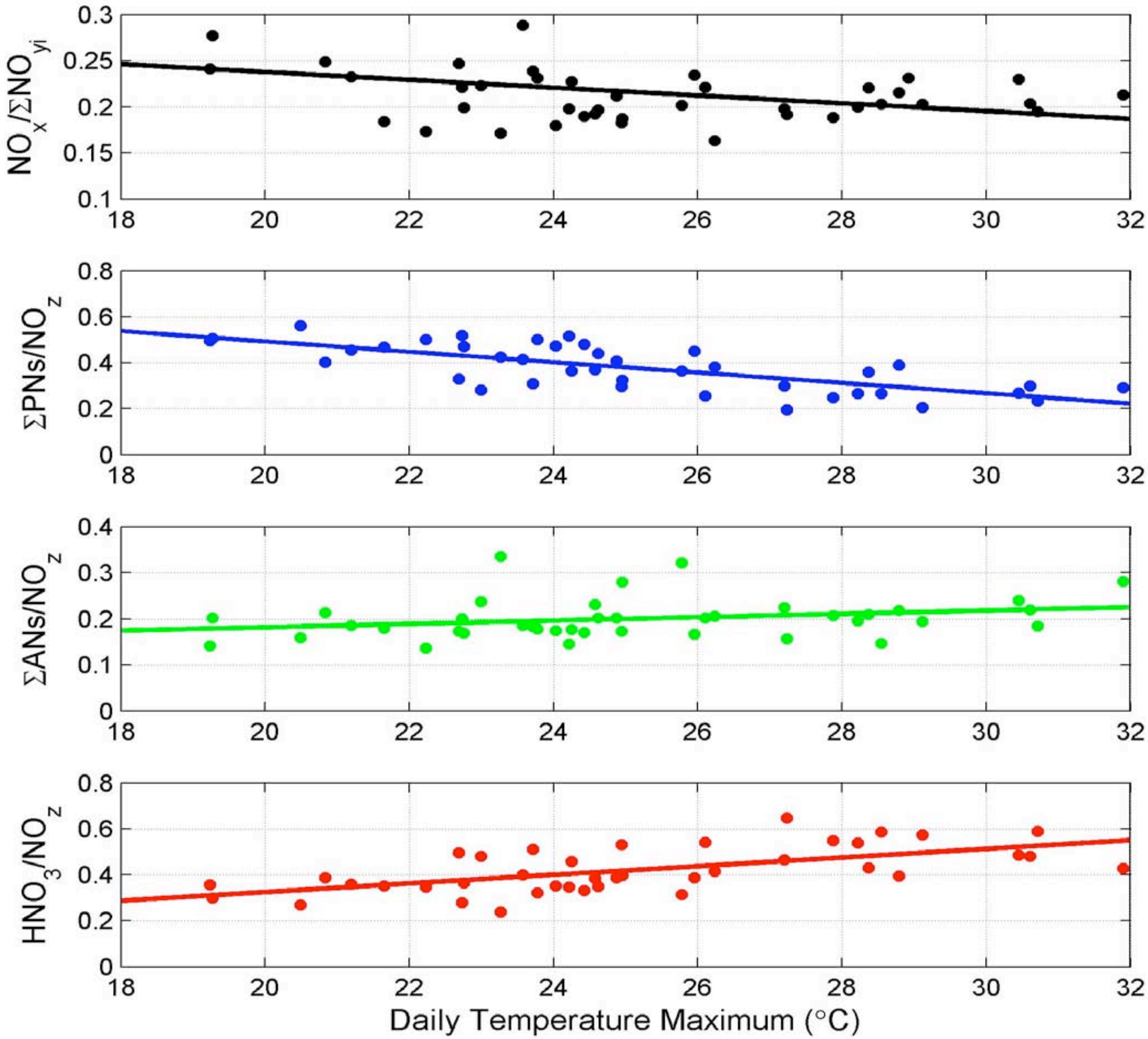
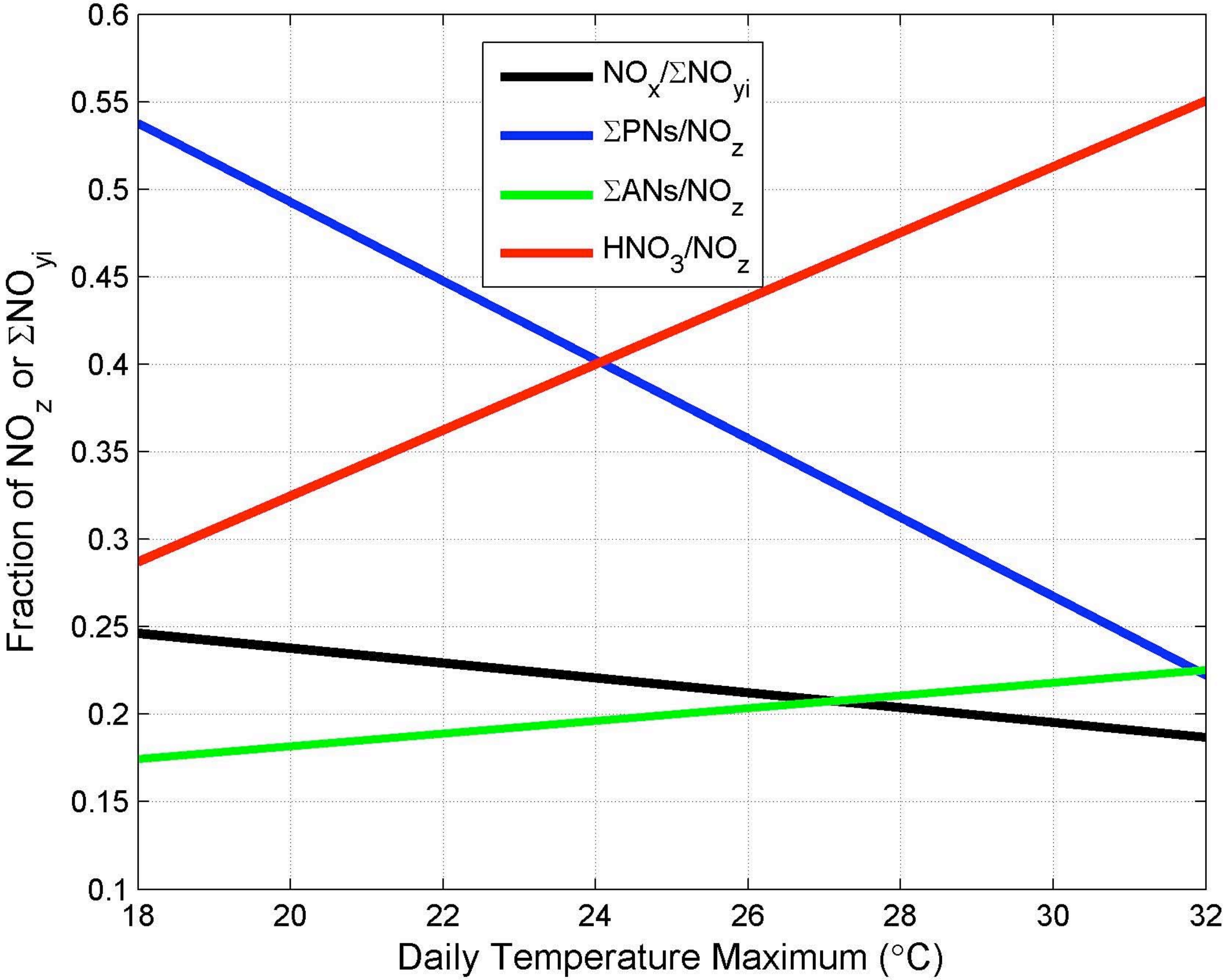


Figure 4. Best fit lines (from Figure 1) for $NO_x/\Sigma NO_{yi}$, $\Sigma PNs/NO_z$, $\Sigma ANs/NO_z$, HNO_3/NO_z vs. daily maximum temperature (T_{max}) averaged (median). Calculated from weekday only, daily averaged values averaged for hours of 12-16. See Figure 1 caption for line fit parameters.



Summary

- Factors affecting California air quality:
  - » Population growth
  - » Technology change
  - » Climate change
- Climate change “moves the goalposts” by offsetting emission control benefits
- San Francisco Bay area more susceptible than Central Valley to changes in climate/Pacific Ocean inflow

Summary of O_3 Effects