Impact of Global Climate Change on California Urban Air Quality

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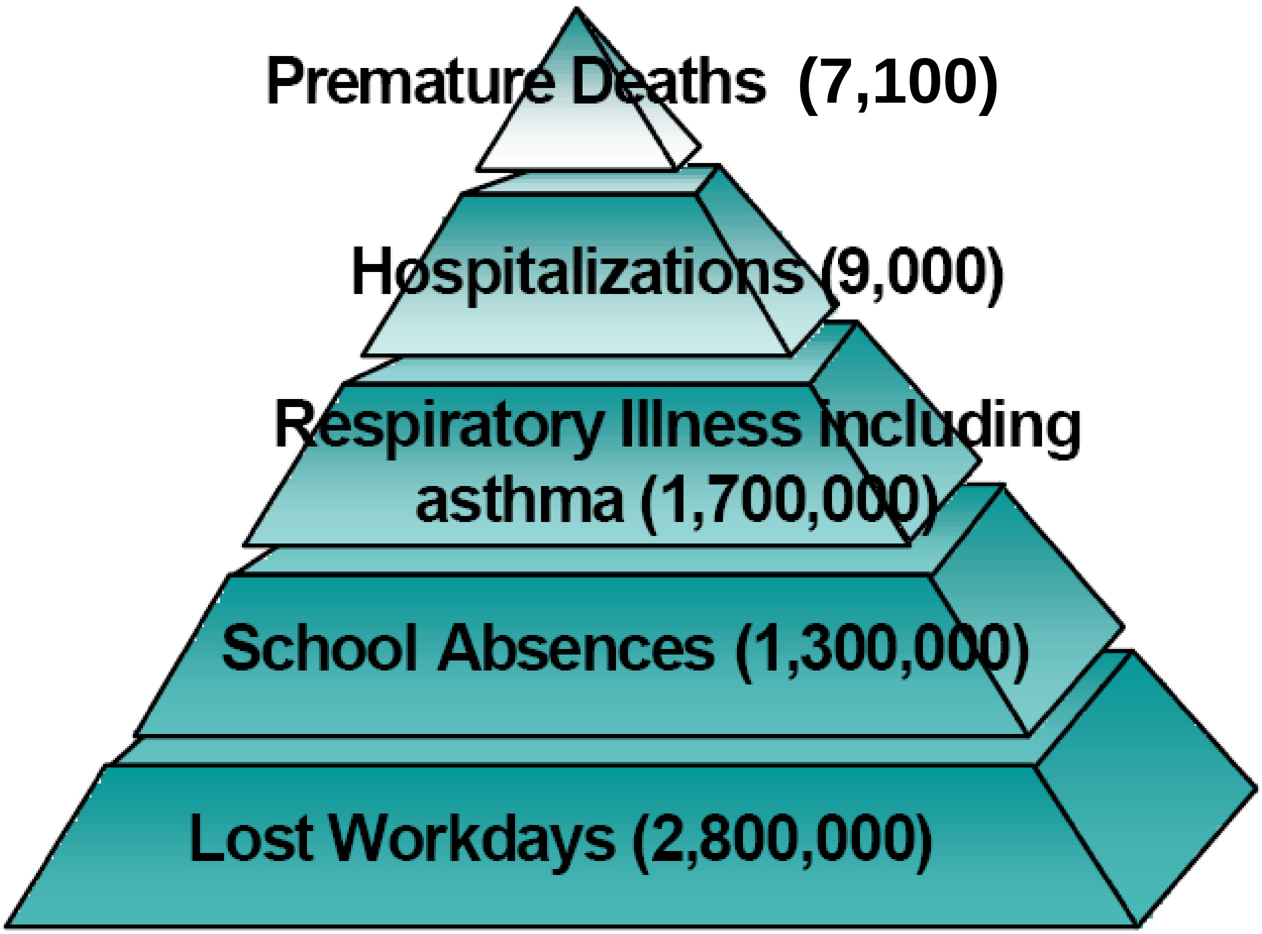
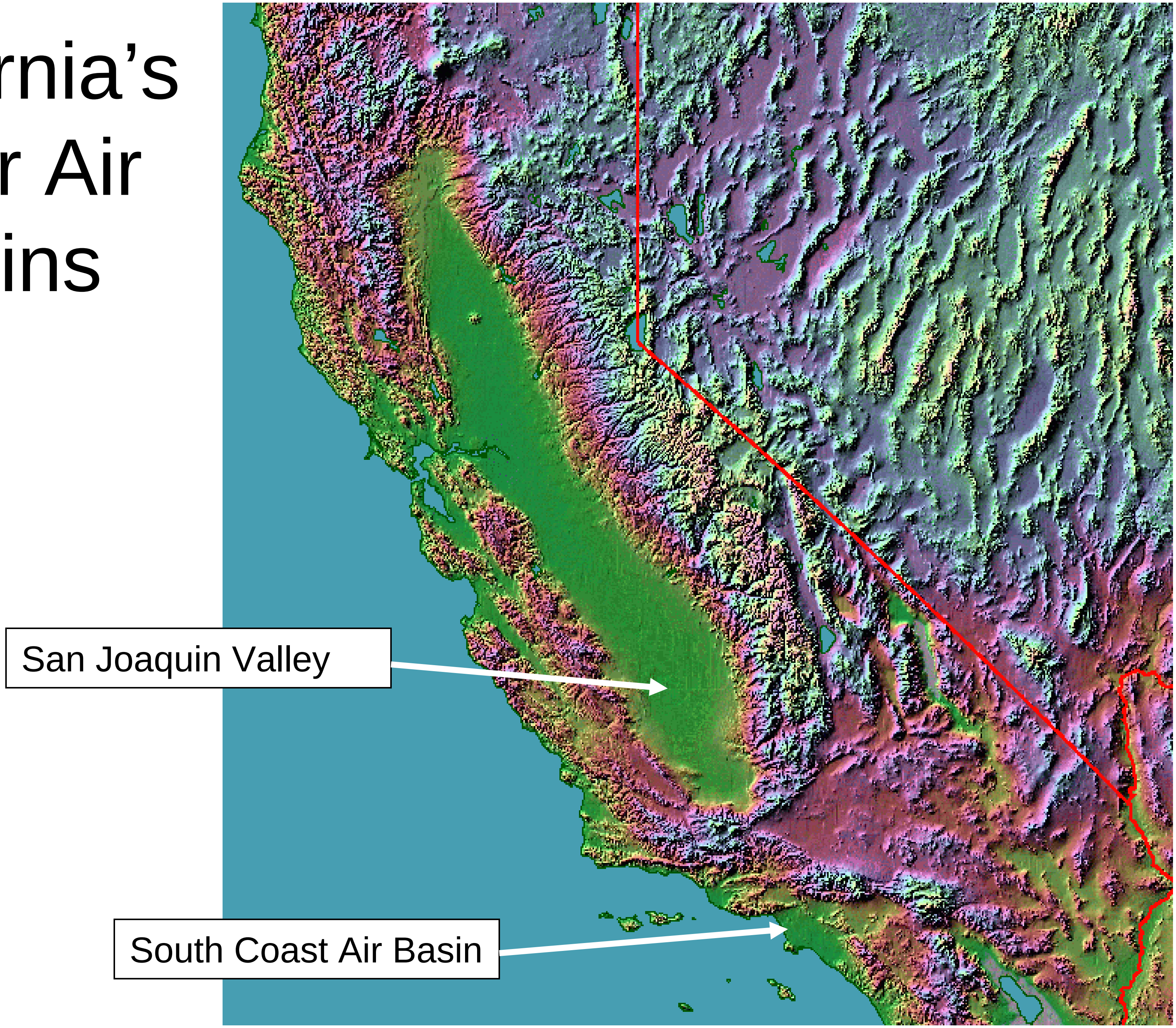
Health Impacts of Air Pollution in California (per year)



Source: Recent Research Findings: Health Effects of Particulate Matter and Ozone Air Pollution, January 2004. California Air Resources Board (http://www.arb.ca.gov/research/health/fs/PM-03fs.pdf)

California's Major Air Basins



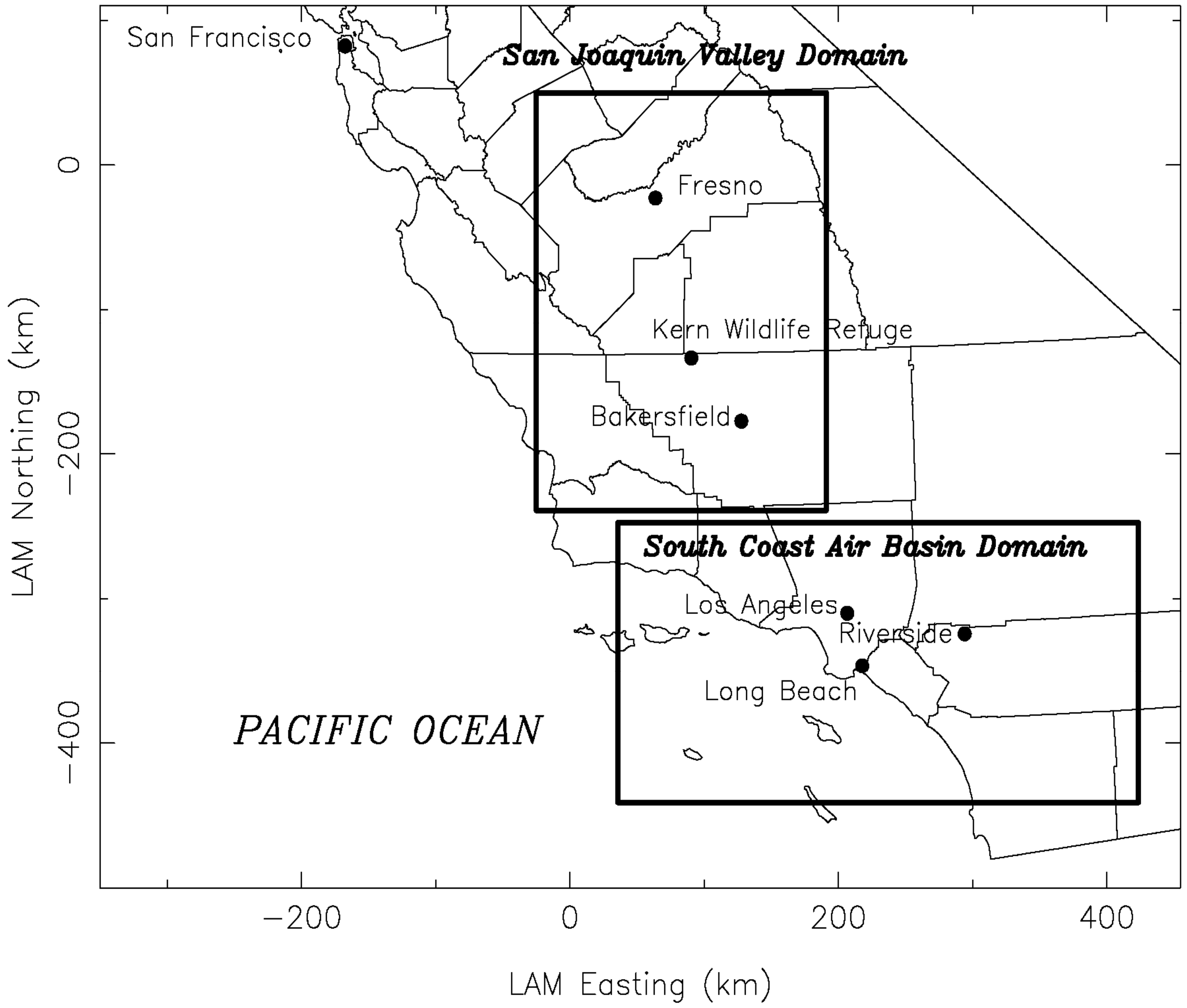
How Will Climate Change Affect Air Quality?

- Air pollution events occur when meteorology traps emissions close to the surface
- Climate change will affect multiple variables simultaneously
  - Temperature, relative humidity, wind speed, mixing depth, cloud cover, precipitation, etc.

Approach#1: Dynamic Downscaling

- Two Basic Steps:
  - GCM output drives Regional Climate Model (RCM)
  - RCM output + Emissions Inventory drives Chemical Transport Model (CTM)
- Simulate enough future ozone episodes to characterize statistical properties
- Advantages
  - Includes our full understanding of atmospheric processes
  - Can extrapolate outside of historical conditions
- Disadvantages
  - We might not understand all of the atmospheric processes
  - Limited by missing information
  - Very computationally expensive

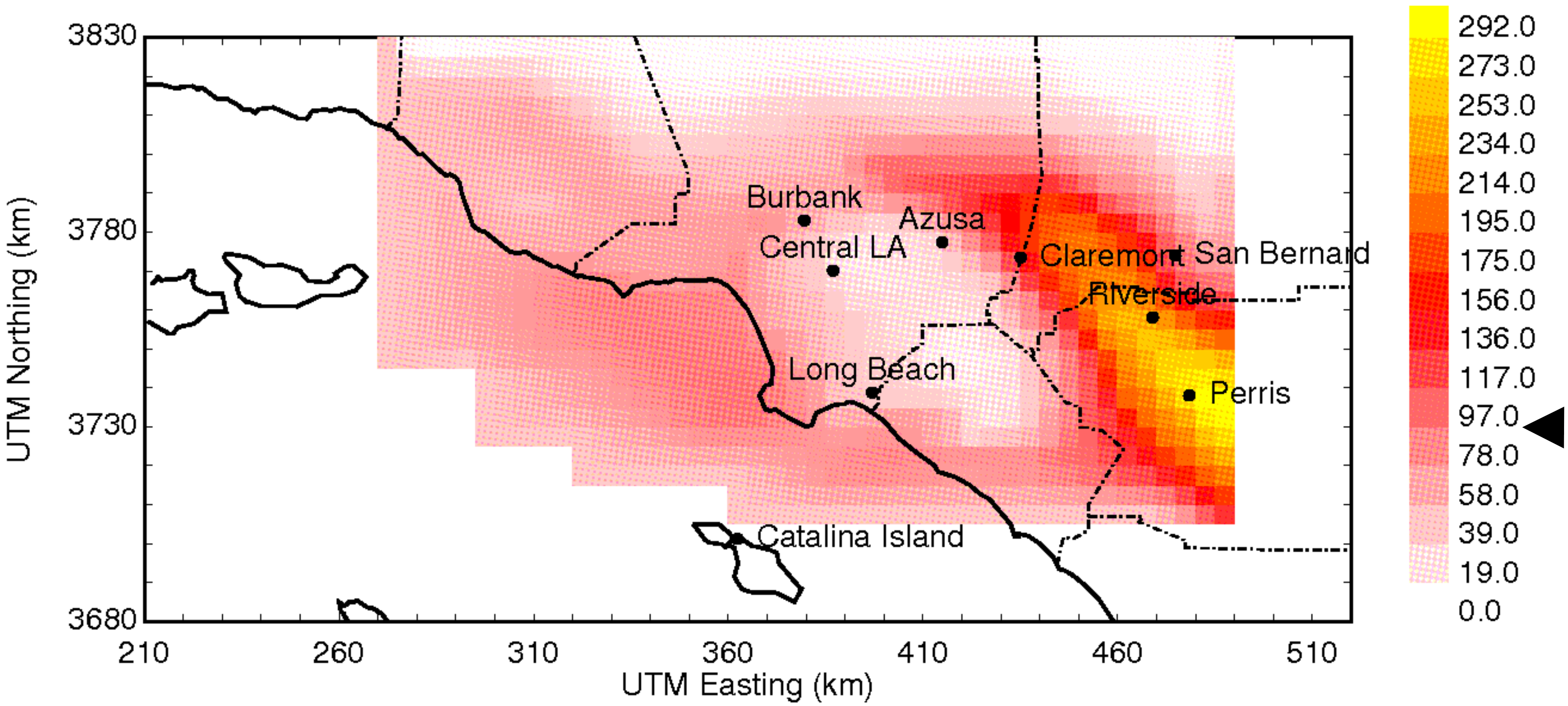
Modeling Domains



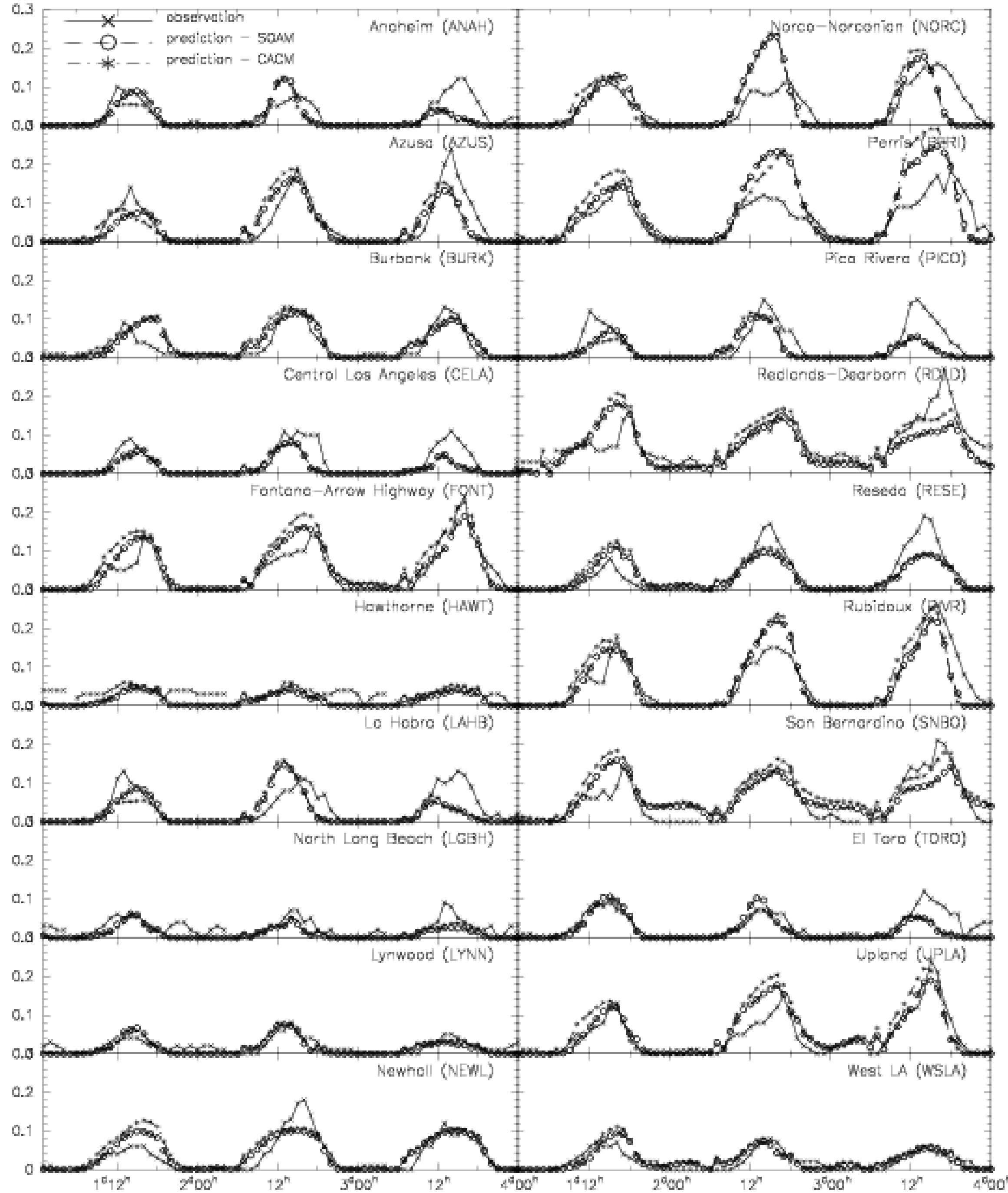
SoCAB September 7-9, 1993

- Extremely hot episode with inland temperatures greater than 35^{o}C
- Elevated temperature inversion
- Upper winds from the northwest
- Surface winds light from the west during the day, stagnant at night

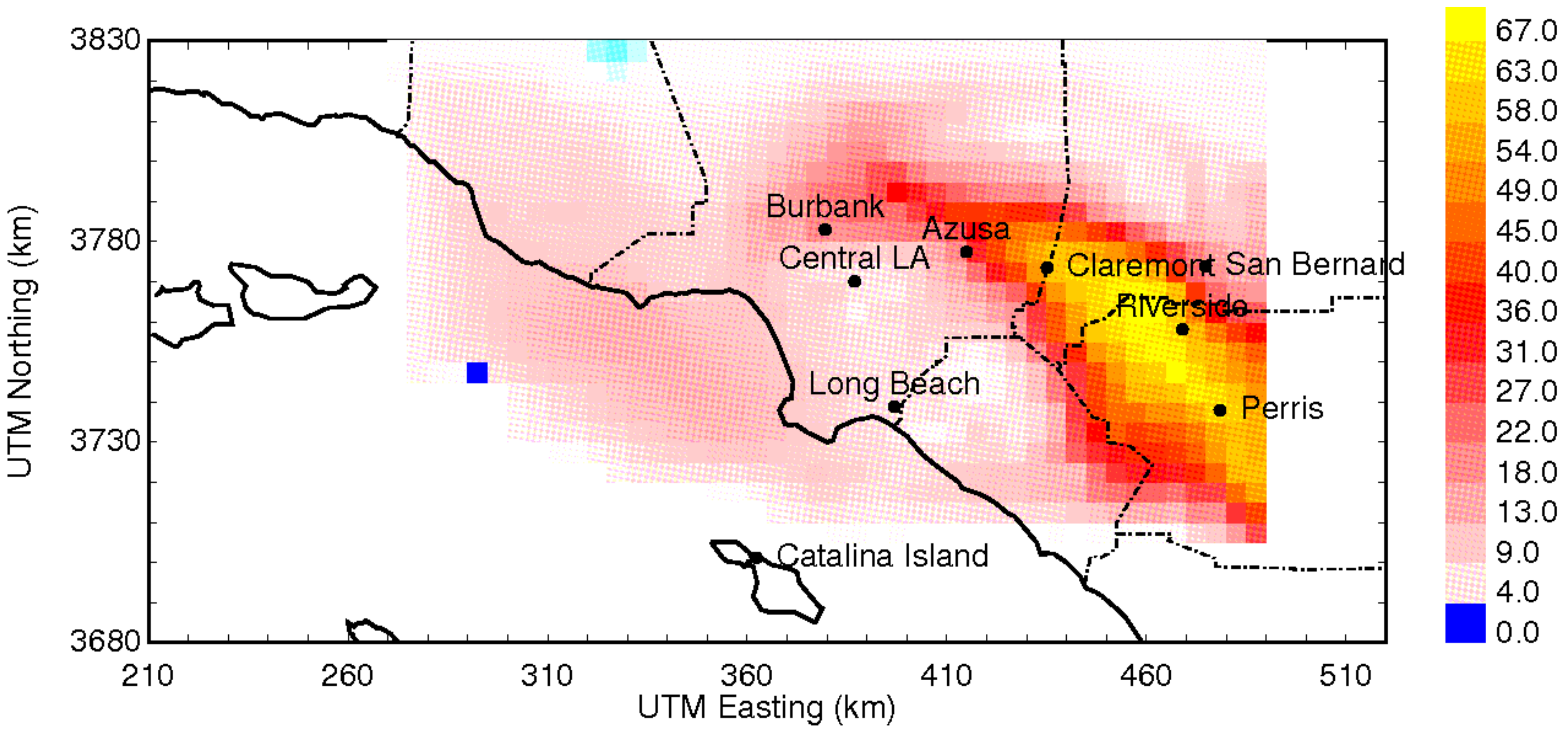
1hr-Average O3 Concentration (ppb) at 1500PST on Sept 9, 1993



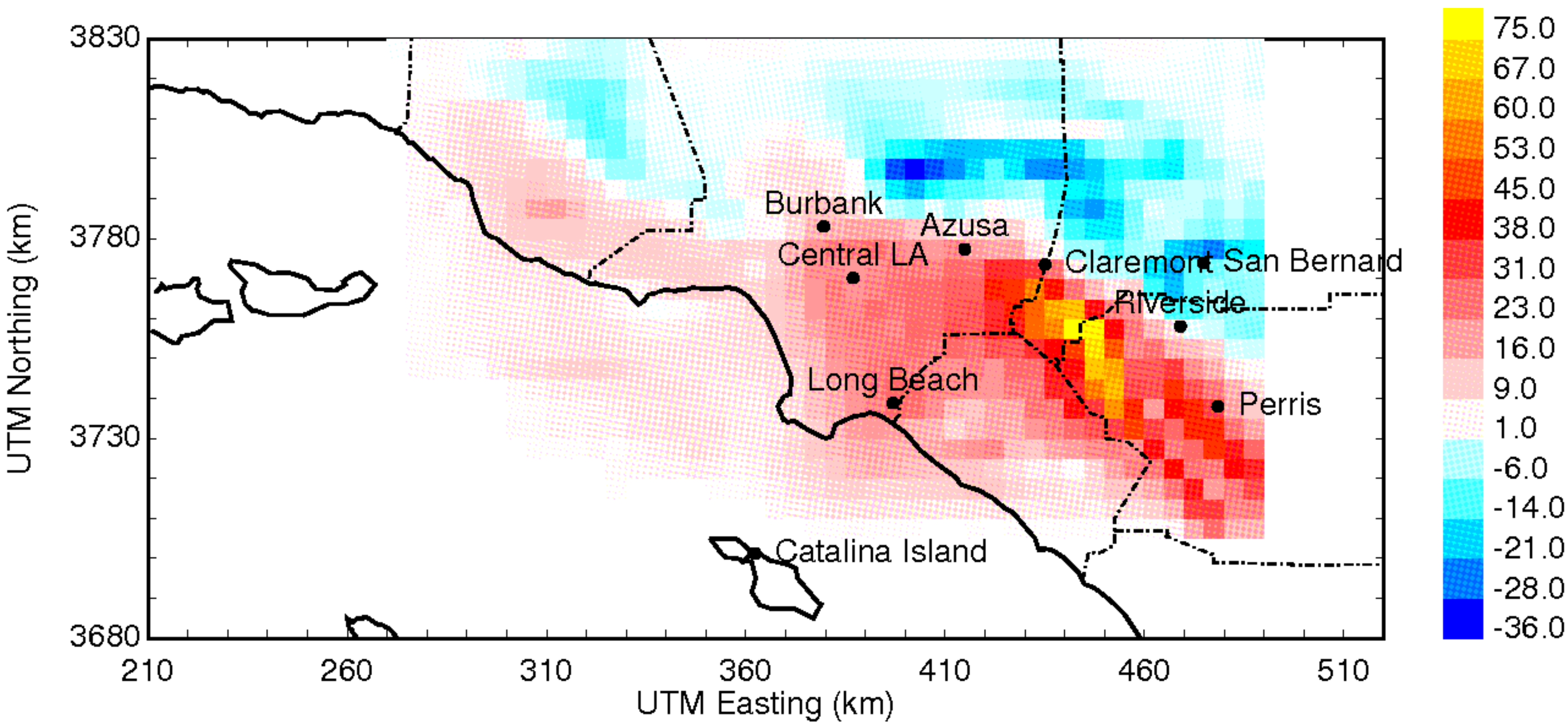
Comparison to Measurements for Ozone:



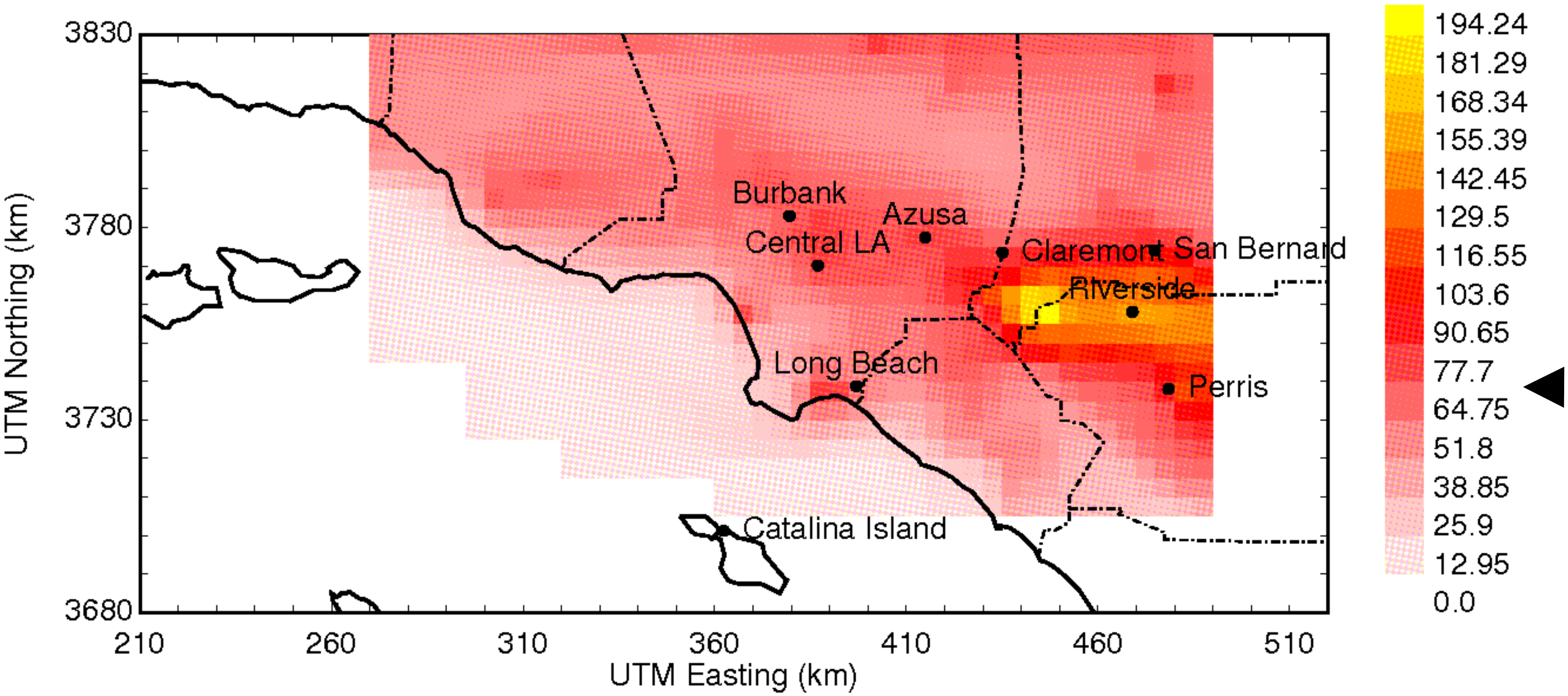
1hr-Average O3 Concentration Difference (ppb) Caused by +5K With Constant RH



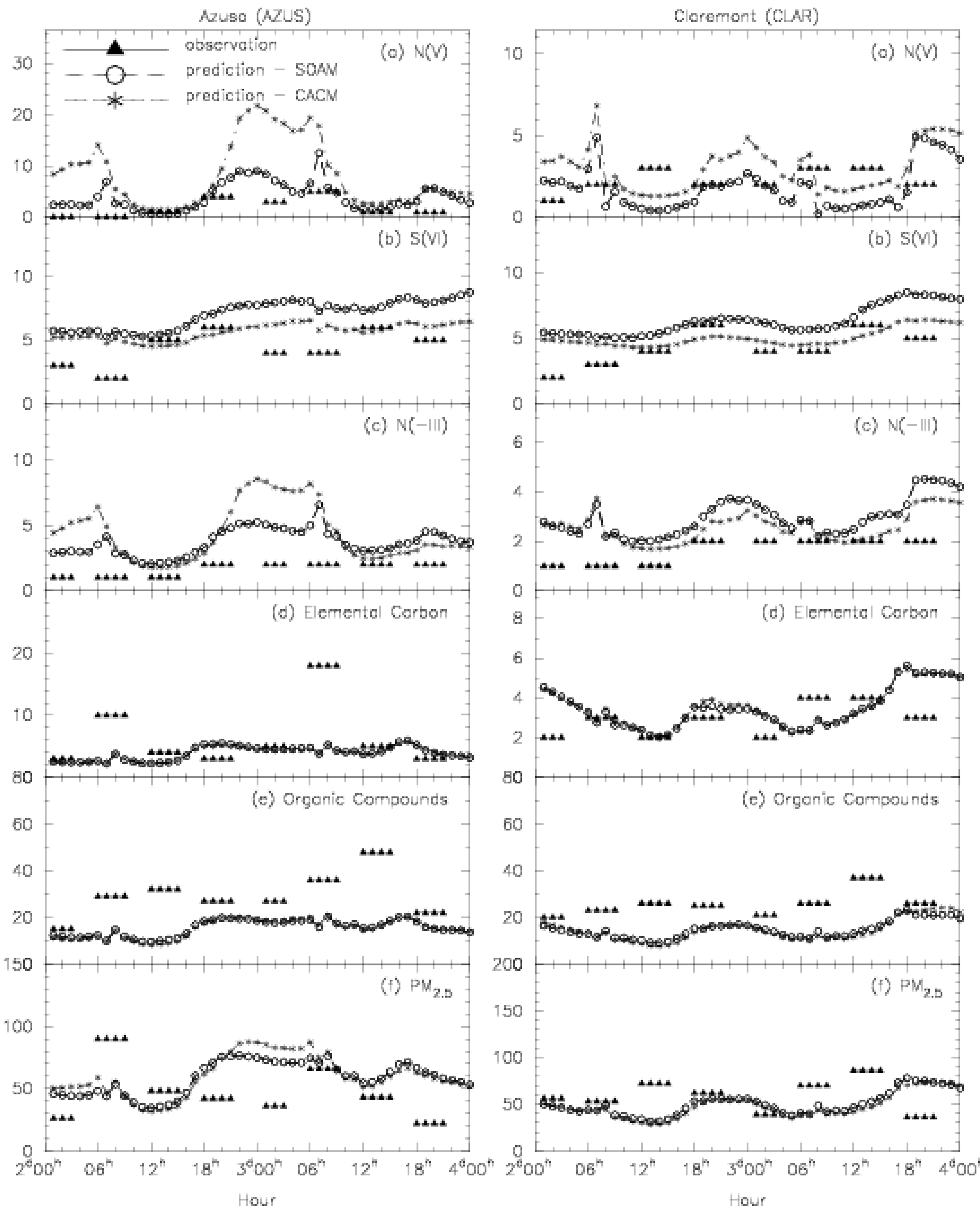
1hr-Average O3 Concentration Difference (ppb) Caused by +50% Increase in Mixing Depth



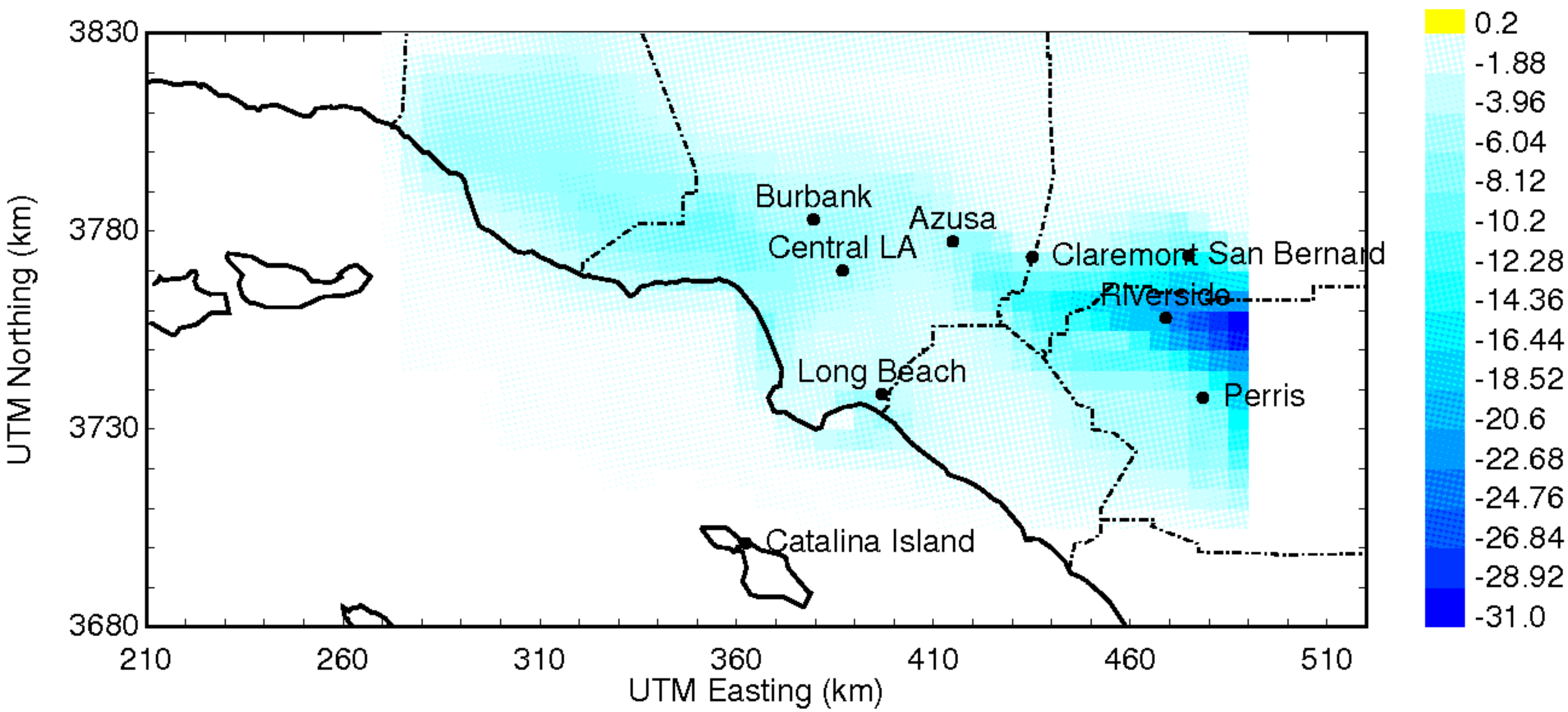
24hr-Average PM2.5 Concentration ($\mu g\ m^{-3}$) on Sept 9, 1993



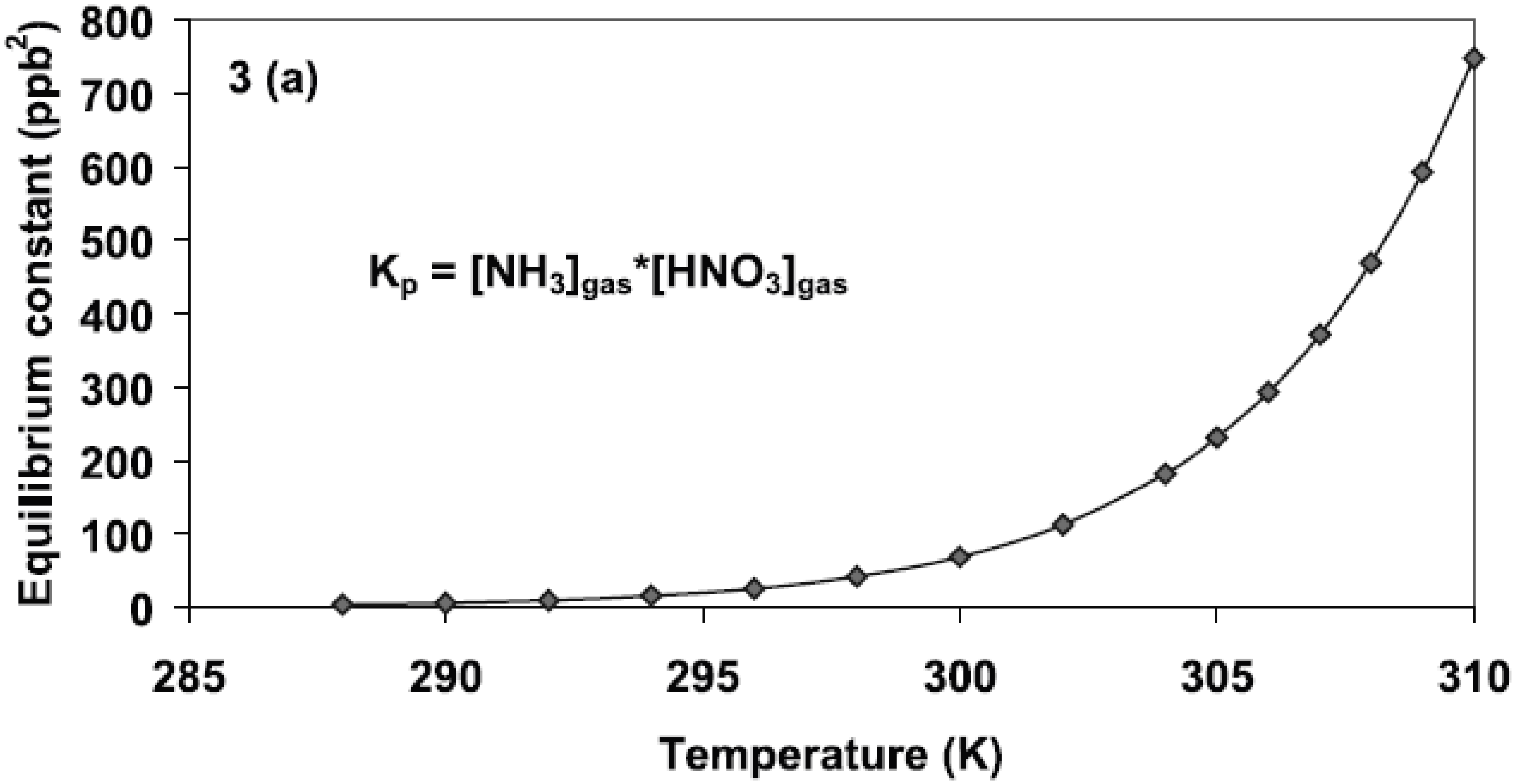
Comparison to Measurements for Particle Mass and Composition:



24hr-Average PM2.5 Concentration Difference ($\mu g\ m^{-3}$) Caused By +5K



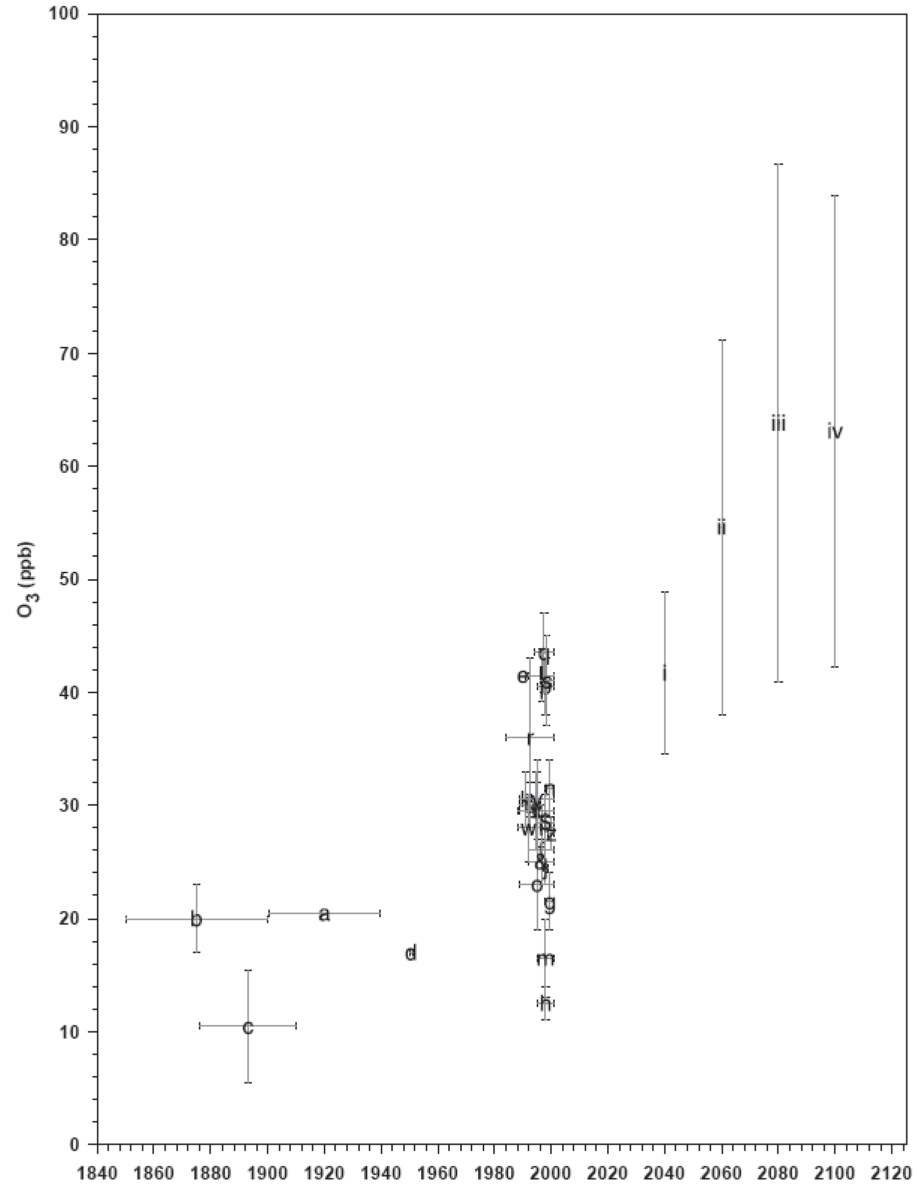
Equilibrium Dissociation Constant for Ammonium Nitrate



Trends for Background O3

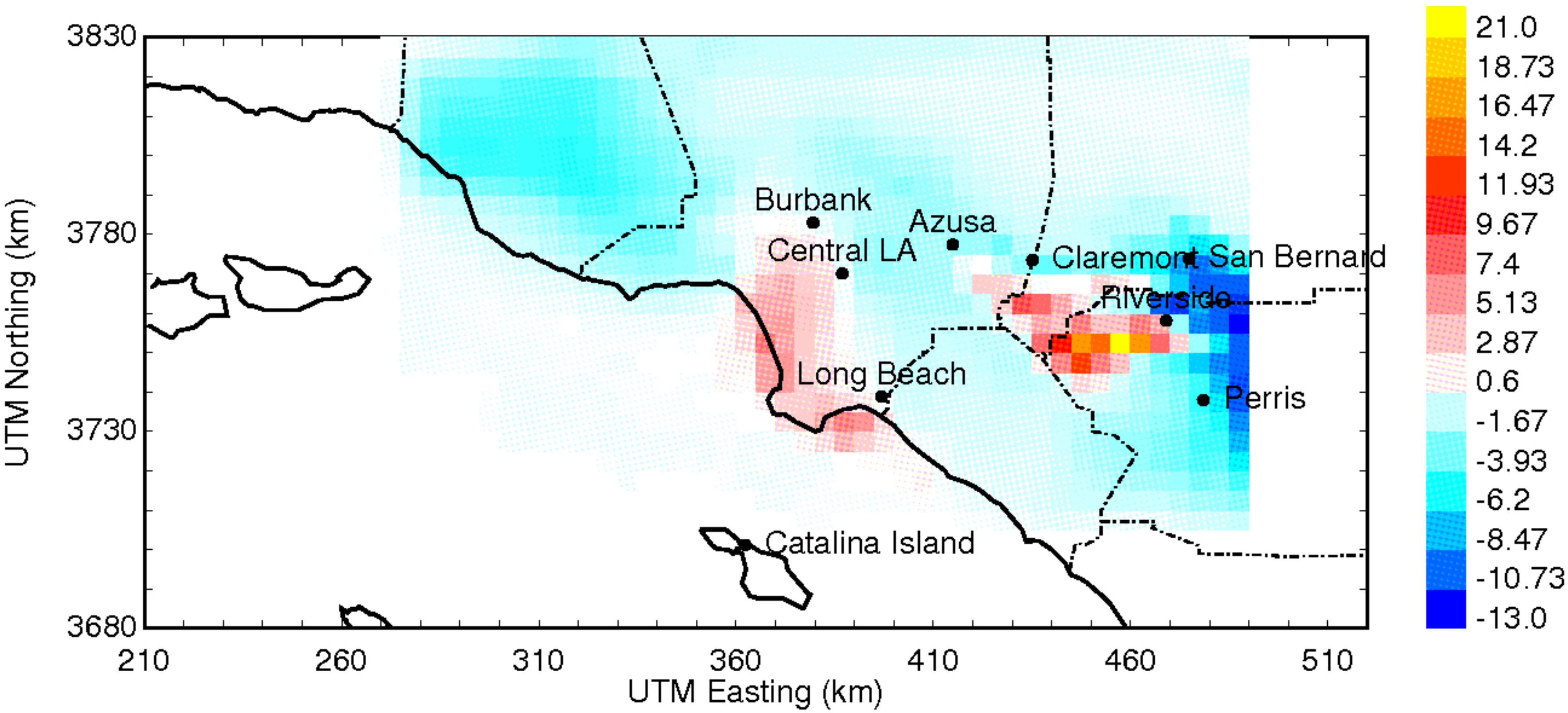
Background O3 concentrations have increased over the past 100 years.

Projections by IPCC estimate future concentrations at ~60ppb.

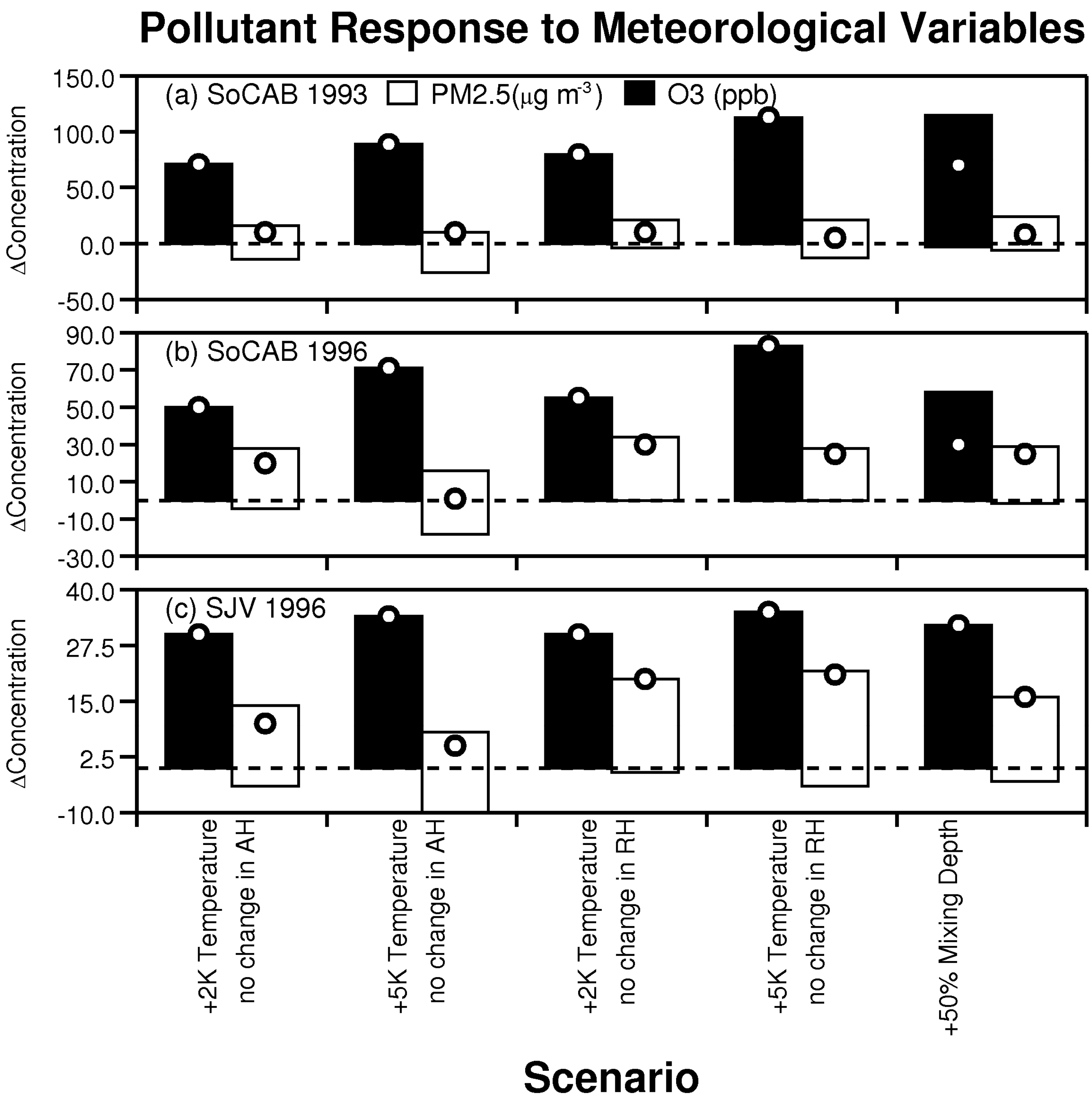


Source: R. Vingarzan, “A review of ozone background levels and trends”, Atmospheric Environment, 38: 3431-3442.

24hr-Average PM2.5 Concentration Difference ($\mu g\ m^{-3}$) Caused By +5K With Constant RH and 60ppb Background O3



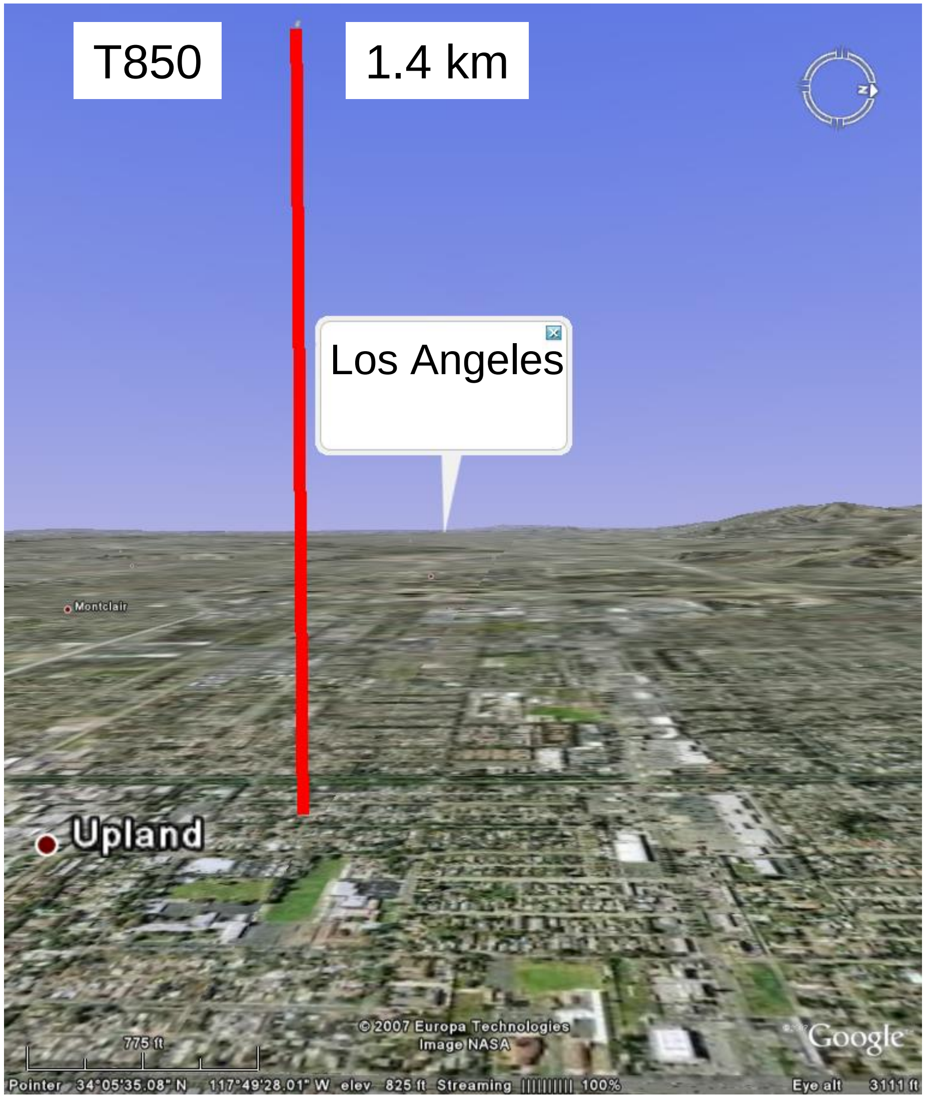
Summary of Pollutant Response Across All Episodes (with 60ppb Background O3):



Approach #2: Statistical Downscaling

- Use historical measurements to find relationship between ozone and meteorology
- Directly predict future ozone concentrations based on GCM output
- Advantages
  - Skips the computationally expensive stuff in the middle
  - Based on observed behavior, so guaranteed to be correct for historical conditions
- Disadvantages
  - Black box approach
  - Dangerous to extrapolate outside historical conditions

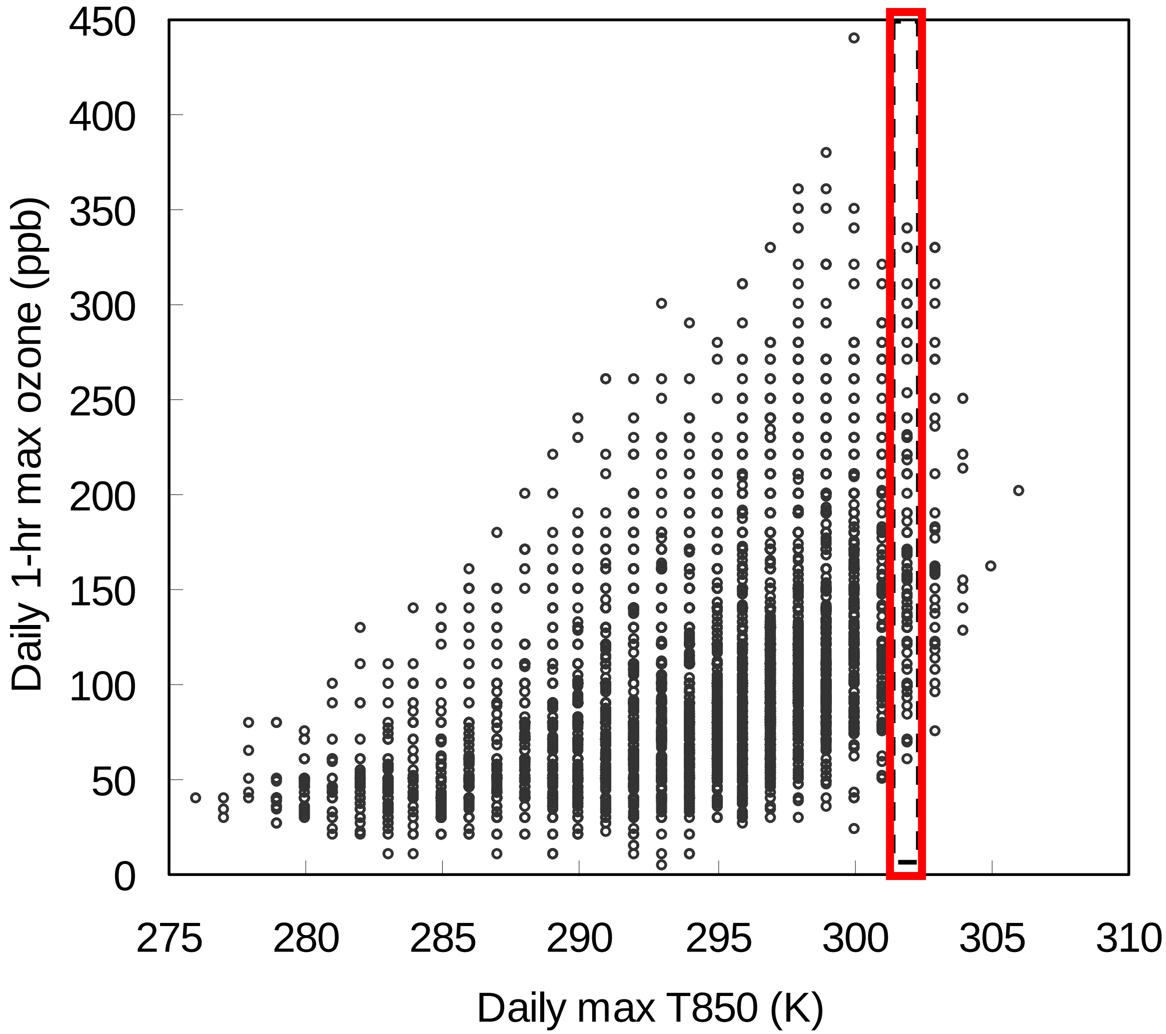
Statistical Downscaling for Ozone With Upper Air Temperature (T850)



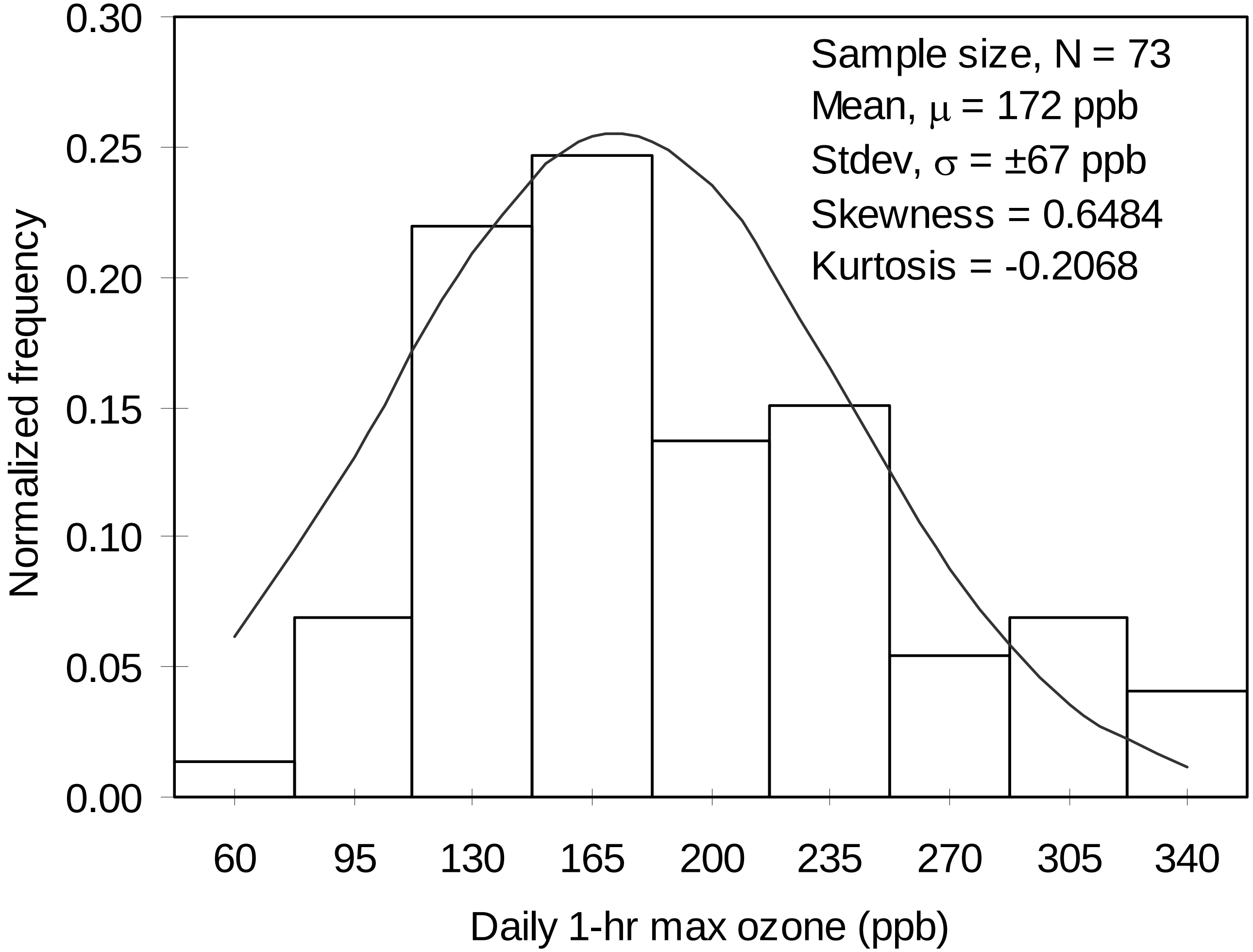
Why Should T850 be correlated with Surface Ozone?

- Ozone is formed in the atmosphere and mixes to the surface
- Warmer temperatures increase the speed of chemical reaction
- Warmer temperatures increase the rate of emissions for organic compounds
- A layer of warmer air above cooler air is stable
  - Caps the atmosphere trapping pollutants

Observed Ozone Concentrations vs T850 at Upland (SoCAB), CA (1980-2004)

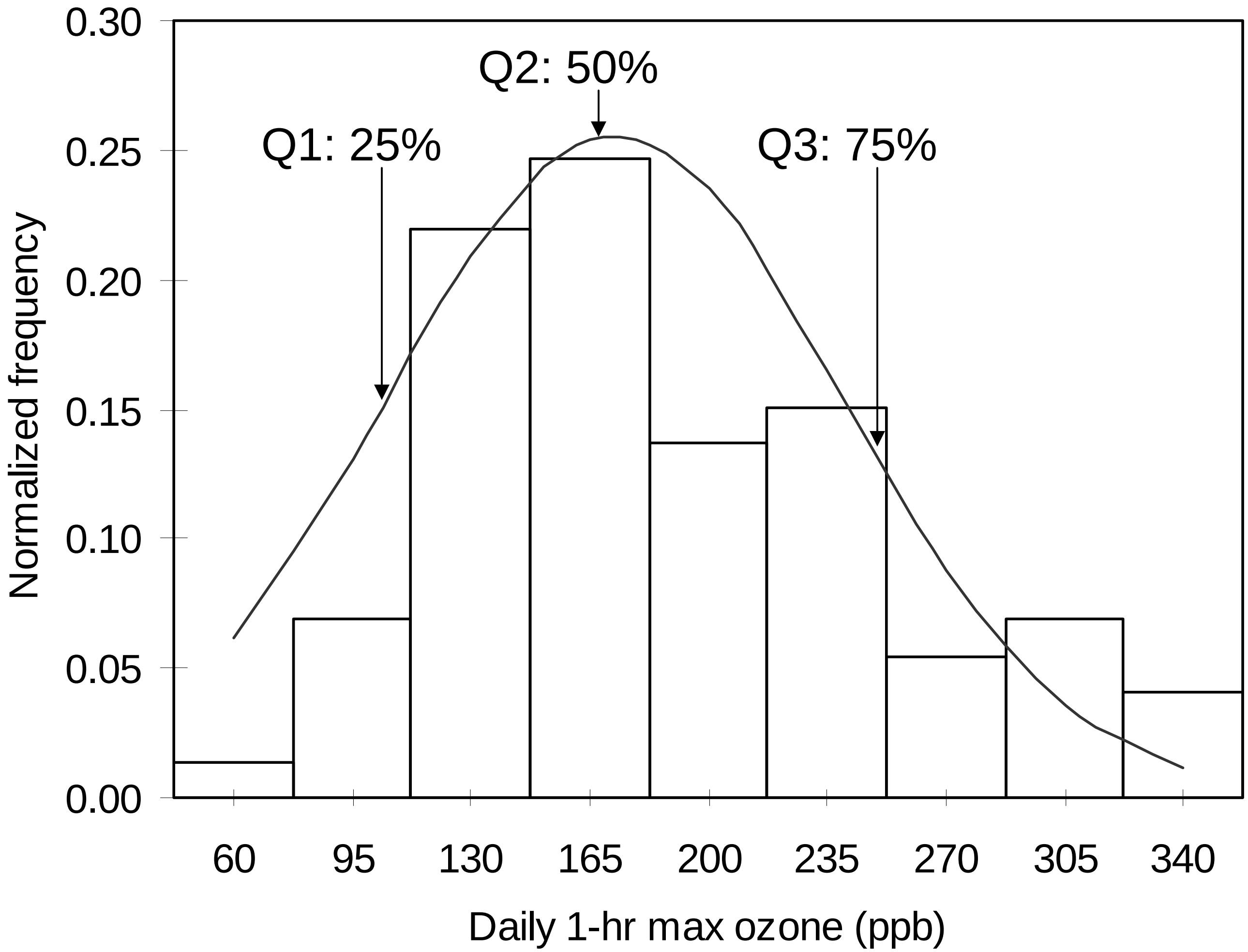


Frequency Distribution: Observed daily 1-hr max ozone concentrations for T850=302K Upland (SoCAB), CA (1980 - 2004)

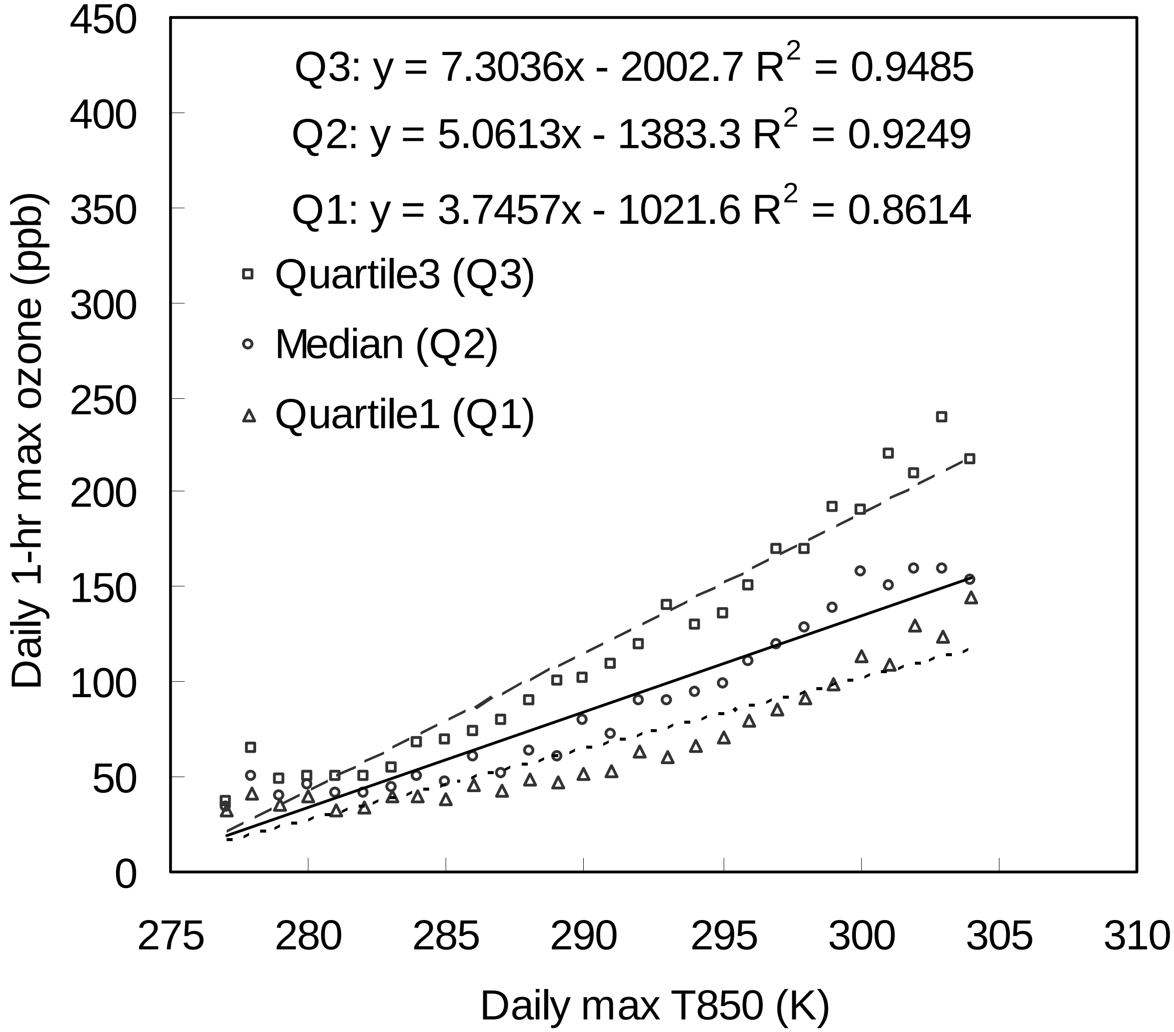


Ozone Quartile Concentration Ranges

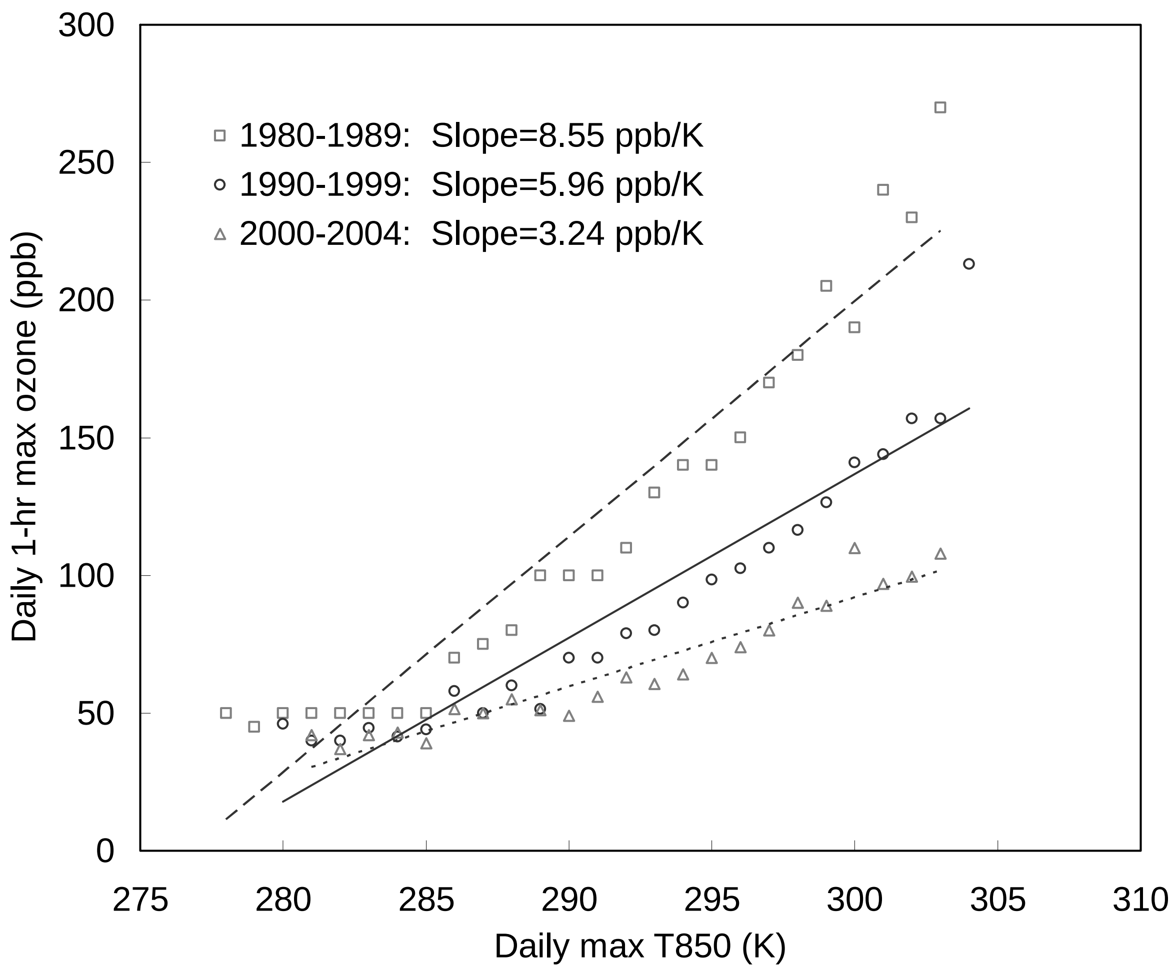
Q1 – 25% of all values below
Q2 – 50% of all values below
Q3 – 75% of all values below



Quartile Ozone Concentrations vs.T850 at Upland CA (1980-2004)



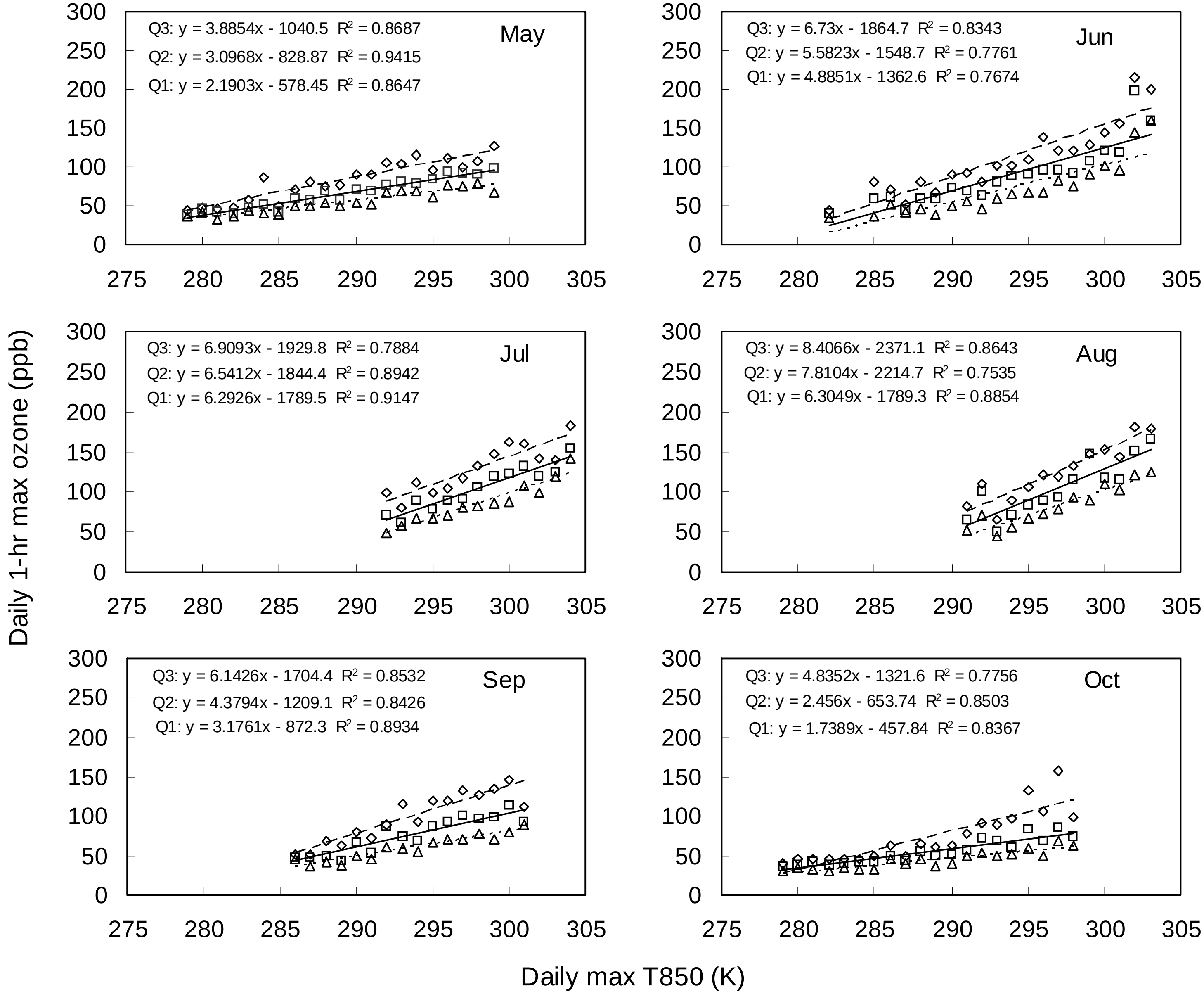
Long Term Trends Are Apparent in the Measured T850 vs. Ozone Relationship



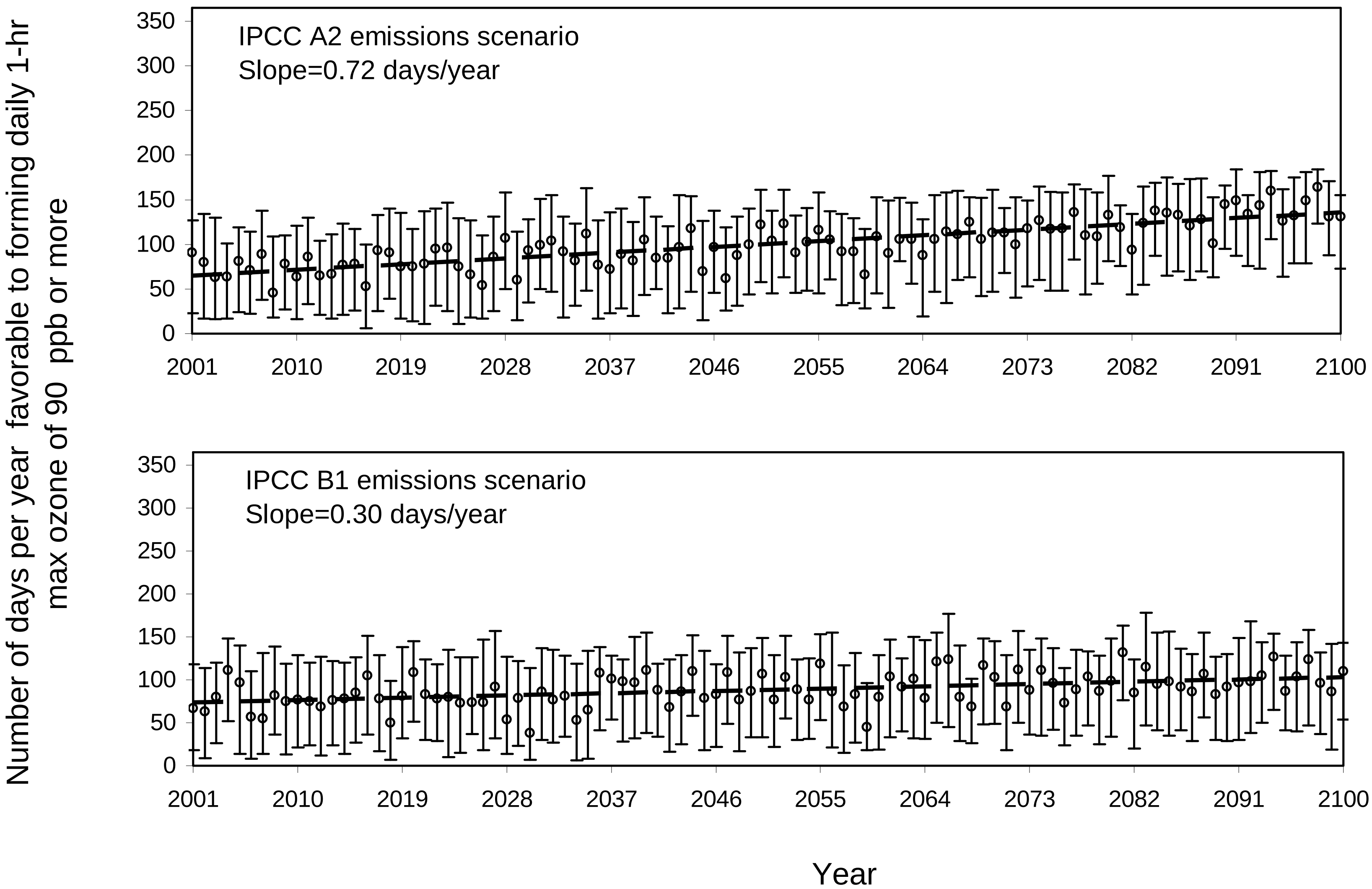
Seasonal (Monthly) Trends in the Ozone-T850 Relationship

Upland, CA

(1990 – 2004)



Number of Days per Year Conducive to Forming 1-hr Max Ozone > 90 ppb in Southern California.



Conclusions

- Increased temperatures
  - favor the formation of more ozone
  - encourages evaporation of ammonium nitrate
- Increased background O3
  - produces higher nitrate concentrations
- Increased humidity
  - favors the formation of ozone and ammonium nitrate
- Increased mixing depths provide more dilution of primary emissions
  - Lowers primary PM2.5
  - May increase ozone and secondary PM2.5

Conclusions

- Statistical downscaling of ozone results provides an efficient method to estimate future ozone concentrations
- Long-term emissions trends account for most of the scatter in the historical ozone-T850 relationship
- Seasonal variation in ozone-T850 relationship is likely caused by biogenic effects
- Future increases in temperature will encourage more ozone formation
  - SoCAB: A2=0.7days/yr; B1=0.3 days/yr
- California will need additional emissions reductions to compensate for this “Climate Penalty”

Acknowledgements

- United States Environmental Protection Agency Project#R-82824201-01
- California Air Resources Board Contract # 04-349