Climate Impacts on Airborne Particle Concentrations in California: Implications for Atmospheric Deposition

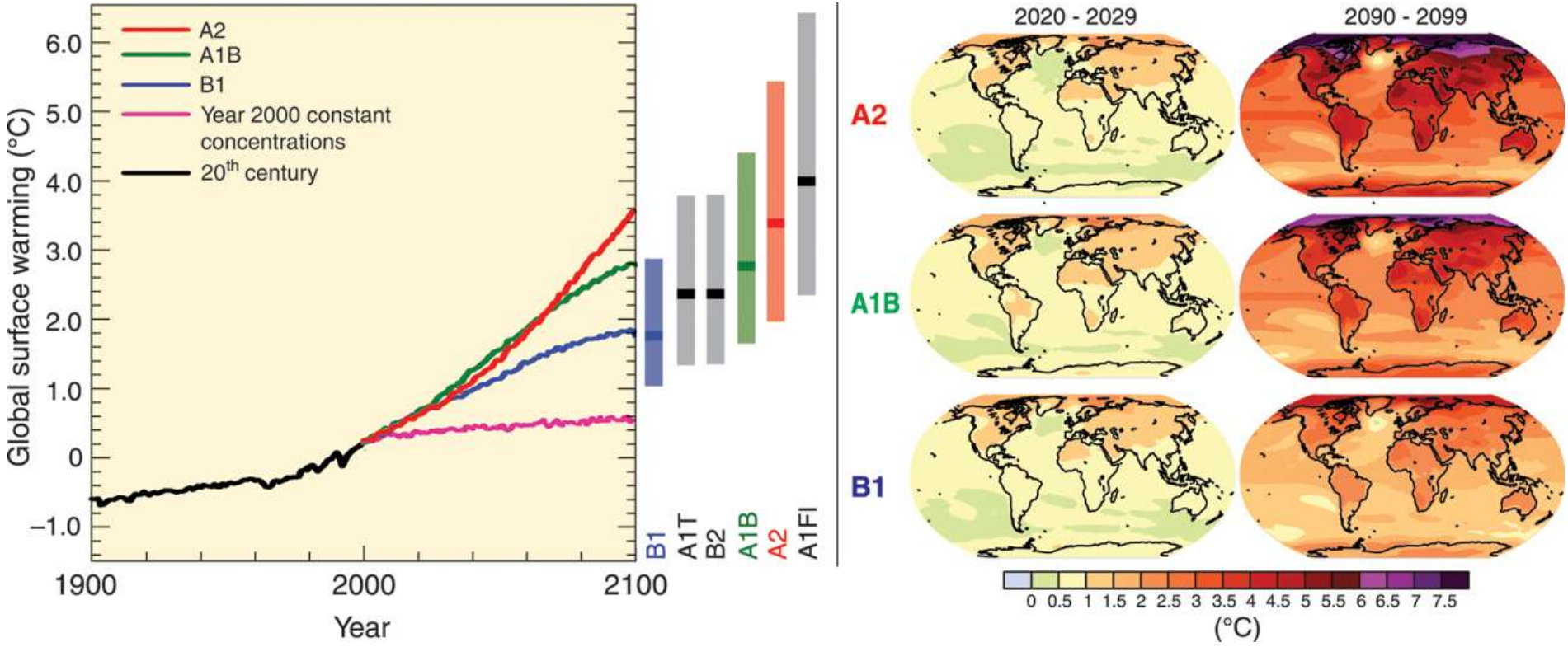
Abdullah Mahmud[1], Mark Hixson[1], Zhan Zhao[2], Shuhua Chen[2], and Michael Kleeman[1]

[1]Civil and Environmental Engineering UC Davis

[2]Atmospheric Science, UC Davis

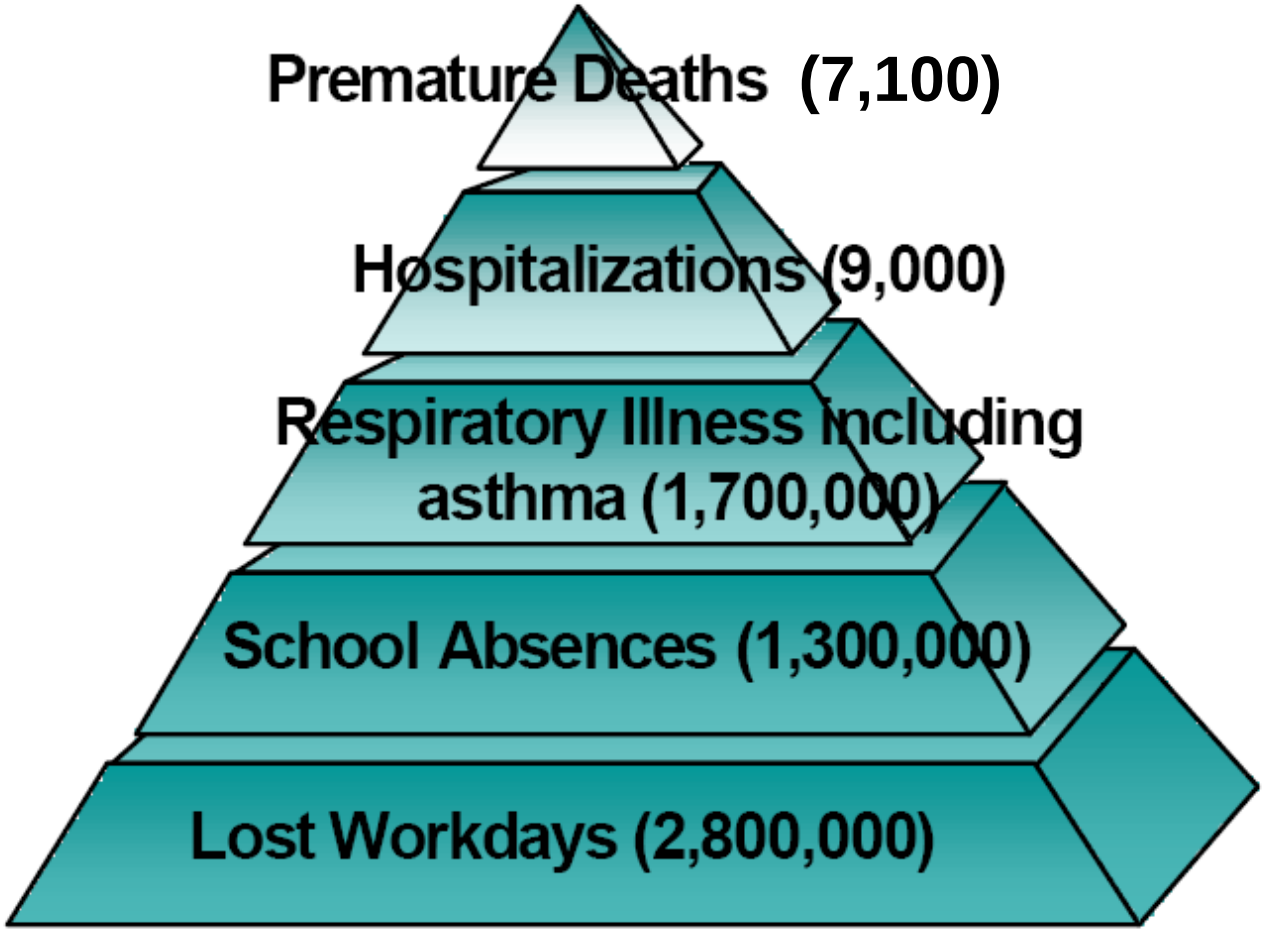
March 18, 2008

Problem: Climate Change Alters Atmospheric Conditions That Will Influence Air Pollution



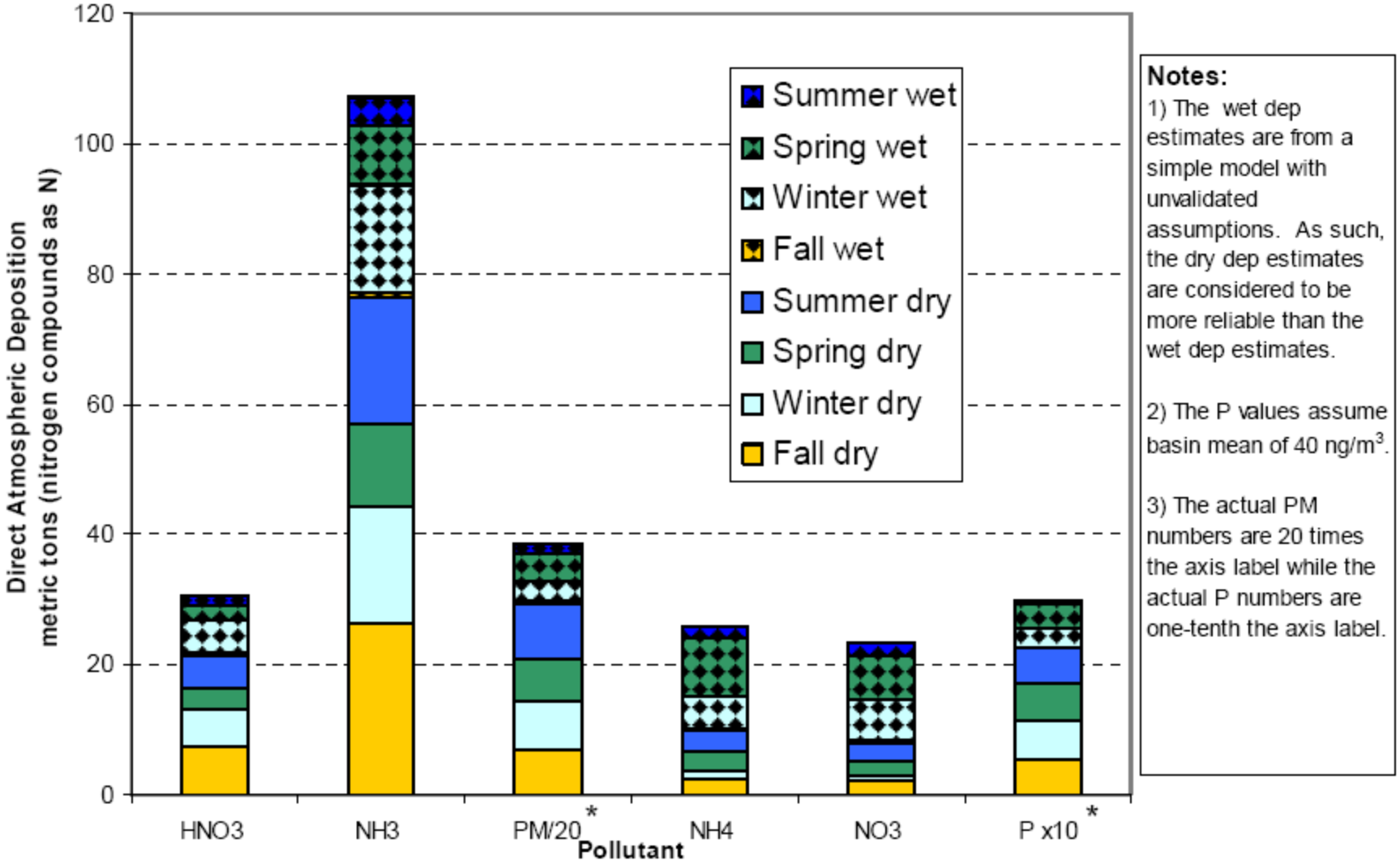
Source: IPCC Fourth Assessment Report, Climate Change 2007. Intergovernmental Panel on Climate Change, http://www.ipcc.ch/graphics/gr-ar4-syr.htm.

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)

Figure ES-1. LTADS Central Estimates of Seasonal Total Atmospheric Deposition to Lake Tahoe
(metric tons/year)*

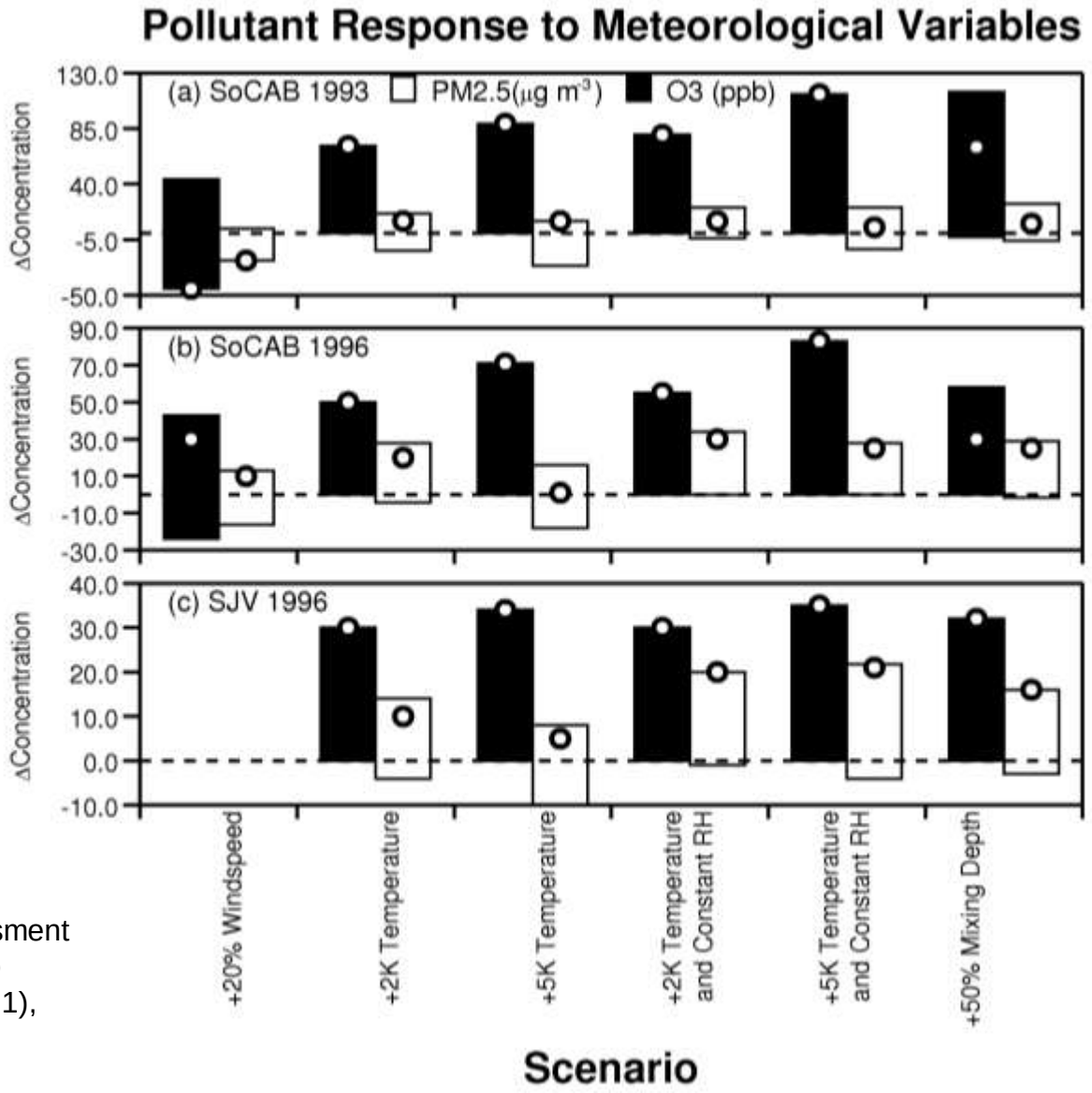


* Note adjustment to PM and P values. Actual PM dep is 20 times greater and actual P dep is 10 times less than indicated on Y-axis.

Source: Lake Tahoe Atmospheric Deposition Study, Final Report Sept 2006. California Air Resources Board (http://www.arb.ca.gov/research/ltads/final/intro.pdf)

Problem: How Will PM2.5 Respond?

Summary of Pollutant Response Across All Episodes:



Source: Kleeman, M.J. A Preliminary Assessment of the Sensitivity of Air Quality in California to Global Change. Climatic Change, 87 (Suppl 1), pp273-292, 2008.

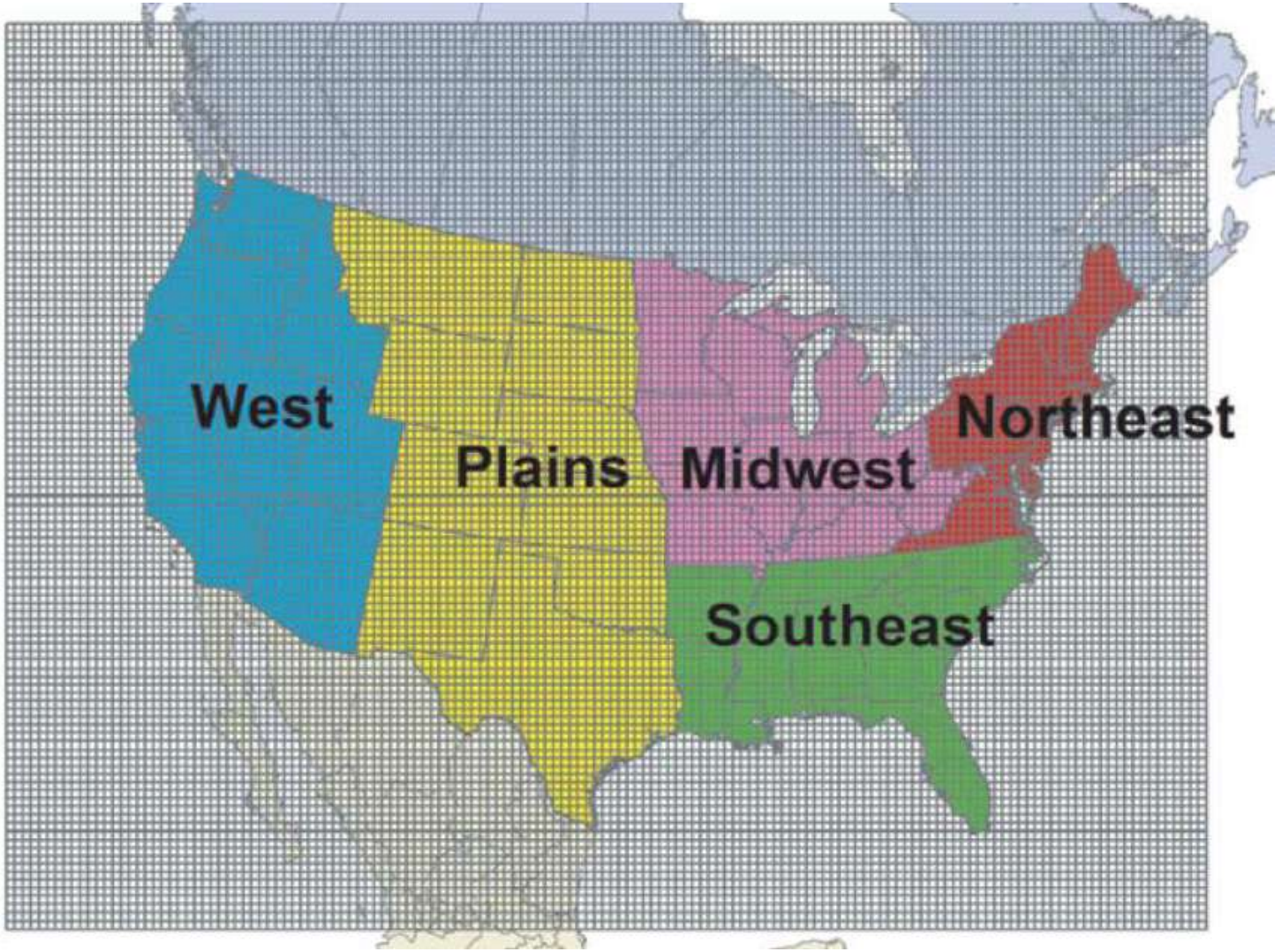
Previous Work

36KM Grids

1 Year Full Comparison (2001 vs. 2050)

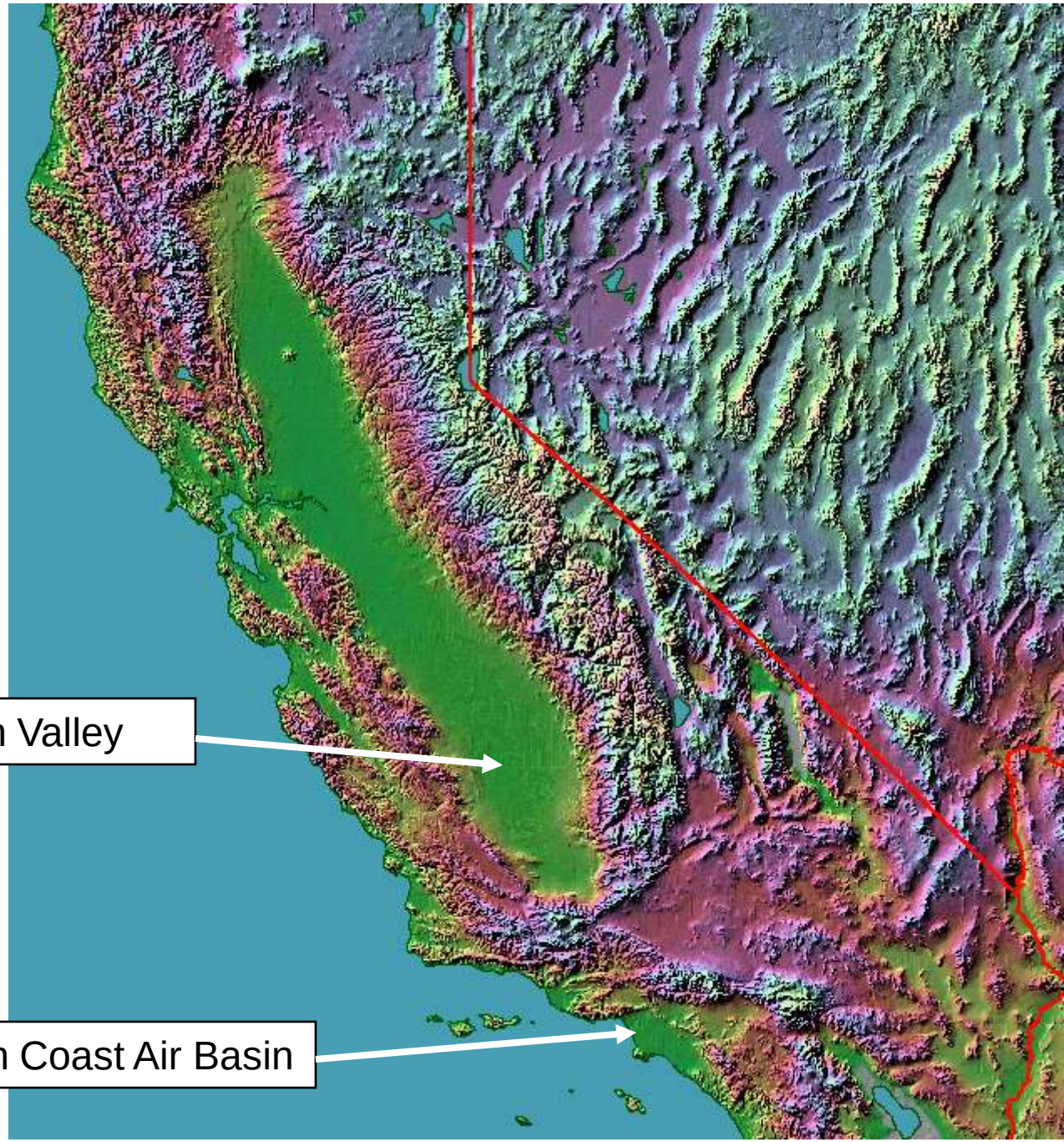
3 Years Partial Comparison

(2000-02 vs. 2049-51)



Source:Tagaris E, Manomaiphiboon K, Liao KJ, Leung LR, Woo JH, He S, Amar P, Russell AG. Impacts of global climate change and emissions on regional ozone and fine particulate matter concentrations over the United States. Journal of Geophysical Research 10.1029/2006JD008262 (2007).

California's Major Air Basins



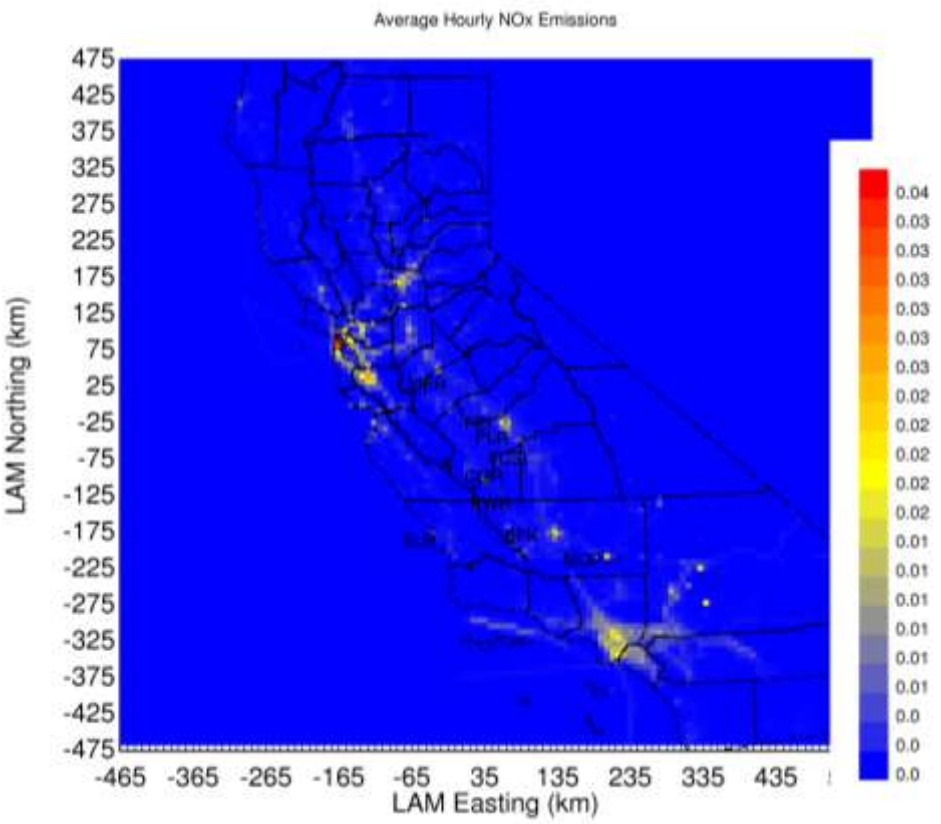
Current Approach: PCM Downscaling

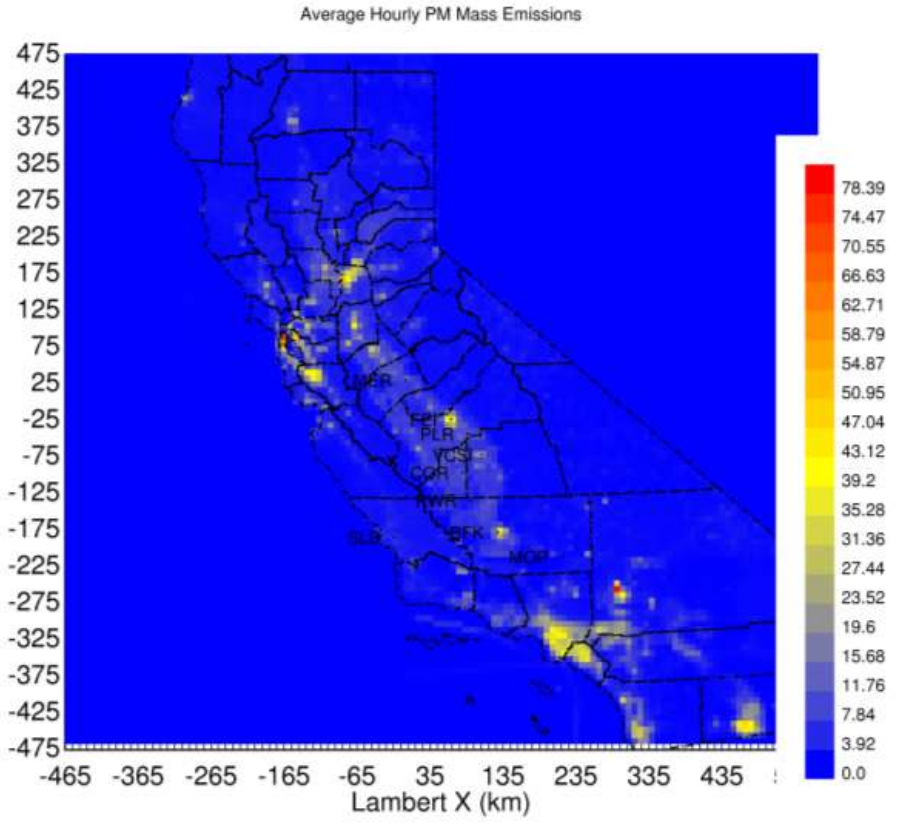
- Parallel Climate Model simulations
  - Business as usual emissions scenario
  - 2000-06 and 2047-2053
  - Approximately 100km resolution
- Down-scaling to 4km resolution using the Weather Research Forecast Model
  - No data assimilation
  - Up-scaled to 8km for air quality models
- 7 Year Simulation Windows to Capture Enso
  - 2000-06 vs. 2047-53

Current Approach: Emissions

- State-wide Inventory
  - CARB (NOx, SOx, VOC, NH3, PM)
- SoCAB Inventory
  - AQMD (NOx, SOx, VOC, PM)
  - CIT/UCD (NH3)
- Biogenic Temperature Correction
  - CARB biogenic model (hourly average)
- Mobile Source Temperature Correction
  - EMFAC (hourly average)

NOx and PM Emissions Example





SJV: 25,000 sq miles
NOx = approx 500 tons/day
SoCAB: 6,500 sq miles
NOx = approx 1000 tons/day

SJV: 25,000 sq miles
PM10 = approx 180 tons/day
SoCAB: 6,500 sq miles
PM10 = approx 400 tons/day

Current Approach: Air Quality Model

- UCD-CIT Source-oriented Air Quality Model
  - Carter 1990 photochemical mechanism with updates to key-rate constants
  - Fully dynamic exchange between gas and particle phase
  - Full decomposition of gas-phase rxns to track source contributions to secondary particulate nitrate, sulfate, and ammonium ion
  - Internal tracers to track source contributions to primary particulate matter
- 153 days simulated in 5-6 days of real time
- 28 simulated years in 5-6 months

Air Quality Model

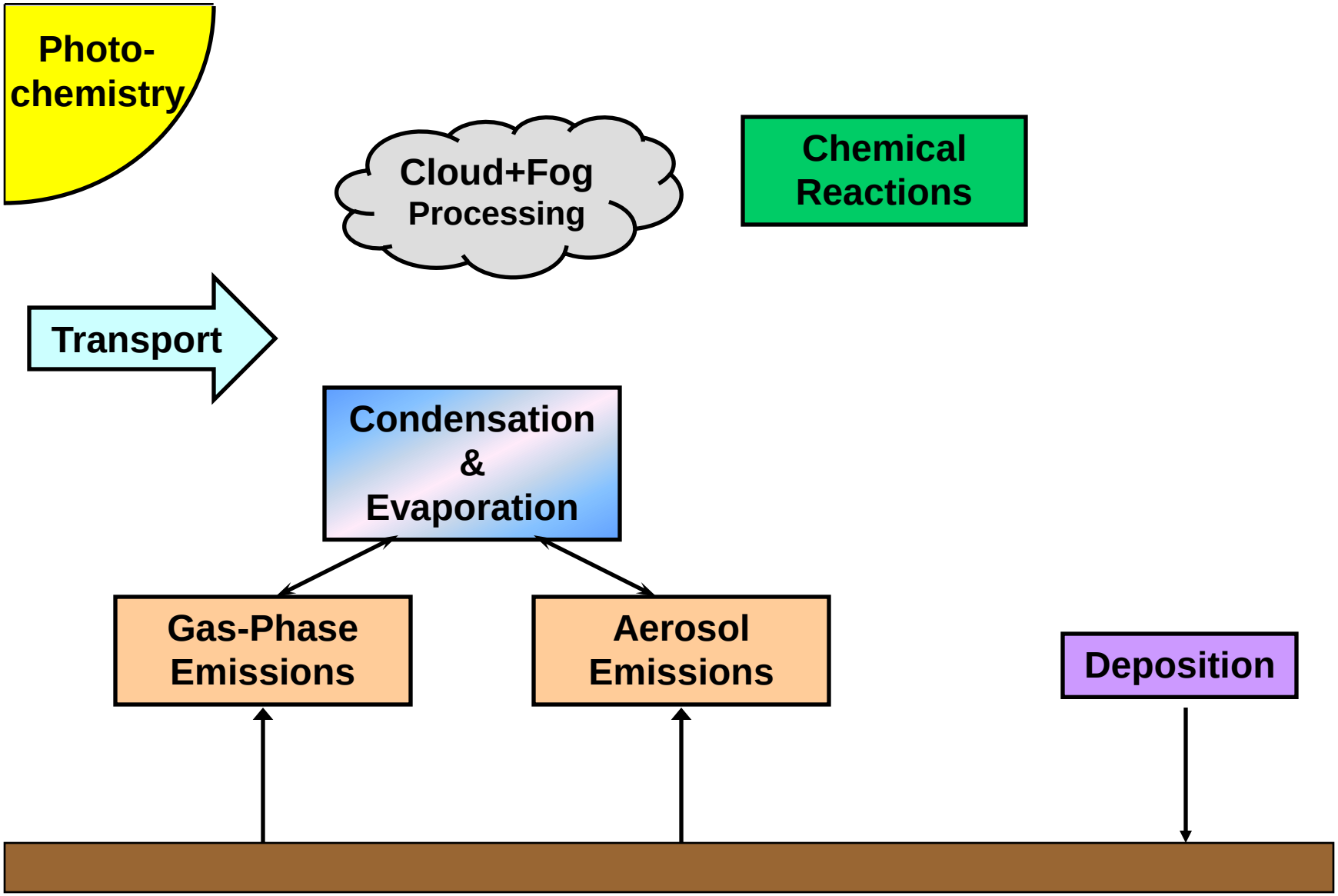
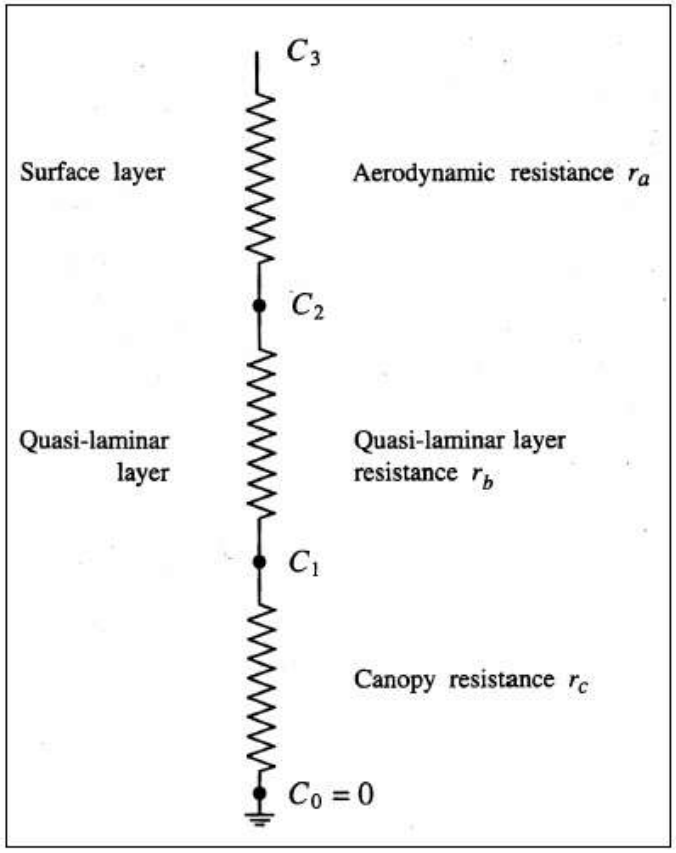
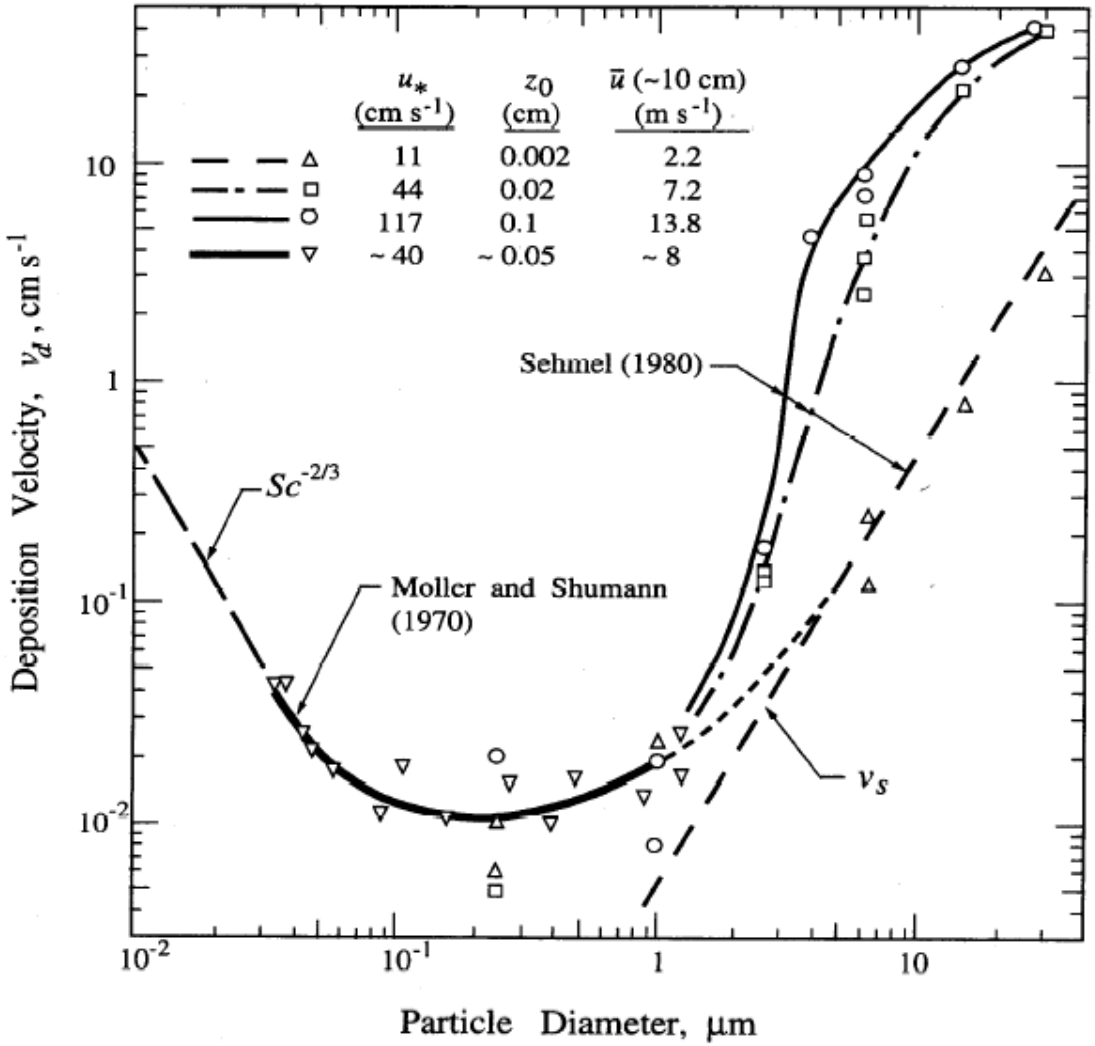


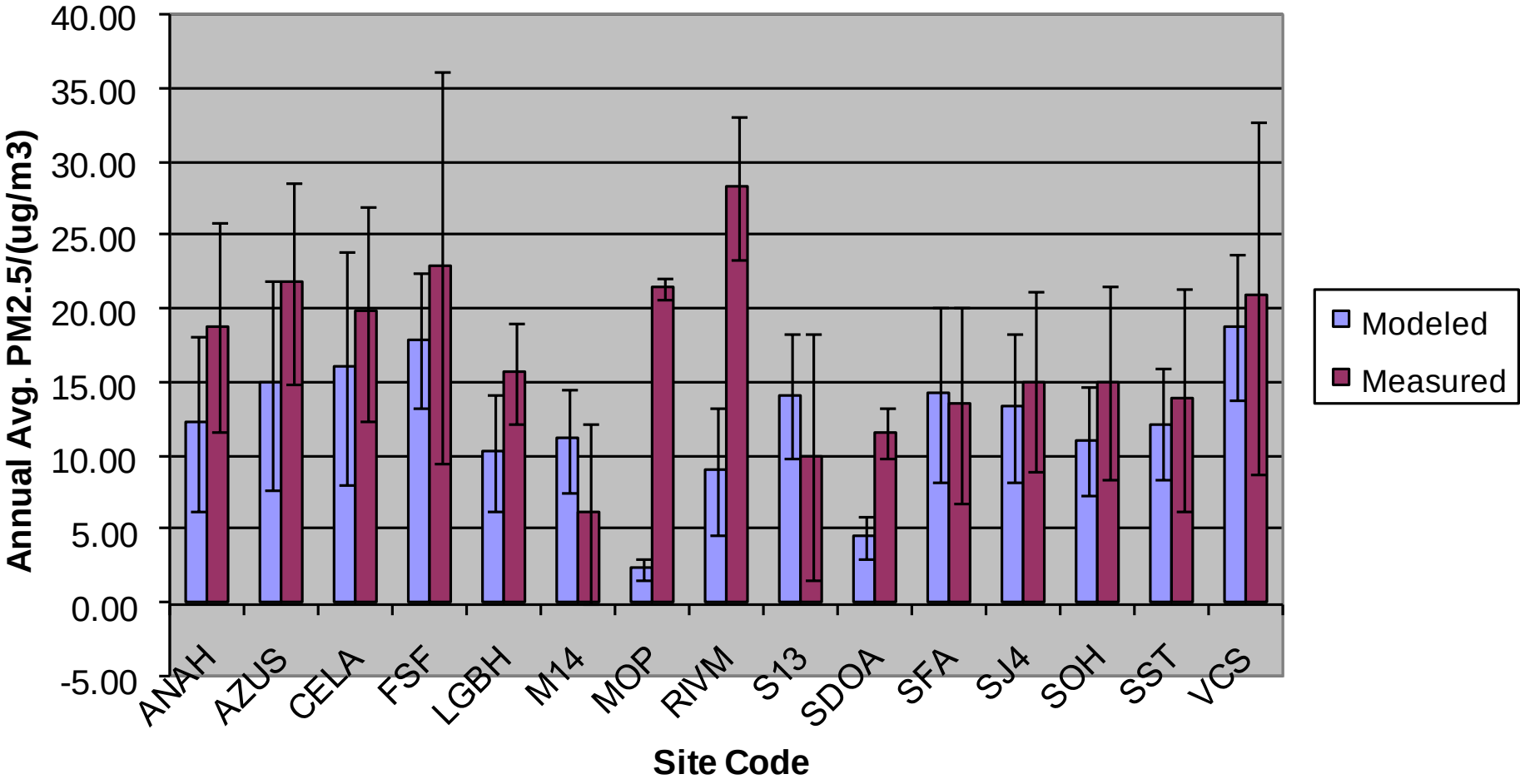
Figure courtesy of Prakash Bhave, US EPA.

Model Deposition Calculations

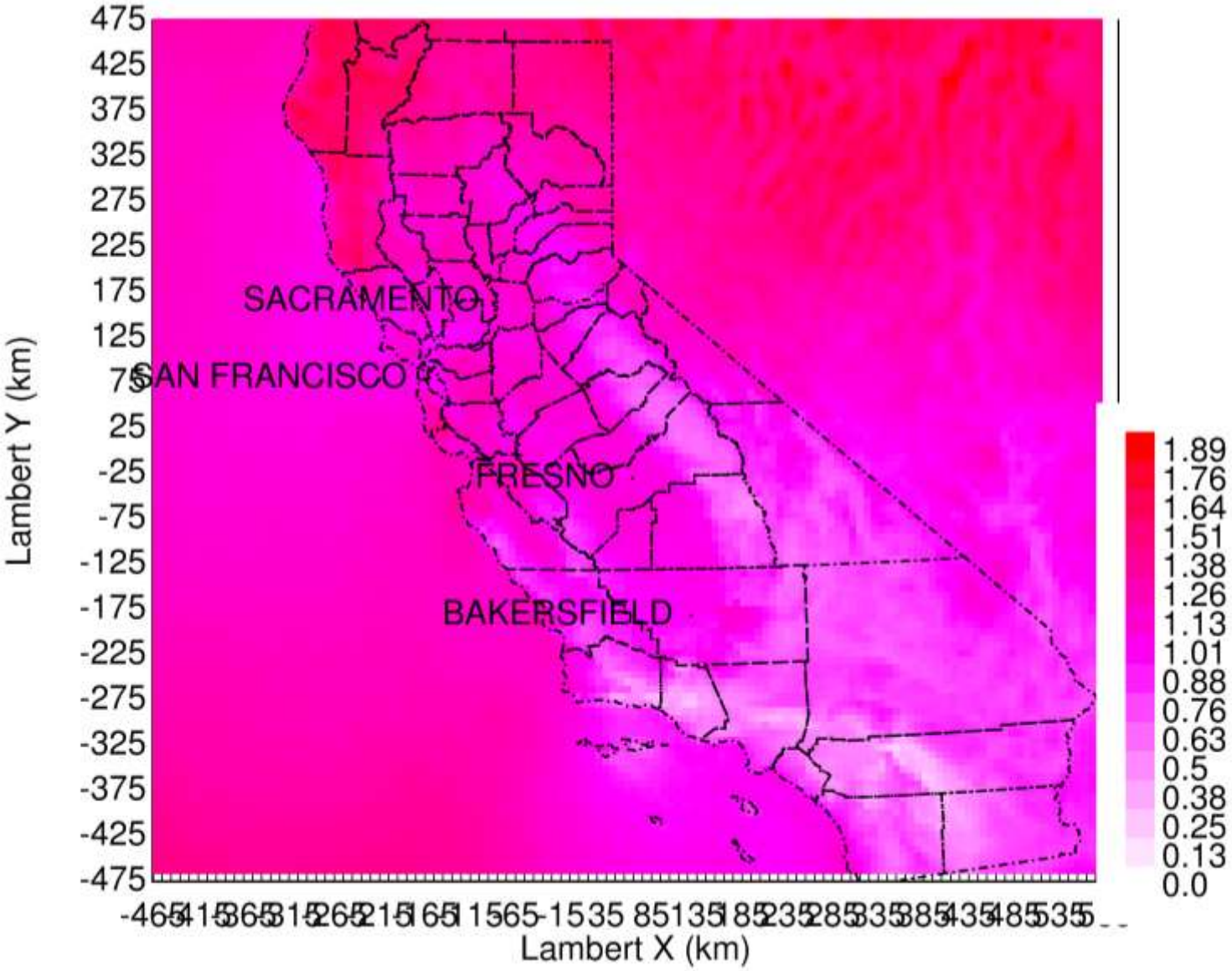




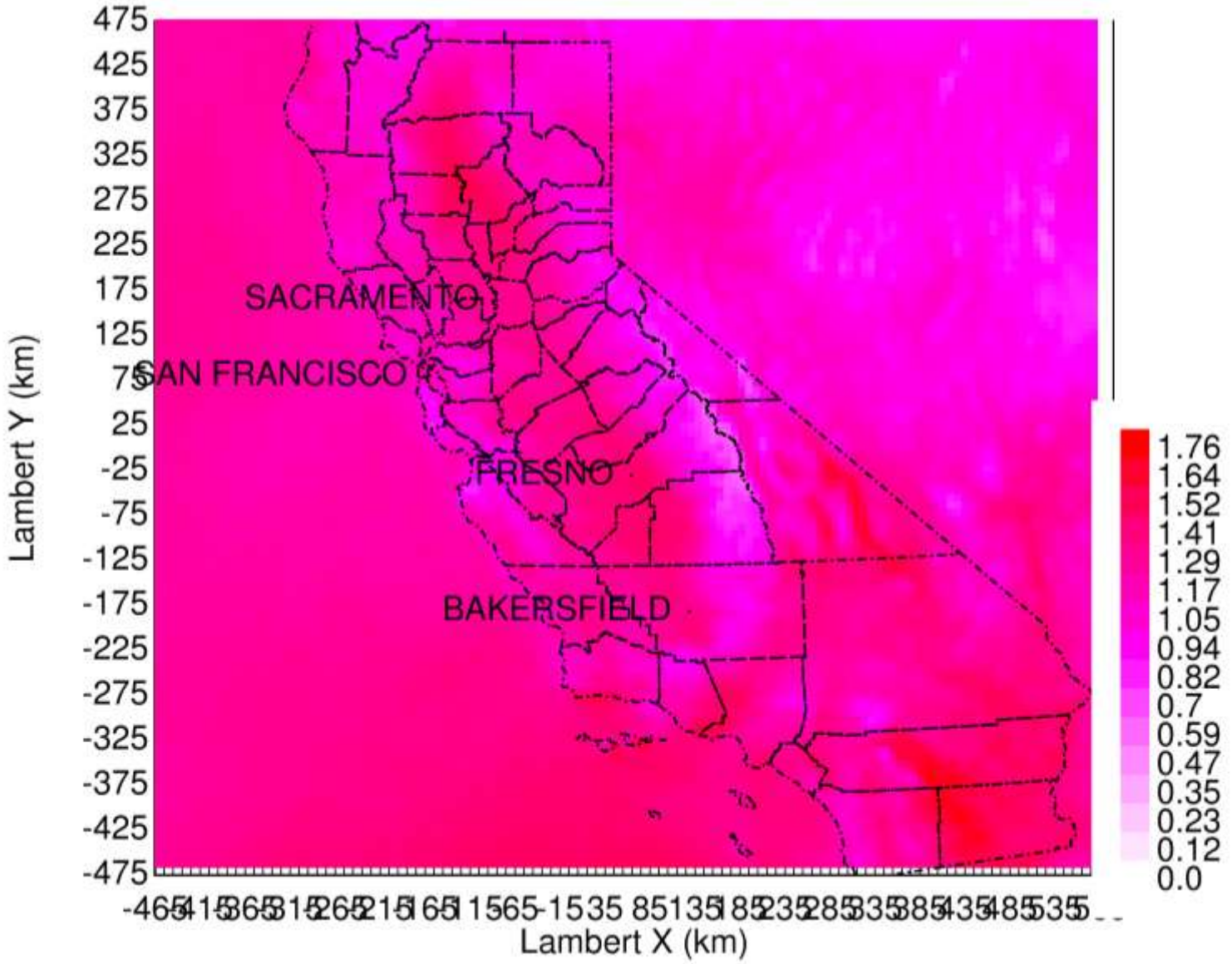
Annual Average PM2.5 Concentrations at different CA sites (2001)



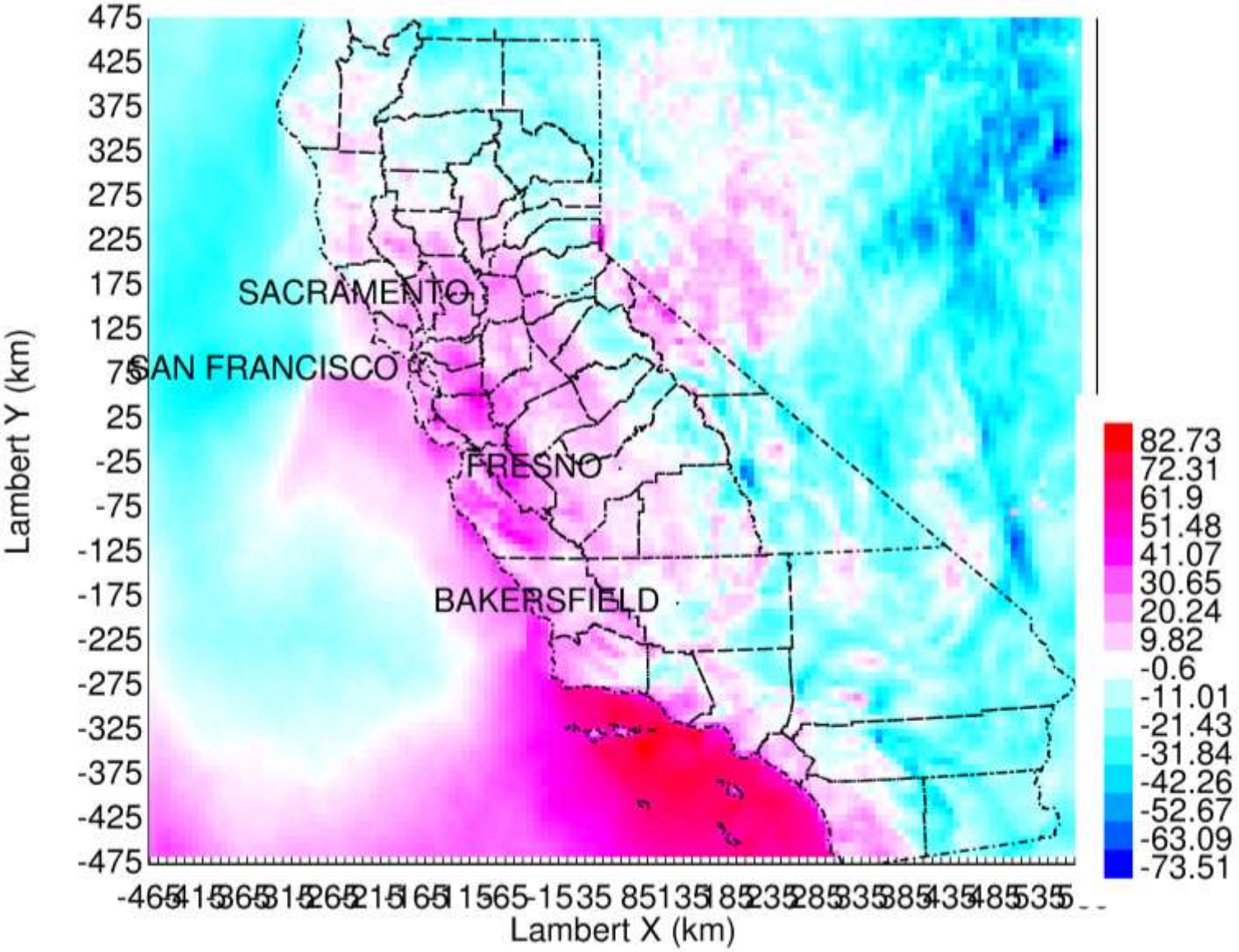
How Does Climate Affect Temperature?



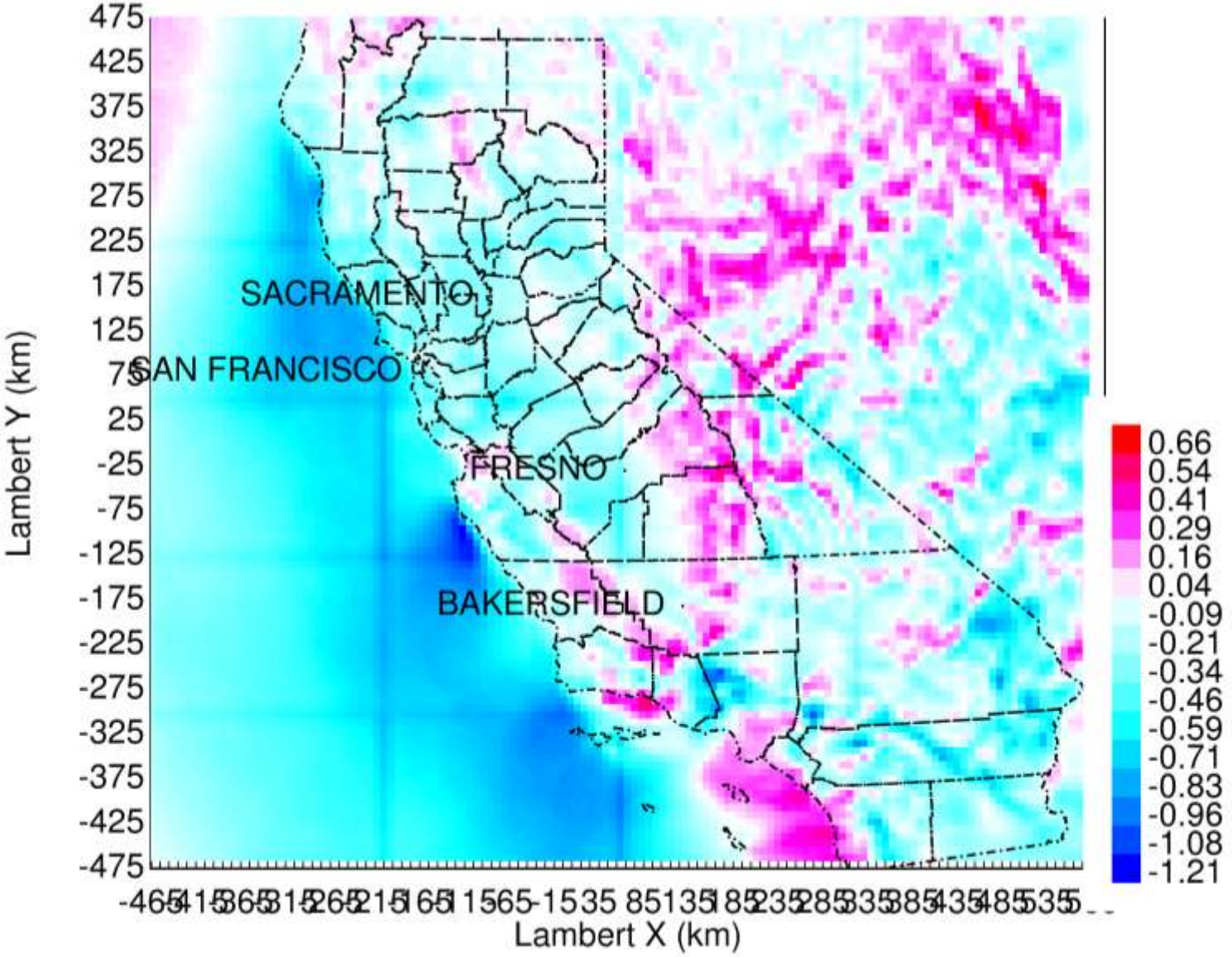
How Does Climate Affect Absolute Humidity?



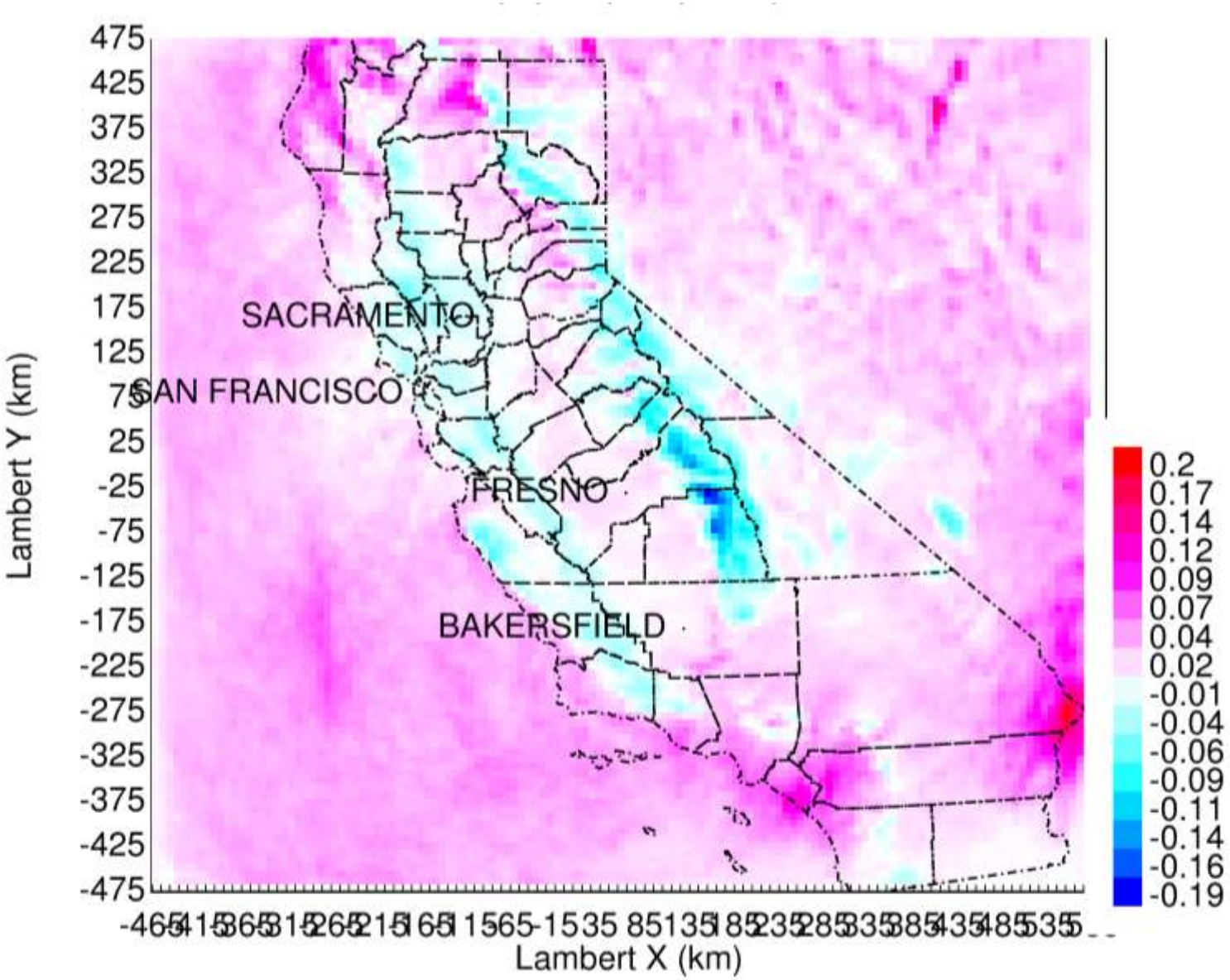
How Does Climate Affect Mixing Depth?



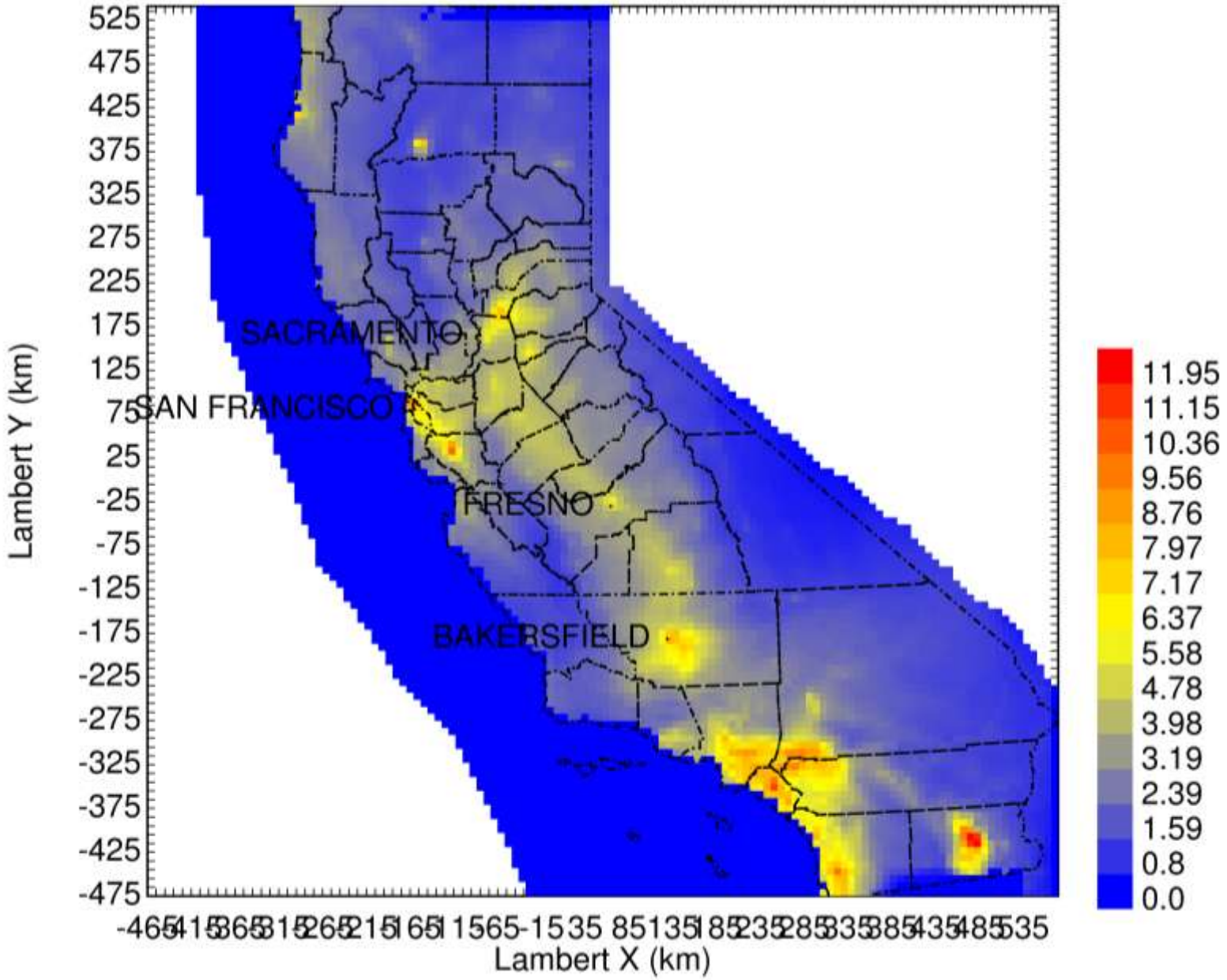
How Does Climate Affect Wind Speed?



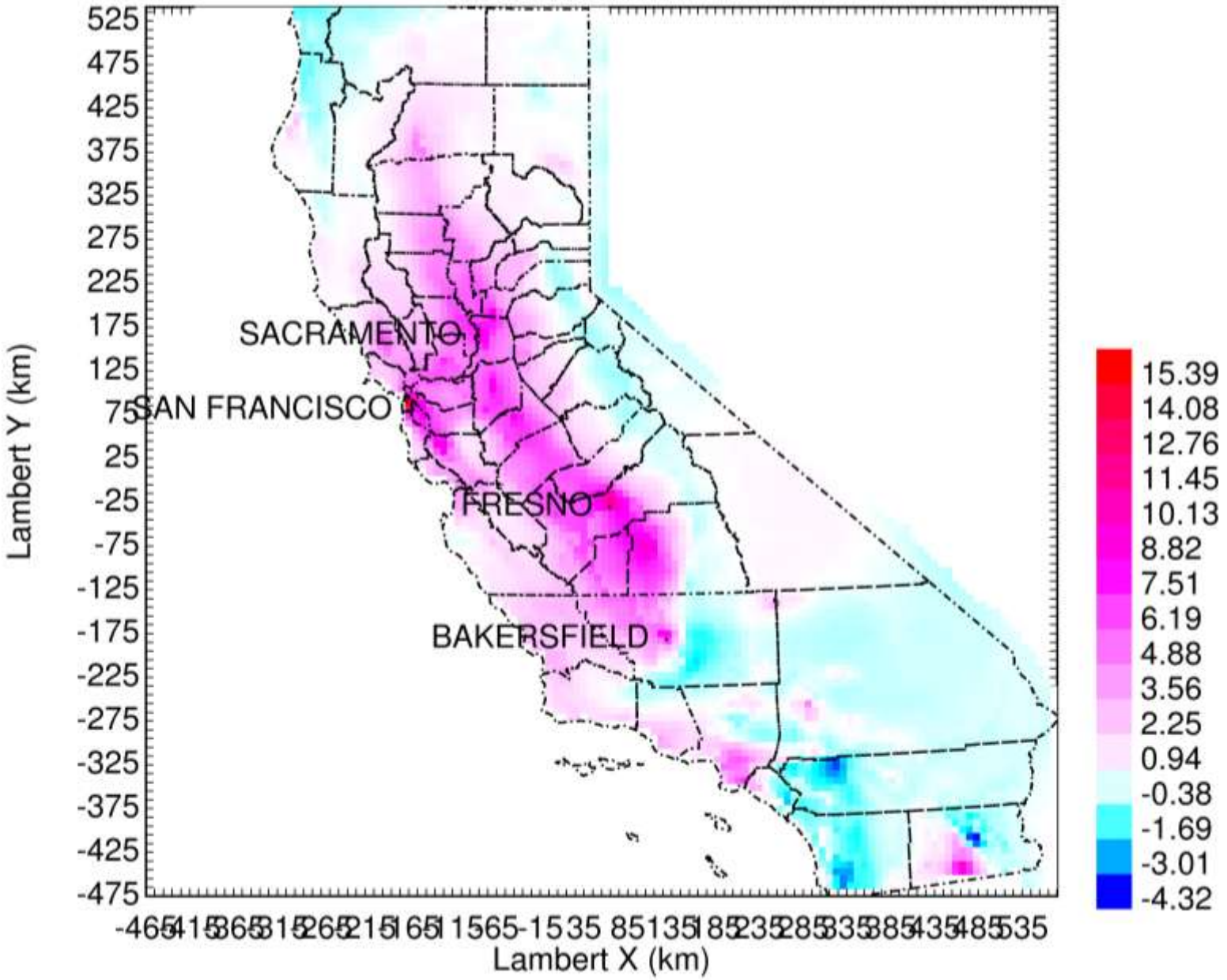
How Does Climate Affect Precip?



Basecase PM2.5 Concentrations



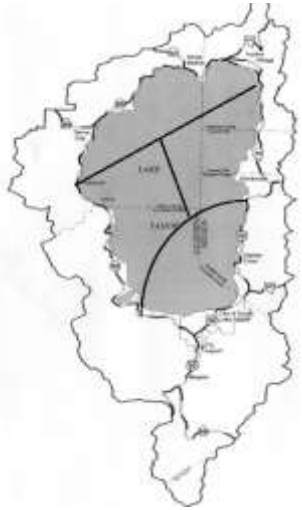
Influence of Climate on PM2.5 (Annual Avg)

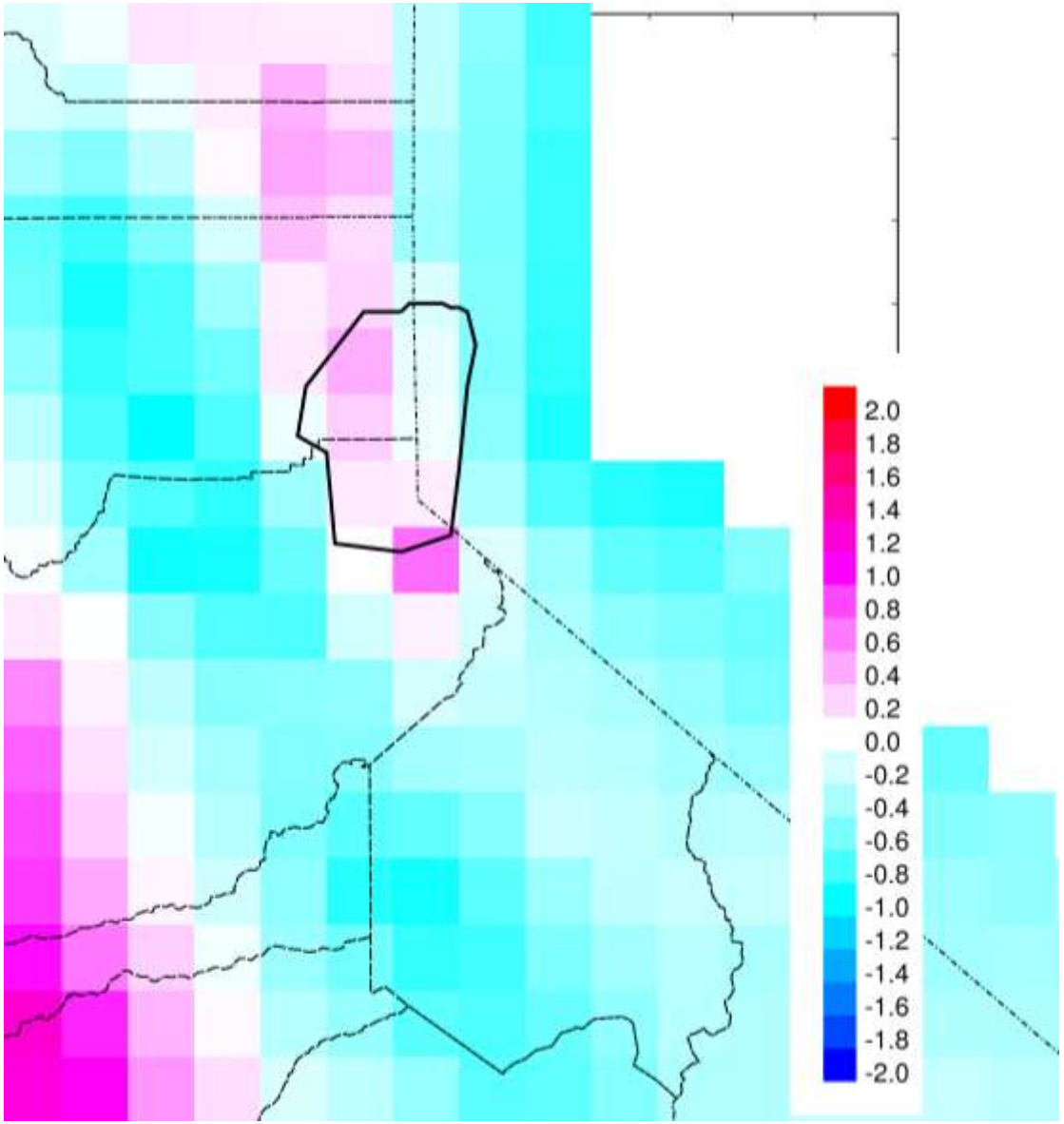


Influence of Climate on Lake Tahoe PM2.5

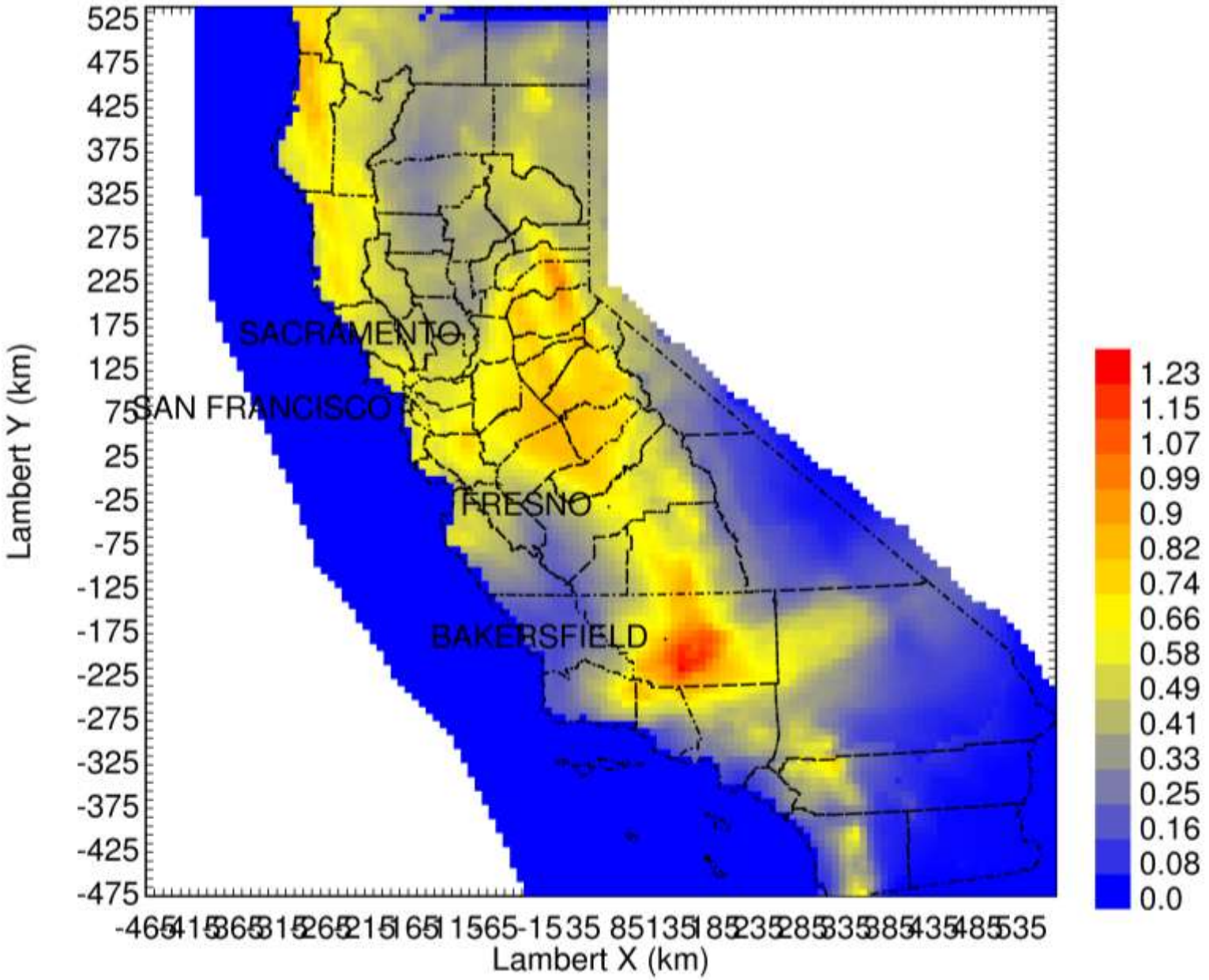
Δ Lake Avg = +0.17 ug/m3
Δ Basin Avg = +0.28 ug/m3

Δ Deposition = +26-43 tons/yr

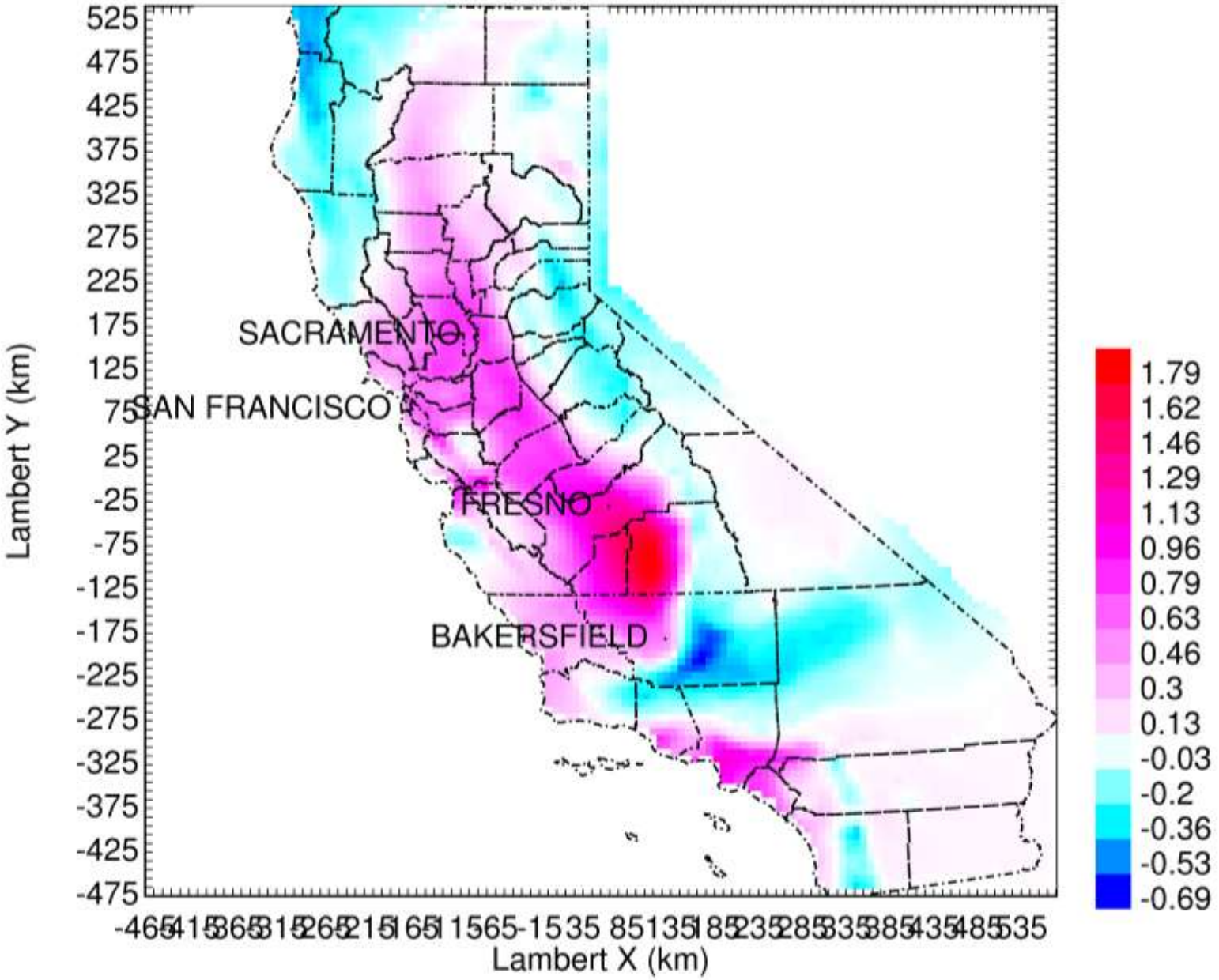




Basecase PM2.5 NO3- Concentrations



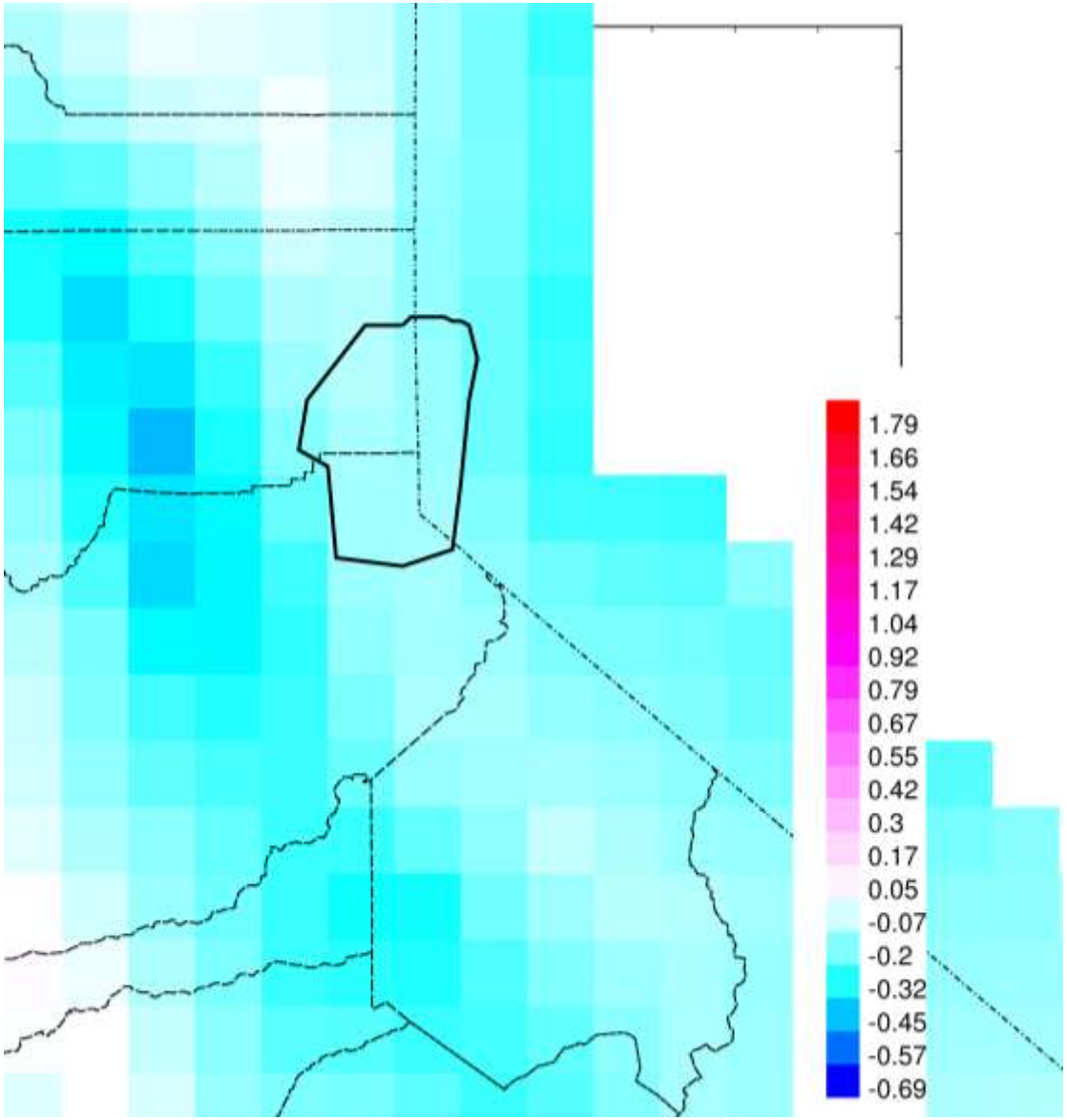
Influence of Climate on PM2.5 NO3- (Annual Avg)



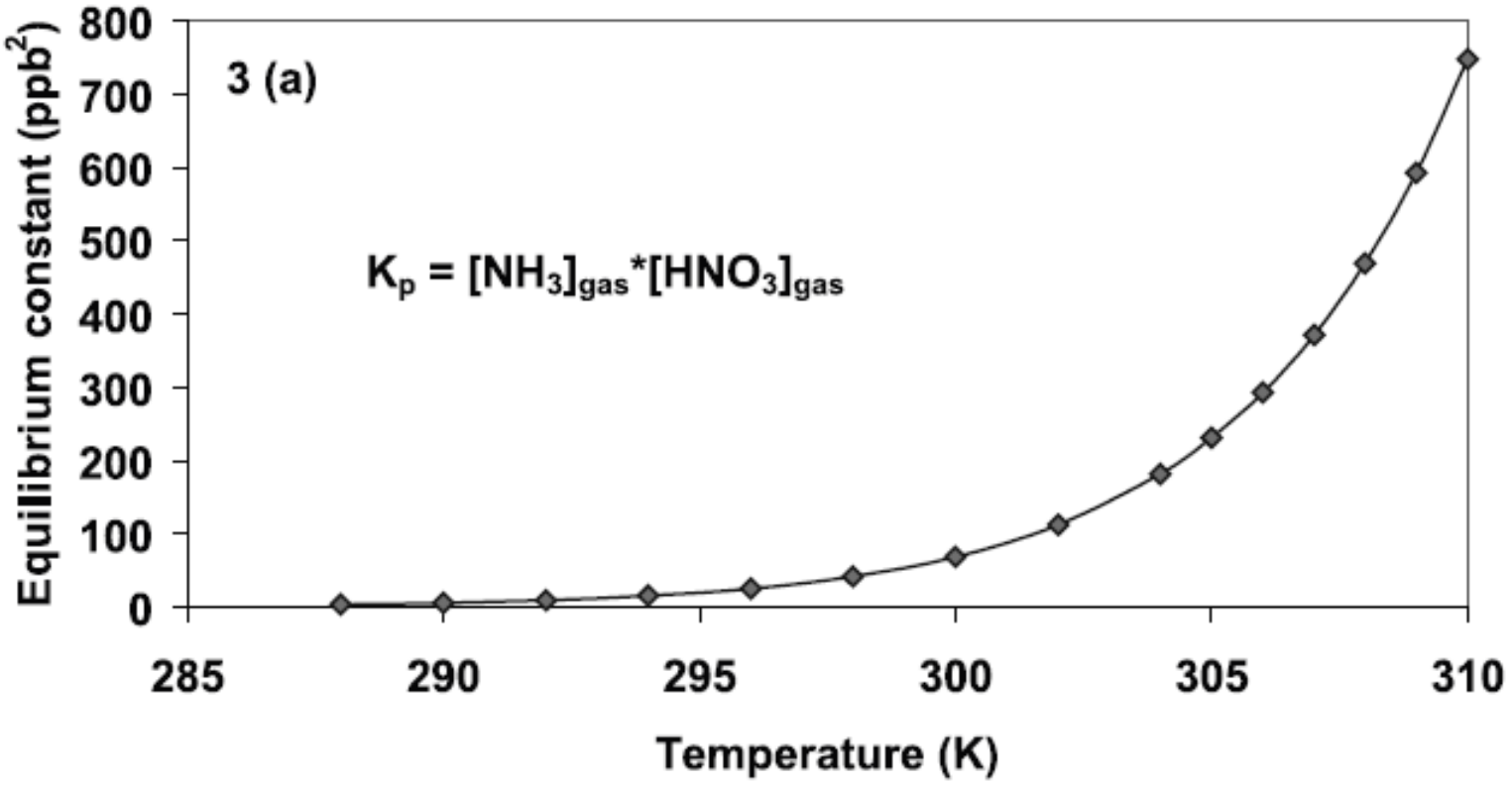
Influence of Climate on Lake Tahoe PM2.5 NO3-

Δ Lake Avg = -0.15 ug/m3
Δ Basin Avg = -0.18 ug/m3

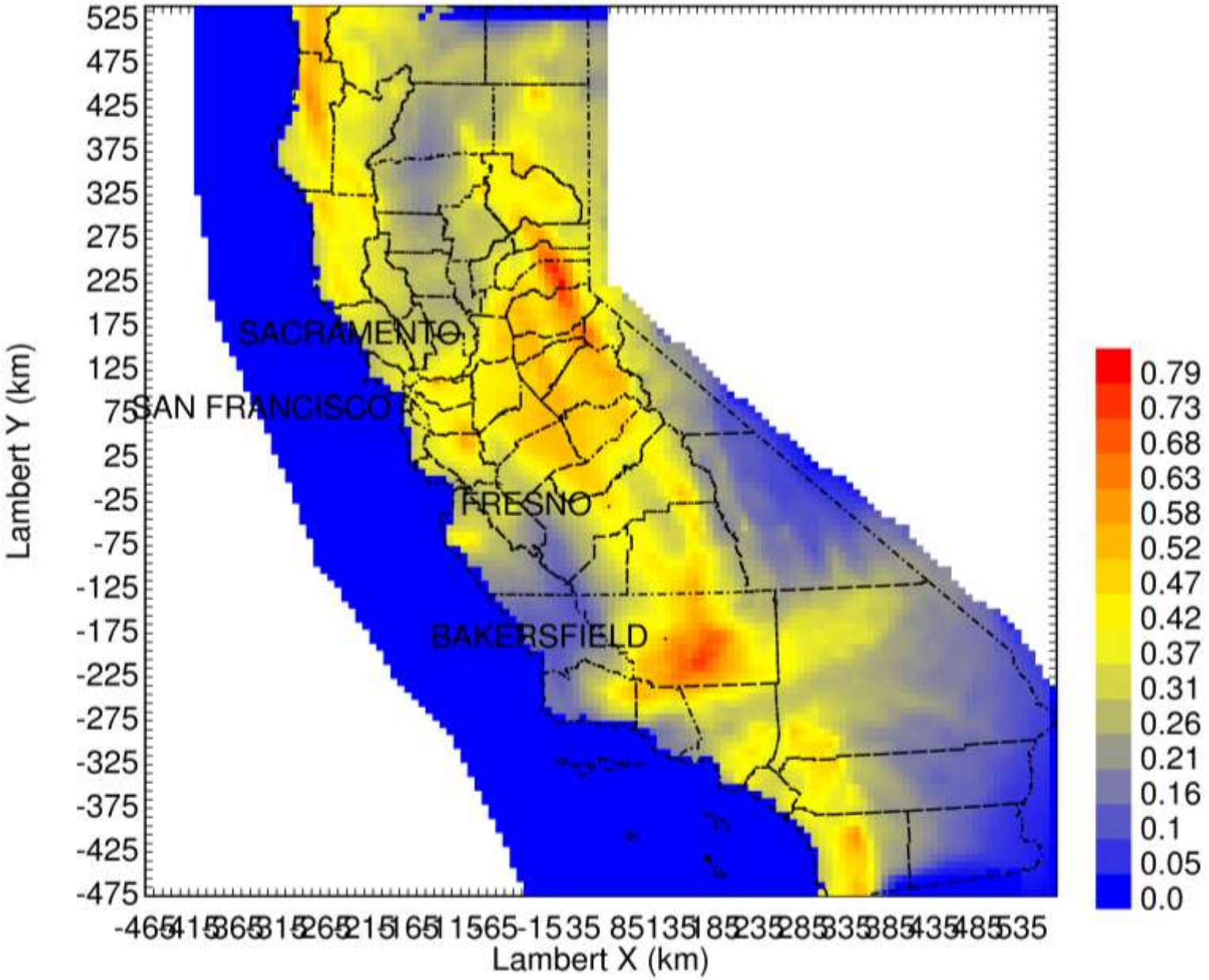
Δ Deposition = -23 to -27 tons/yr



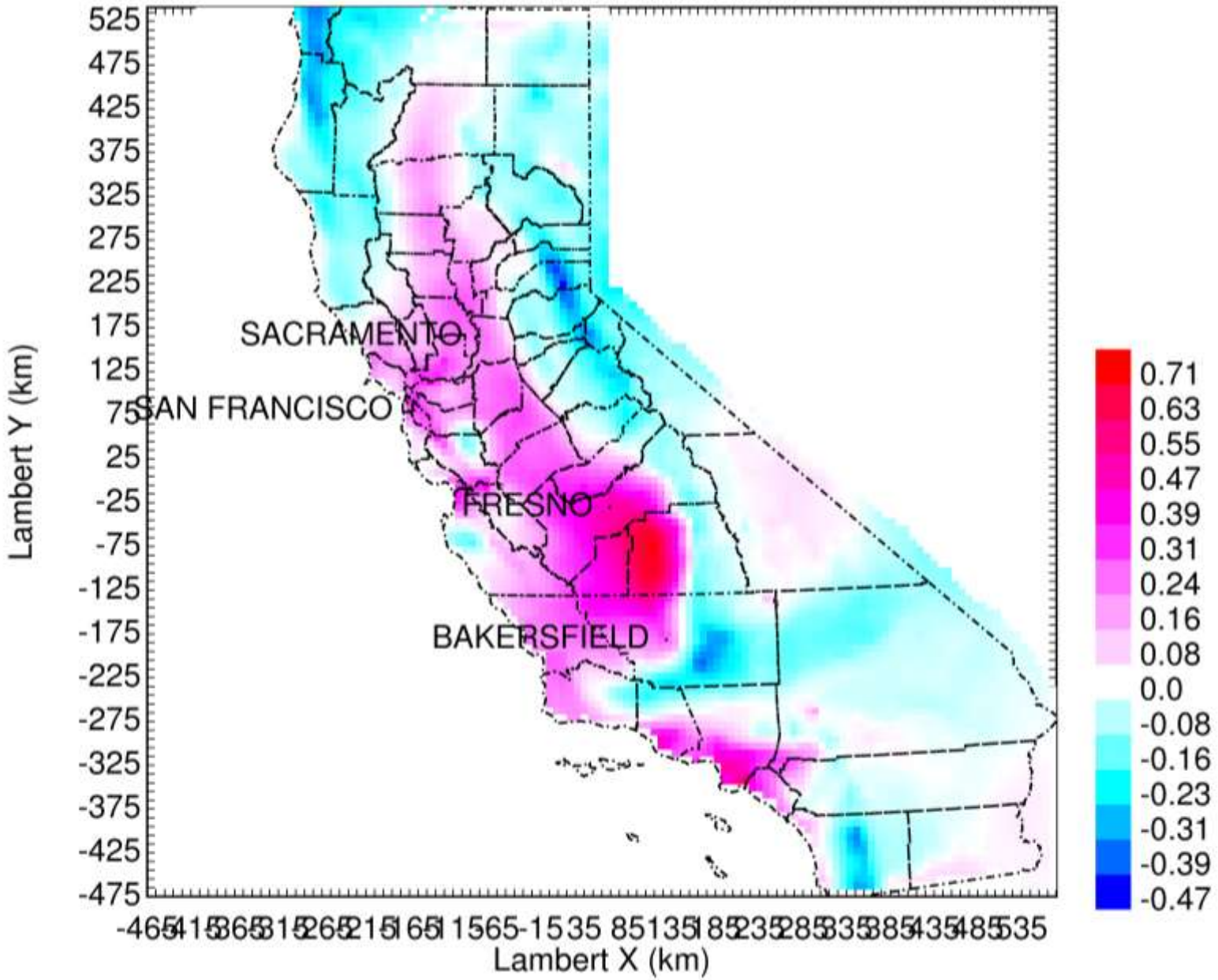
Equilibrium Dissociation Constant for Ammonium Nitrate



Basecase PM2.5 NH4+ Concentrations



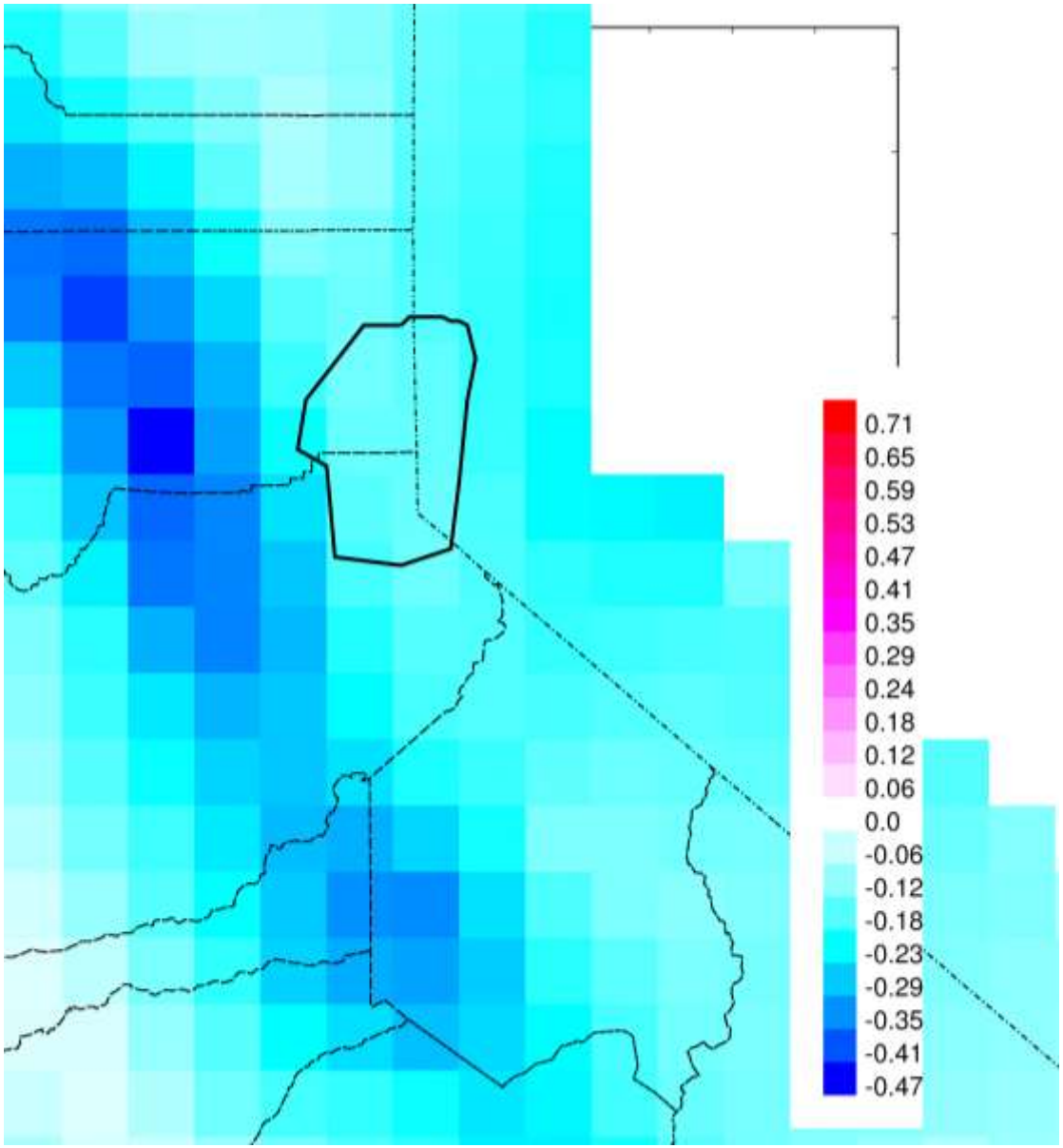
Influence of Climate on PM2.5 NH4+ (Annual Avg)



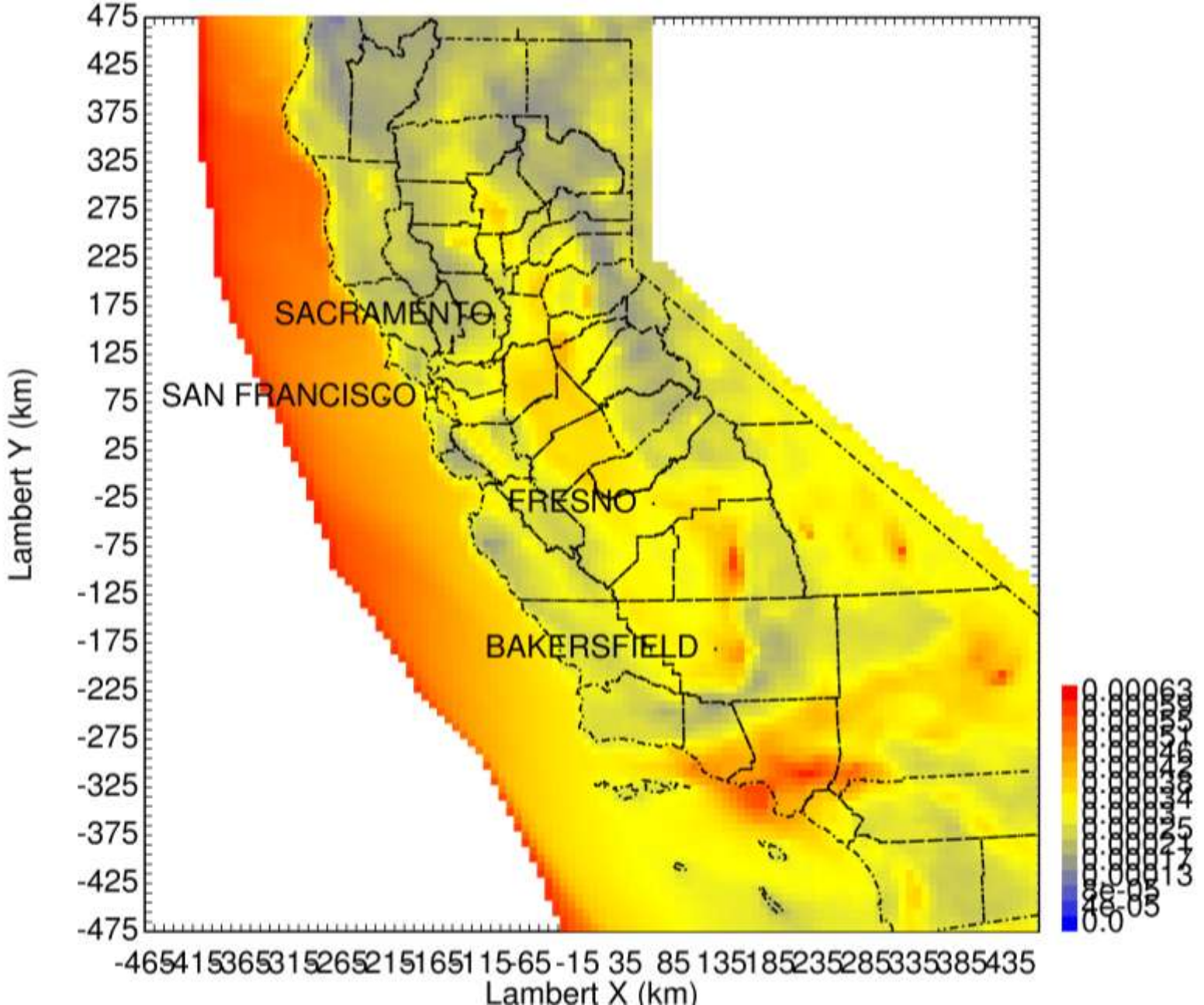
Influence of Climate on Lake Tahoe PM2.5 NH4+

Δ Lake Avg = -0.16 ug/m3
Δ Basin Avg = -0.19 ug/m3

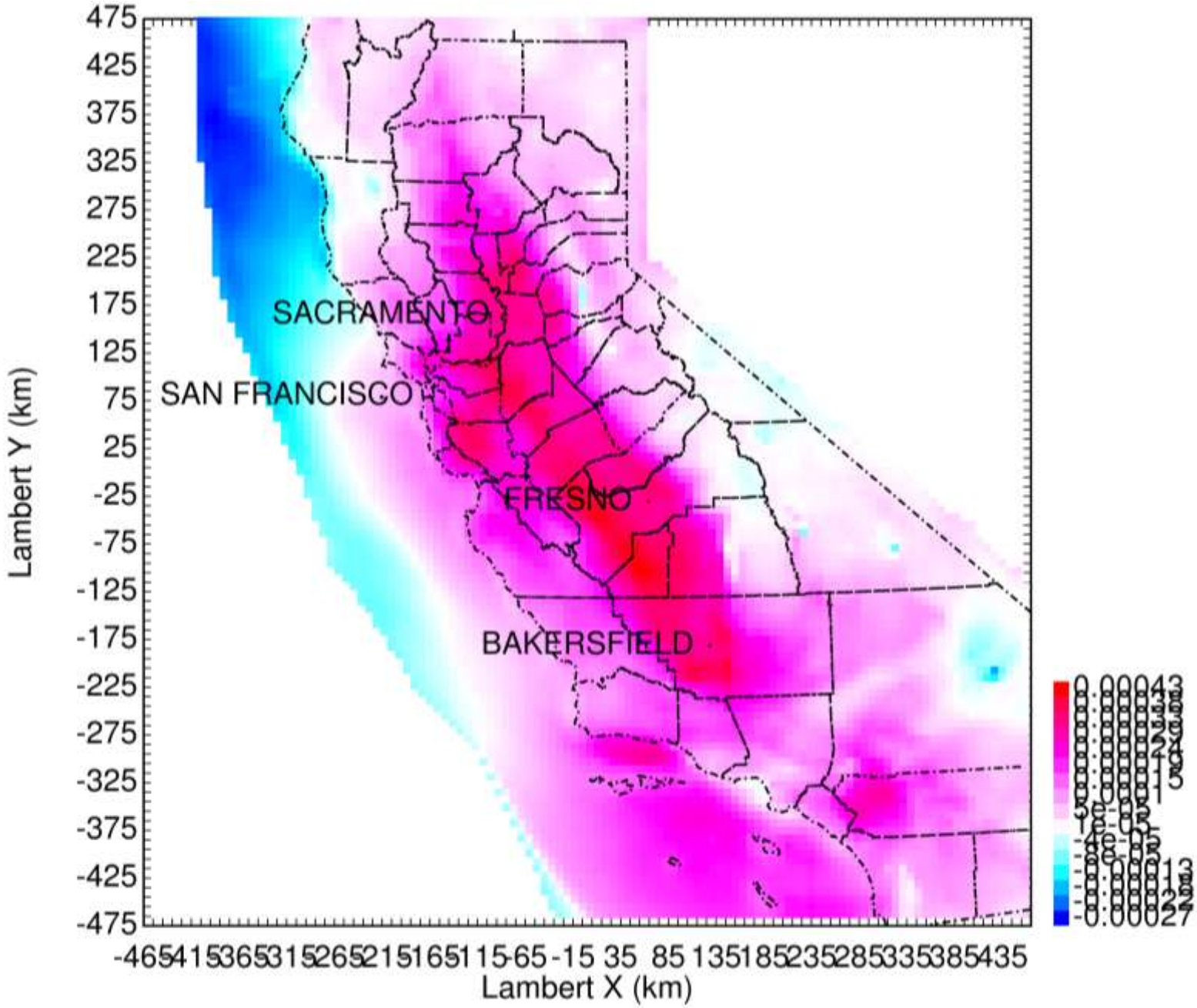
Δ Deposition = -25 to -29 tons/yr



Basecase HNO3 Concentrations



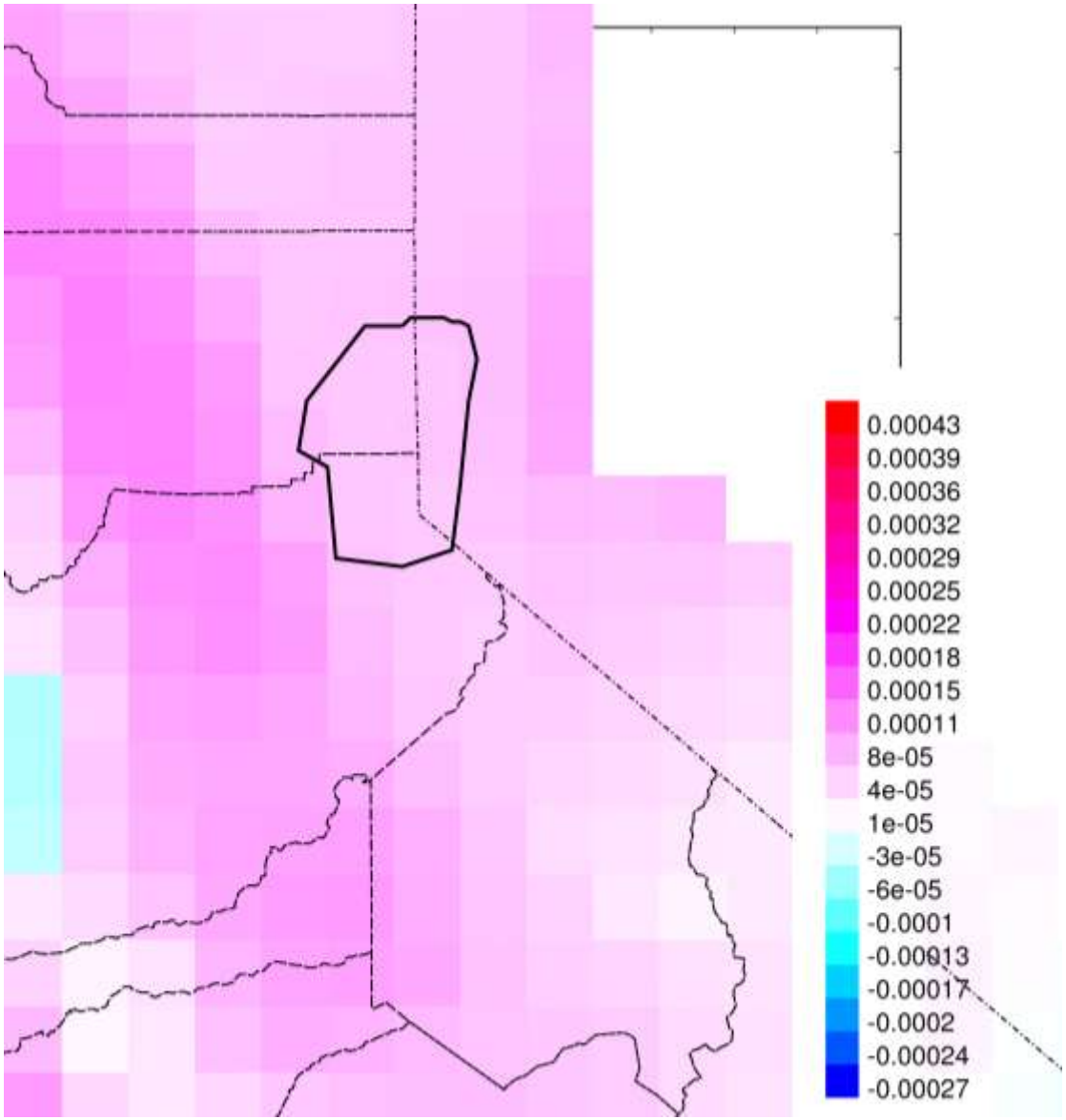
Influence of Climate on HNO3 (Annual Avg)



Influence of Climate on Lake Tahoe HNO3

Δ Lake Avg = +0.06 ppb
Δ Basin Avg = +0.06 ppb

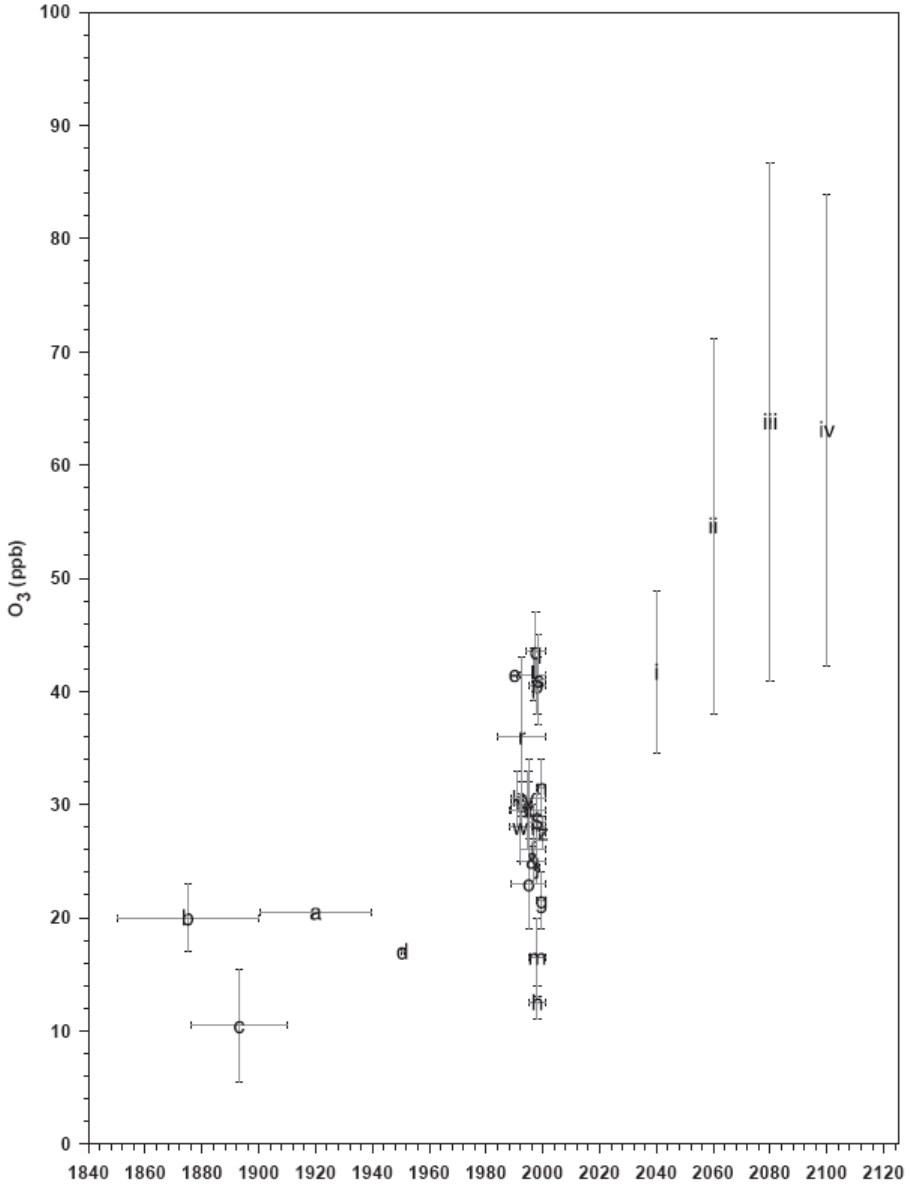
Δ Deposition = +24 tons/yr



Trends for Background O3

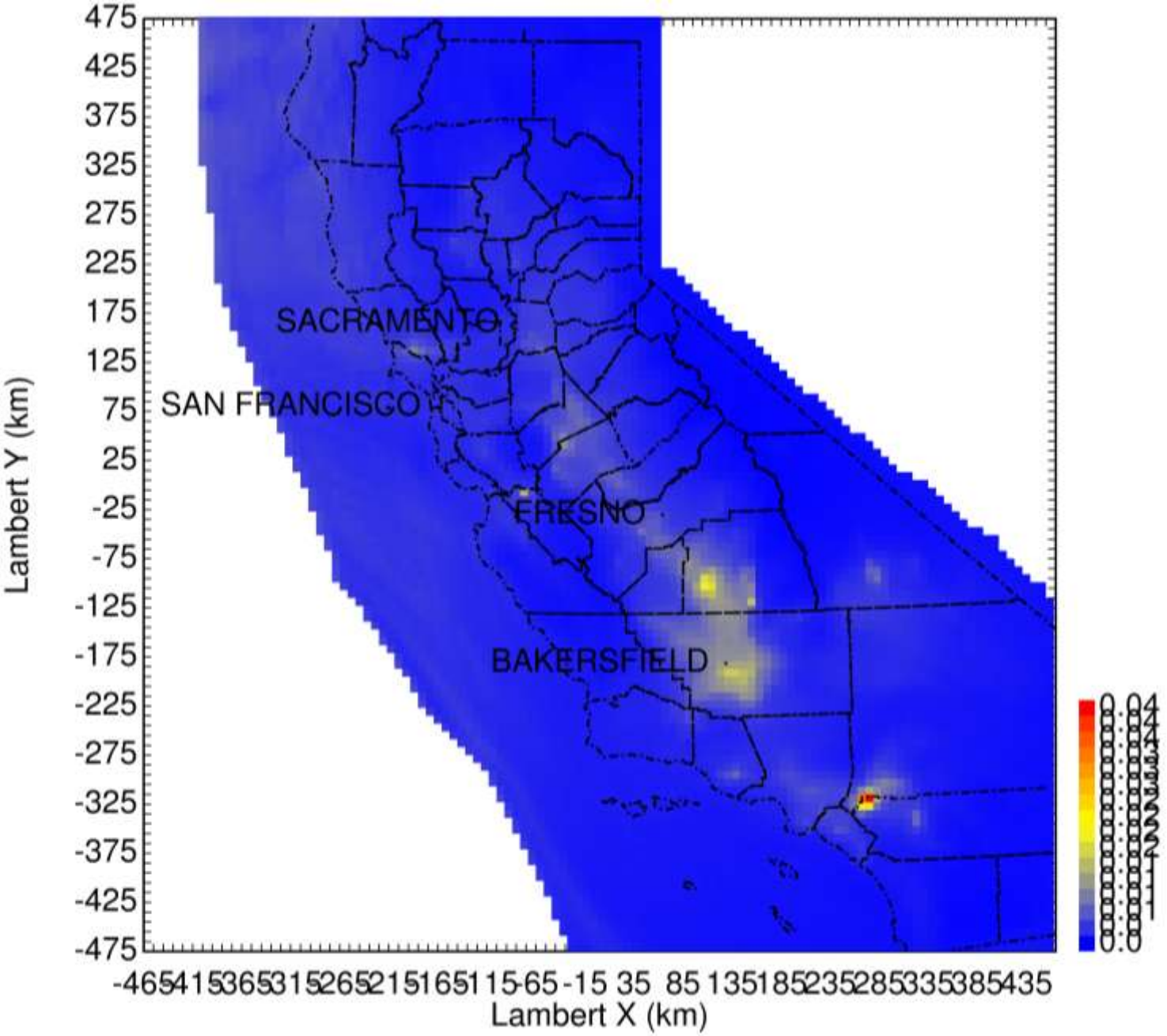
Background O3 concentrations have increased over the past 100 years.

Projections by IPCC estimate future concentrations at ~60ppb.

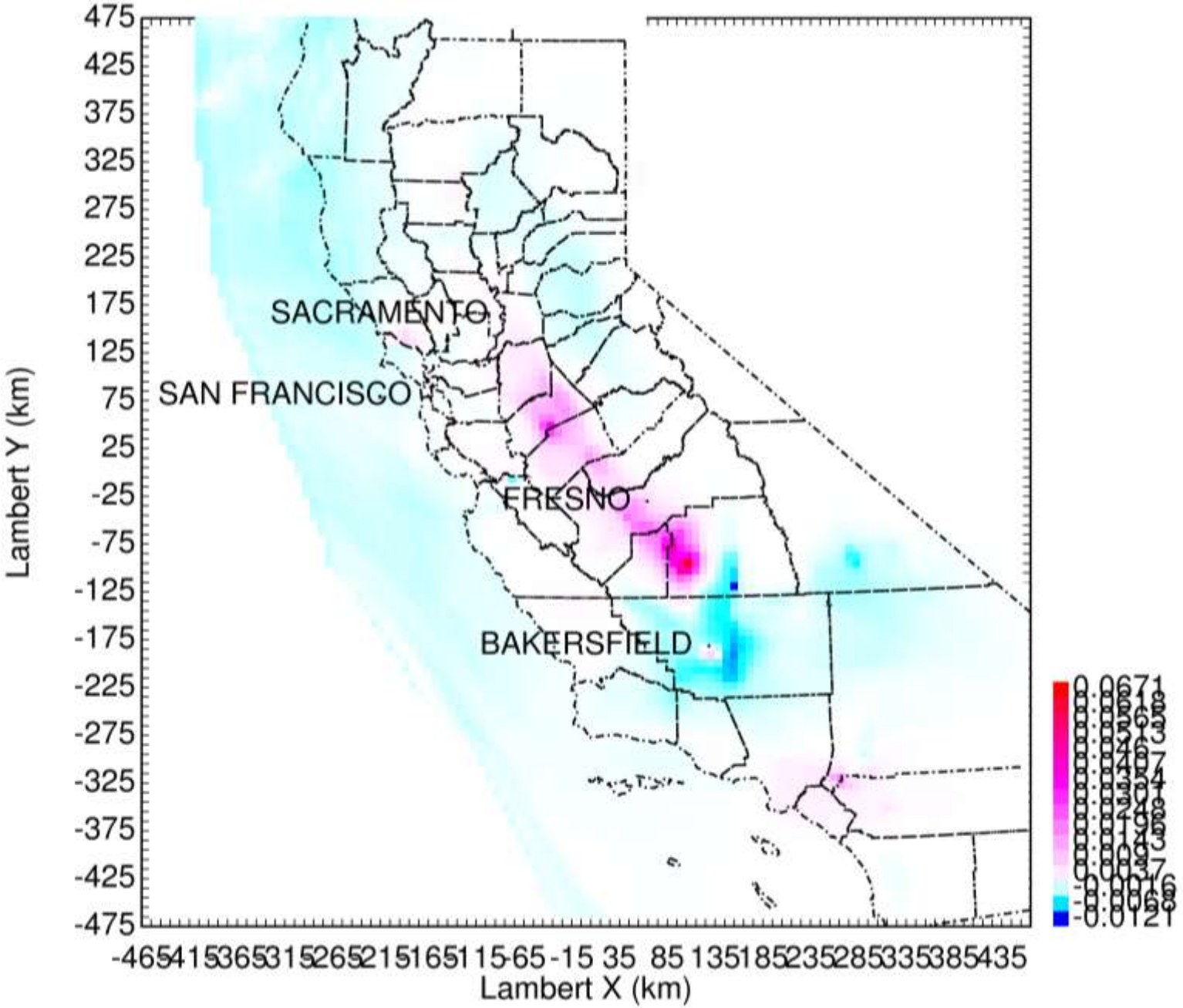


Source: R. Vingarzan, “A review of ozone background levels and trends”, Atmospheric Environment, 38: 3431-3442.

Basecase PM2.5 NH3 Concentrations



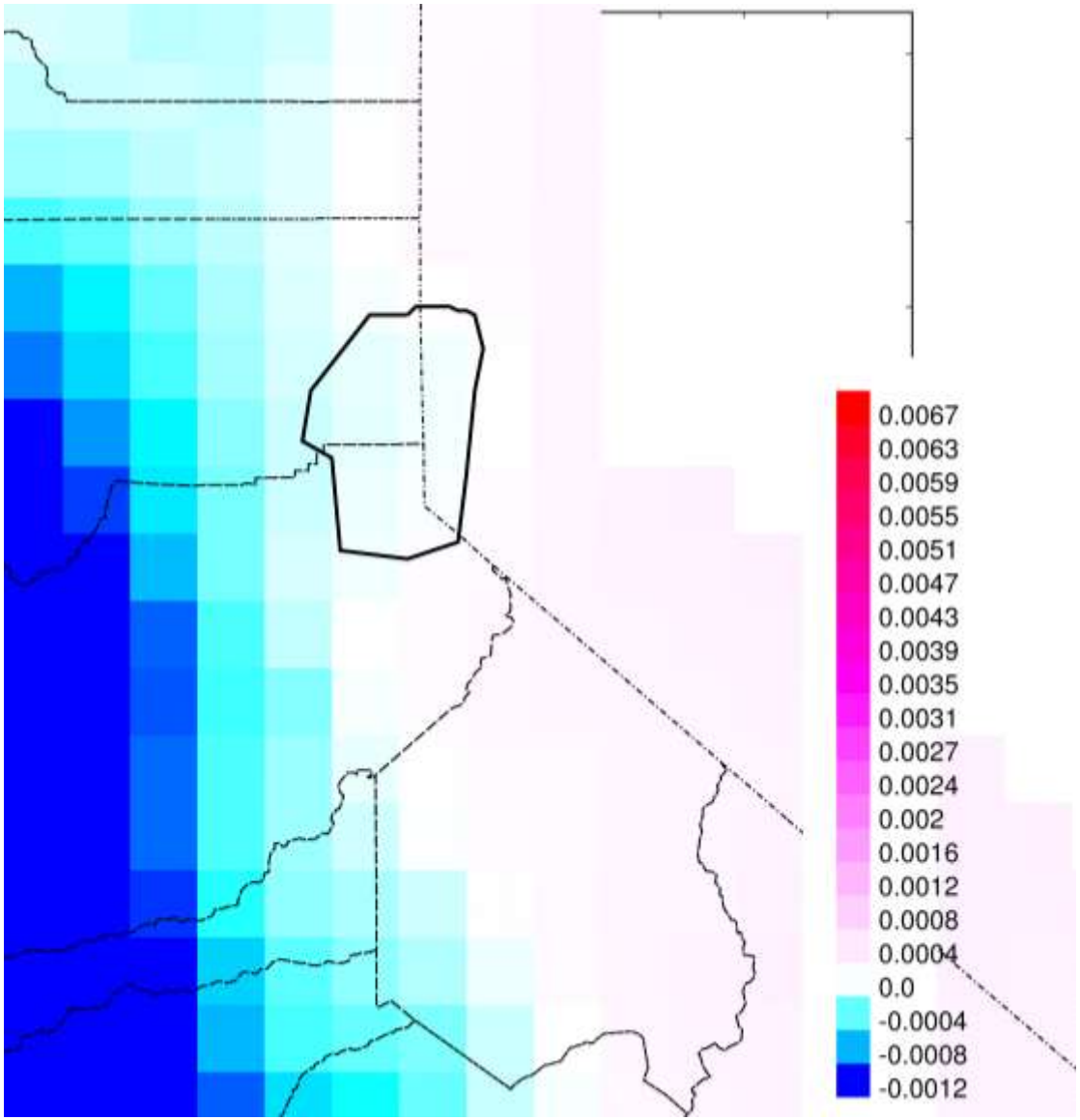
Influence of Climate on NH3 (Annual Avg)



Influence of Climate on Lake Tahoe NH3

Δ Lake Avg = -0.05 ppb
Δ Basin Avg = -0.03 ppb

Δ Deposition = -3 to -5 tons/yr



Conclusions

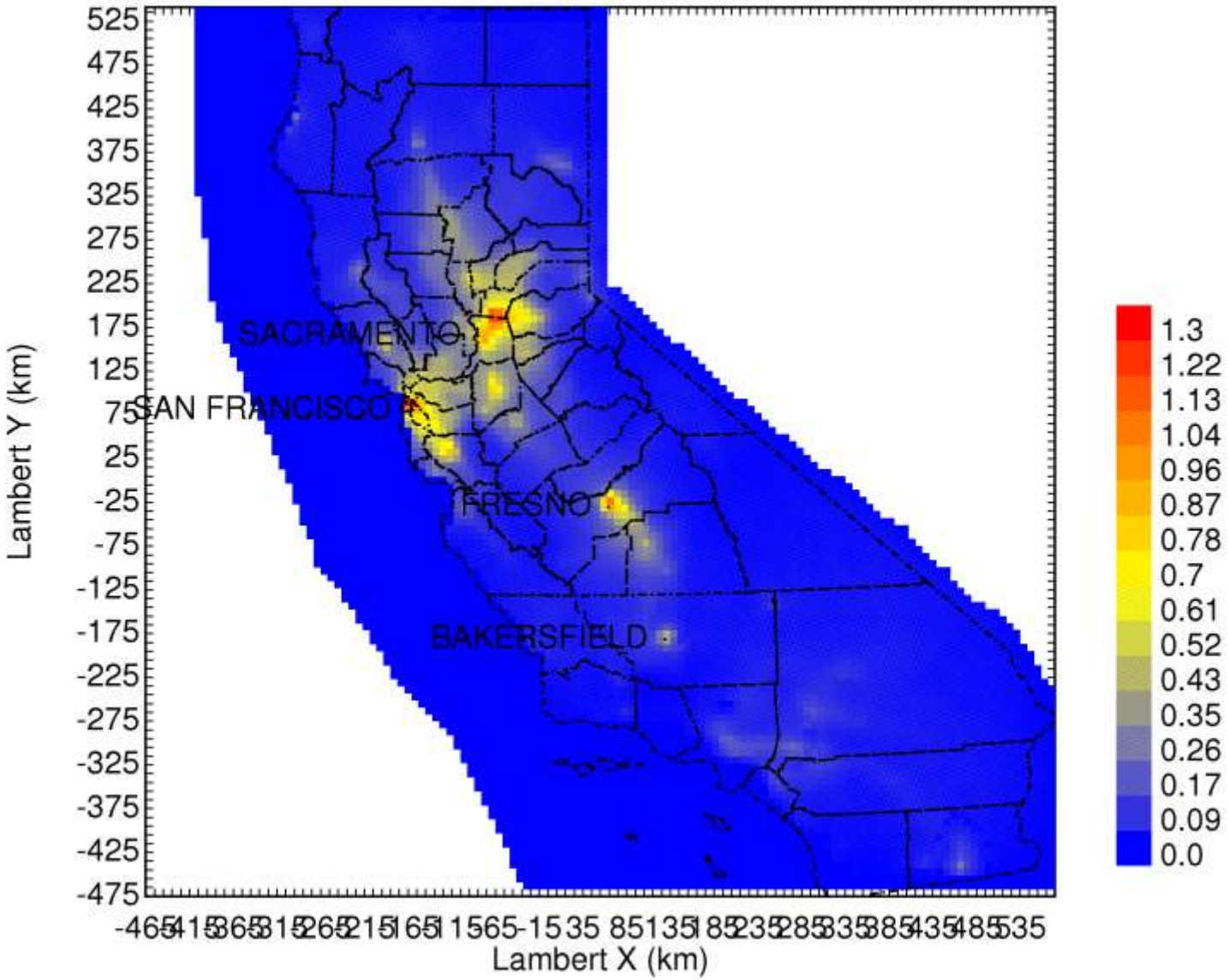
- California's extreme topography makes climate downscaling difficult
- US-wide simulations performed at 36km likely too coarse for Lake Tahoe
- Statewide simulations performed at 8km likely too coarse for Lake Tahoe
- Need to simulate >7yrs to capture ENSO cycle

Acknowledgements

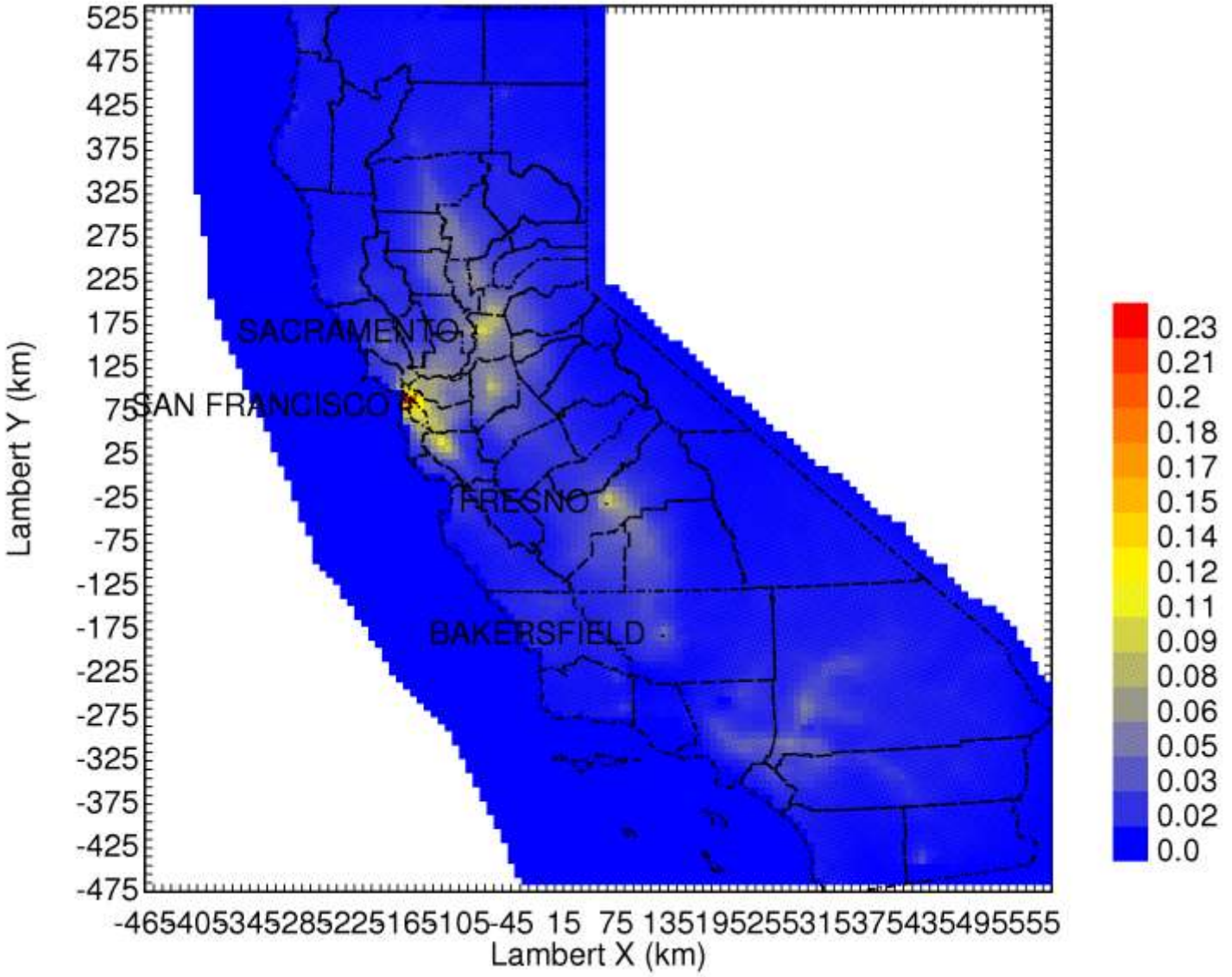
- California Air Resources Board (CARB) Project # 04-349
- Nehzat Motallebi (CARB)
- EPA Science to Achieve Results Project # RD-83184201

EXTRA SLIDES

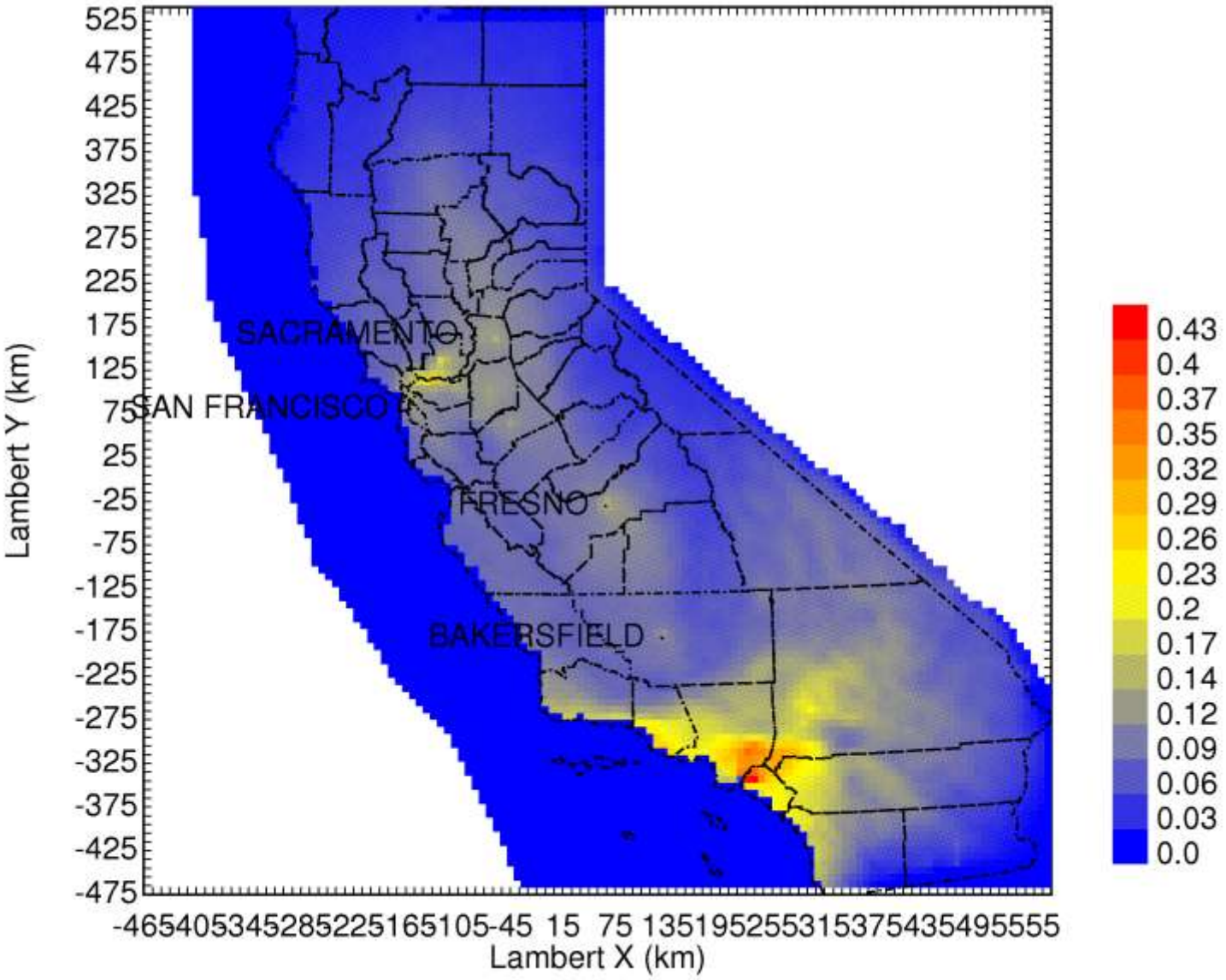
Influence of Climate on OC



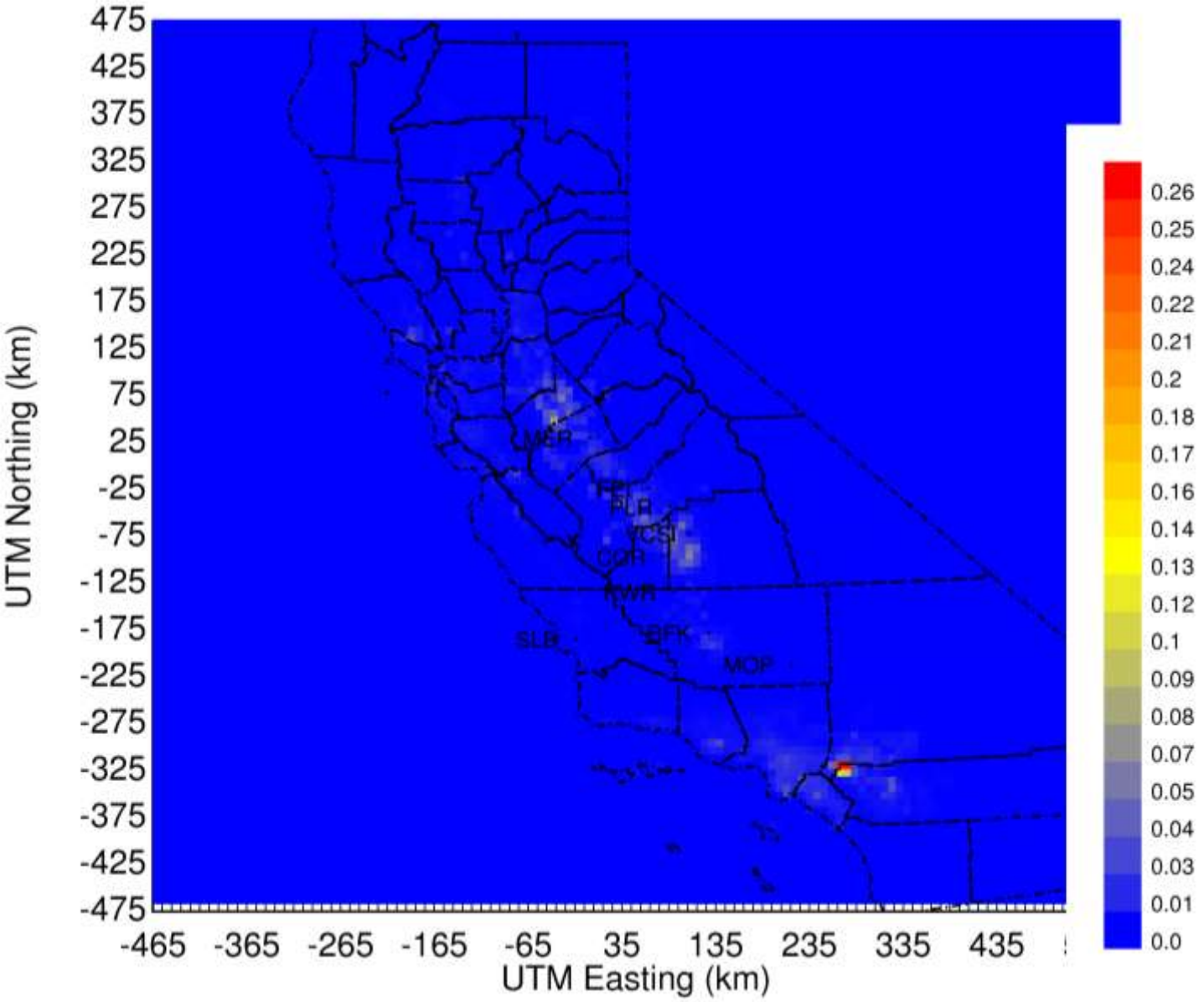
Influence of Climate on EC



Influence of Climate on Sulfate



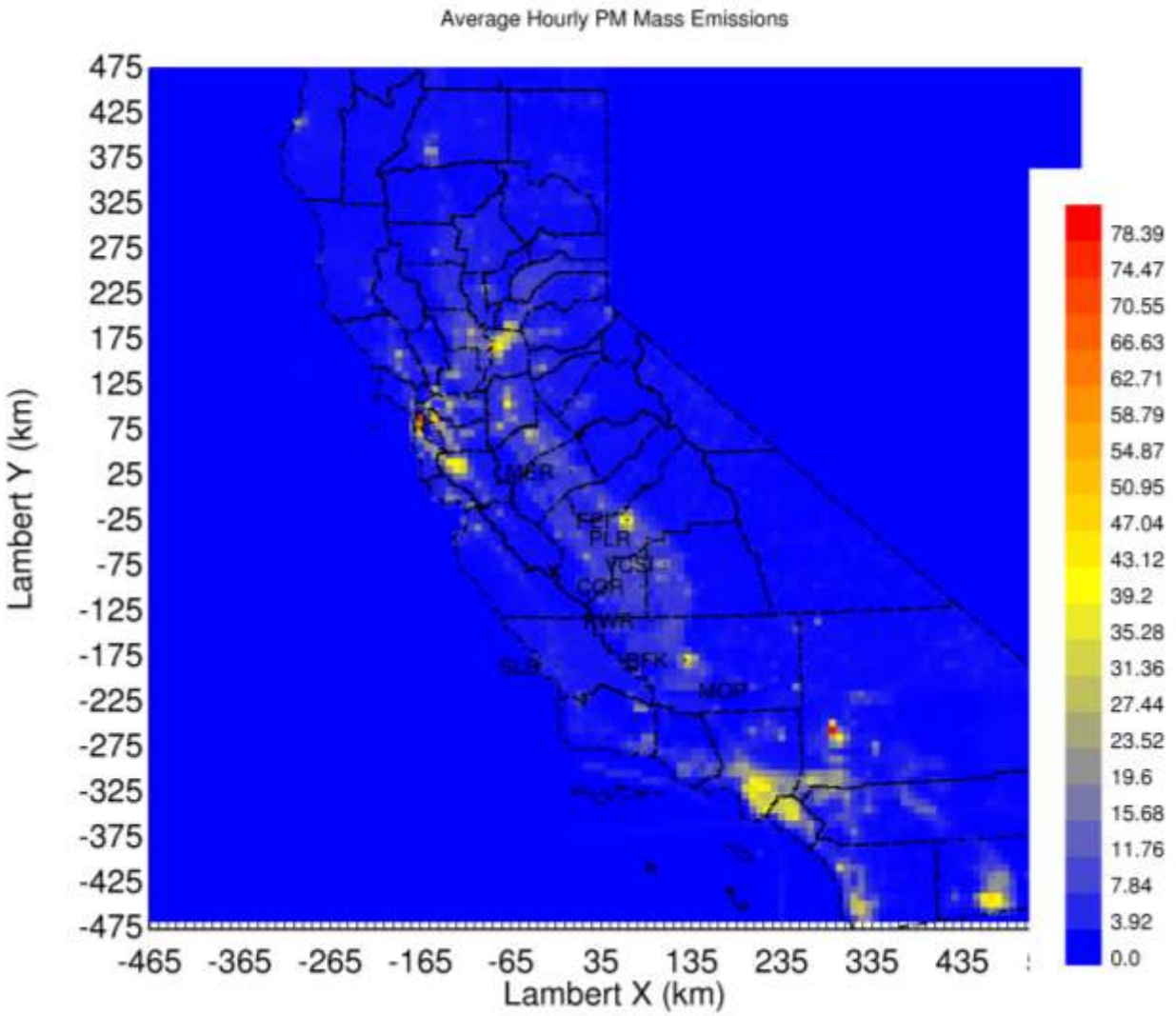
NH3 Emissions Example

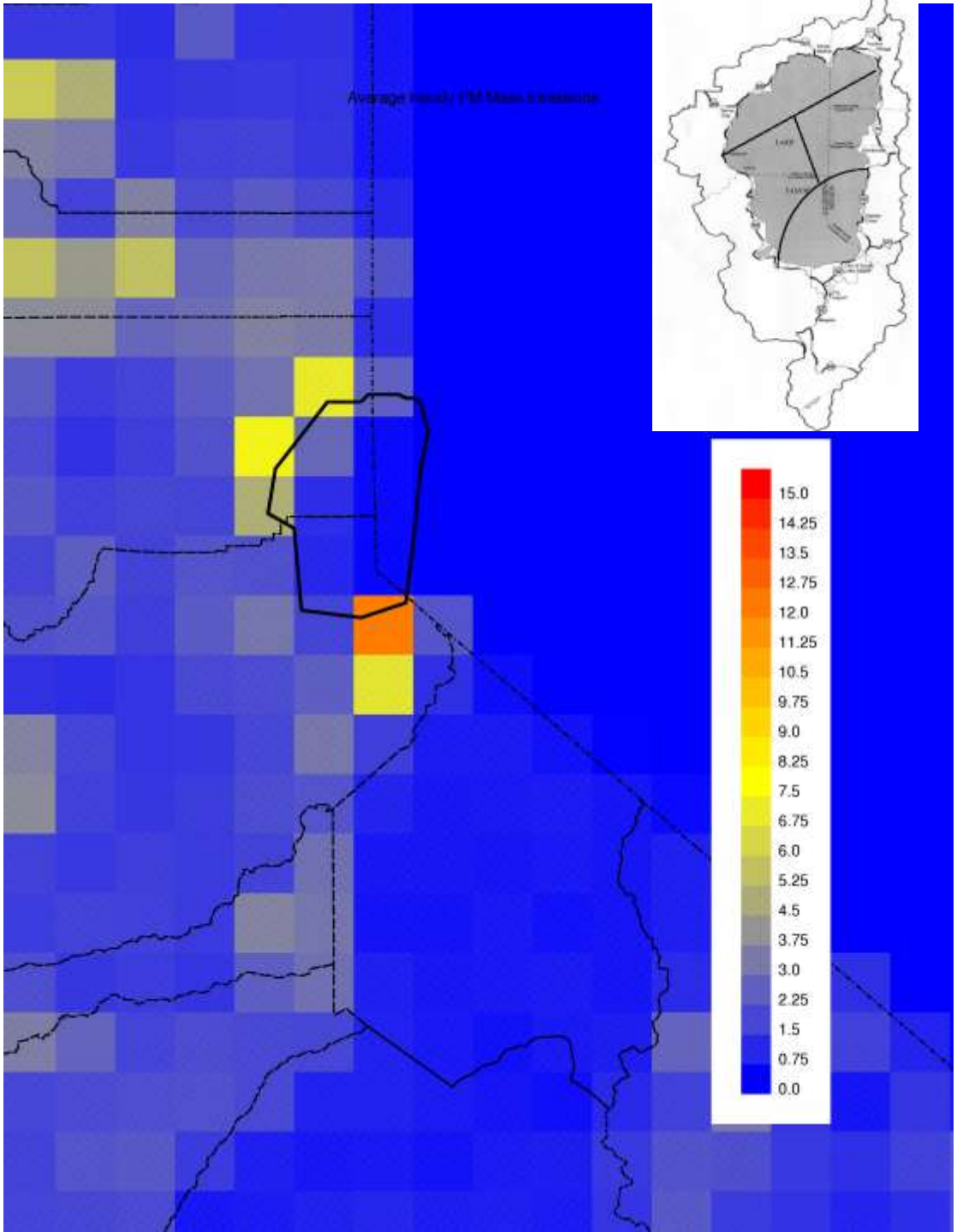


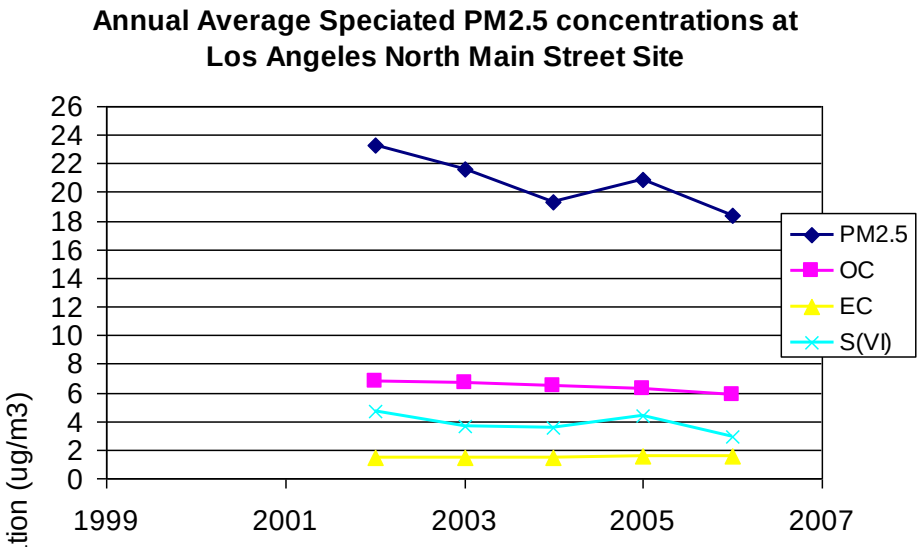
PM Emissions Example

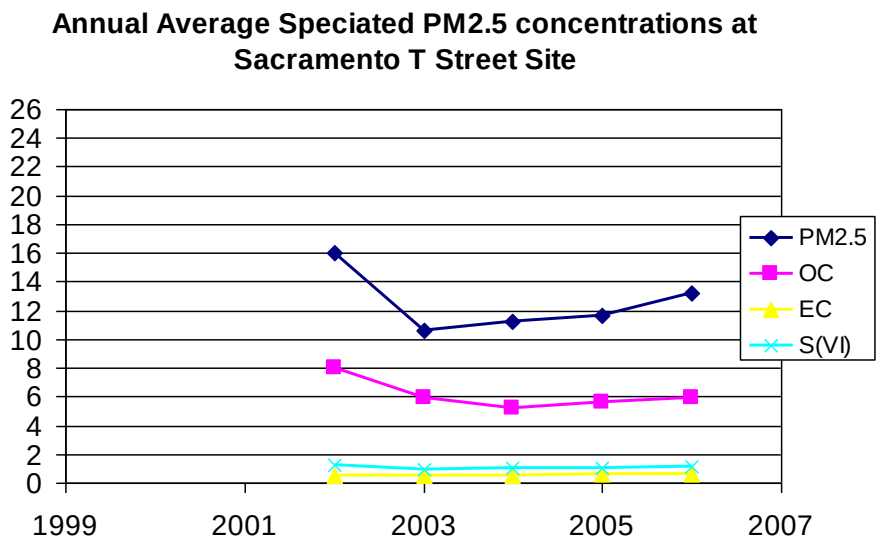
SJV: 25,000 sq miles
PM10 = approx 180 tons/day

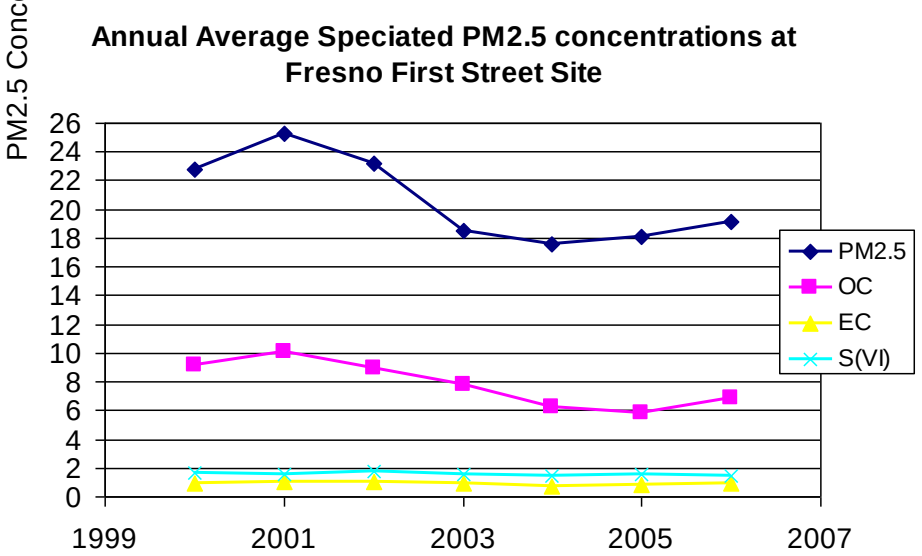
SoCAB: 6,500 sq miles
PM10 = approx 400 tons/day

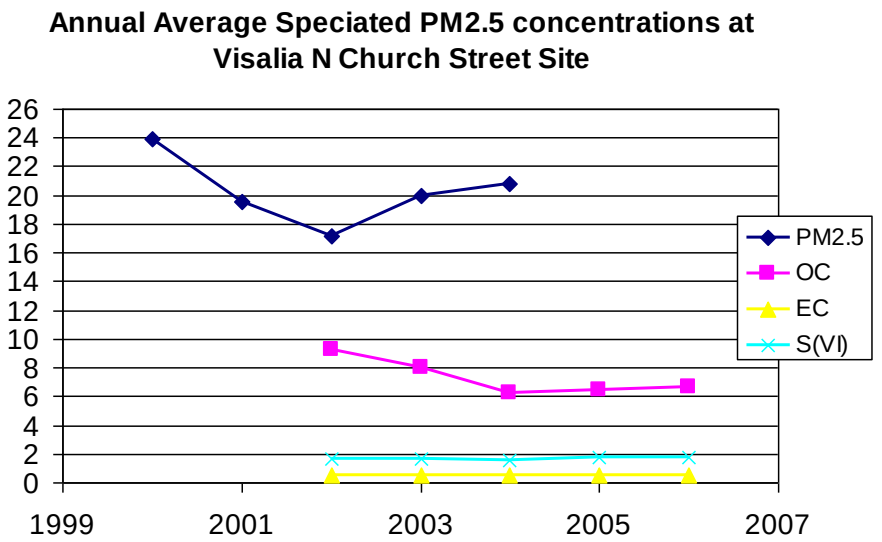



15.0
14.25
13.5
12.75
12.0
11.25
10.5
9.75
9.0
8.25
7.5
6.75
6.0
5.25
4.5
3.75
3.0
2.25
1.5
0.75
0.0

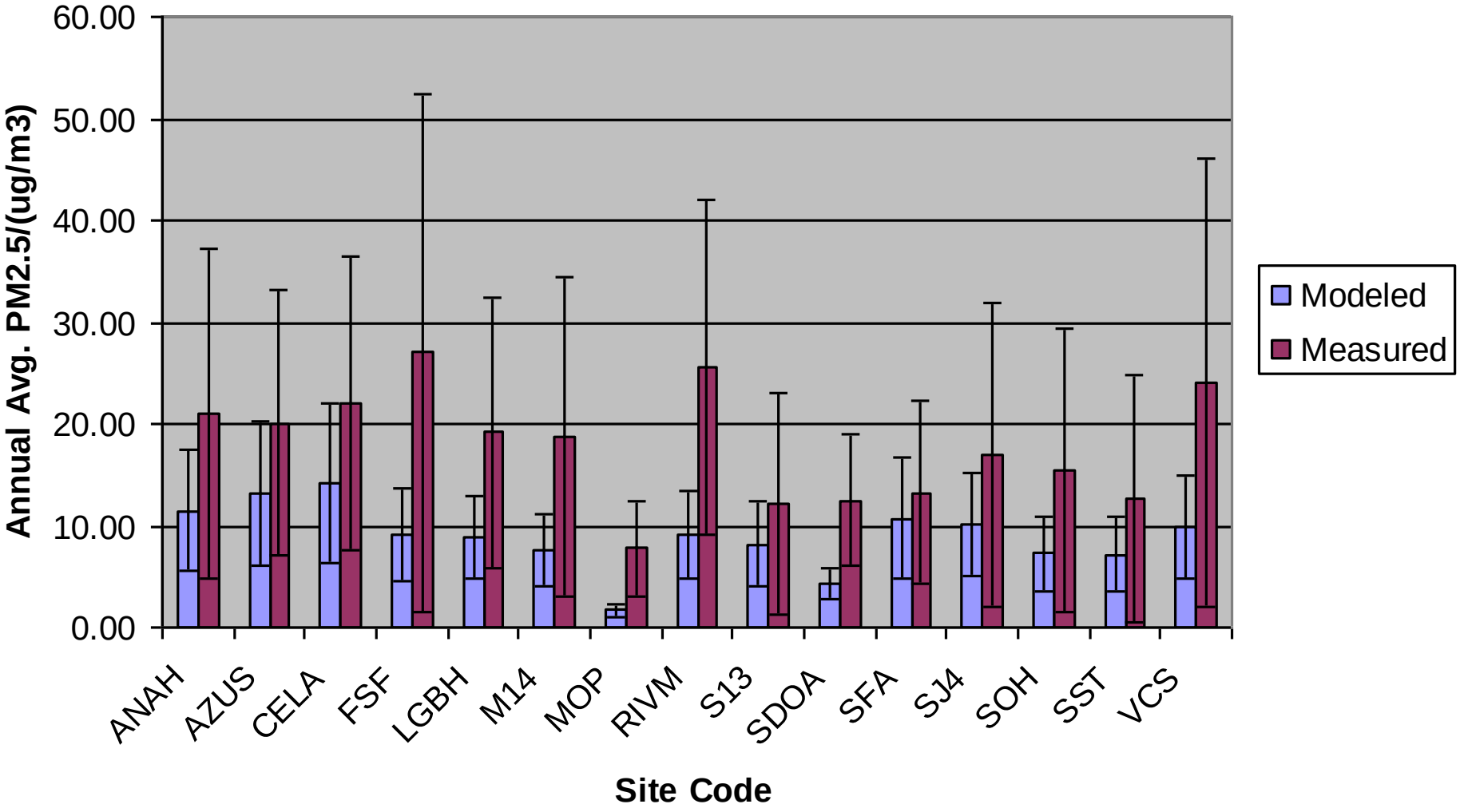

Annual Average Speciated PM2.5 concentrations at Los Angeles North Main Street Site
PM2.5 Concentration (ug/m3)
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1999
2001
2003
2005
2007
PM2.5
OC
EC
S(VI)


Annual Average Speciated PM2.5 concentrations at Sacramento T Street Site
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1999
2001
2003
2005
2007
PM2.5
OC
EC
S(VI)


Annual Average Speciated PM2.5 concentrations at Fresno First Street Site
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1999
2001
2003
2005
2007
PM2.5
OC
EC
S(VI)


Annual Average Speciated PM2.5 concentrations at Visalia N Church Street Site
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1999
2001
2003
2005
2007
PM2.5
OC
EC
S(VI)

Year


Annual Average PM2.5 Concnetrations at different CA sites (2000)
Annual Avg. PM2.5/(ug/m3)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
ANAH
AZUS
CELA
FSF
LGBH
M14
MOP
RIVM
S13
SDOA
SFA
SJ4
SOH
SST
VCS
Site Code
Modeled
Measured