

# **Photochemical Air Quality Modeling: Policy-Relevant Scientific Investigations**

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**California Environmental Protection Agency**



**Air Resources Board**

# Policy-Relevant Science



- Generally top-down
  - Given a policy issue, identify and use best available science to address it
  - ARB supports applicable research and has a 3-5 year plan
  - Research is mostly out-sourced with small in-kind contributions, and now beginning collaborations
  - Field studies (CCOS, SCOS, and CRPAQS) provide opportunities and resources for long-term collaborative scientific investigations

# Organizational Structure



- California Environmental Protection Agency (Cal/EPA) - [www.calepa.ca.gov](http://www.calepa.ca.gov)
  - Air Resources Board (ARB) - [www.arb.ca.gov](http://www.arb.ca.gov)
    - Planning and Technical Support Division (PTSD) – Robert Fletcher, Chief
      - Modeling and Meteorology Branch – Donald McNerny
        - Modeling Support Section (Andrew Ranzieri)
        - Control Strategy Evaluation Section (John DaMassa)
        - Meteorology Section (Arndt Lorenzen)

# Modeling Sections



- Major focus areas
  - Air quality, emissions, and meteorology modeling
  - Air toxics and permit modeling, Environmental Justice, Regional toxic background
  - Field program planning, execution, data analysis, and database management
- Highly trained staff
  - Expertise in chemistry, physics, atmospheric sciences, engineering, computer science, and mathematics
  - Ph.D. (9), MS (8), and BS (2) + a graduate student and a near-future postdoctoral fellow
  - Five Staff Air Pollution Specialists and five PE's

# Major Projects



- Attainment Demonstrations for State Implementation Plans (SIPs) - San Joaquin Valley, South Coast etc.
- Toxics modeling for Neighborhood Assessment Program - Barrio Logan in San Diego as a pilot program
- Ozone modeling for
  - Southern California Ozone Study (SCOS)
  - Central California Ozone Study (CCOS)

# Major Projects (Cont.)



- Database management (CCOS, SCOS, CRPAQS, etc.)
- Modeling support for evaluating emerging technologies (diesel particulate traps, ozone scavenging catalysts, etc.)
- Border planning – CA/Northern Mexico
- Transport assessment for ozone and PM
- Particulate and visibility modeling for California Regional Particulate-Matter Air Quality Study (CRPAQS)



REGION IX  
AIR QUALITY  
ATTAINMENT DESIGNATIONS  
FOR  
OZONE  
1-HOUR STANDARD



CALIFORNIA

NEVADA

ARIZONA

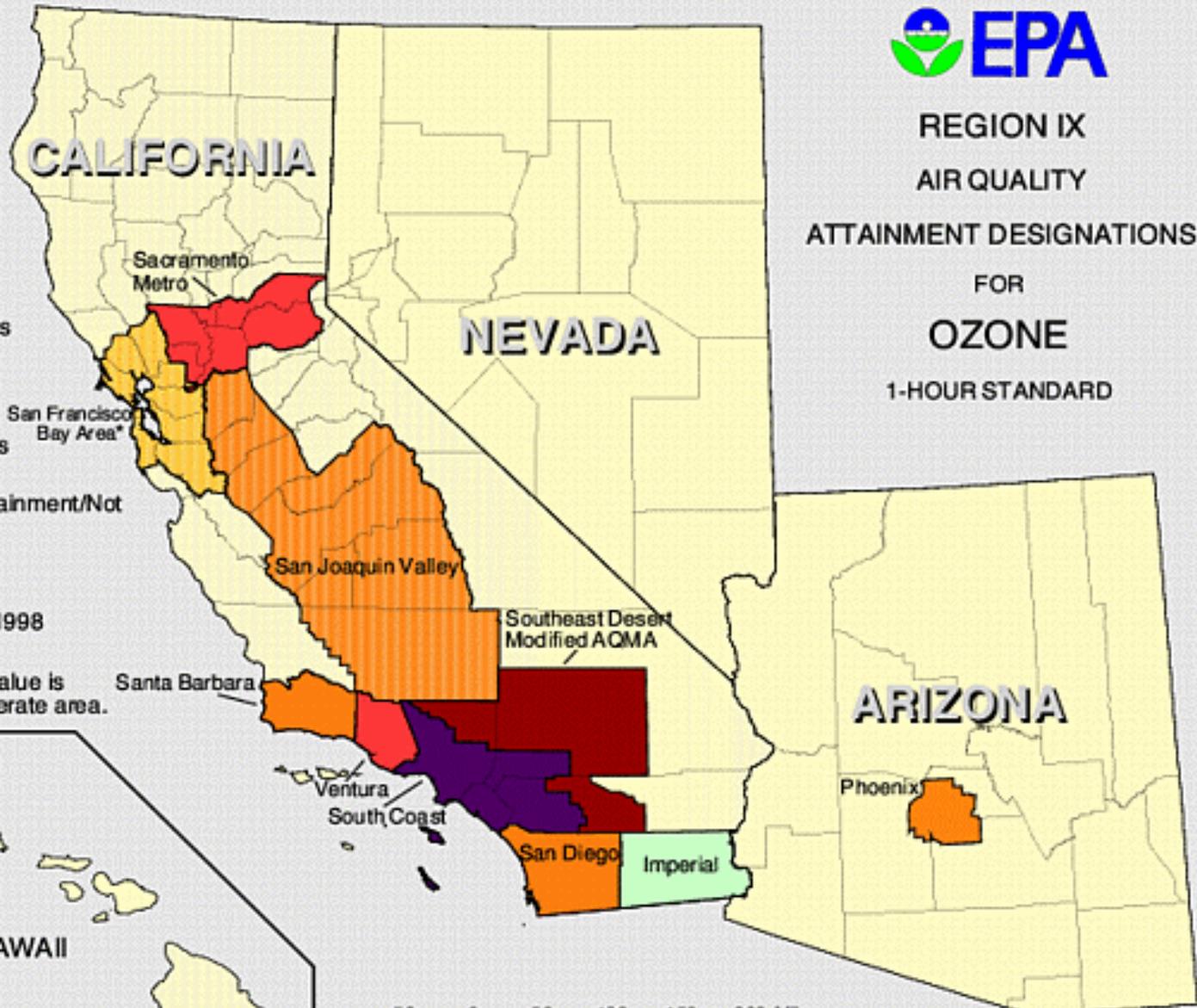
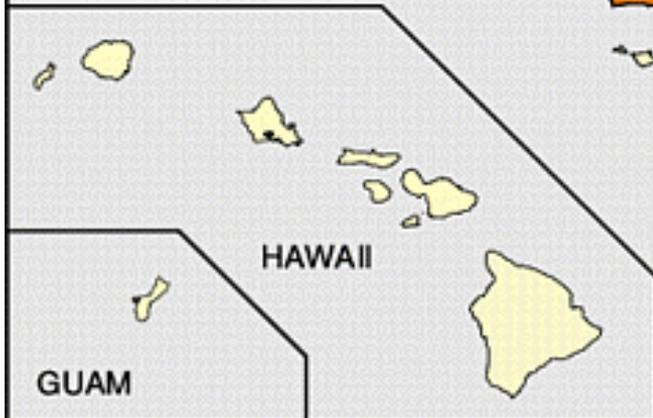
CLASSIFICATION:

-  Extreme - 20 years
-  Severe - 17 years
-  Severe - 15 years
-  Serious - 9 years
-  Moderate - 6 years
-  Transitional
-  Unclassifiable/Attainment/Not Applicable

Last Update: August 1998

NOTE:

Bay Area's design value is equivalent to a moderate area.



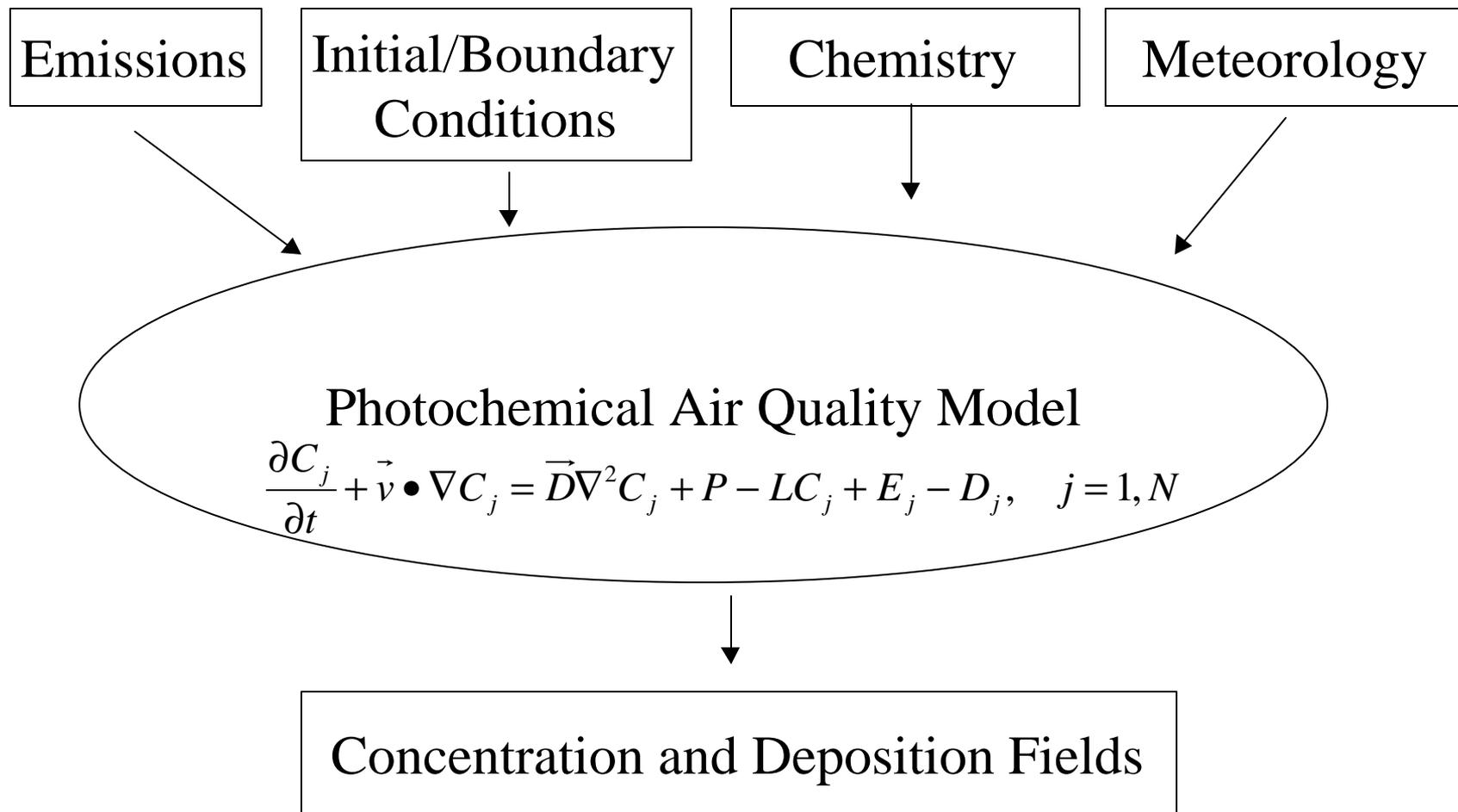
50 0 50 100 150 200 Miles

# San Joaquin Valley Ozone Story



- Classified as “serious” in 1990 and given until 1999 to attain NAAQS
- SIP was submitted in 1994 based on SARMAP and was approved in 1997
- Failed to attain in 1999 and bumped-up to “severe-15” with attainment in 2005
- New SIP is now in preparation and air quality modeling is required for Attainment Demonstration

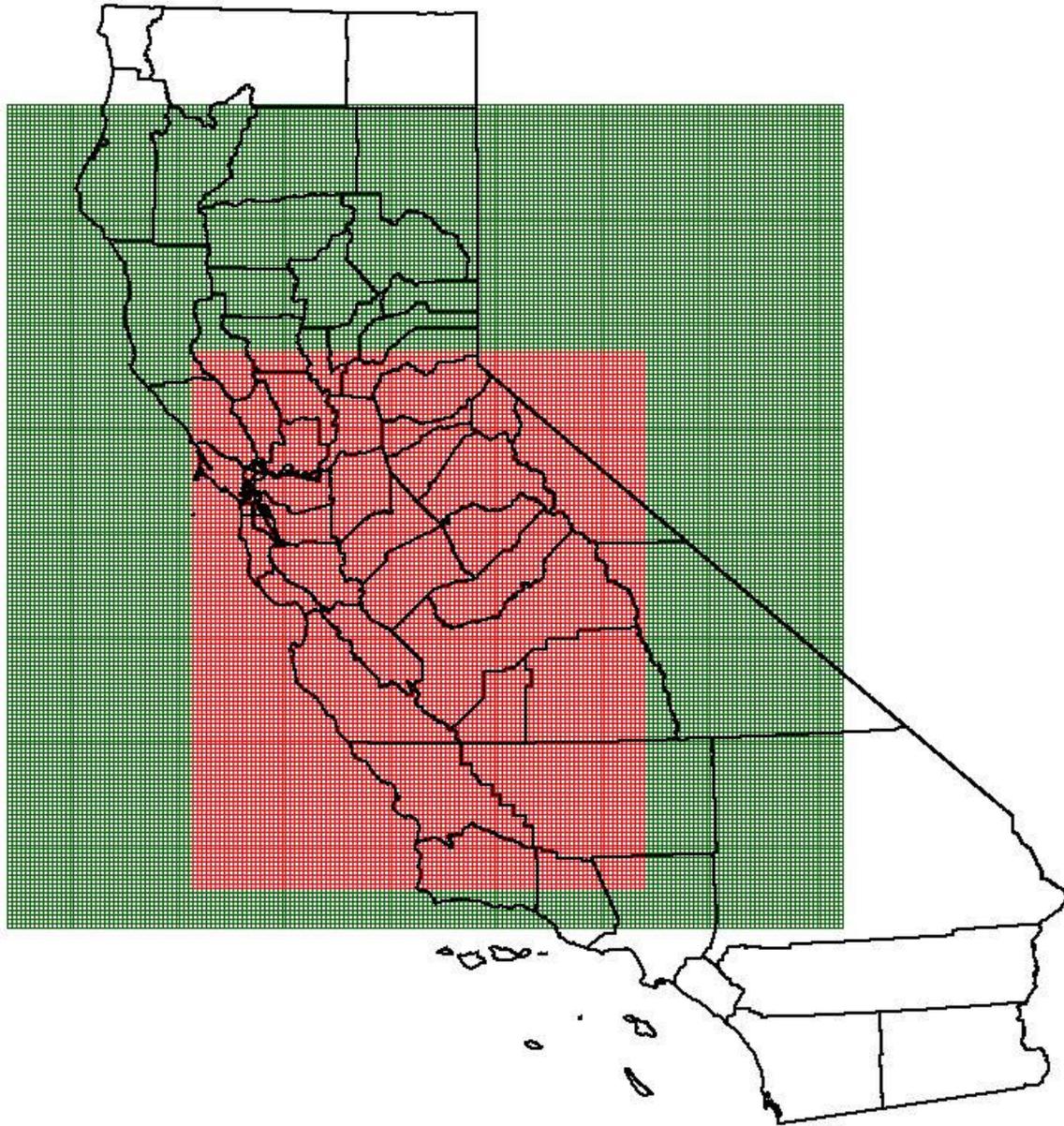
# Air Quality Modeling

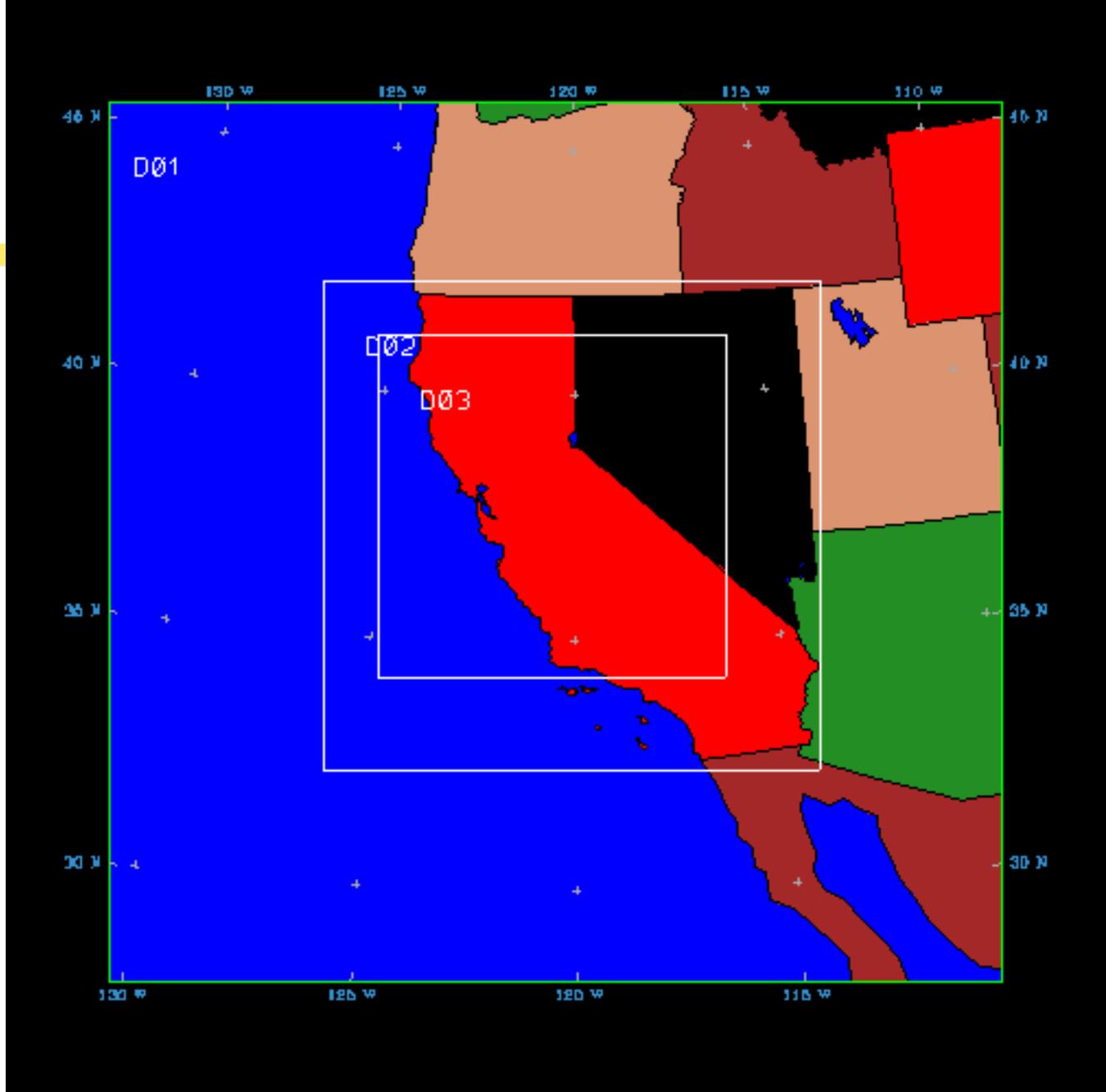


# Models



- Emissions:
  - EMS-95 - ARC/INFO and SAS based
  - Plans for SMOKE
- Meteorology:
  - MM5 – Prognostic
  - DWM
  - Plans for others
- Air Quality
  - SARMAP Air Quality Model (SAQM)
  - Models-3/CMAQ

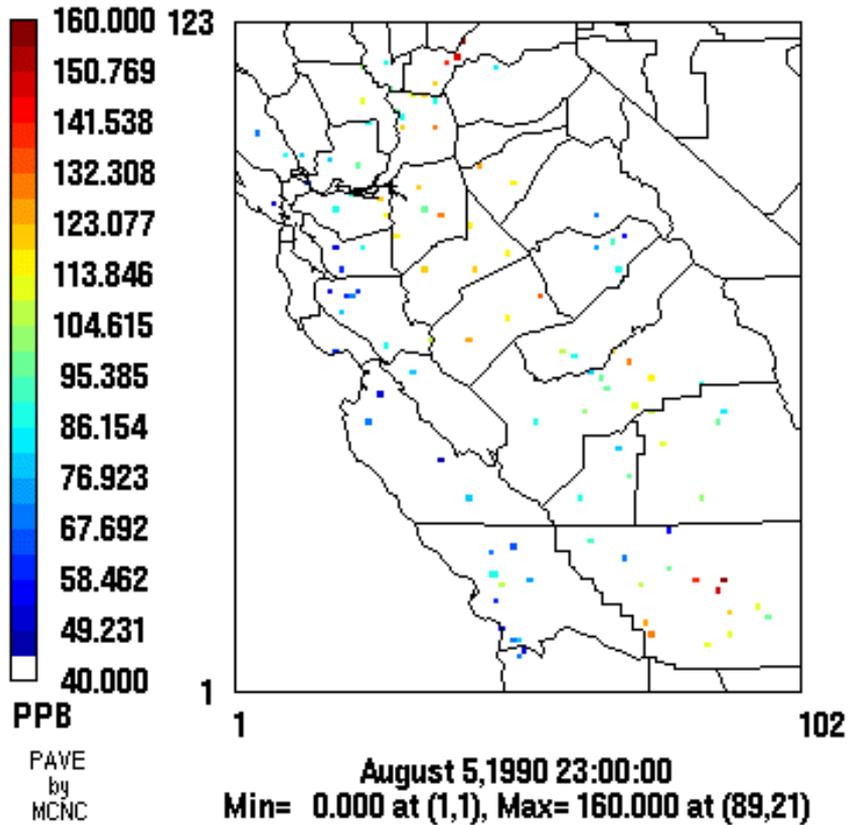




# August 5<sup>th</sup>, 1990

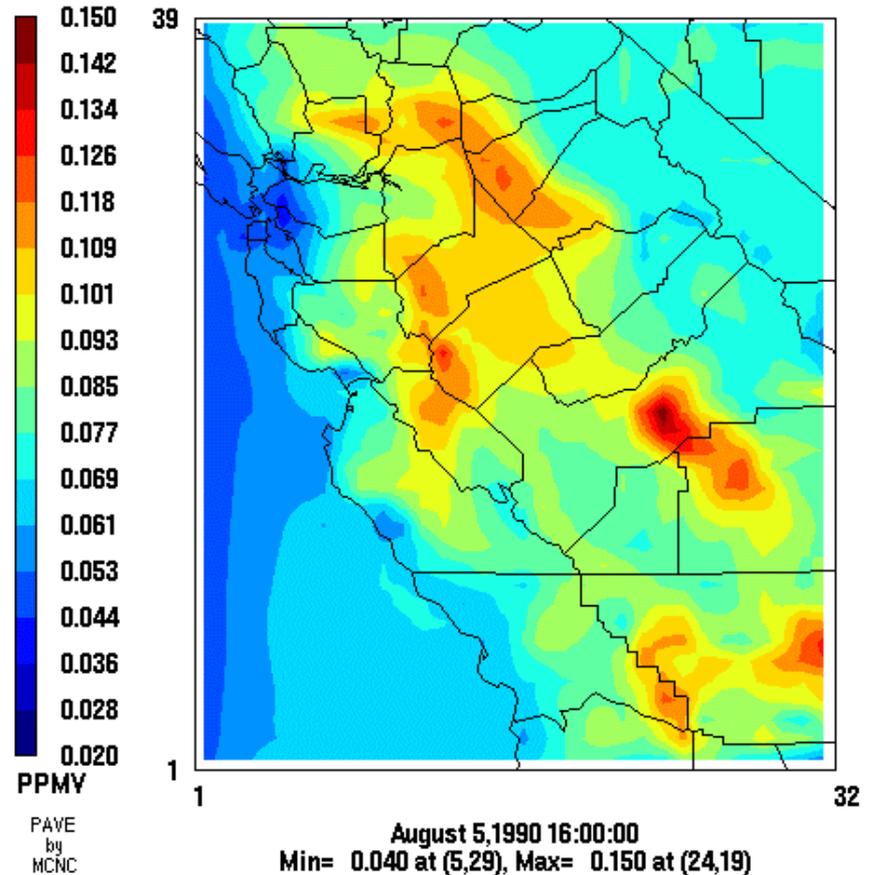
## AIRS Daily O3 Maximum Con.

airs.o3.aug90.max.cdf

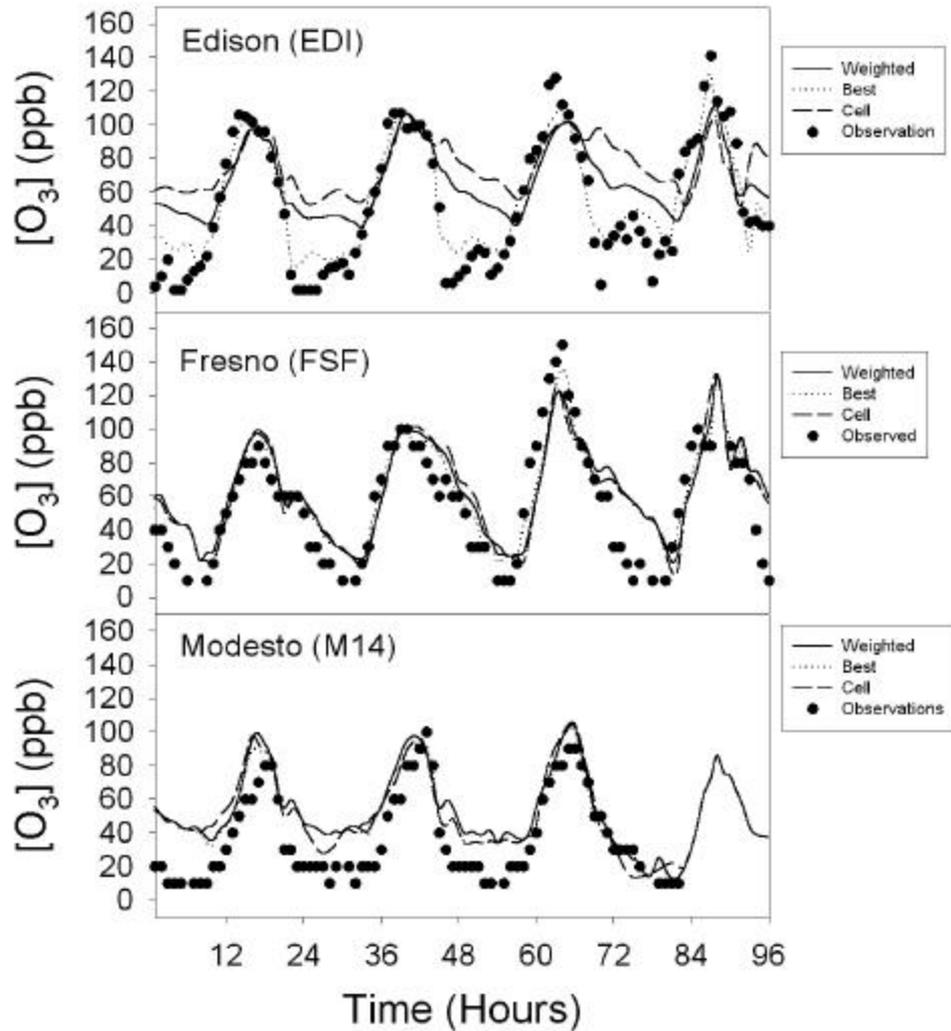


## Layer 1 O3b

b=90\_214a.cdf



# 1990 12 km<sup>2</sup>



1990

August 5<sup>th</sup>

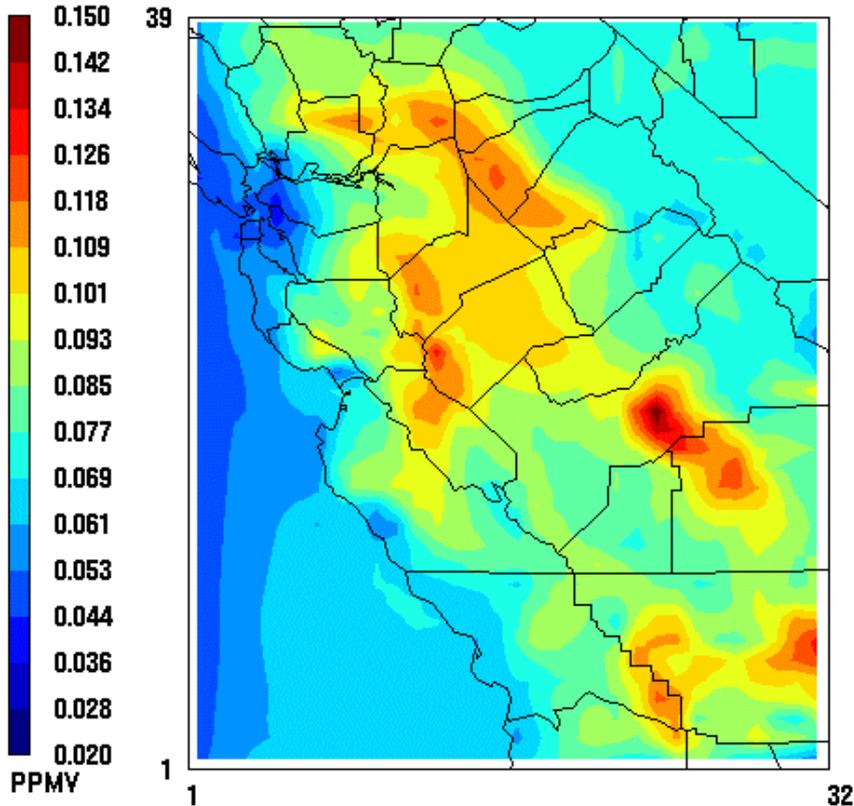
2005

Layer 1 O3b

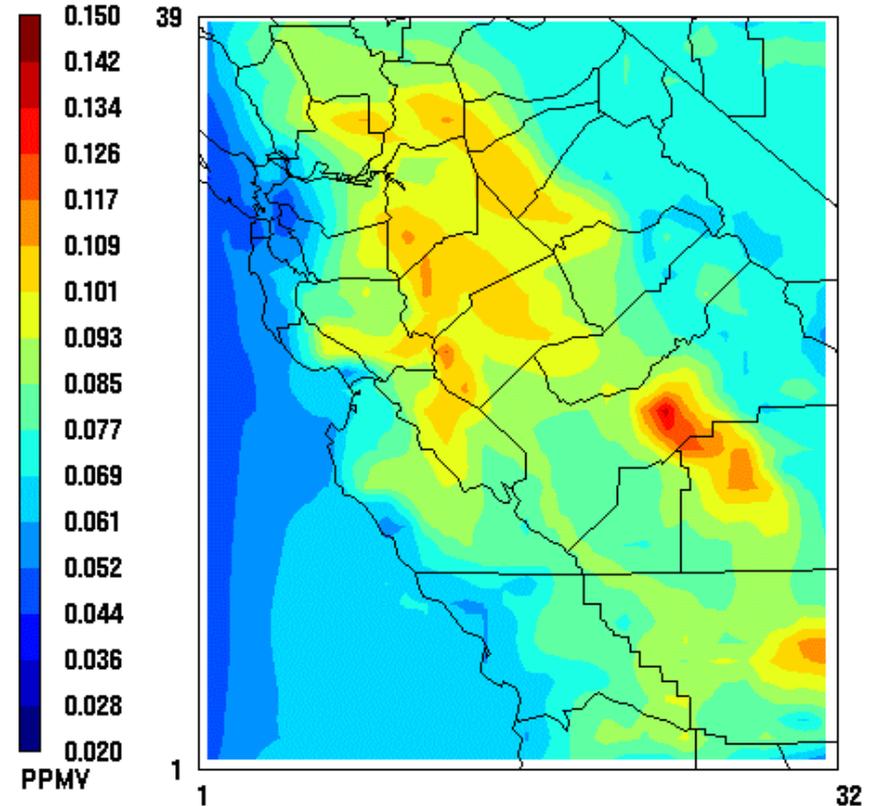
Layer 1 O3a

b=90\_214a.cdf

a=05\_214a.cdf



August 5, 1990 16:00:00  
Min= 0.040 at (5,29), Max= 0.150 at (24,19)



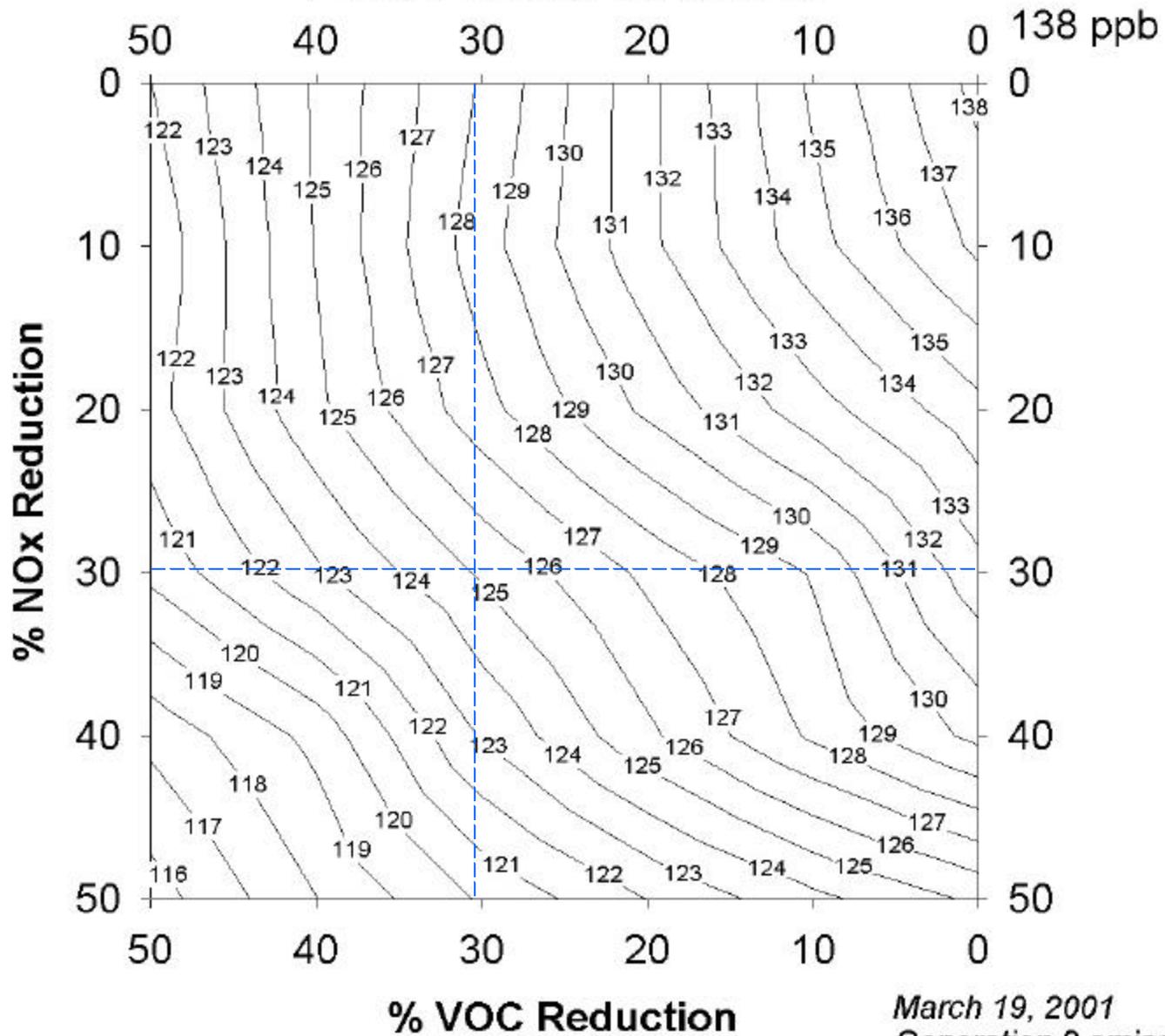
August 5, 1990 16:00:00  
Min= 0.044 at (1,31), Max= 0.138 at (24,19)

# Carrying Capacity Diagrams



- Provide **rough** estimates of emission reductions needed to achieve a target ozone concentration so that planning can begin
- Emission reductions are domain-wide
- Only anthropogenic emissions are reduced
- All categories are reduced equally
- Final emission control strategies must be re-simulated with the model

# Fresno County 08/05/2005



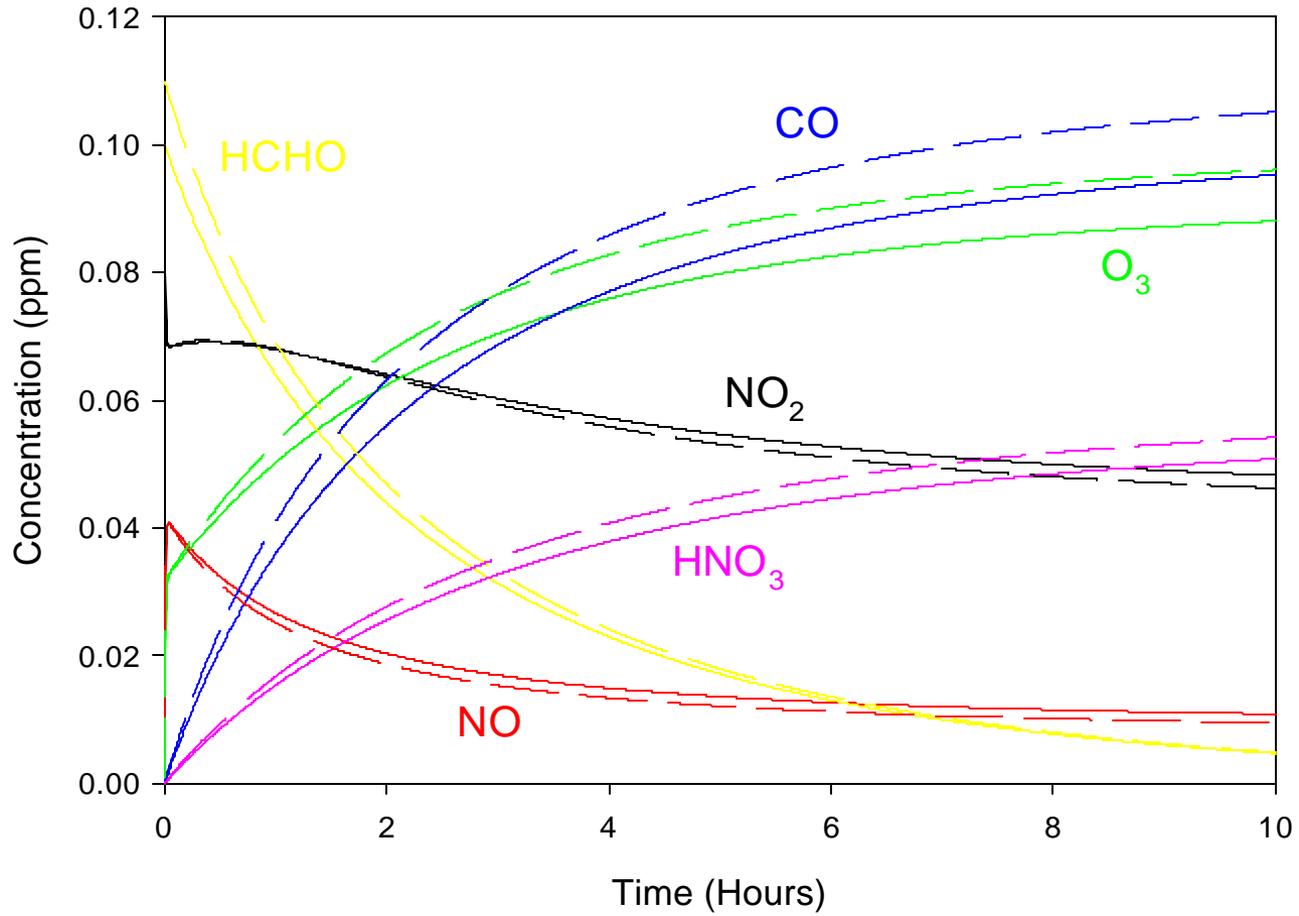
March 19, 2001  
Generation 2 emissions.

# Photochemical Reactivity

- VOCs enhance the formation of O<sub>3</sub> (with very few exceptions)
- This enhancement can be quantified as Incremental Reactivity (IR)

$$IR_{VOC} = \frac{\partial[O_3]}{\partial E_{VOC}} = \lim_{\Delta E_{VOC} \rightarrow 0} \frac{\Delta[O_3]}{\Delta E_{VOC}}$$

- IR is the change in [O<sub>3</sub>] for a small change in the emissions of a VOC and it is different for different VOCs



# Future



- Various emission sensitivity studies
- Further evaluation of boundary conditions
- Continuation of higher grid resolution (4 km<sup>2</sup>)
- Increase number of vertical layers (Exact layer mapping with MM5)
- Alternative models (e.g., Models-3/CMAQ)
- SAPRC-99 chemistry
- State-wide domain
- CCOS episode(s)
- Attainment demonstration(s)

# Particulate Matter Modeling



- Techniques are still being developed
- Further technical expertise and computational resources are required compared to ozone modeling
- Two recognized experts at UCD
  - Anthony Wexler – LAWR, Civil and Env. Eng., Mechanical and Aeronautical Eng.
  - Michael Kleeman – Civil and Env. Eng.
- A comprehensive database for model evaluation will be available for the first time (CRPAQS)

# IMS-95 Modeling Experience



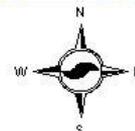
- The Integrated Monitoring Study (IMS-95)
- To support planning of a larger study
- Very small domain (a “postage stamp”)
- Limited set of measurements

# California Regional PM<sub>10</sub>/PM<sub>2.5</sub> Air Quality / Central California Ozone Study

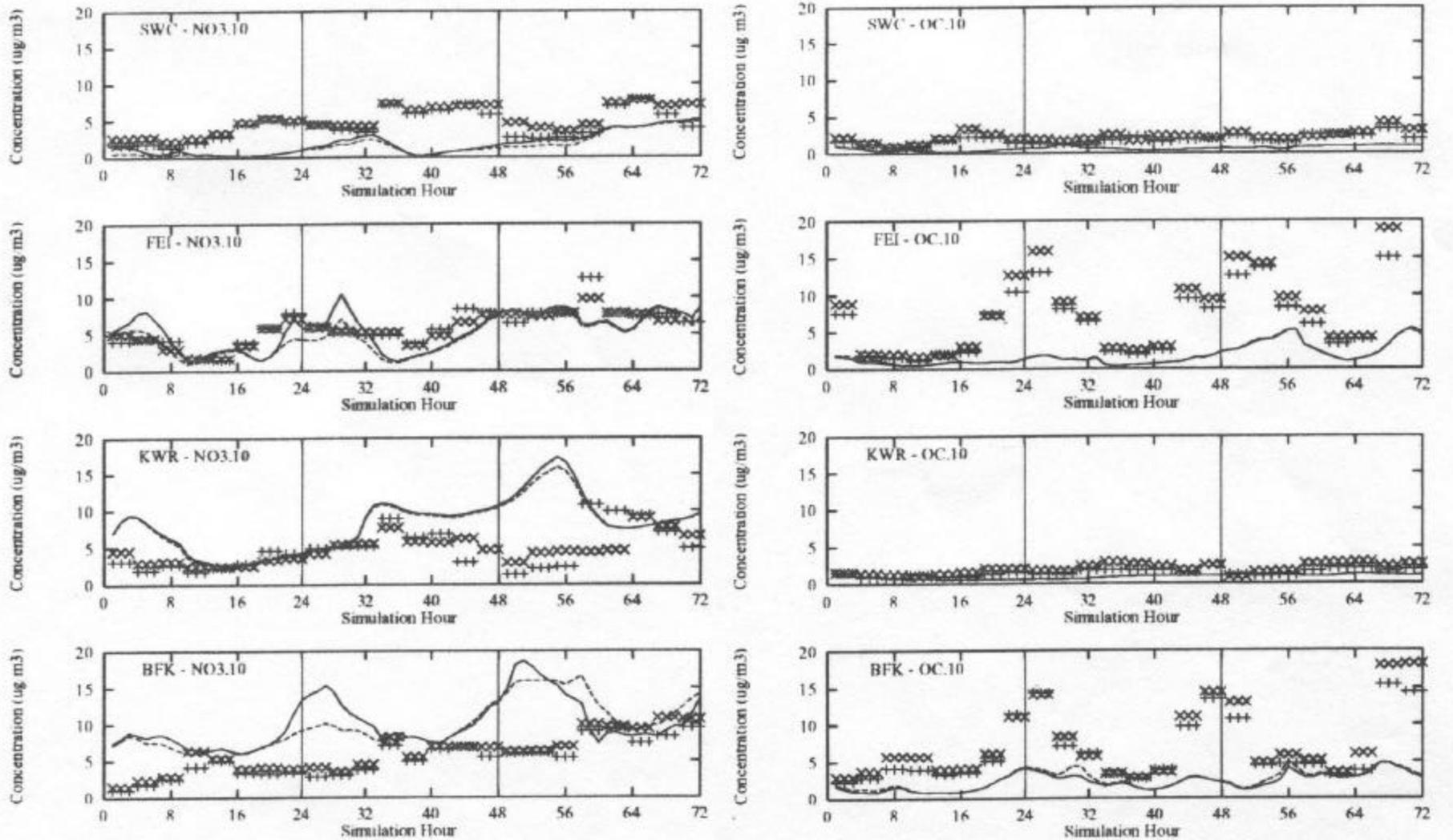


0 50 100 150 200 Miles

 California Environmental Protection Agency  
Air Resources Board



# UAM-AERO RESULTS FOR IMS-95



# Lessons Learned from IMS-95



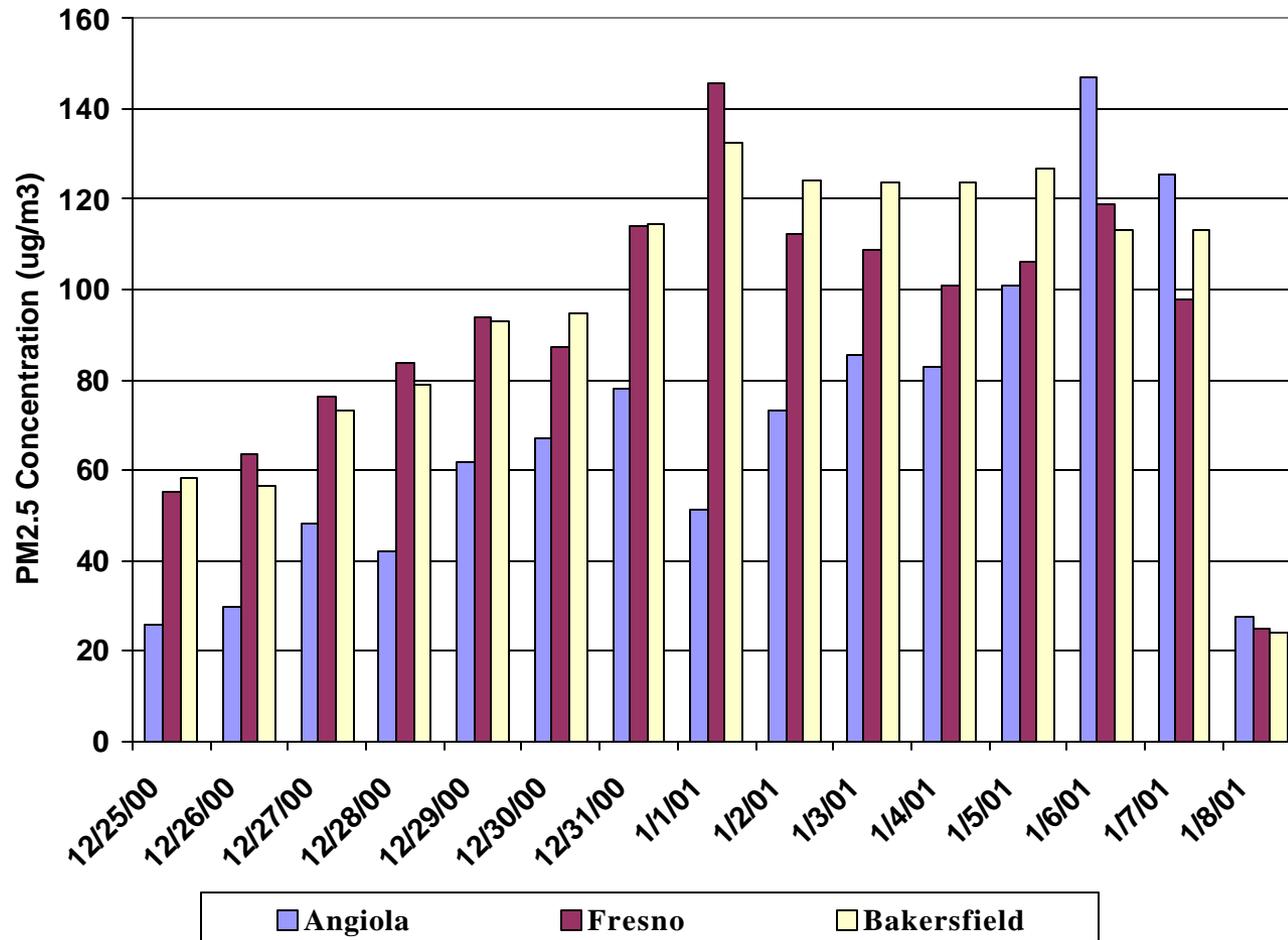
- Domain too small, boundary effects too significant
- Not enough field data with spatial and temporal resolution
  - Air quality including VOC, boundary conditions etc.,
  - Upper air meteorology measurements
  - Fog
- Science needs updates

# Current Air Quality Studies



- Two major field studies in central and northern California in 2000
  - California Regional Particulate-Matter Air Quality Study (CRPAQS)
    - Federal, state, local, and industry collaboration
    - ~\$27+ million
    - Based on the findings of IMS-95 (~\$5 million)
  - Central California Ozone Study (CCOS)
    - State and local government collaboration now attracting federal funds
    - ~\$10 million spent and ~\$8 million needed

# PM2.5 Concentrations at Three Anchor Sites During Wintertime Episode



# Key Questions To Be Addressed



- Are exceedances local or regional in nature, or a combination of both?
- Which PM components should controls be focused on?
- What are the specific sources which are contributing to PM exceedances?
- Will the same strategies be effective for both the annual and the 24-hour standards?

# Modeling & Data Analysis



- Develop an integrated set of PM modeling methods
- Conduct data analysis to support modeling and provide a conceptual framework for understanding the nature and causes of PM exceedances
- Provide tools for decision makers to explore “what-if” scenarios

# Near-Term Modeling Plan



- PM modeling is more complex than ozone modeling. Requires additional technical abilities and computational resources
- Familiarization with methods and initial capacity building are essential
- Revisiting of IMS-95 modeling as a warm-up process
- Close collaborations with UCD faculty and hiring a postdoctoral fellow

# Regional Haze



(a)



(b)



(c)



(d)

*Fig. 3.2. The effect of regional or uniform haze on a Glacier National Park vista. The view is of the Garden Wall from across Lake McDonald. Atmospheric particulate concentrations associated with photographs (a), (b), (c), and (d) correspond to 7.6, 12.0, 21.7, and 65.3  $\mu\text{g}/\text{m}^3$ .*

From "Introduction to Visibility" by W.C. Malm, CIRCA, Colorado State University, 1999, page 11

# Regional Haze Rule



## ■ Justification:

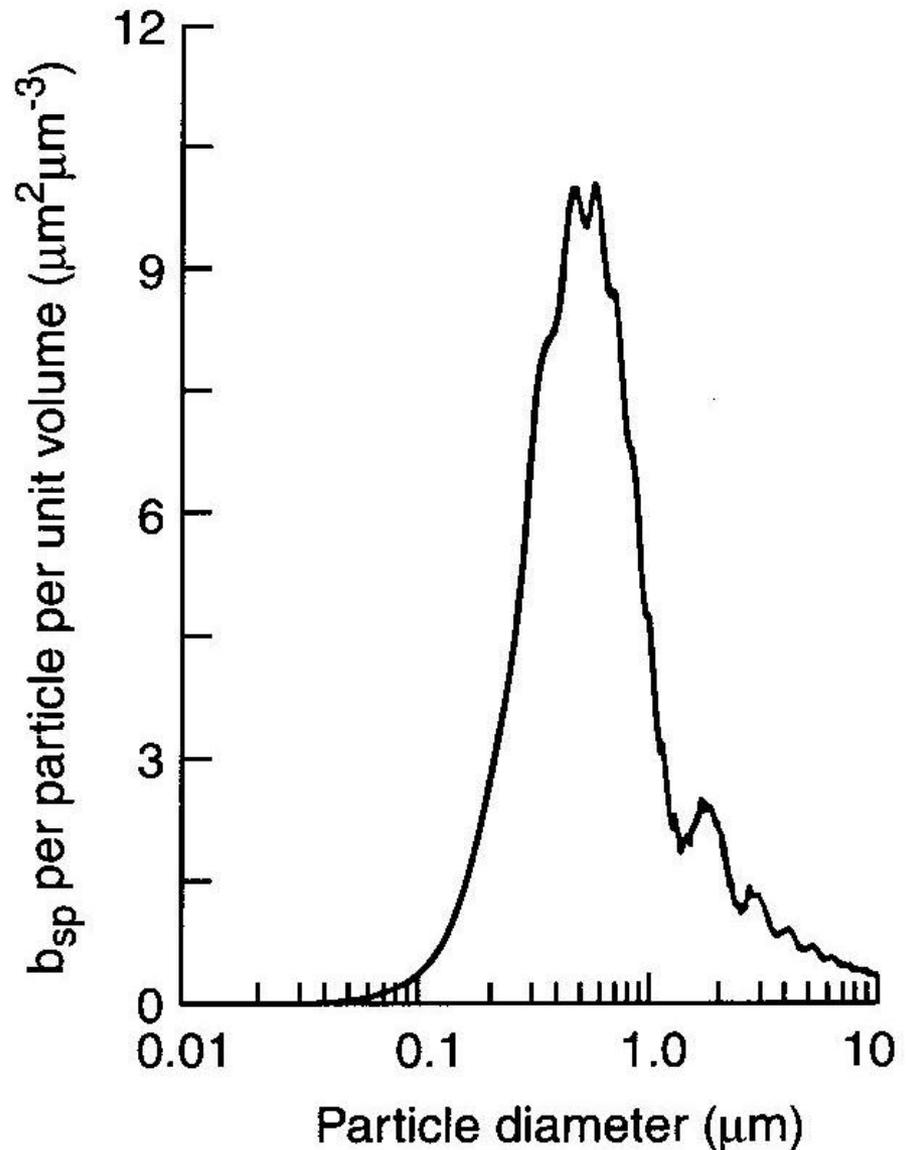
- Visibility is a basic indicator of air quality
- Good visibility is valued by people
- $PM_{2.5}$  that causes health effects contribute significantly to regional haze

## ■ Legal Mandate:

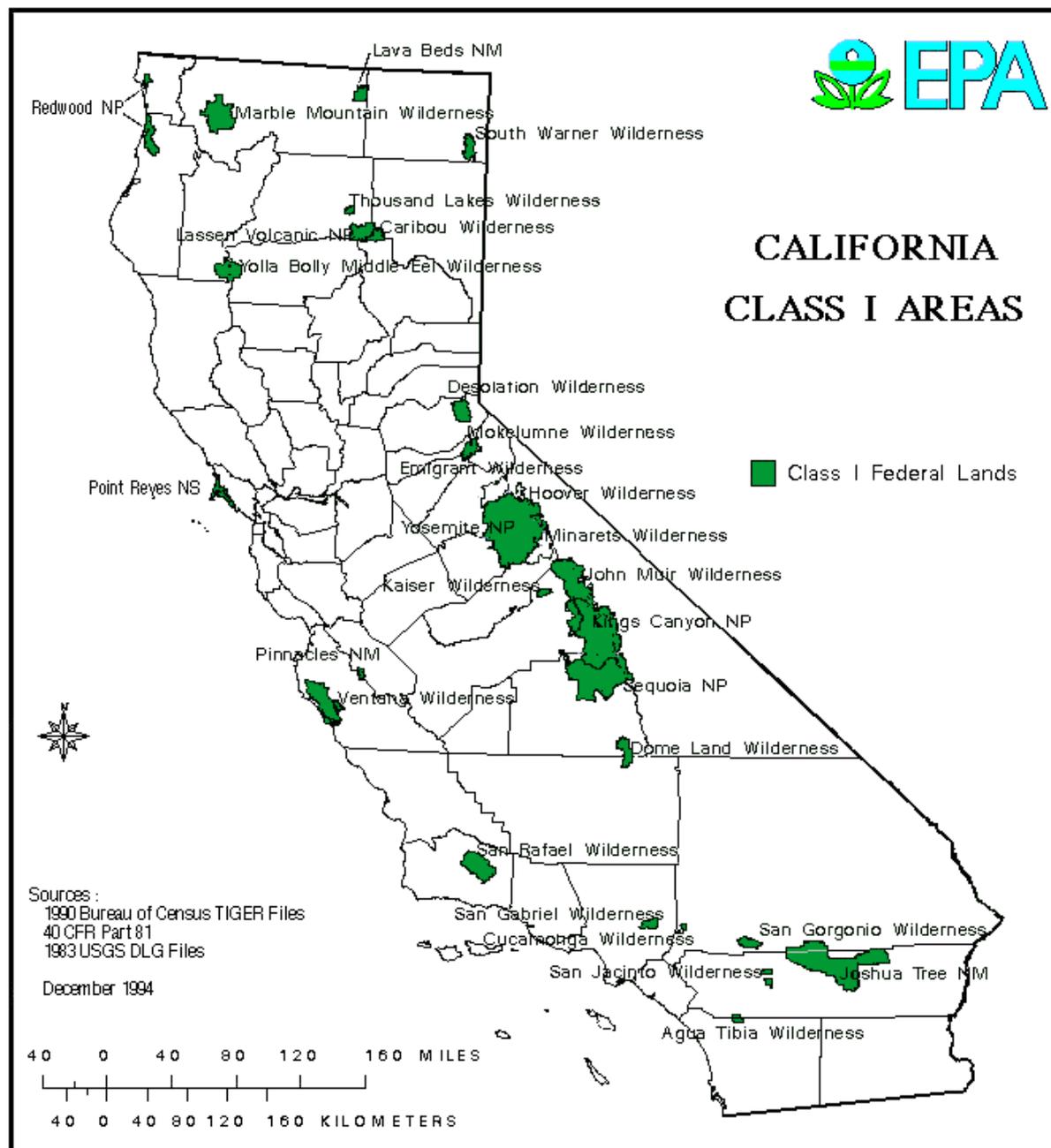
- Amendments to the Clean Air Act
- Covers 156 mandatory Class I Federal areas

# Extinction Due to Particles

Calculations carried out in developing smoke screens during World War II indicated that most of the light scattering in the atmosphere is due to particles in the 0.1-1  $\mu\text{m}$  range. (Remember, wave length of visible light is in the 0.4-0.7  $\mu\text{m}$  range and scattering is efficient when the diameter of the particle and the wave length of light are comparable.)



From "Chemistry of the Upper and Lower Atmosphere", Finlayson-Pitts and Pitts, Academic Press, 2000, page 369



# Regional Collaborations



- Regional haze is a multi-State issue
- US is divided into five regional planning bodies
- West is in the WRAP (Western Regional Air Partnership) covering states west of Colorado
- All GCVTC (Grand Canyon Visibility Transport Commission) states are in the WRAP (plus more)
- WRAP Regional Modeling Center (RMC) is at UC Riverside
- ARB preparing to do comparable modeling

# Computational Resources



- Older high-end expensive computers being phased out
- Shift towards cost-effective multi-processor PCs. SAQM and MM5 codes are parallelized
- Initial Beowulf systems being constructed
- Significant computer funds through CRPAQS for in-kind work



Thank You!