Atmospheric Issues - Chemical Releases

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Topics

1. Emissions of chemical into the atmosphere
2. Atmospheric transport, diffusion and deposition
3. Chemical reactions
4. Air quality management
5. The role of computer models

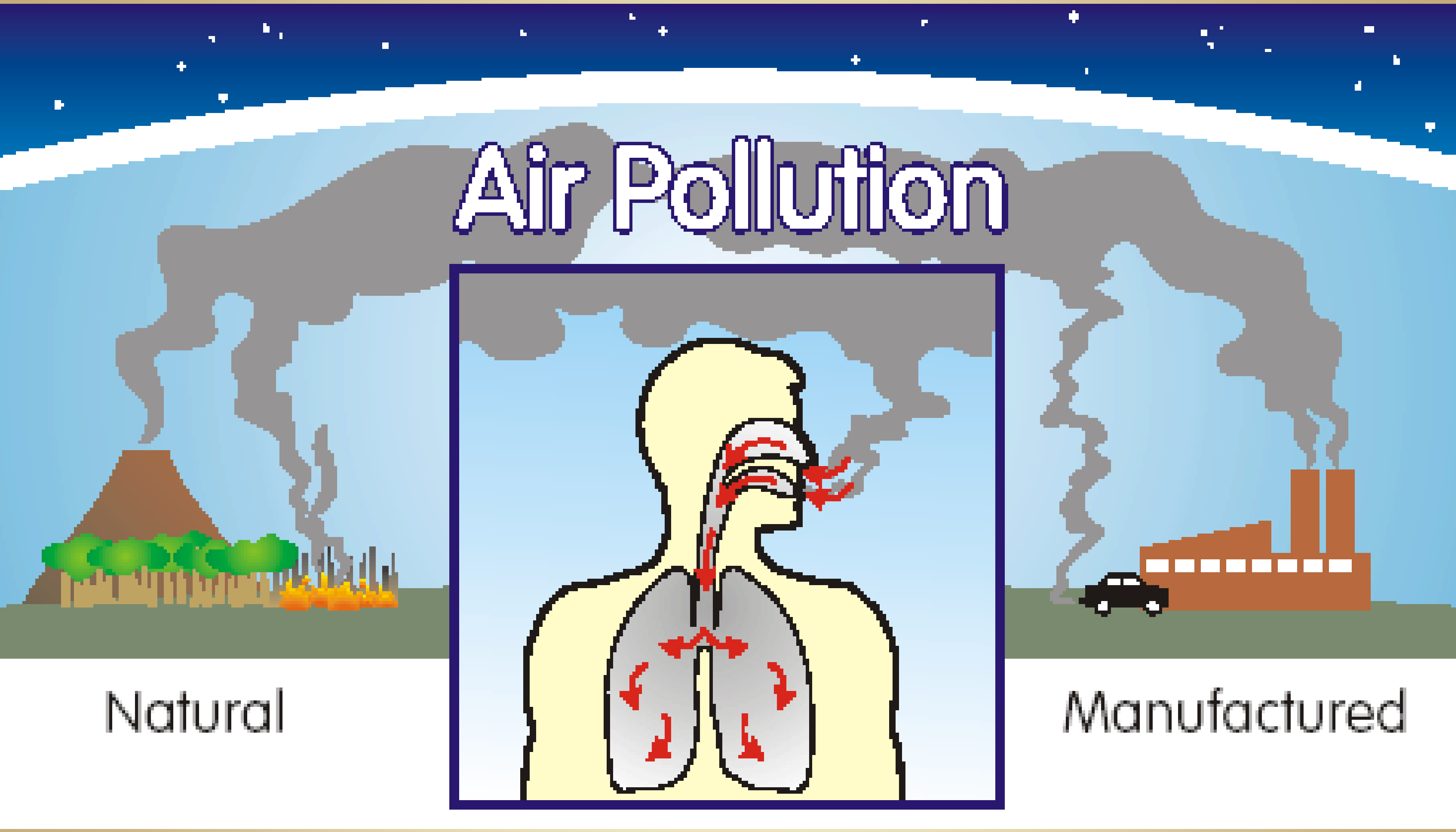
1. Chemical Releases

- Anthropogenic ("man-made"), e.g., power plants
  - Industrial activities, e.g., from stacks
  - Urban activities, e.g., heating
  - Transportation, e.g., cars and trucks
- Natural, e.g., volcanoes

- Planned, e.g., regular industrial production
- Unplanned, e.g., accidental releases

- Traditional ("criteria") chemicals, e.g., SO2, CO, O3
- Air Toxics, e.g., benzene

- Primary emissions (e.g., NO, CO)
- Secondary chemicals (e.g., O3 and a fraction of PM2.5)


Air Pollution
Natural
Manufactured

Adverse Effects

The World Health Organization states that 2.4 million people die each year from causes directly attributable to air pollution, with 1.5 million of these deaths attributable to indoor air pollution.

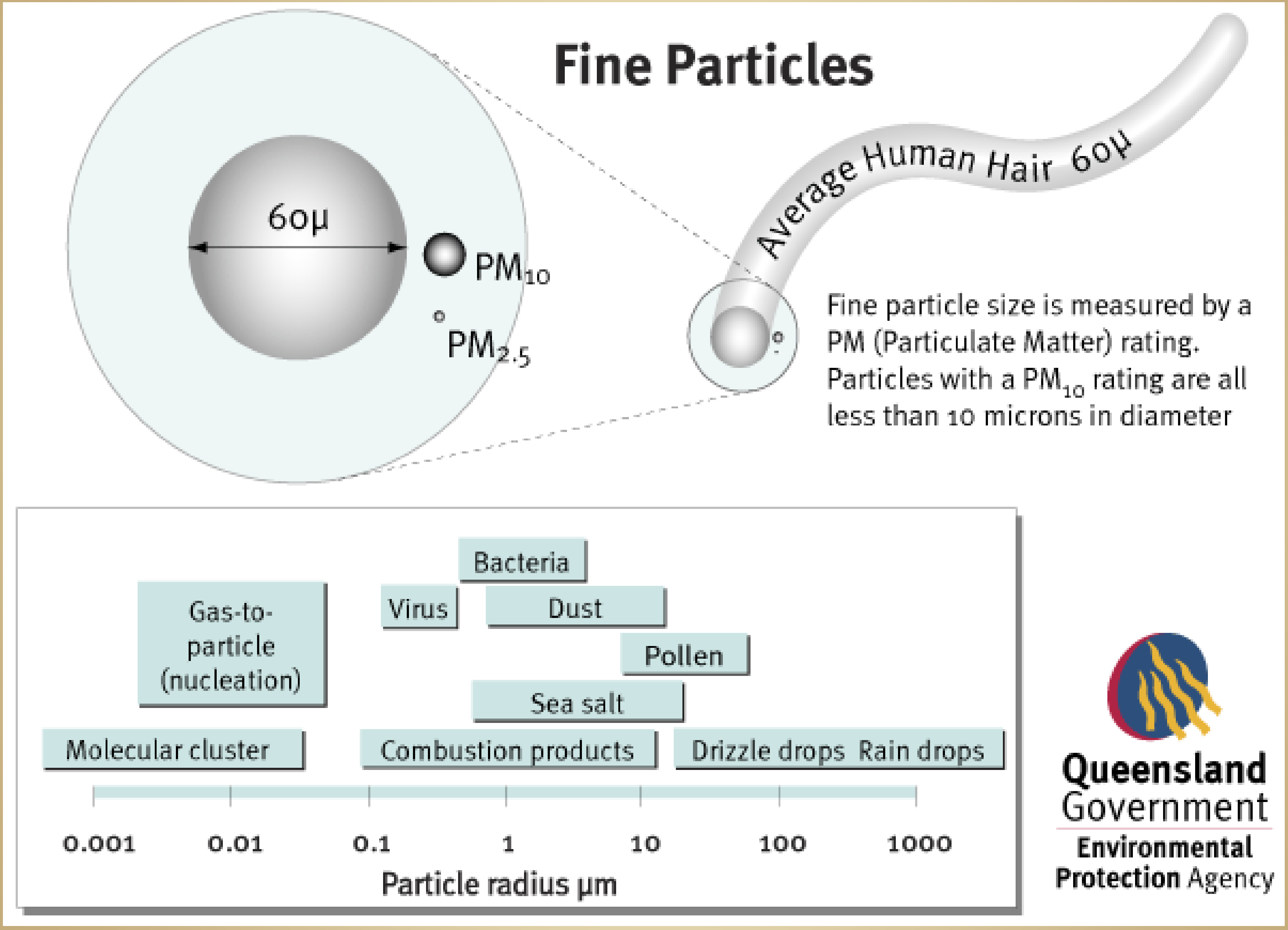
http://www.who.int/entity/quantifying_ehimpacts/countryprofilesebd.xls

2. Atmospheric Transport, Diffusion and Deposition

- Pollutants carried by the wind (Meteorology)
- Diffused by atmospheric turbulence (Meteorology)
- Deposited at the ground by dry and wet processes
- transport.pdf

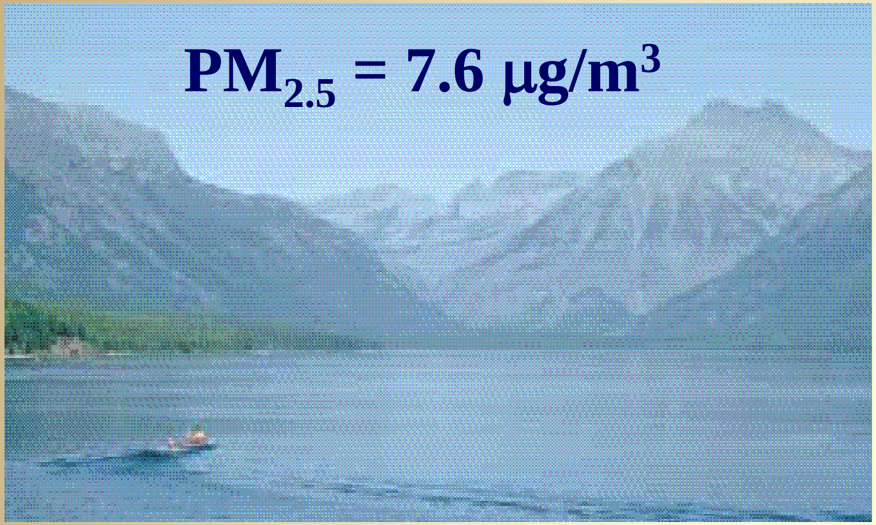
3. Chemical Reactions

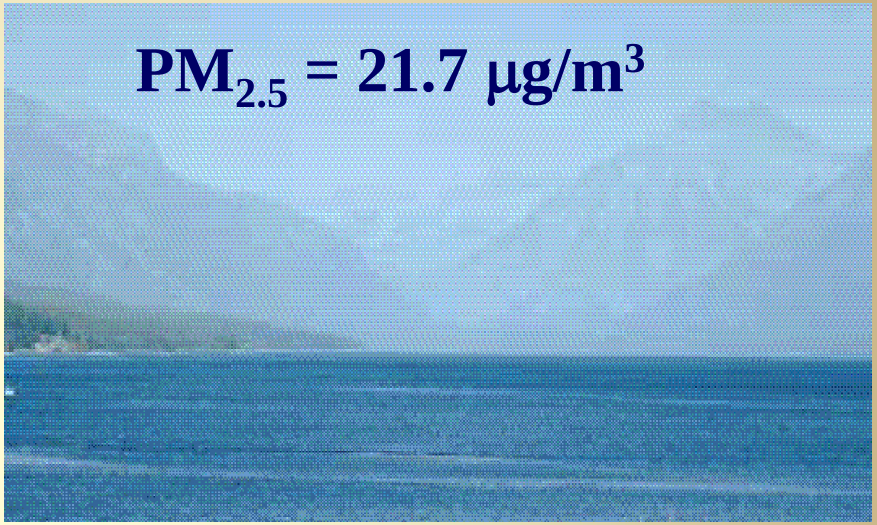
- Creation of urban smog
  - Ozone
  - Photochemical smog
  - urban chemistry.pdf
- Long range transport of urban and industrial plumes
  - Secondary PM2.5
    - SO_2 → sulfates
    - NO_x → nitrates
    - VOC → organic particles
  - Acidic deposition

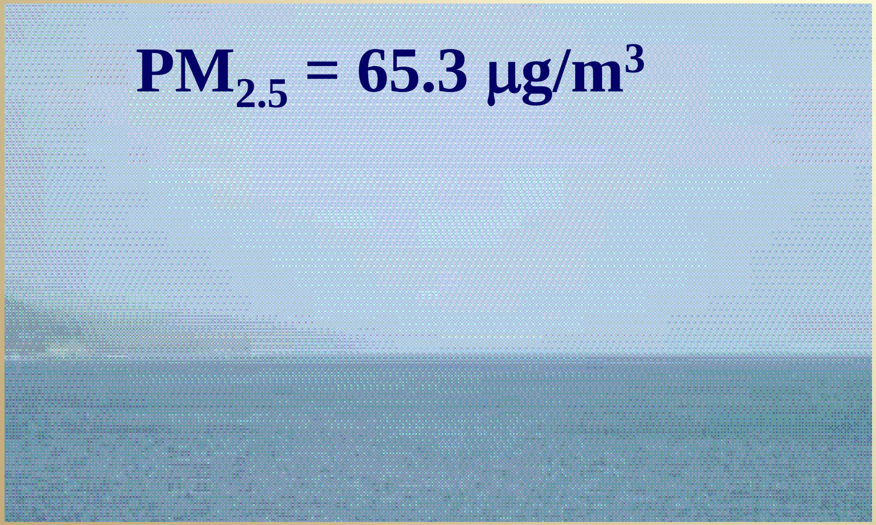

Fine Particles
60µ
PM10
PM2.5
Average Human Hair 60µ
Fine particle size is measured by a PM (Particulate Matter) rating. Particles with a PM10 rating are all less than 10 microns in diameter
Bacteria
Gas-to-particle (nucleation)
Virus
Dust
Pollen
Sea salt
Molecular cluster
Combustion products
Drizzle drops Rain drops
0.001
0.01
0.1
1
10
100
1000
Particle radius µm
Queensland Government
Environmental Protection Agency

Particles and Visibility

(Photos below generated by computer simulation)

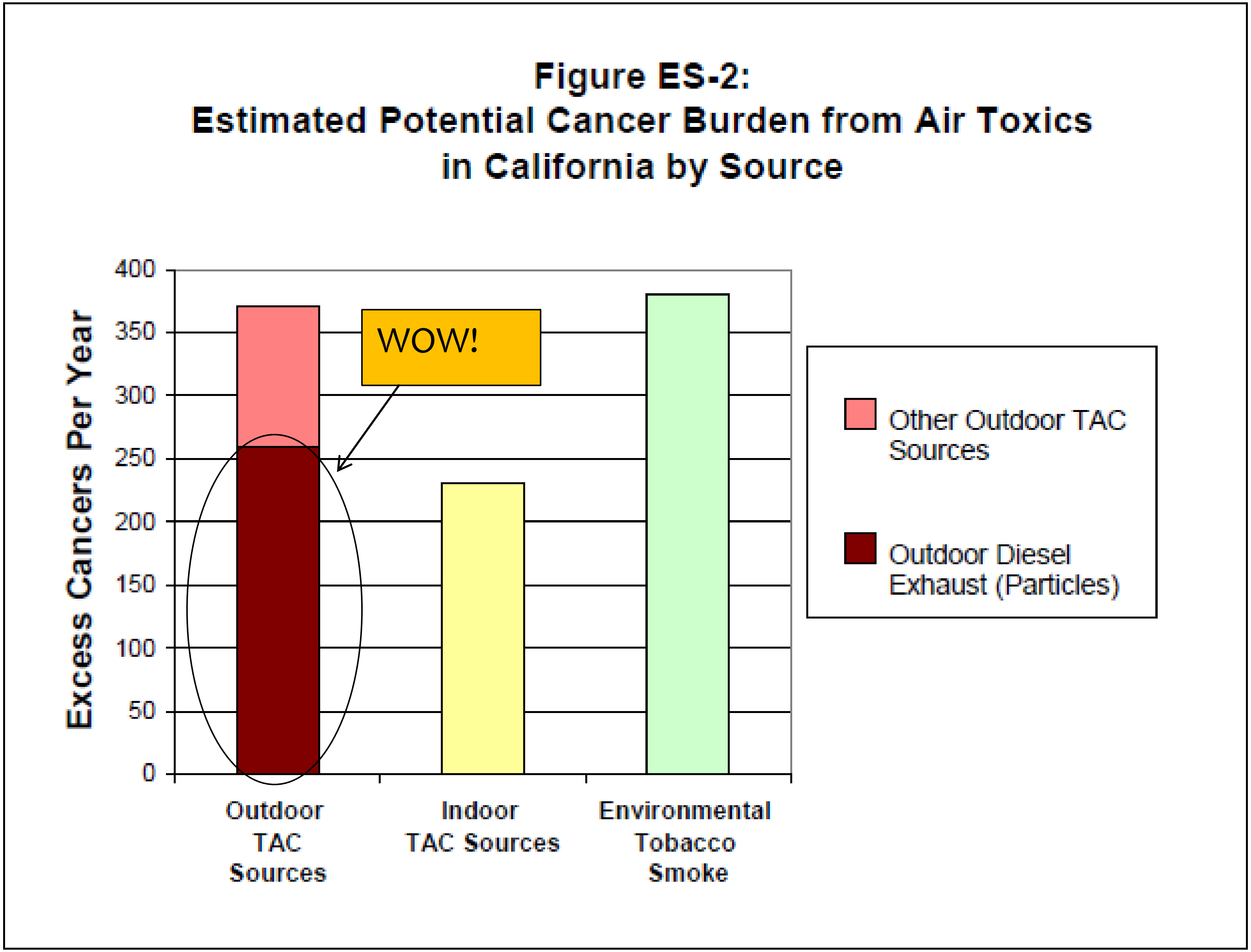






Diesel Particulate Matter (DPM)

- A particularly dangerous portion of PM2.5
- Comprised mostly of
  - Soot ("elemental carbon")
  - Many different forms of "organic carbon"
- Sources: Diesel fueled engines (stationary and mobile)
  - Heavy-duty trucks
  - Construction equipment
  - Others …



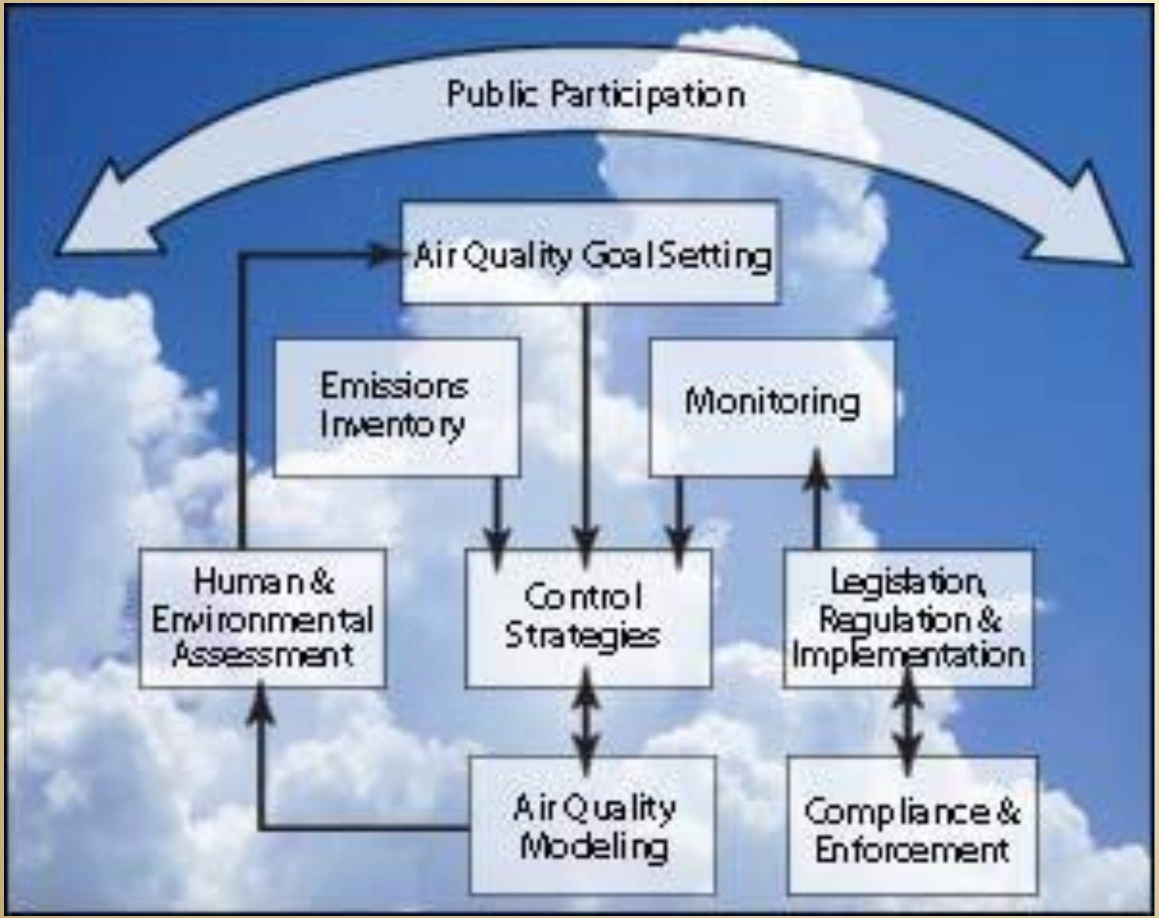
Note: TAC = "Toxic Air Contaminant", which is comprised of many air pollutants that are toxic
http://www.arb.ca.gov/research/apr/reports/l3041.pdf

4. How do we Manage Air Pollution?

- “Routine” management al local level
  - To achieve pre-defined air quality goals
  - To protect human health and the environment
- Emergency management
  - Emergency preparedness
  - Emergency response
- Large scale issues
  - Long-range pollution within a country
  - Trans-boundary pollution
  - Global issues
- Computer modeling is the key tool, e.g., in the US …

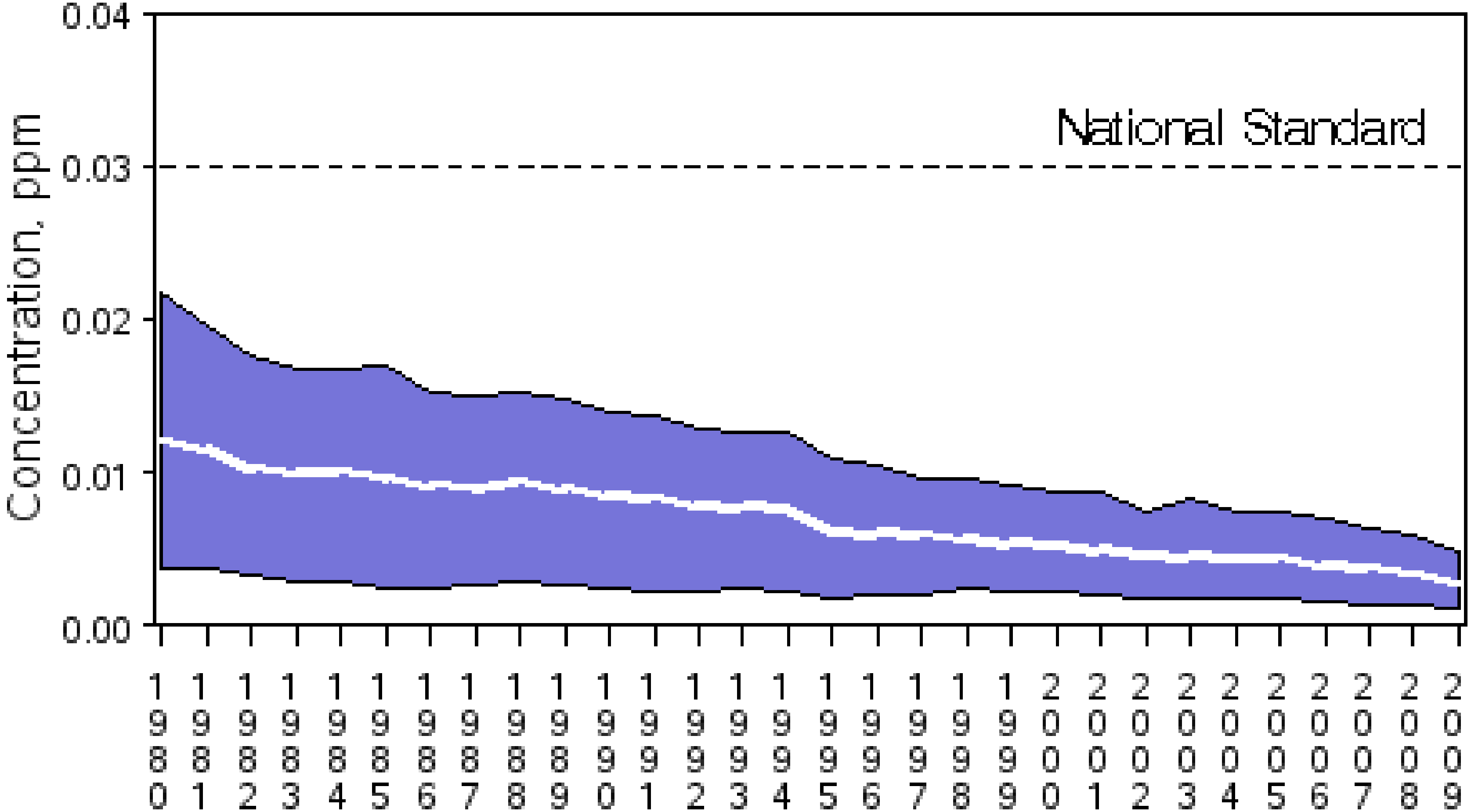
Air Quality Management

The US EPA Approach



SO2 Air Quality, 1980 - 2009

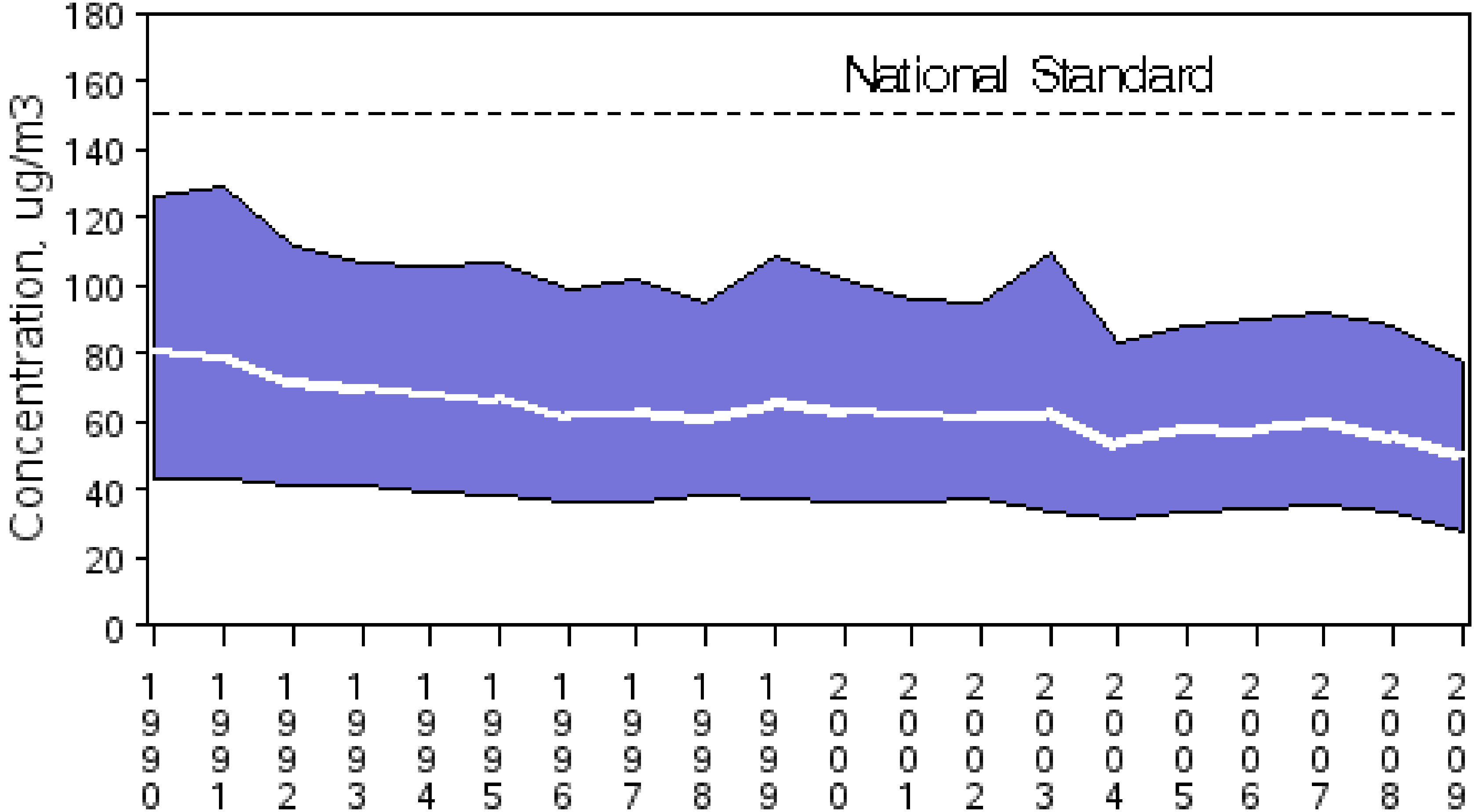
(Based on Annual Arithmetic Average)
National Trend based on 134 Sites



1980 to 2009 : 76% decrease in National Average

PM10 Air Quality, 1990 - 2009

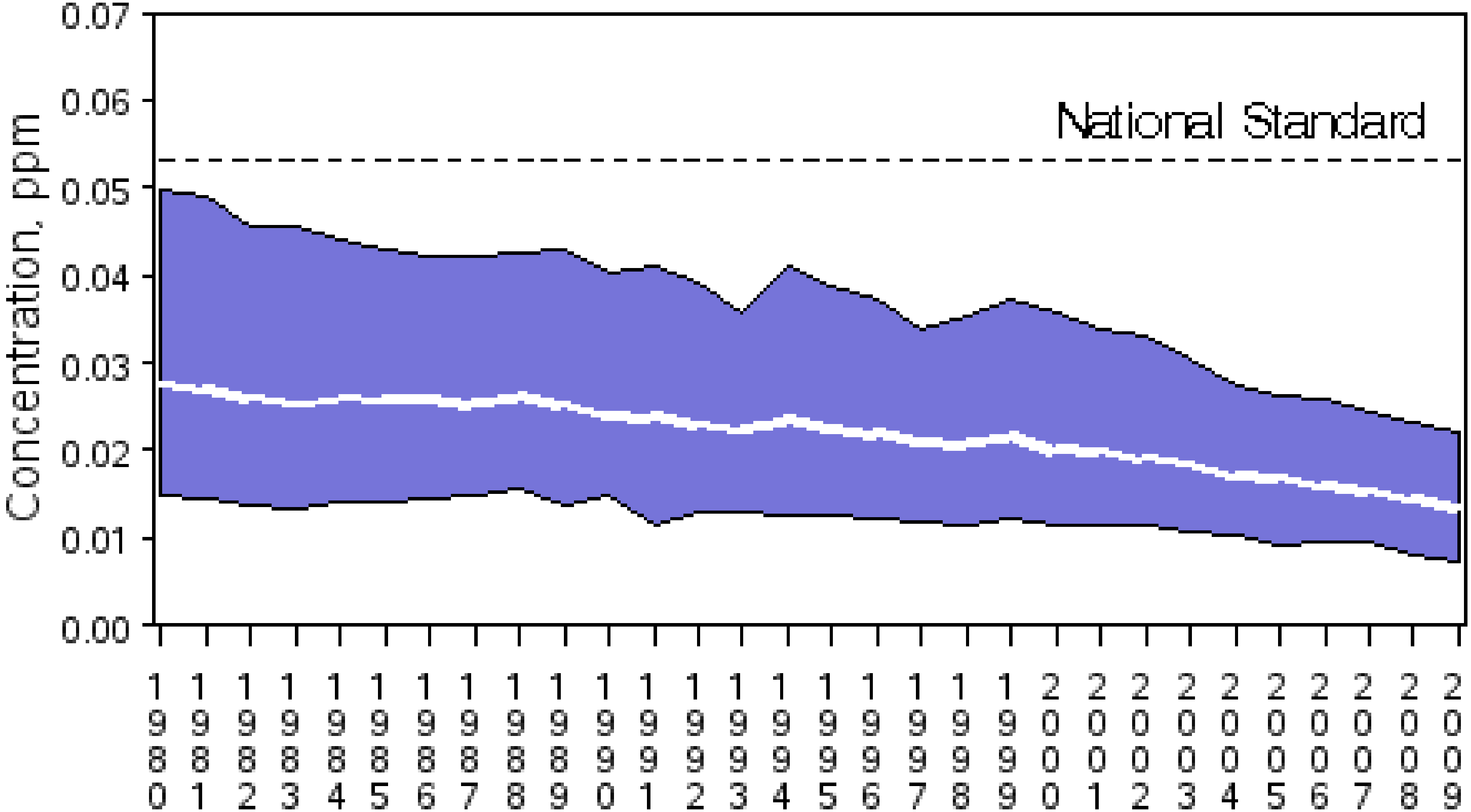
(Based on Annual 2nd Maximum 24-Hour Average)
National Trend based on 310 Sites



1990 to 2009 : 38% decrease in National Average

NO2 Air Quality, 1980 - 2009

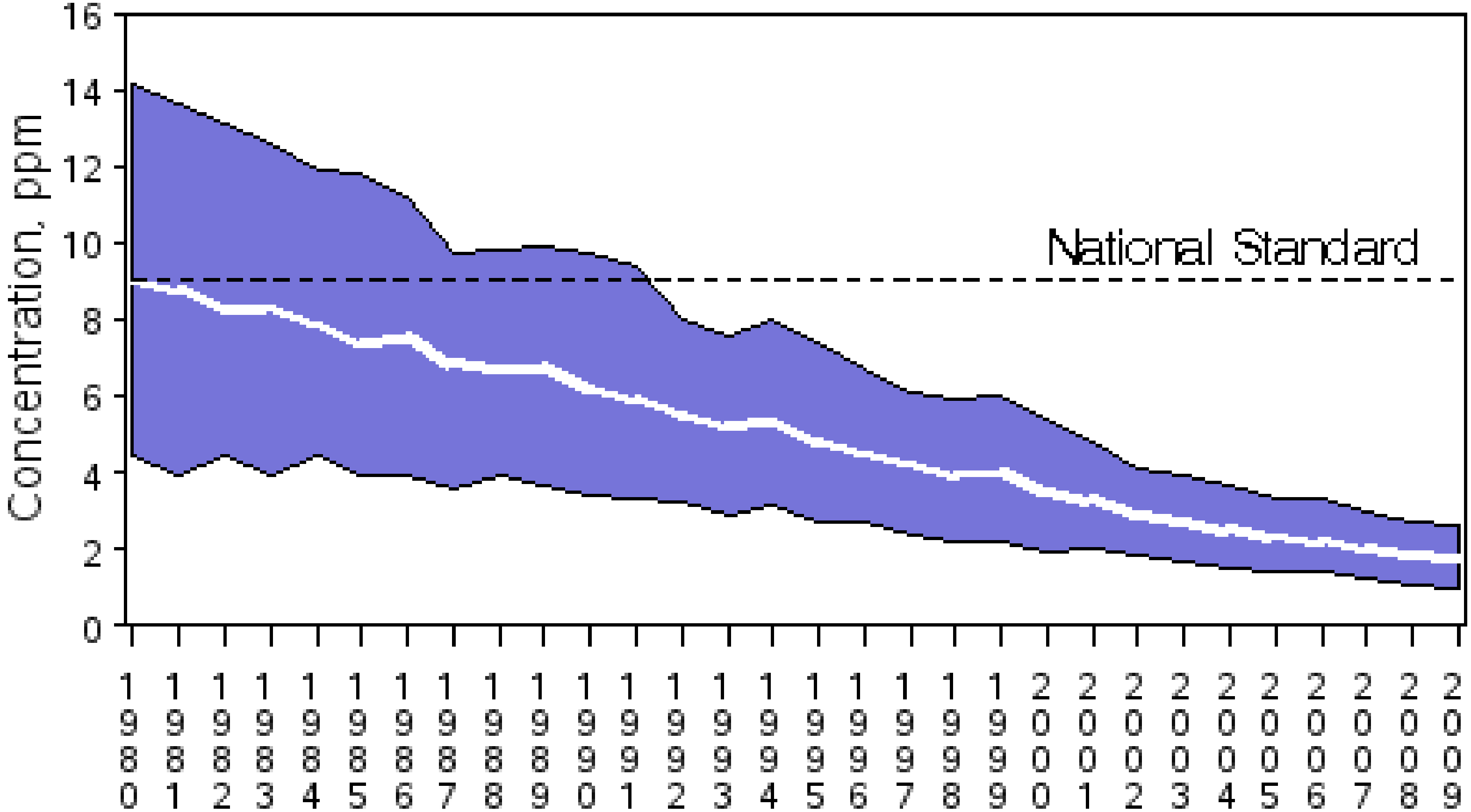
(Based on Annual Arithmetic Average)
National Trend based on 81 Sites



1980 to 2009 : 48% decrease in National Average

CO Air Quality, 1980 - 2009

(Based on Annual 2nd Maximum 8-hour Average)
National Trend based on 114 Sites

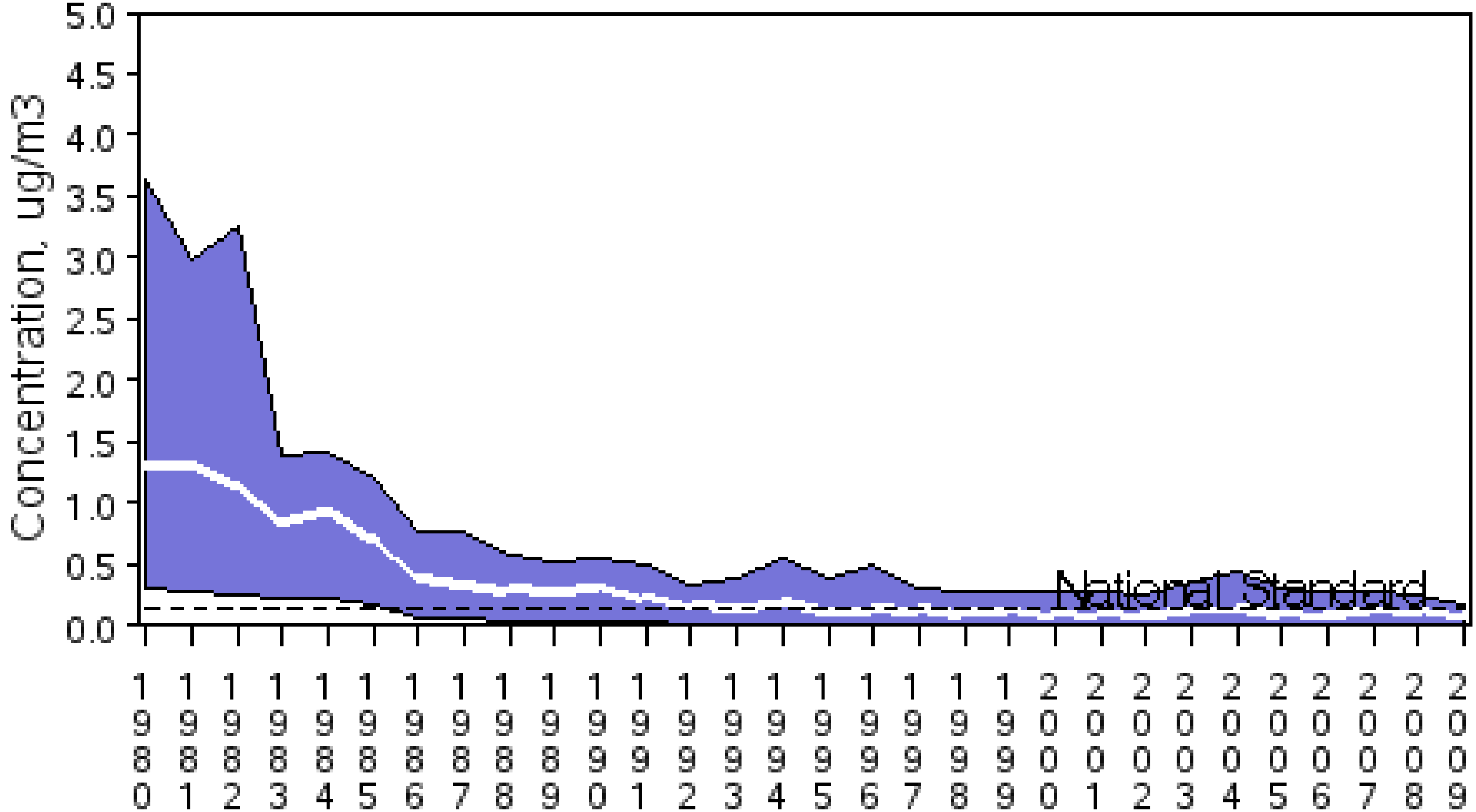


1980 to 2009 : 80% decrease in National Average

Lead Air Quality, 1980 - 2009

(Based on Annual Maximum 3-Month Average)

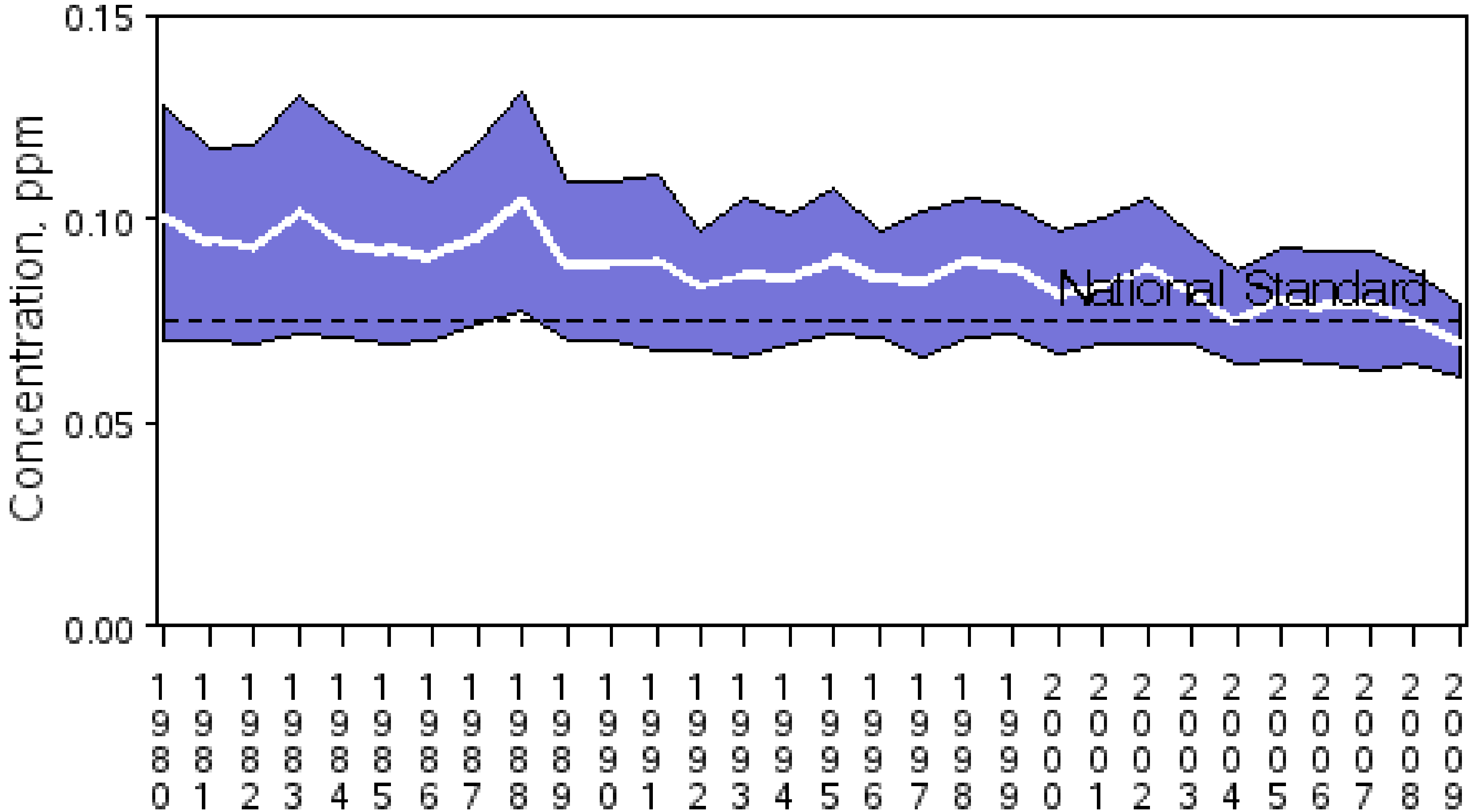
National Trend based on 20 Sites



1980 to 2009 : 93% decrease in National Average

Ozone Air Quality, 1980 - 2009

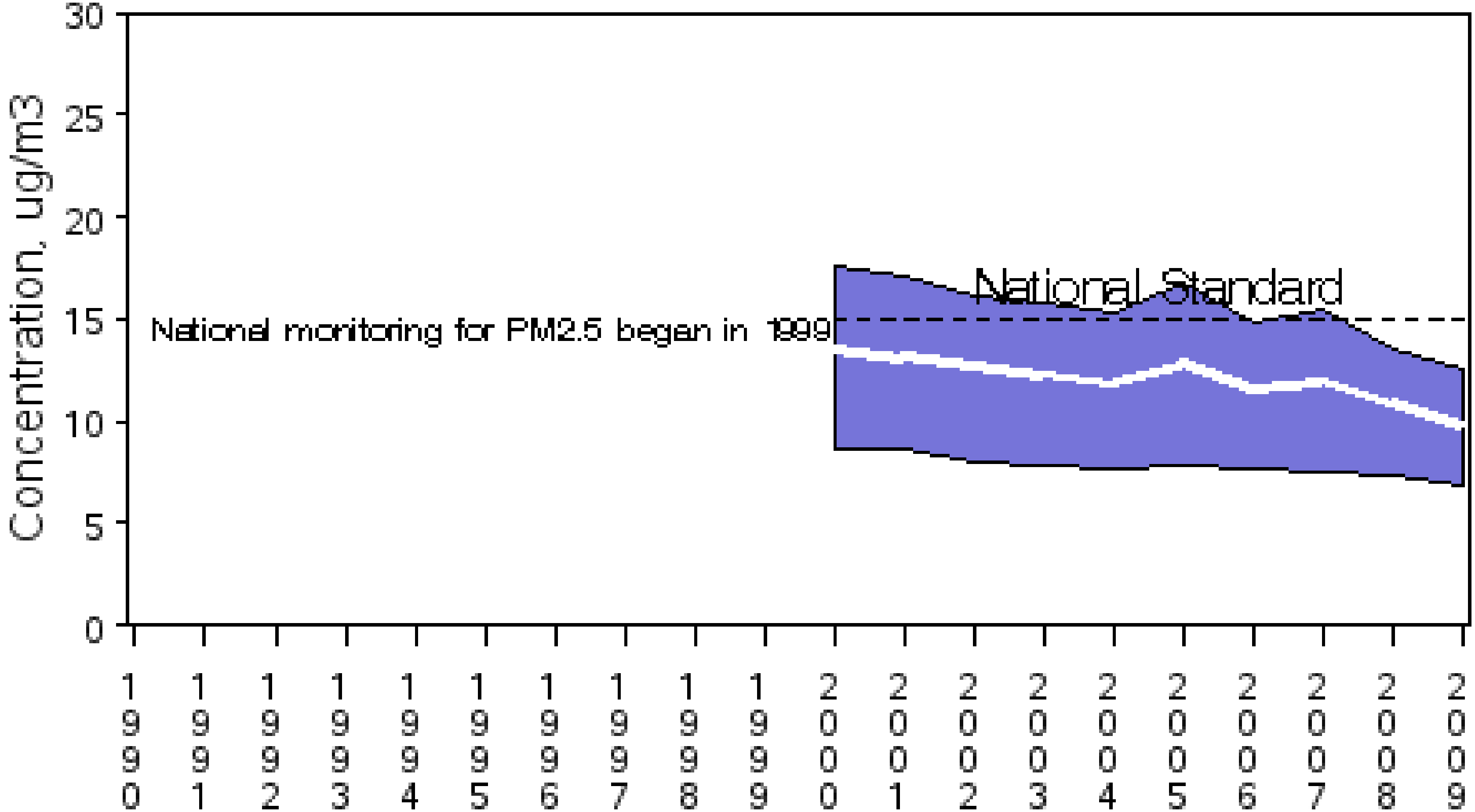
(Based on Annual 4th Maximum 8-Hour Average)
National Trend based on 255 Sites



1980 to 2009 : 30% decrease in National Average

PM2.5 Air Quality, 2000 - 2009

(Based on Seasonally-Weighted Annual Average)
National Trend based on 724 Sites



2000 to 2009 : 27% decrease in National Average

Los Angeles (1950s)

Hollywood Citizens News Collection, Los Angeles Public Library

The Los Angeles Case →

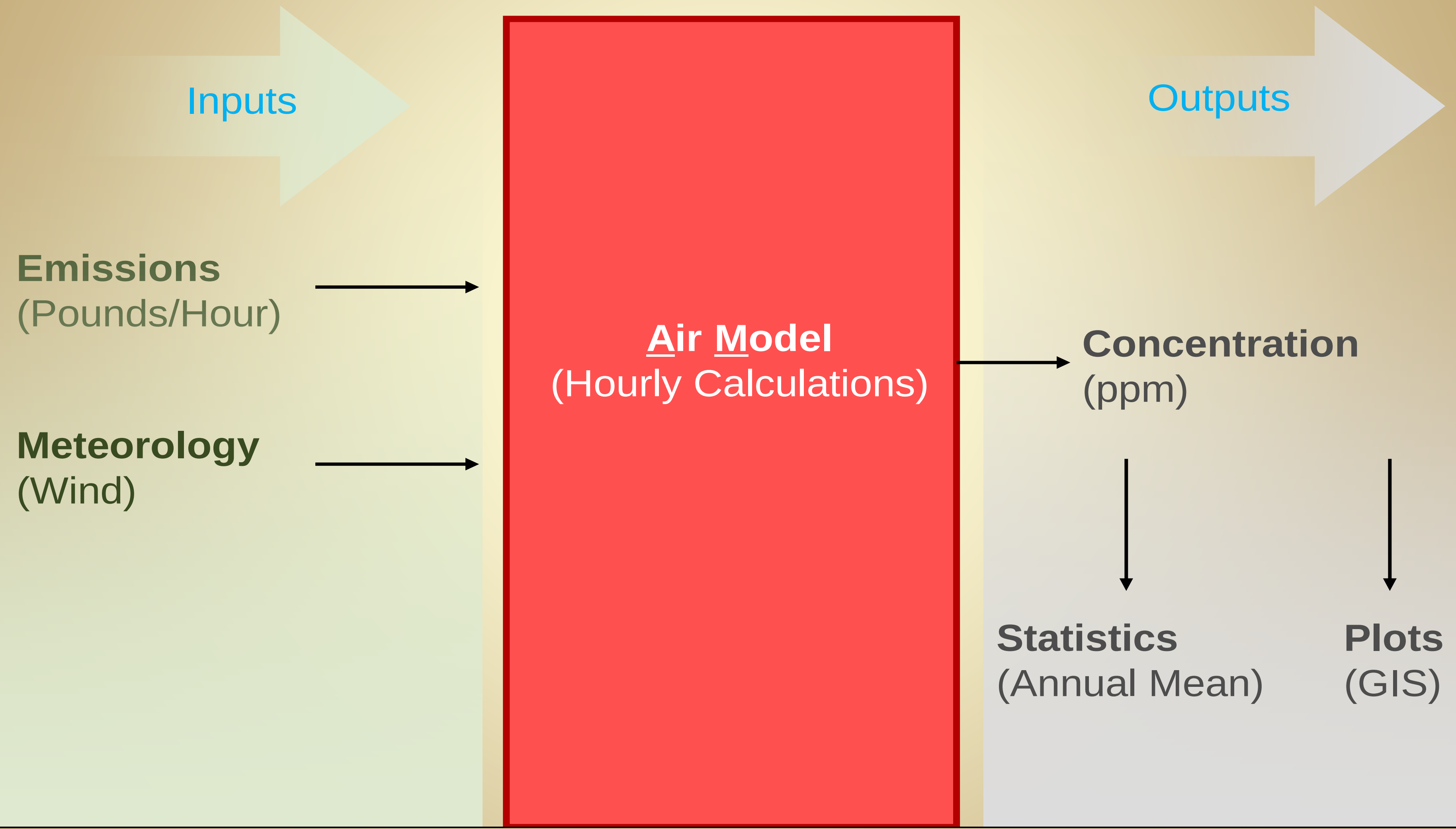
More on Air Quality Management

→

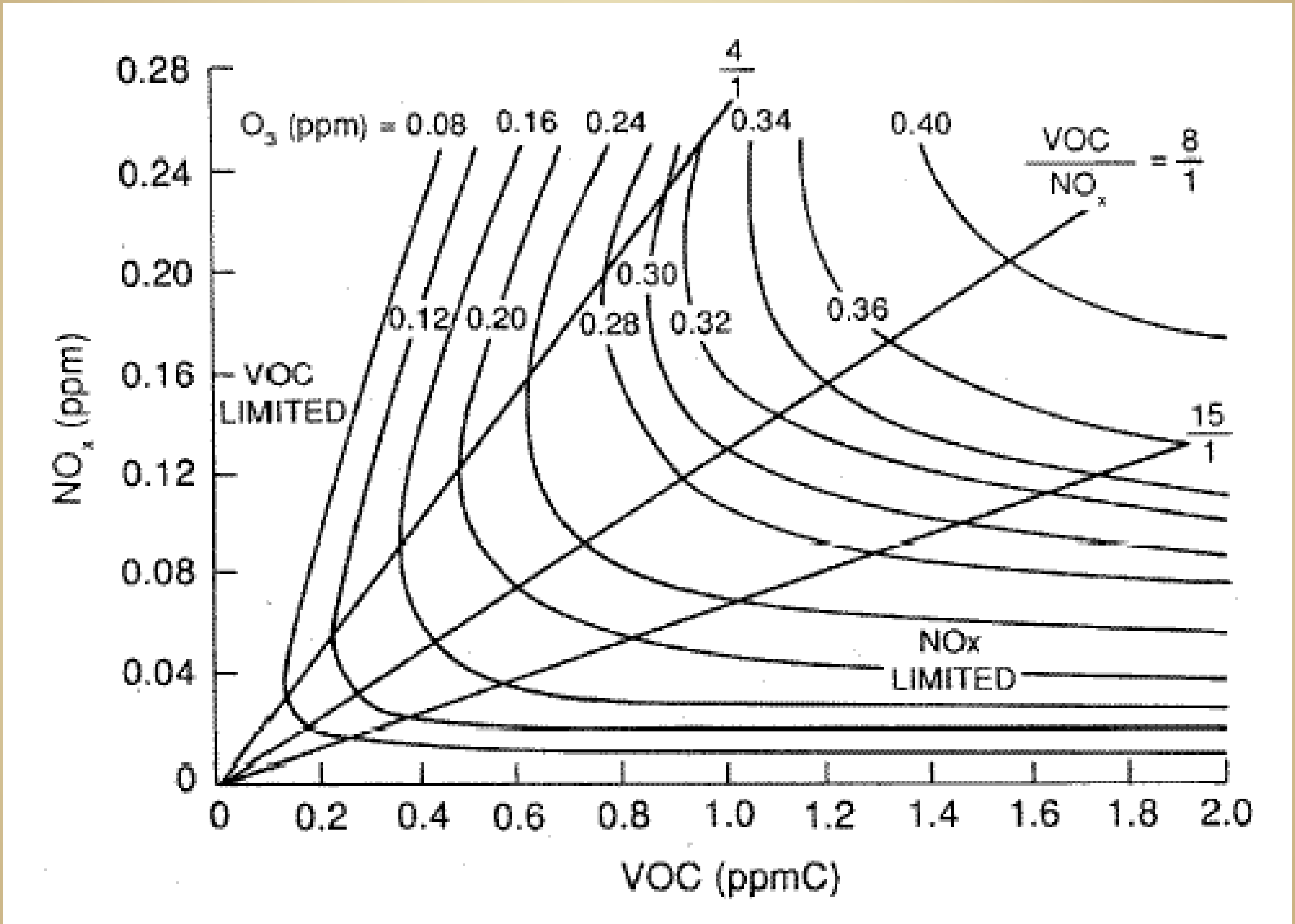
5. Air Quality Modeling

- Air Quality modeling is the mathematical simulation/prediction of ambient concentrations/depositions of air pollution, based on measured/calculated inputs.
- Air quality modeling is the necessary substitute for ubiquitous air quality monitoring, which is impossible.
- More importantly:
  - measurements cannot distinguish between the contributions of different emissions. Models can.
  - Models can simulate the past, present, and future air pollution
  - Models incorporate best deterministic/statistical science

Air Modeling Methodology



Challenge: Non-Linearity (e.g. Ozone)



Empirical kinetic modeling approach (EKMA) diagram. SOURCE: NRC 1991, adapted from Dodge 1977.

Modeling for air quality management purposes

- Two broad categories:
  - dispersion modeling - used to predict ambient concentrations
  - receptor-based (or source apportionment) models - use ambient data to determine the sources.
- Other categorization:
  - on the required model inputs (i.e., meteorological data);
  - on the spatial scale (global; regional-to-continental; local-to-regional; local);
  - on the temporal scale (episodic models, long-term models);
  - on the treatment of the transport equations (Eulerian, Lagrangian models);
  - on the treatment of various processes (chemistry, wet and dry deposition);
  - and on the complexity of the approach.
- The choice of model depends on a combination of the available data and the needs of the researcher

Choice of Models

- U.S. EPA's detailed recommendations
  http://www.epa.gov/scram001/guidance/guide/appw_03.pdf
- Many of the models are available for direct download at the U.S. EPA Support Center for Regulatory Air Models (SCRAM)
  http://www.epa.gov/scram001/
- On-line course offered by the Air Pollution Training Institute
  http://yosemite.epa.gov/oaqps/EOGtrain.nsf/DisplayView/SI_410_0-5?OpenDocument
- Advanced courses on air quality modeling
  http://www.wessex.ac.uk/courses/air-quality/page-3.html (PZ)
  http://www.shodor.org/os411/
  http://www.weblakes.com/training/index.html
  http://trinityconsultants.com/Training/
- My 1990 APM book online:
  http://www.envirocomp.com/pops/airpollution.html
- Comprehensive AQM book series:
  http://envirocomp.org/books/aqm.html

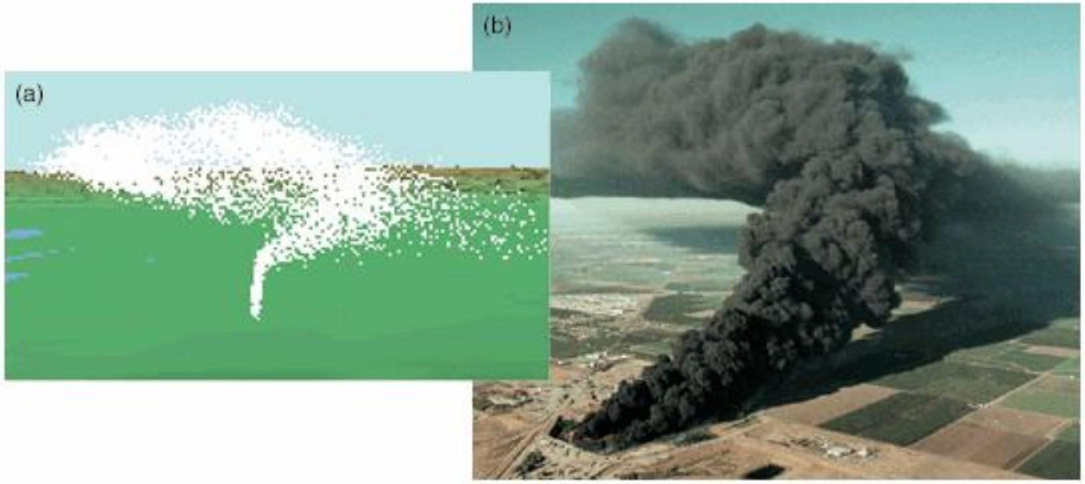
Modeling of Emergencies

- Emergency preparedness
  - Modeling of pre-defined possible events
  - Preparation of “what if” scenarios
  - Training
- Emergency response
  - Semi-automatic computer systems to guide decision-makers during accidental releases
  - Fast response is essential
- Accident Reconstruction
  - Assessment of responsibility
  - Litigation

Plume/Puff Modeling

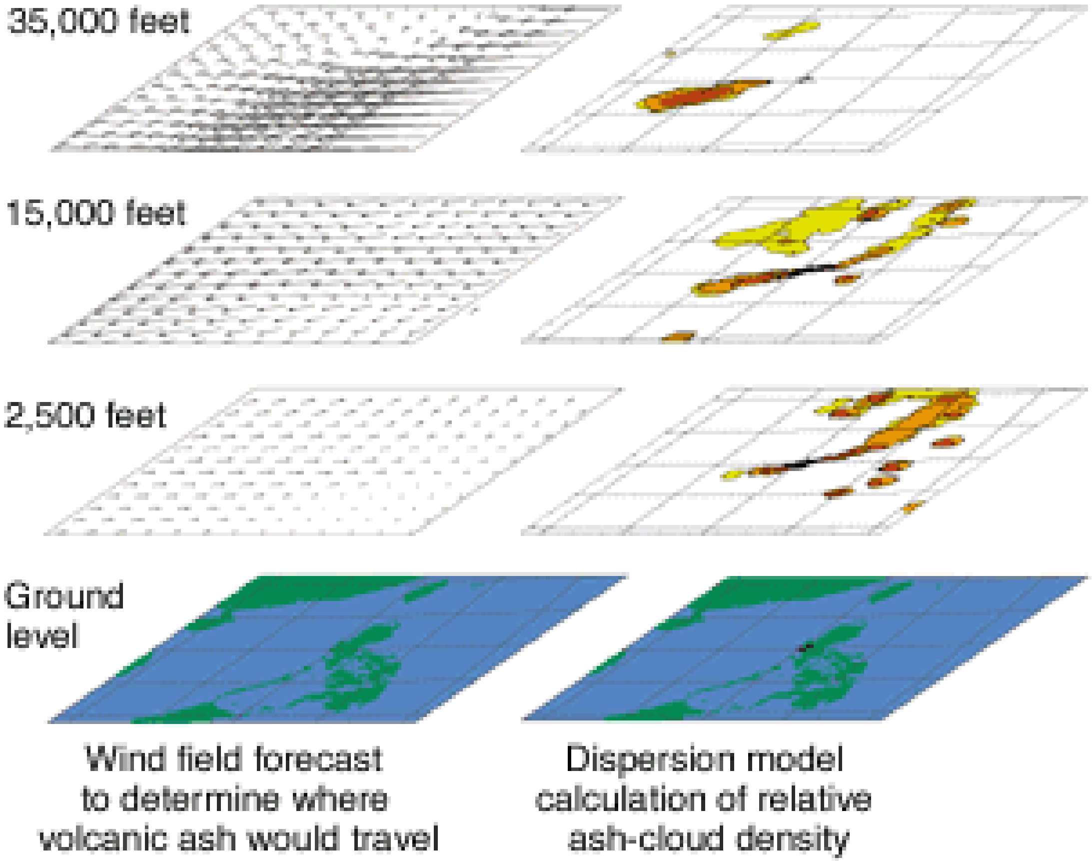
- EPA models vs. other models
- Simple models (e.g., a steady state Gaussian Plume model) vs. complex models (e.g., a dynamic puff model)
- Example of application of MONTECARLO (20 y ago)
- Today's animation capabilities – M case

Examples…



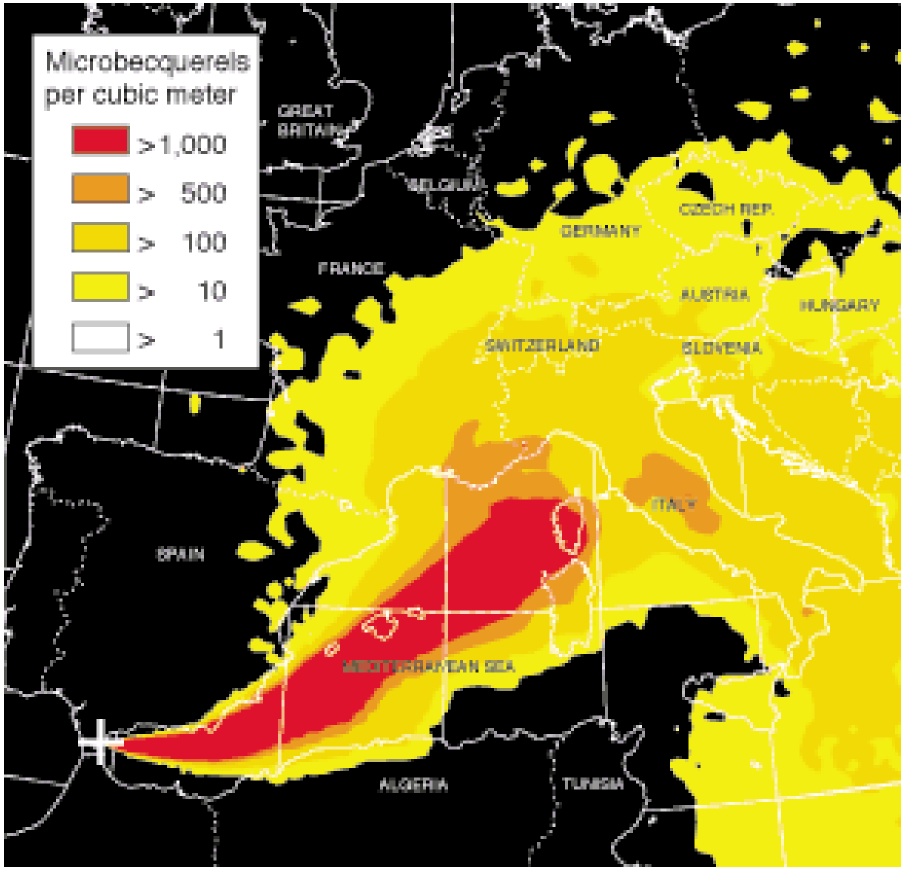
Tire Fire in Tracy, CA (August 1998) – emergency forecast

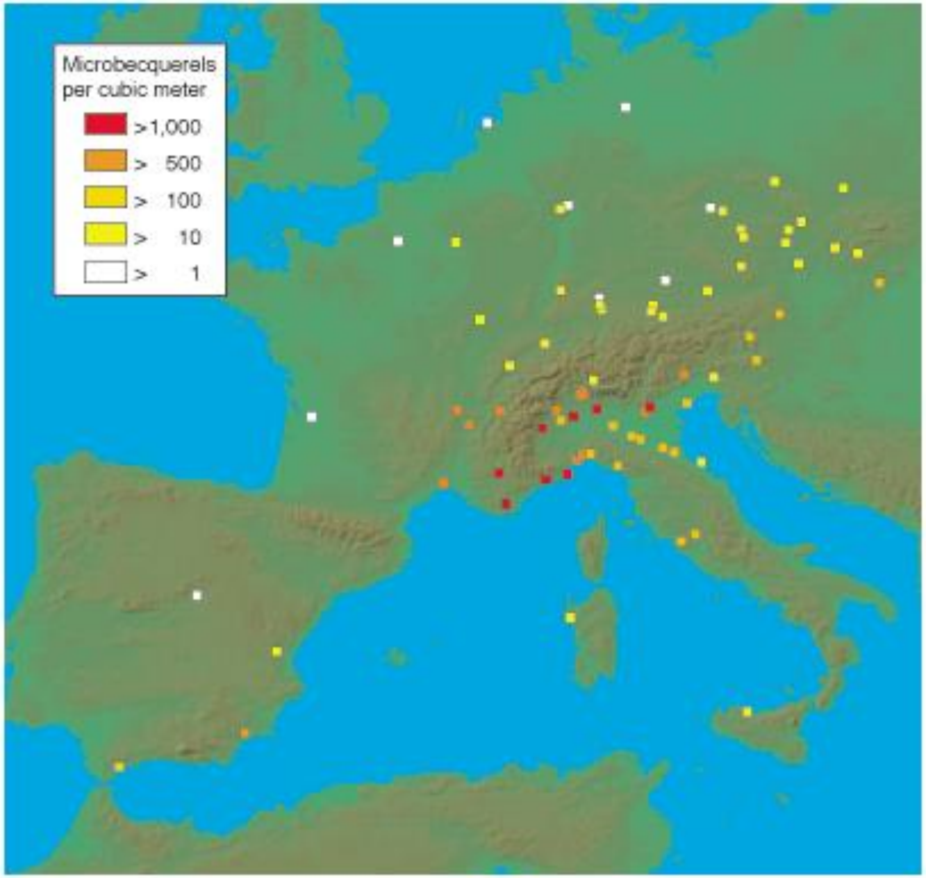
Examples…



Mount Pinatubo Eruption (June 1991) – ash cloud forecast

Examples …



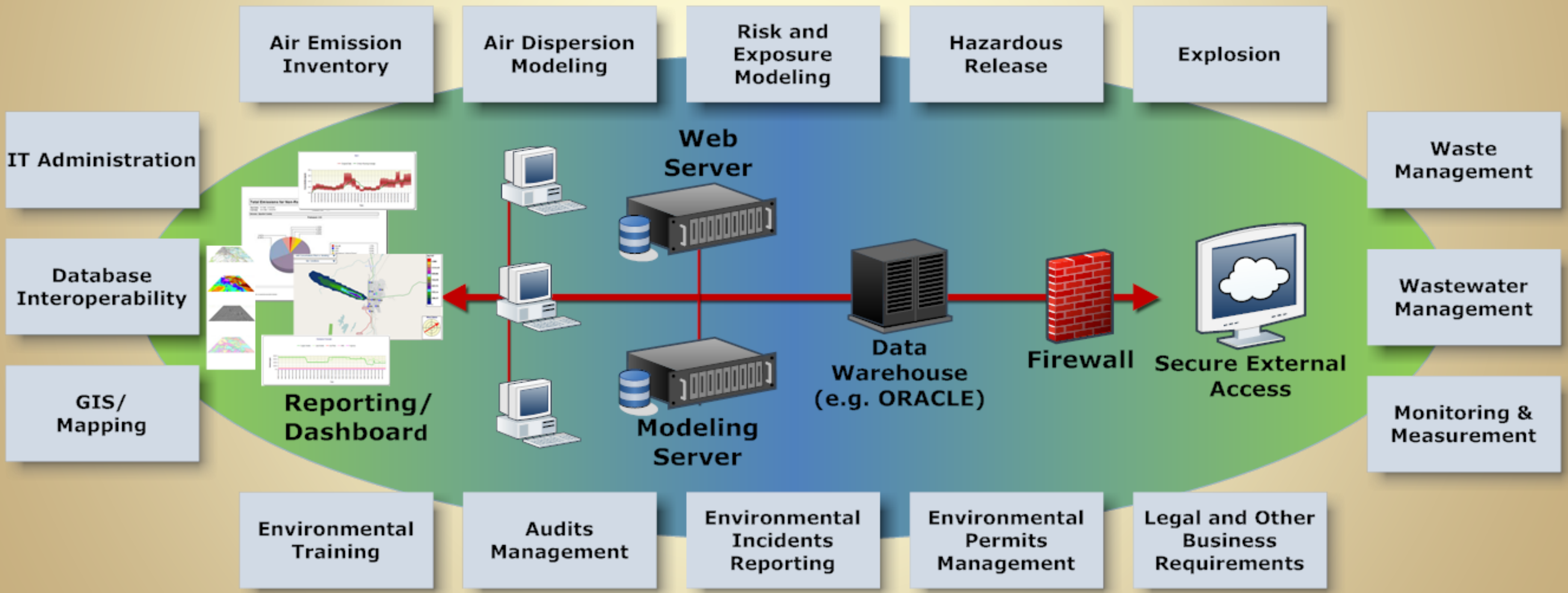


Radioactive Release: Cesium-137
from Algeciras, Spain
(last week of May 1998)

In the Future…

- Fully computerized emergency response systems
- Automatic computer modeling and forecast
- Warning and decision support
- … even Artificial Intelligence features

CONCEPTUAL OVERVIEW – (Courtesy of Lakes Environmental Software)



Animations

The hyperlinks below activate two animations:

1. Real time plume animation of a fictitious accidental release
2. Animation of the plume forecast in the following hours for a fictitious accidental release

Thanks!

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Wisdom!

1. The serenity to accept the things I cannot change;
2. The courage to change the things I can;

and most importantly:

3. The wisdom to know the difference