Why Forecast Air Quality?

- Protect public health
  - Allows the public to plan activities that avoid exposure
  - Allows sensitive individuals to plan activities and healthcare
- Effectively run a voluntary emissions reduction program

  - Participation depends on forecast accuracy and timeliness
  - Affects the public's activities
  - Affects sponsor or donor agency support
- Conduct special sampling

  - Allows sufficient time to prepare monitoring equipment and personnel
  - Lets researchers sample pre-episode conditions

Short Course on Air Quality Forecasting

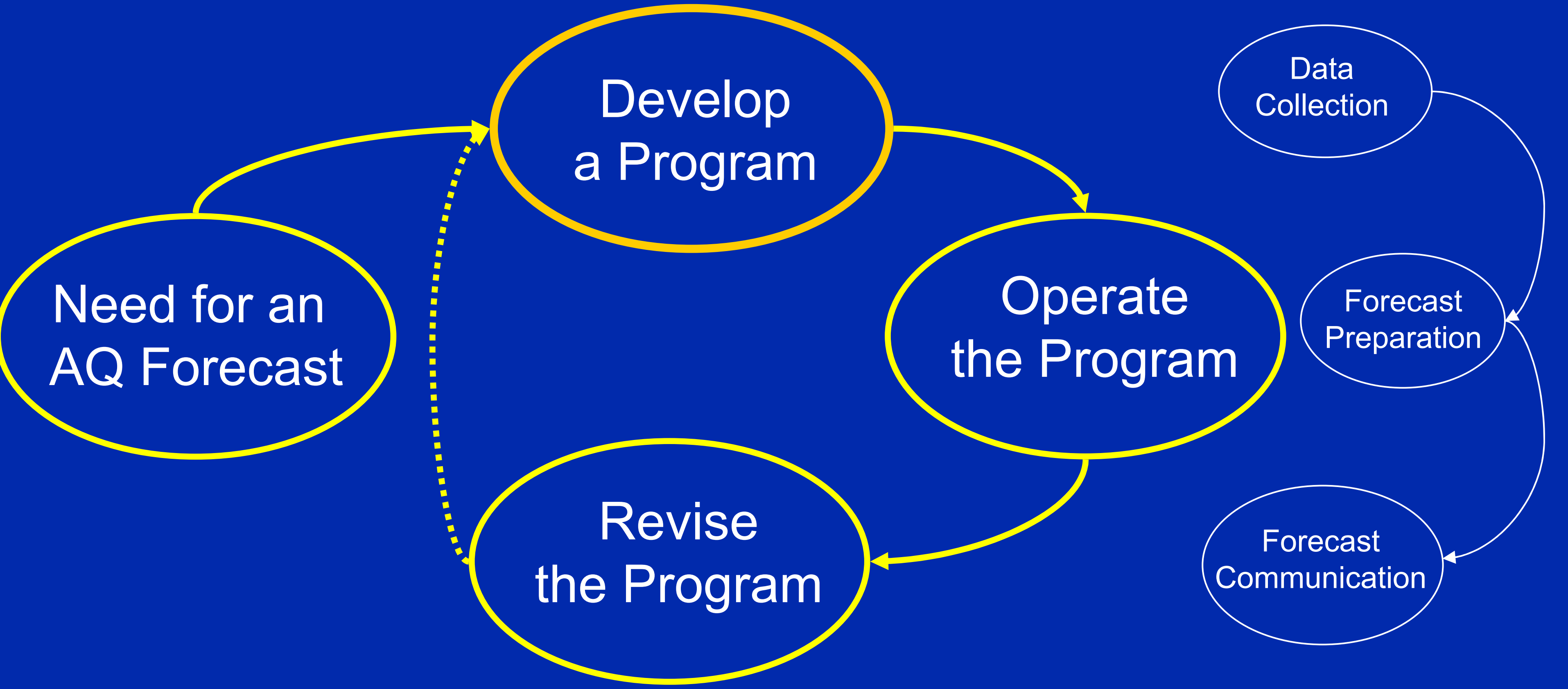
Course Objectives

Give you the necessary knowledge to develop, implement, and evaluate a basic forecasting program

- Understand the meteorological processes that affect pollution concentrations
- Learn more about meteorological and air quality forecasting products
- Learn how to use and evaluate meteorological forecast data (case studies)
- Discuss the tools available for air quality forecasting
- Discuss how to develop, operate, and maintain a forecasting program

Forecasting Programs

The Process of Developing, Operating, and
Improving an Air Quality Forecasting Program



What's New in This Year's Course

- Includes a different pollutant
  - $PM_{2.5}$
  - Year-round pollutant forecasting
- Has more instructors
  - From different areas of the country
  - Range of skills and backgrounds
- Incorporates comments from last year's course
- Provides more examples and applications

Short Course – Design Goals

- **Focus.** Forecasting air quality—both $PM_{2.5}$ and ozone concentrations. The approach applies to other pollutants.
- **Practical.** Beyond theory, the course contains practical advice and reference to examples, tools, and methods.
- **Gateway.** The course workbook is a gateway to additional resources.
- **Evolving.** It will improve in time through your feedback.

Forecasting Philosophy (1 of 3)

- More forecasting tools = better results
  - No "silver bullet"
  - Several tools provide a consensus forecast
- Understand how the system works
  - Determine how meteorological processes influence air pollution in your area
  - Forecast the processes that affect air quality, then predict the air quality

Forecasting Philosophy (2 of 3)

Predicting weather (and air quality) requires examining information for several different spatial and time scales.

Global

Space: 4,000 km – 20,000 km

Time : 1 - 2 weeks

Synoptic

Space: 400 km – 4,000 km

Time: 1 day – 1 week

Mesoscale

Space: 10 km – 400 km

Time: 1 hr – 1 day

Urban

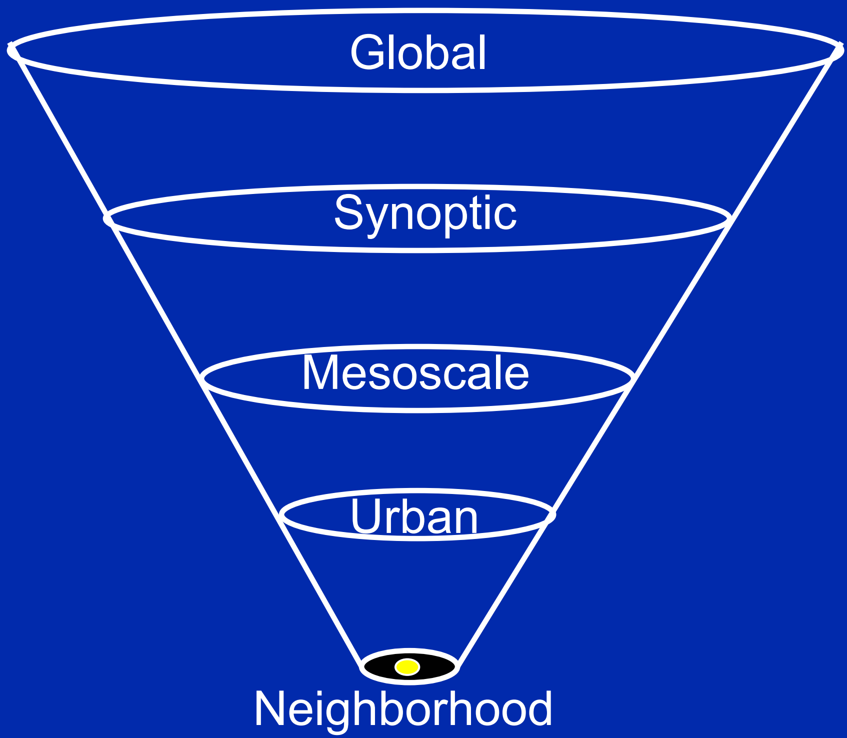
Space: 5 km - 50 km

Time: 1 hr - 4 hr

Neighborhood

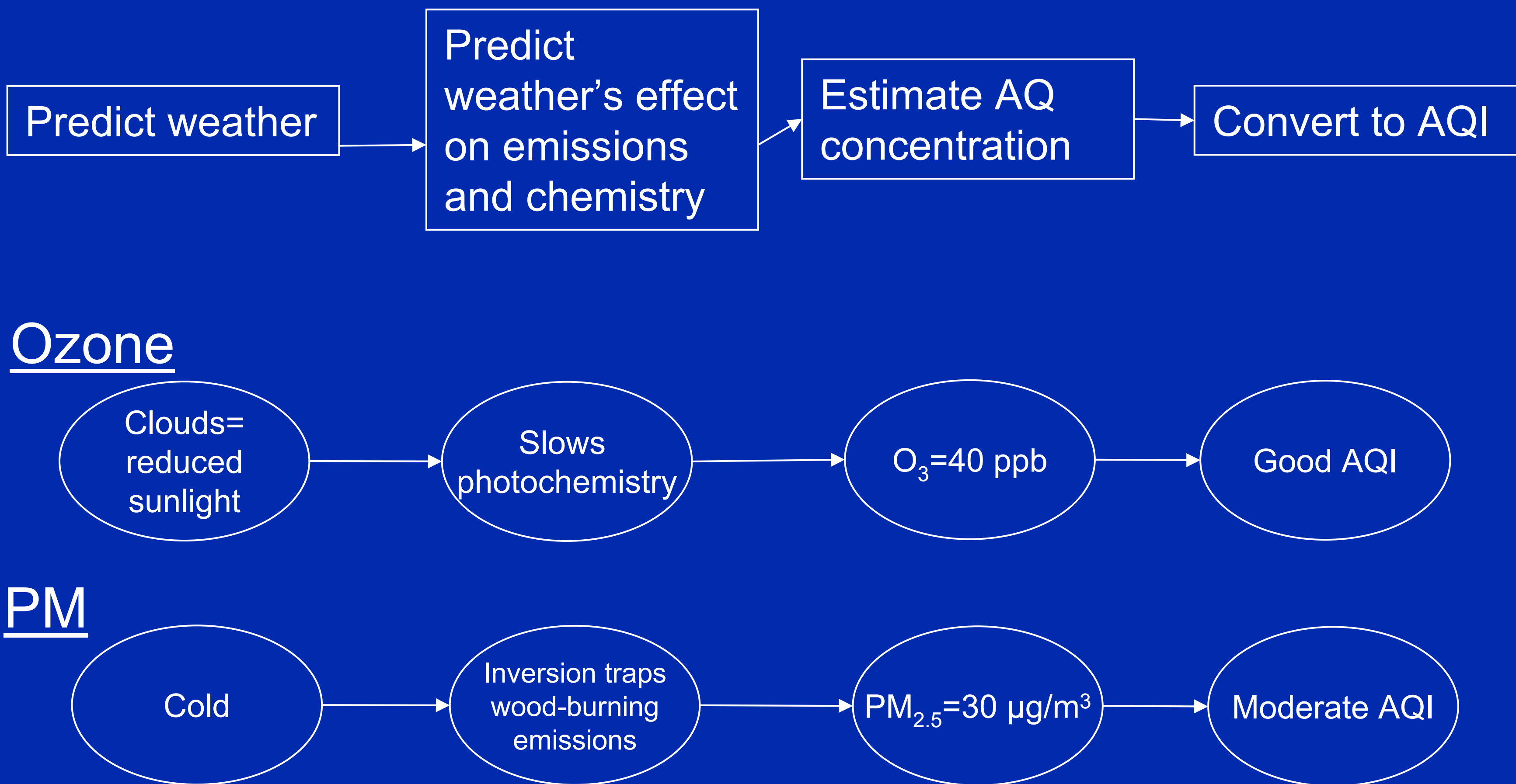
Space: 500 m - 5 km

Time: 1 min – 1 hr



Forecasting Philosophy (3 of 3)

Forecasting Process



Air Quality Background – Types

Primary - emitted directly from a source

Secondary - formed in the atmosphere from reaction of primary pollutants

Precursors - primary pollutants that react to form secondary pollutants

Air Quality Background – Major Pollutants

Pollutant	Abbreviation	Type
Carbon Monoxide	CO	Primary
Sulfur Dioxide	SO_2	Primary
Ozone	O_3	Secondary
Nitrogen Dioxide	NO_2	Secondary
Hydrocarbon Compounds	HC	Primary & Secondary
Particulate Matter	PM	Primary & Secondary

Ozone – Chemistry

Simplified view of ozone chemistry

- $NO_2 + O_2$ + Sunlight → O_3 Production
- $NO + O_3 \rightarrow NO_2 + O_2$ Destruction

- NO + VOC + Sunlight → NO_2 + VOC Production of NO_2

Key processes

- Ample sunlight (UV)
- Limited dispersion
- Limited vertical mixing
- Warm temperatures
- Amble precursors (VOC, NO, NO_2)

PM – Sources and Chemistry

Particulate matter (PM) is a complex mixture of solid and liquid particles that vary in size and composition.

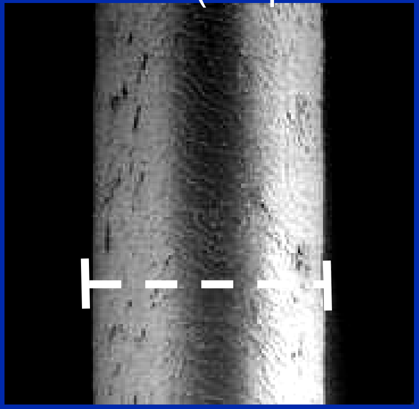
- Size of PM
- Sources
- Composition
- Seasonal and regional differences
- Unusual events
- Formation processes

PM – Size (1 of 2)

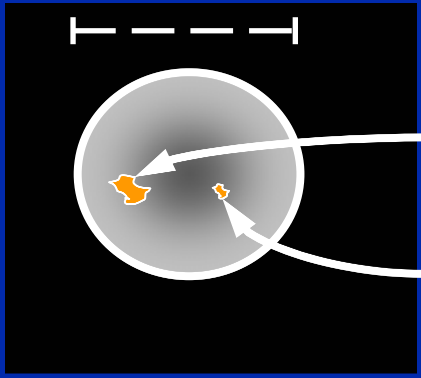
Size of PM

- Particle sizes (0.005 to 100 µm)
- Ultrafine Particles (<0.1 µm)
- Fine Particles (0.1 and 2.5 µm)
- Coarse Particles (> 2.5 µm)

Human Hair (70 µm diameter)

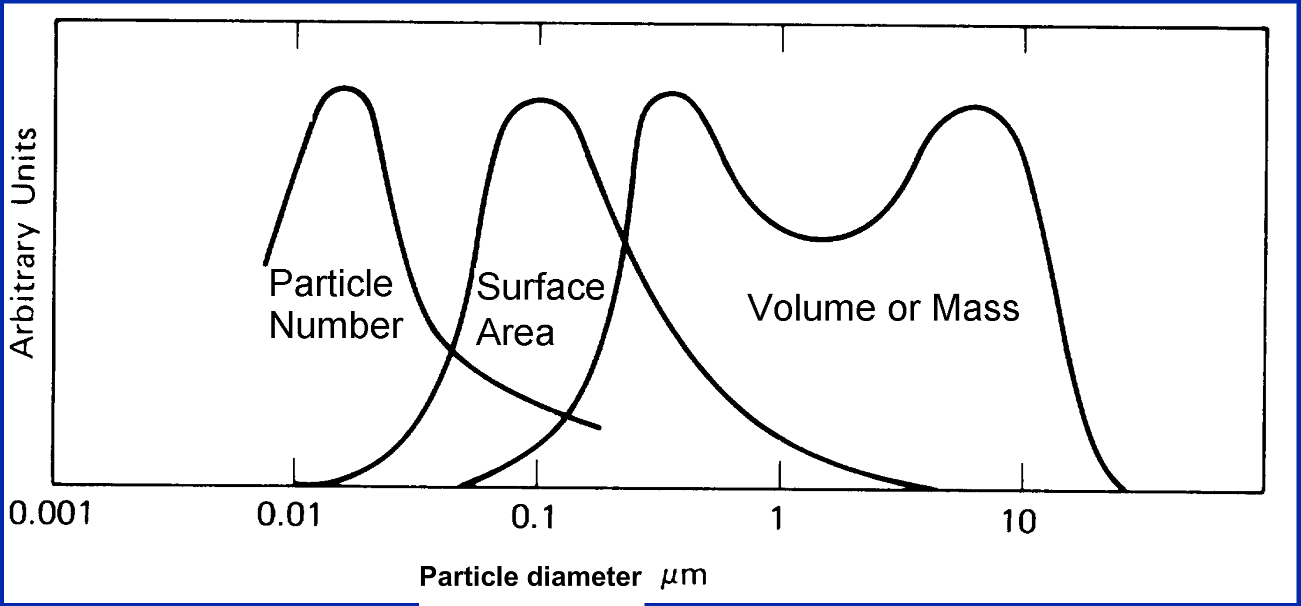


Human hair cross section (70 µm)



M. Lipsett, California Office of Environmental Health Hazard Assessment

PM – Size (2 of 2)



Adapted from Husar (1999)

Name	Ultrafine	Fine ($PM_{2.5}$)	Coarse (PM_{10})
Particle size	very small	small	larger
No. of particles	most	moderate	least
Amt. of mass	small	moderate	most
Residence time	days-week	week-month	hours-day
Removal process	coagulation	condensation	sedimentation

PM – Sources

PM is composed of a mixture of primary and secondary compounds.

Primary PM (directly emitted):

- Suspended dust
- Sea salt
- Organic carbon
- Elemental carbon
- Metals from combustion
- Small amounts of sulfate and nitrate

Secondary PM (gases that form PM in the atmosphere):

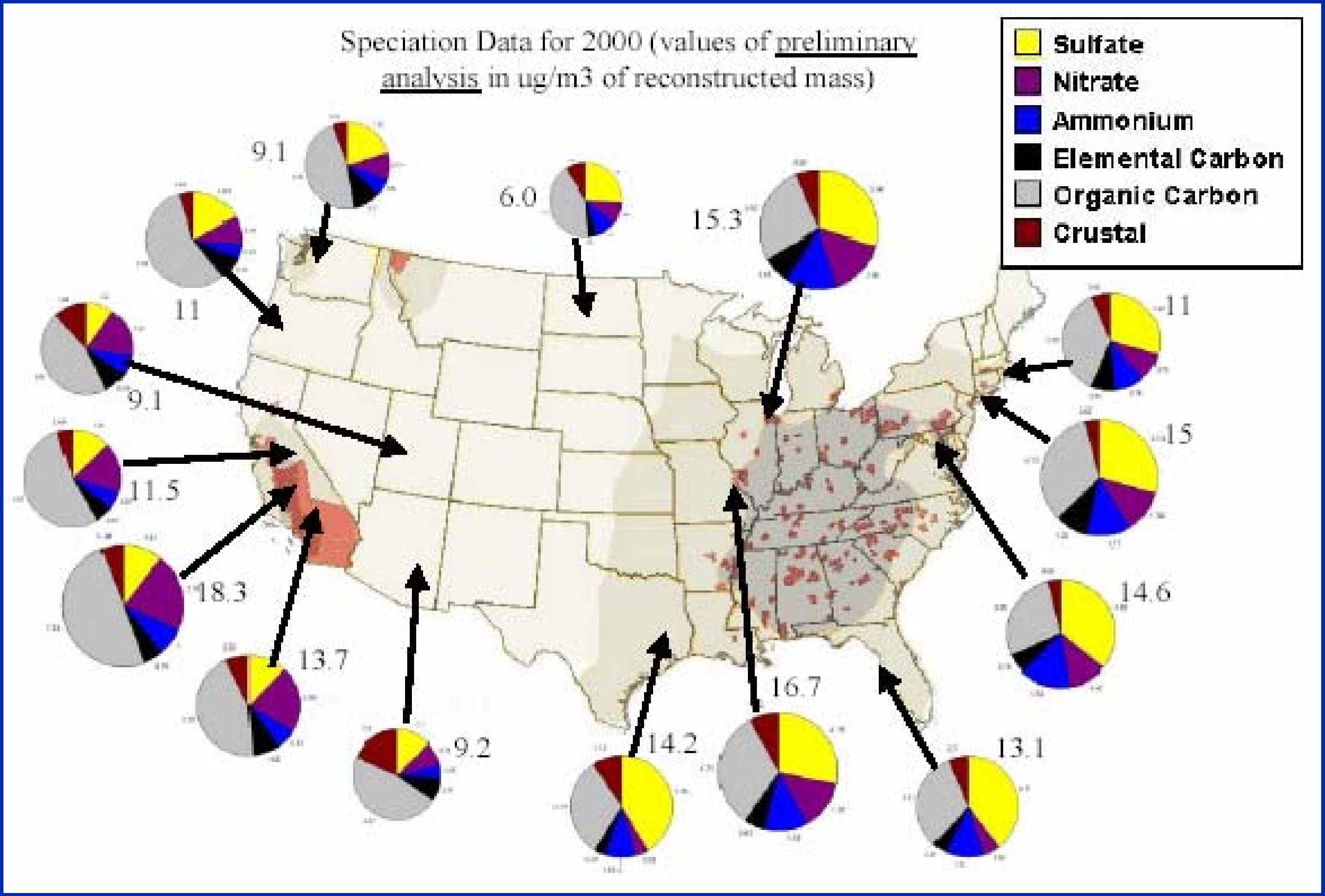
- Sulfur dioxide (SO_2): forms sulfates
- Nitrogen oxides (NO_x): forms nitrates
- Ammonia (NH_3): forms ammonium compounds
- Volatile organic compounds (VOC): forms organic carbon compounds

$PM_{2.5}$ Composition

- Most PM mass in urban and nonurban areas is composed of a combination of the following chemical components:
  - **Geological Material –** suspended dust consists mainly of oxides of Al, Si, Ca, Ti, Fe, and other metal oxides.
  - **Sulfate –** results from conversion of SO_2 gas to sulfate-containing particles.
  - **Nitrate –** results from a reversible gas/particle equilibrium between ammonia (NH_3), nitric acid (HNO_3), and particulate ammonium nitrate.
  - **Ammonium –** ammonium bisulfate, sulfate, and nitrate are most common.
  - **NaCl –** salt is found in PM near sea coasts and after de-icing materials are applied.
  - **Organic Carbon (OC) –** consists of hundreds of separate compounds containing mainly carbon, hydrogen, and oxygen.
  - **Elemental Carbon (EC) –** composed of carbon without much hydrocarbon or oxygen. EC is black, often called soot.
  - **Liquid Water –** soluble nitrates, sulfates, ammonium, sodium, other inorganic ions, and some organic material absorb water vapor from the atmosphere.

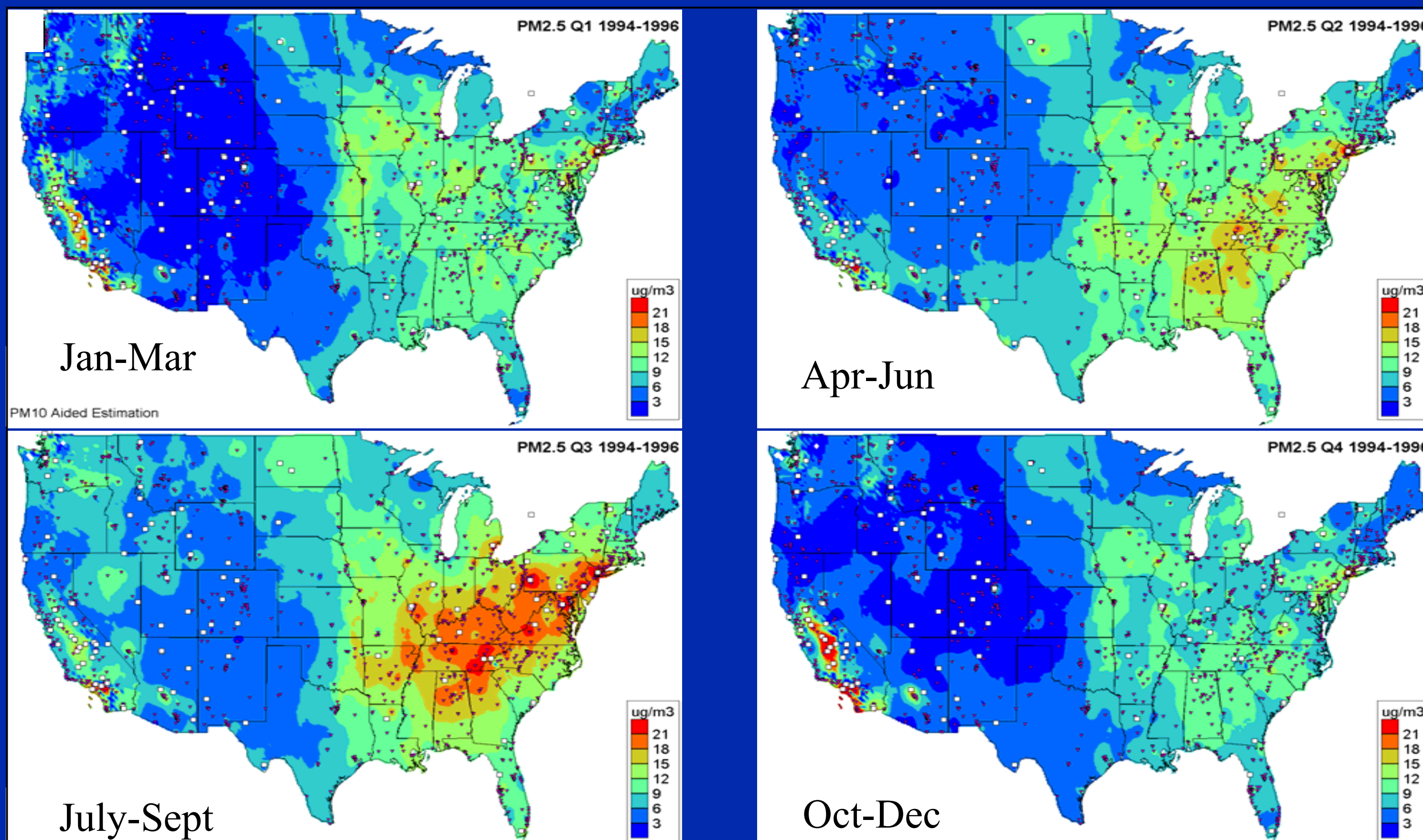
Chow and Watson (1997)

$PM_{2.5}$ – Spatial Patterns



From Solomon and Scheffe (2002)

$PM_{2.5}$ – Seasonal Patterns



Falke (1999)

$PM_{2.5}$ – Unusual Events

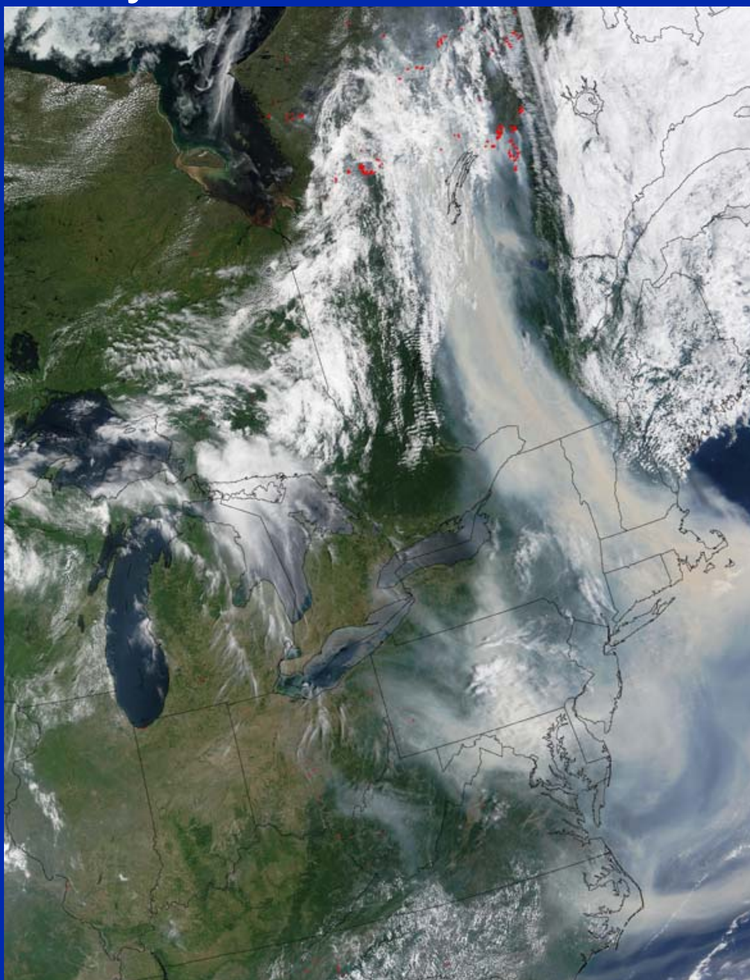
Unusual PM Events

- Agricultural burning - farming byproducts (rice straw, orchard prunings, etc.)
- Wildland fires - 100 to 1000+ acres (biomass: trees, shrubs, grasses, etc.)
- Windblown dust
  - Locally generated airborne dust from winds blowing across agricultural or barren land
  - Global as winds can carry aerosols for weeks and over 1000's of kilometers

See Appendix for Internet links.

PM – Unusual Events

July 7, 2002 at 1115 EST

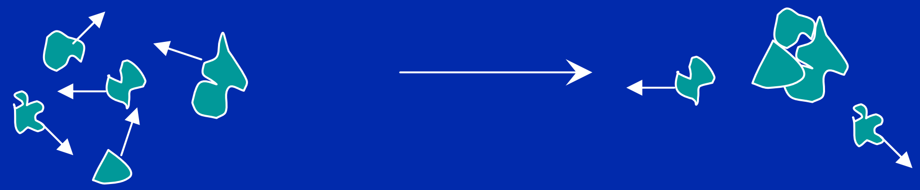


February 26, 2000

http://seawifs.gsfc.nasa.gov/SEAWIFS/HTML/dust.html

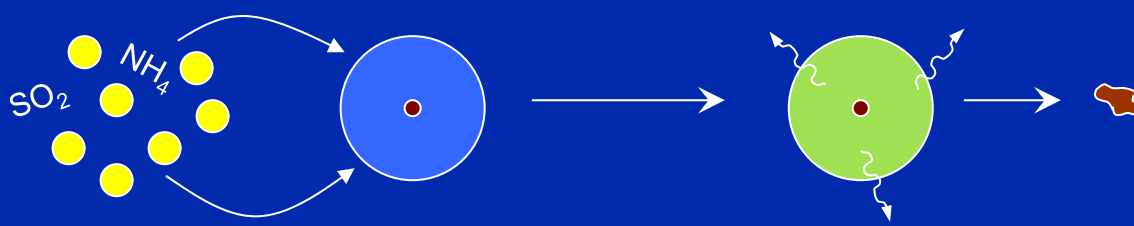
PM – Formation Processes

Coagulation: Particles collide with each other and grow.



Condensation: Gases condense onto a small solid particle to form a liquid droplet.

Cloud/Fog Processes: Gases dissolve in a water droplet and chemically react. A particle exists when the water evaporates.



Ammonium Sulfate

Chemical Reaction: Gases react to form particles.

$$NO_x \rightarrow HNO_3 + NH_3 \xleftrightarrow{\text{Fn (Temp, RH)}} NH_4NO_3 \text{ (particle)}$$

Ammonium Nitrate

Nitric Acid — Ammonia

PM – Formation Processes

Sources | Emissions | PM Formation | PM Transport/Loss | Sample Collection

Chemical Processes

Mechanical → **Particles**
- Sea salt
- Dust

Particles
- NaCl
- Crustal

Combustion → **Particles** and **Gases**
- Motor vehicles
- Industrial
- Fires

Particles
- Soot
- Metals
- OC

Gases
- NO_x
- SO_2
- VOCs
- NH_3

Other gaseous → **Gases**
- Biogenic
- Anthropogenic

Gases
- VOCs
- NH_3
- NO_x

PM Formation (from particles):
gases condense onto particles
cloud/fog processes

PM Formation (from gases):
condensation and coagulation
photochemical production
cloud/fog processes

PM Transport/Loss:
transport
sedimentation (dry deposition)
wet deposition

Sample Collection:
Measurement Issues:
- Inlet cut points
- Vaporization of nitrate, H_2O, VOCs
- Adsorption of VOCs
- Absorption of H_2O

Meteorological Processes

Emissions	PM Formation	PM Transport/Loss	Sample Collection
Winds	Clouds, fog	Winds	Temperature
Temperature	Temperature	Precipitation	Relative humidity
Solar radiation	Relative humidity		Winds
Vertical mixing	Solar radiation		

Summary

- Ozone is a secondary pollutant formed from emissions (NO_x and VOC). It is most prevalent in the summer.
- $PM_{2.5}$ consists of numerous types of solid and liquid particles that are directly emitted (primary) or formed in the atmosphere (secondary). High concentrations occur year round.
- Forecasting air quality requires an understanding of the processes that produce pollution.

- Next step - Meteorology and Air Quality
- Questions