Essential Concepts in Atmospheric Deposition

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State Air Resources Board &

State Water Quality Control Board

California Environmental Protection Agency

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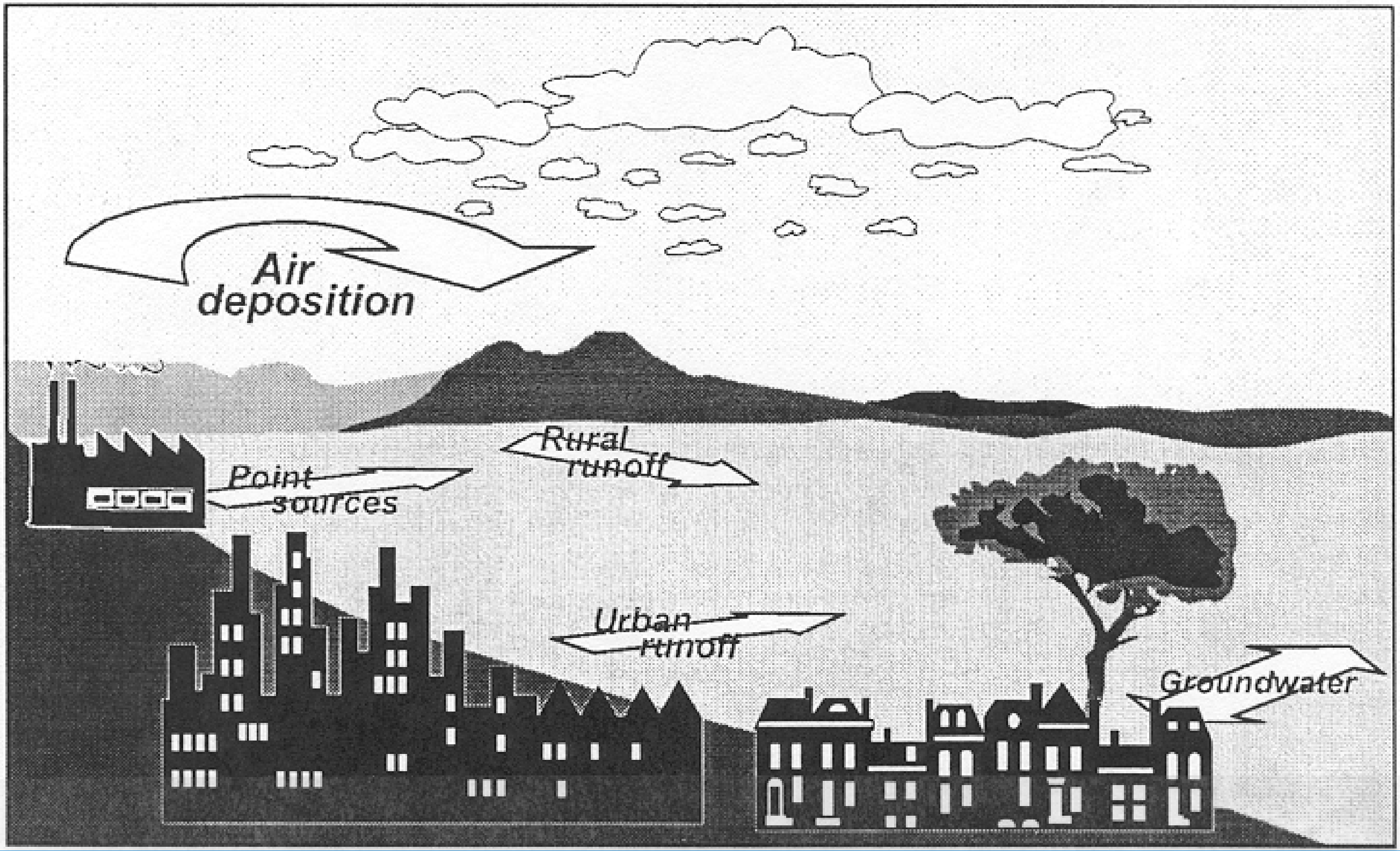
Pollutant Transport Pathways to Waterbodies



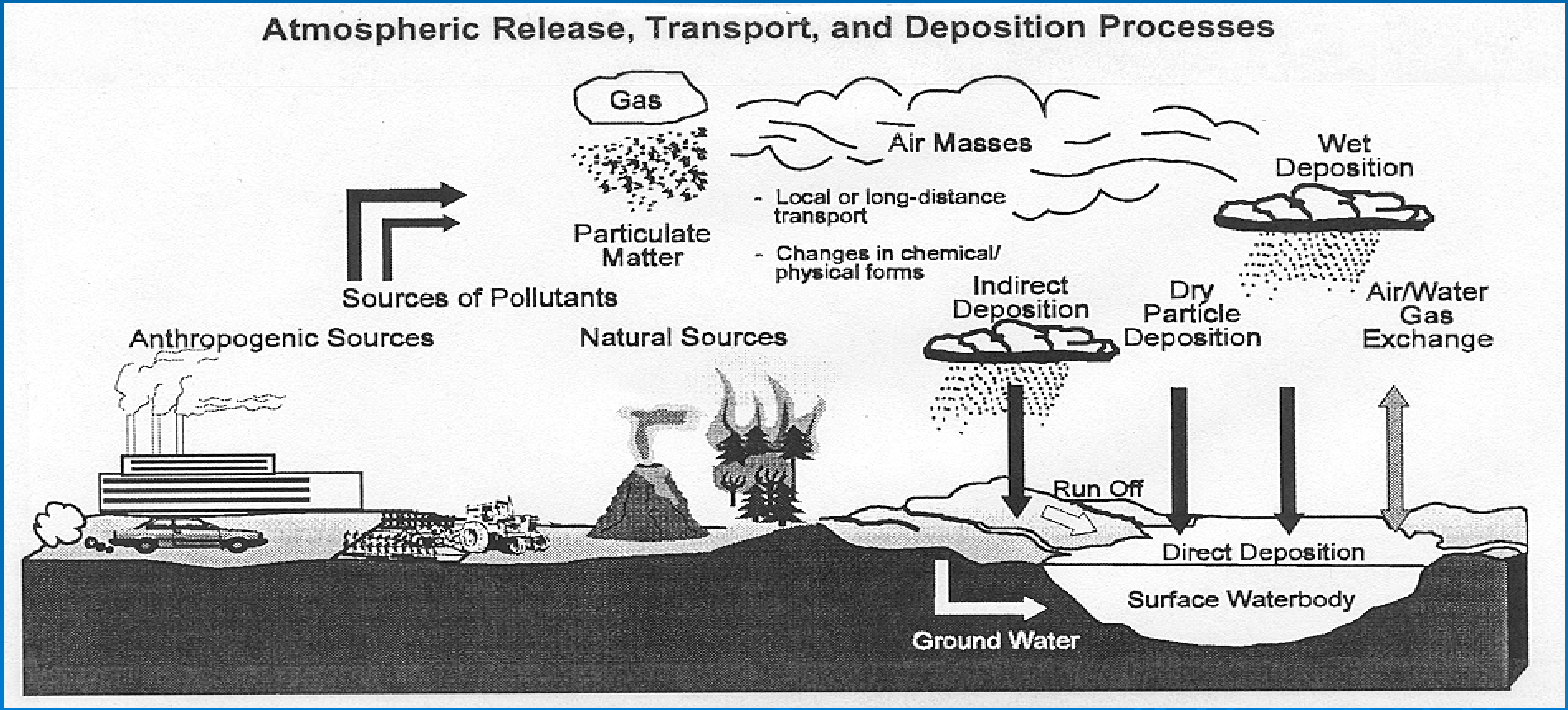
Framework for Assessing Deposition

Deposition Rate =

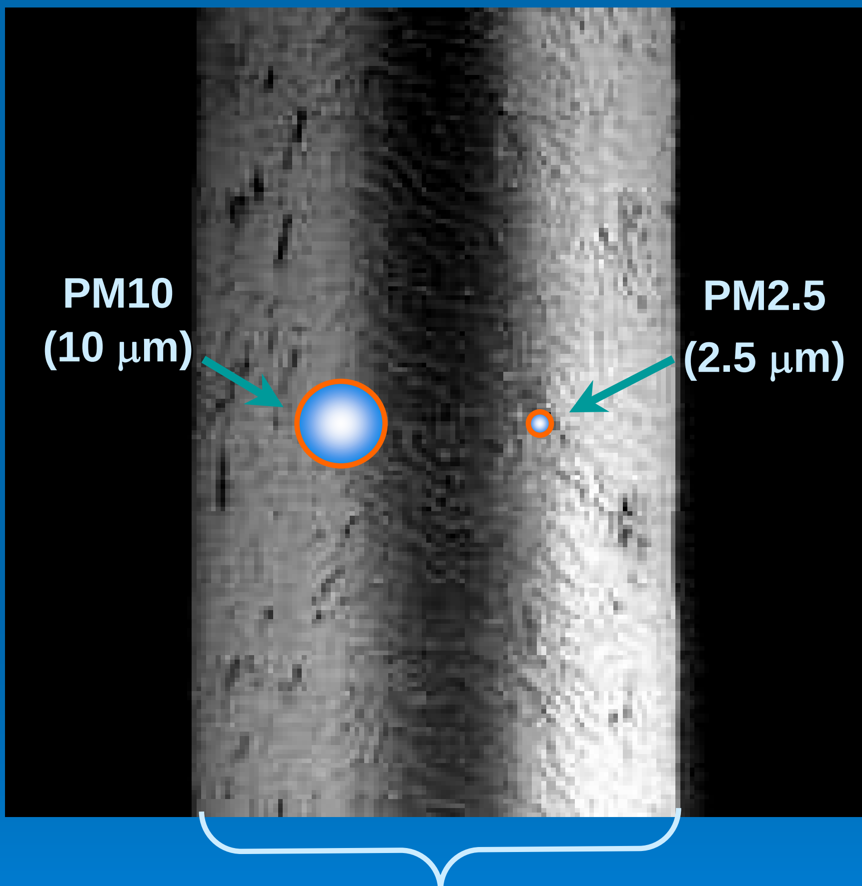
Air Concentration x Deposition Velocity

- Air Concentration
- Deposition processes
- Measurement approaches
- Modeling deposition

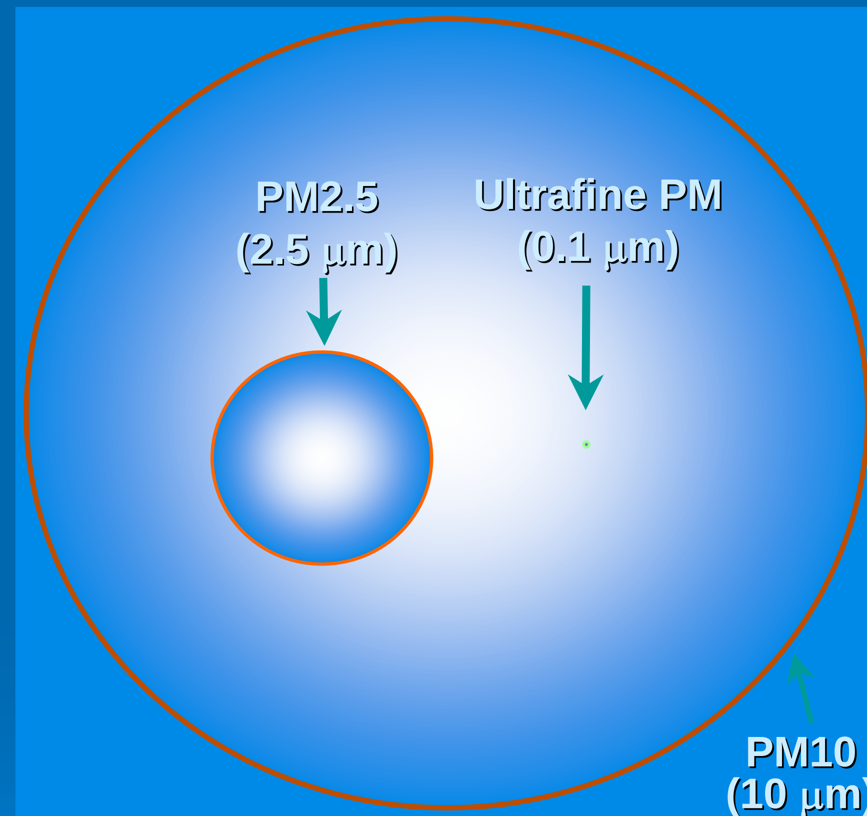
Local and Regional Concentrations



Comparison of PM10, PM2.5, and Ultrafine PM

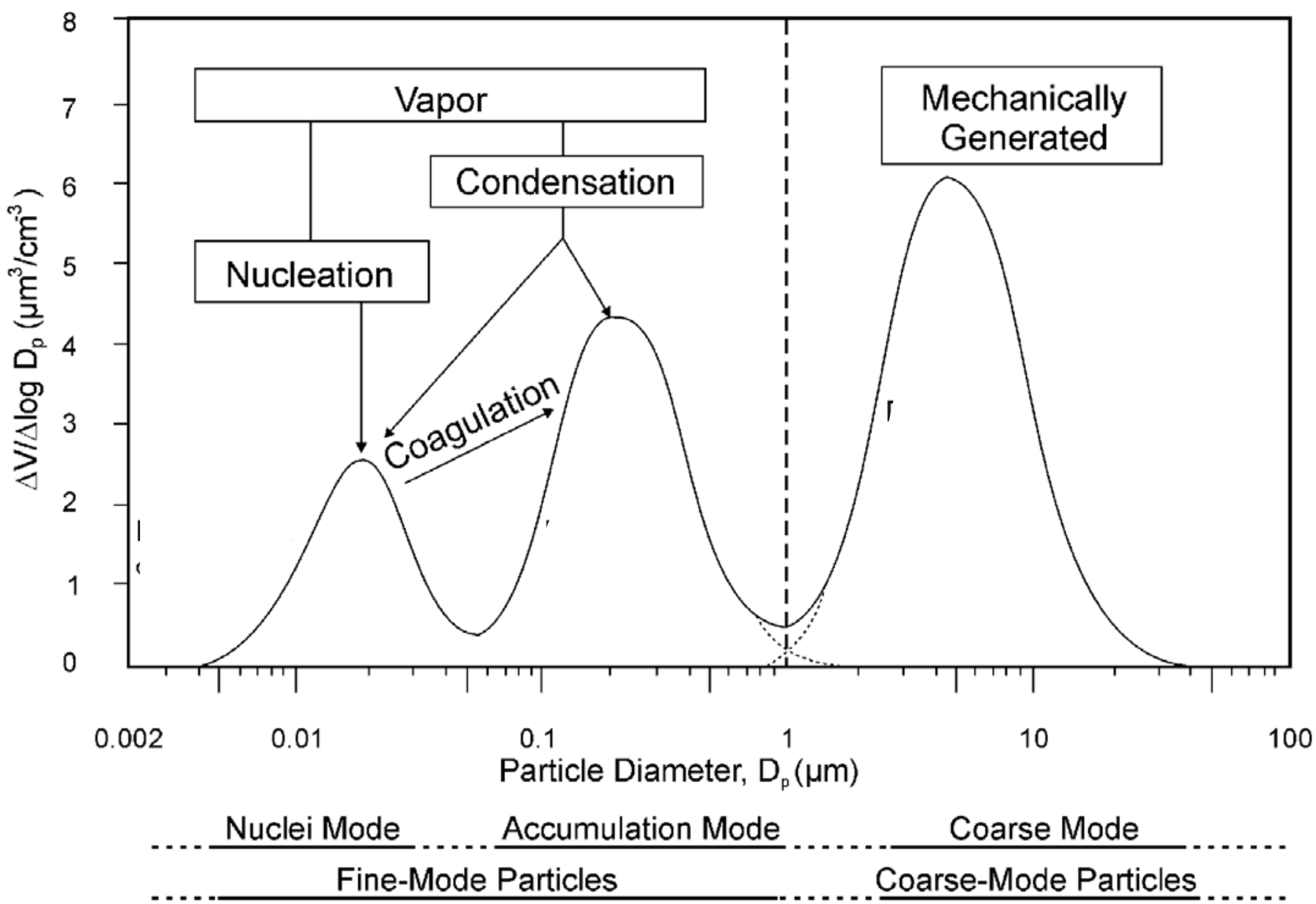


Human Hair
(60 μm diameter)

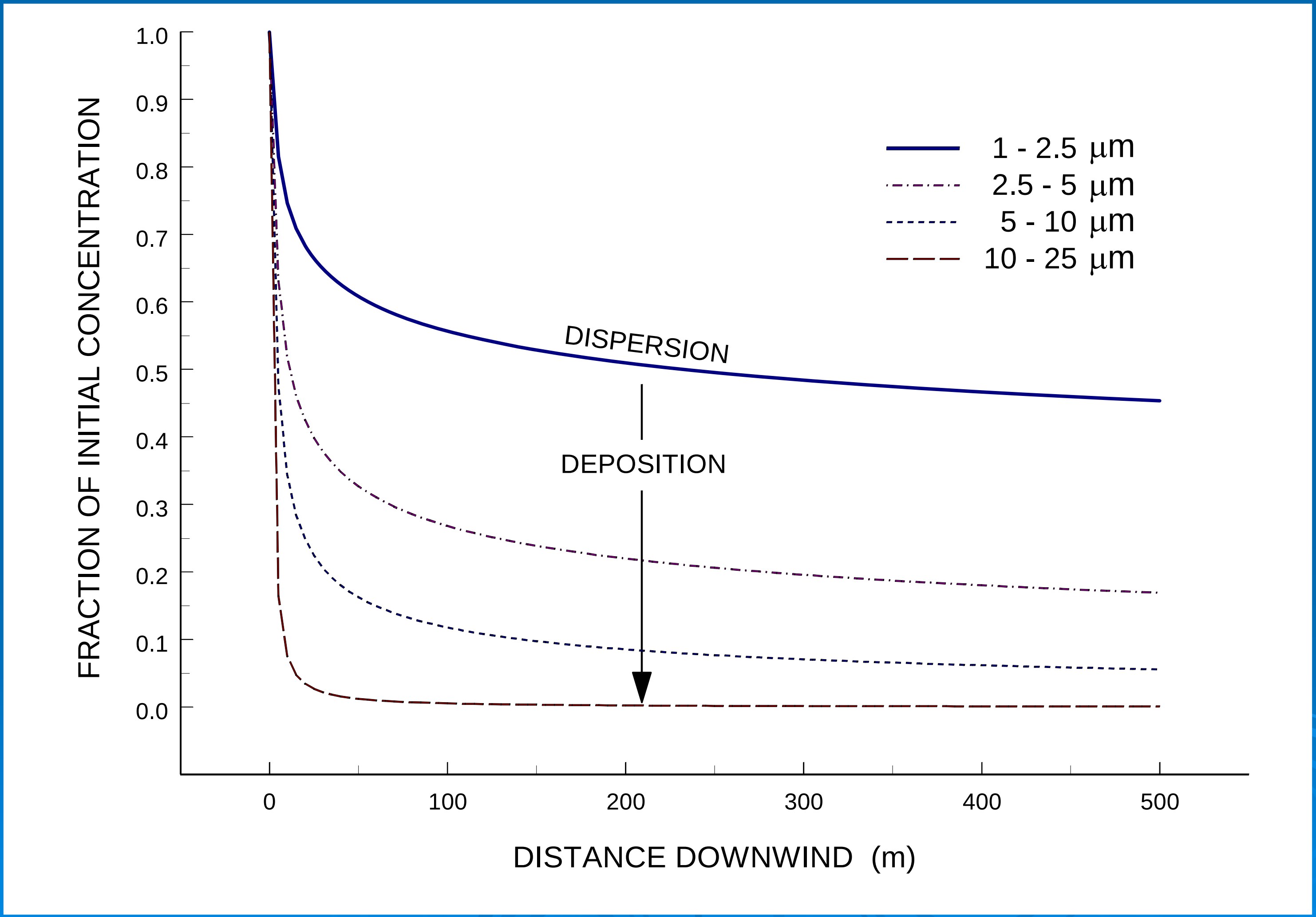


Relative size of particles

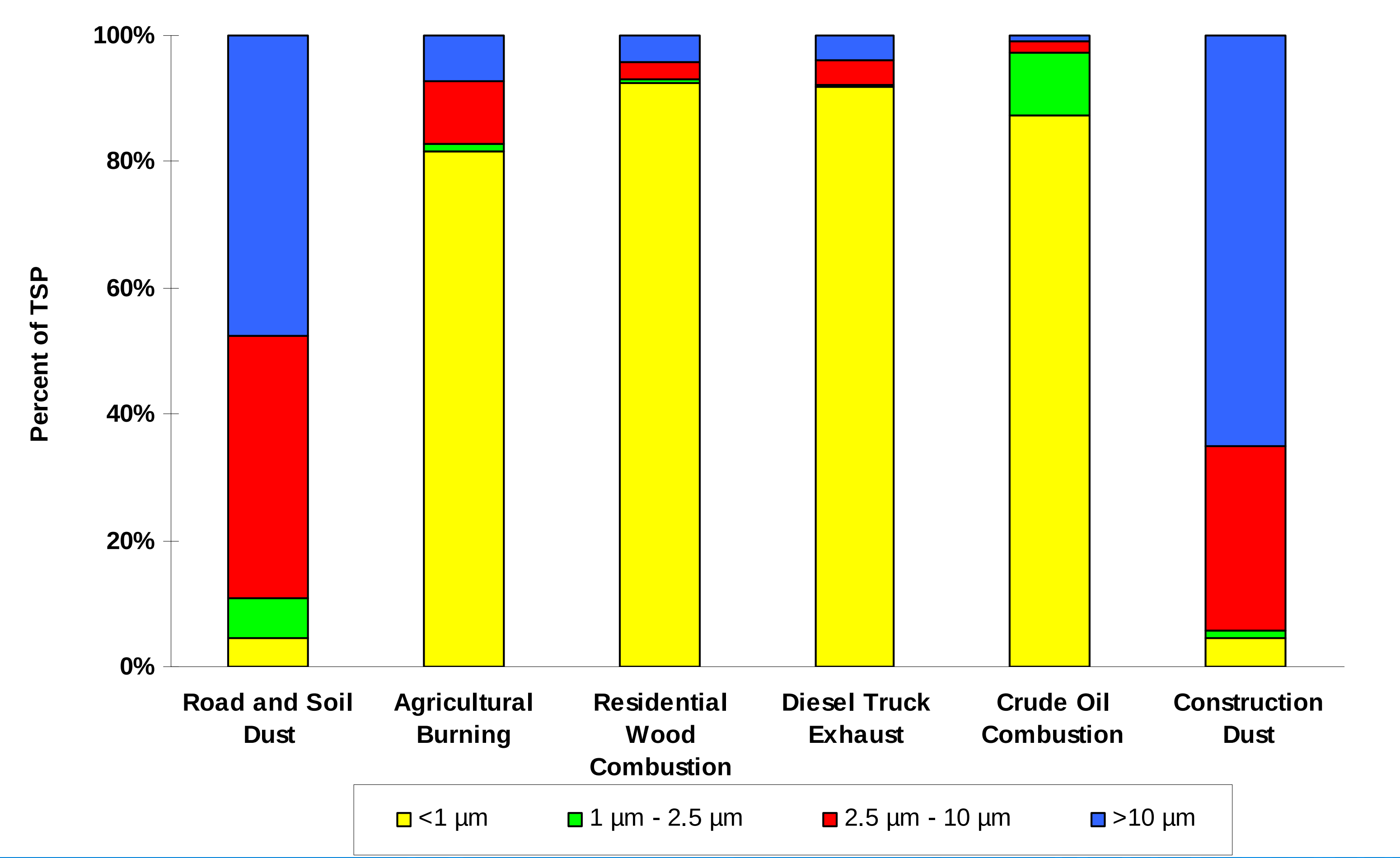
Particle Size Distributions



Measured Particle Concentrations Downwind of a Highway



Particle Size by Source Type



Factors that Influence Air Concentrations

- Proximity to sources
- Wind speed and direction
- Barriers to vertical mixing
- Chemical reactions
- Removal processes

Factors that Influence Dry Deposition

- Size of molecule or particle
  - Molecular diffusion, Brownian motion
- Fine texture of surface
- Affinity of surface and pollutant
  - “Stickiness”, solubility, reactivity
- Turbulent transport (vertical)
  - Wind speed
  - Roughness of landscape
  - Thermal stratification

Laminar-layer Conductance

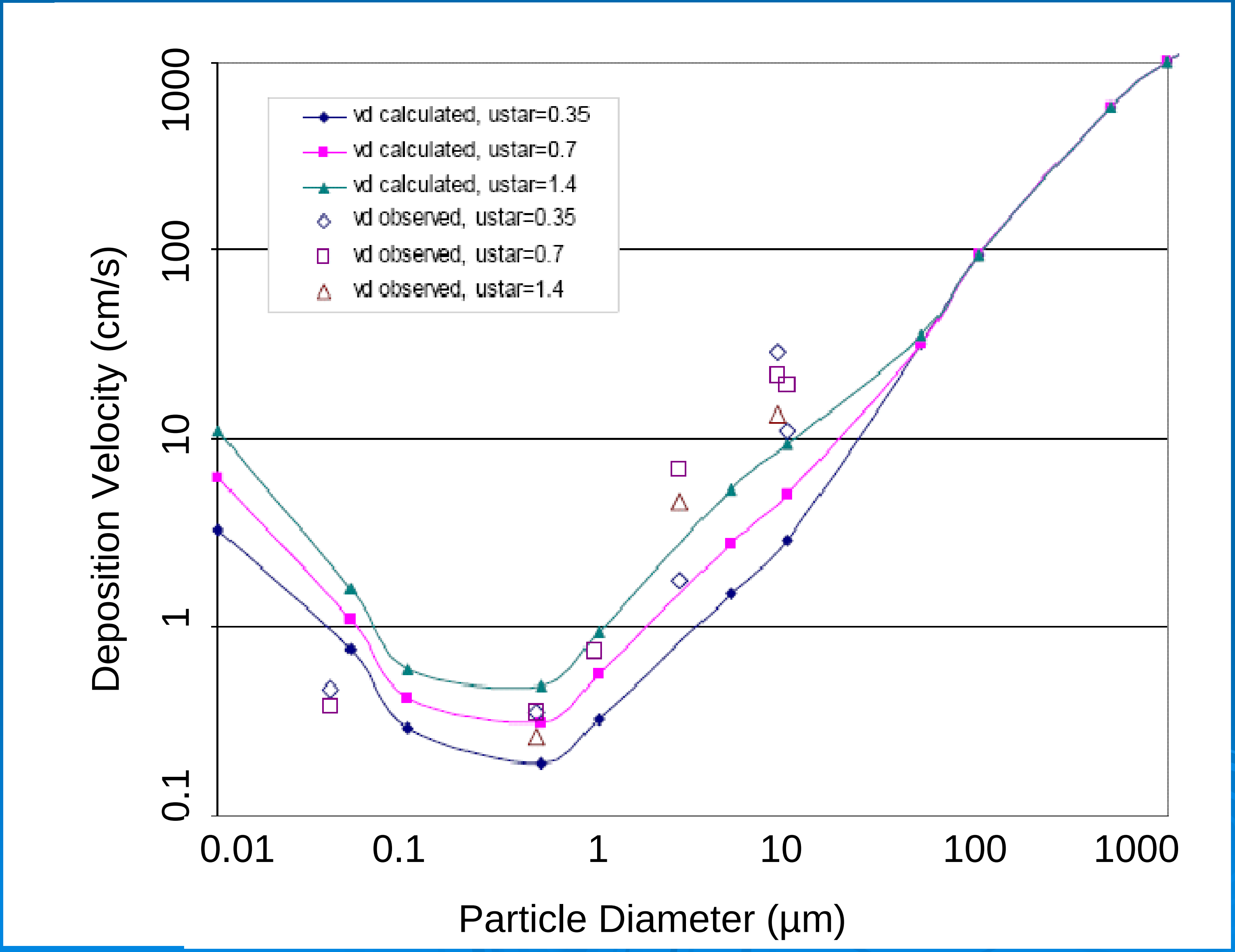
Surface Conductance

Aerodynamic Conductance

- Terminal velocity of large particles
  - Particle density and diameter

Gravitational Settling

Deposition Velocity & Particle Size



Sehmel, 1980

Wet Deposition

- Wet deposition
  - Rainout (soluble gases and fine particles)
  - Washout – interception by falling droplets
- Highly variable spatially
- Higher concentrations at beginning of storm
- Wet deposition measurement
  - May not be proportional to precipitation volume
  - More reliably measured than dry deposition
  - Less affected by spurious turbulence (than dry)

Dry Deposition Measurement Methods

Simpler to deploy

- Surrogate Surfaces
- Mass Balance
- Profile or Flux Gradient
- Eddy Covariance or Accumulation
- Dual Tracer Plume Depletion

More reliable results

Eddy Covariance

- Measure vertical velocity and concentrations of updraft and downdraft
- Sampling rate must be ~10 Hertz or faster
- Product of vertical velocity and concentration is flux
- Orient instruments to predominant wind direction
- Strict criteria for wind direction acceptance angles
- Uniform upwind surface

Surrogate Surfaces

- Literature cautions
  (e.g., Hicks & Wesely, 2000)

- Easy to deploy
- Integrated sample for chemical analysis
- Relative measure
- OK for wet deposition and largest particles
- Increases turbulence
- May not mimic natural surfaces
- Easily contaminated

Modeling Deposition

- Approach I
  - Measure concentrations
  - Model deposition velocities
  - Uses meteorological data
  - Unable to access source attribution
- Approach II
  - Estimate emissions
  - Model concentrations
  - Model deposition velocities
  - Uses meteorological data
  - Greater uncertainty in concentration estimates
  - Source attribution possible
  - Higher cost
  - Longer schedule

Both require extensive measurements or data -- winds, surface roughness, thermal stability, surface texture, particle size distribution, surface affinity.

Conclusions and Summary

- Deposition rate depends on emissions, transport/mixing, surface type, pollutant solubility/reactivity & particle size
- Fine Particles (0-2.5 µm)
  - greatest health relevance (increased disease and premature death)
  - low deposition rates and mass contribution
  - long transport distances
- Coarse Particles (2.5-10 µm)
  - health relevant (increased disease and premature death)
  - moderate deposition rates and mass contribution
  - shorter transport distances
- Large Particles (>10 µm)
  - not health relevant (not inhalable) so relatively sparse data
  - high deposition rates and mass contribution
  - short transport distances
- Measuring dry deposition is complex
- Deposition estimates and models are uncertain

Thank You