Methodology for Estimating Fugitive Windblown and Mechanically Resuspended Road Dust Emissions Applicable for Regional Air Quality Modeling

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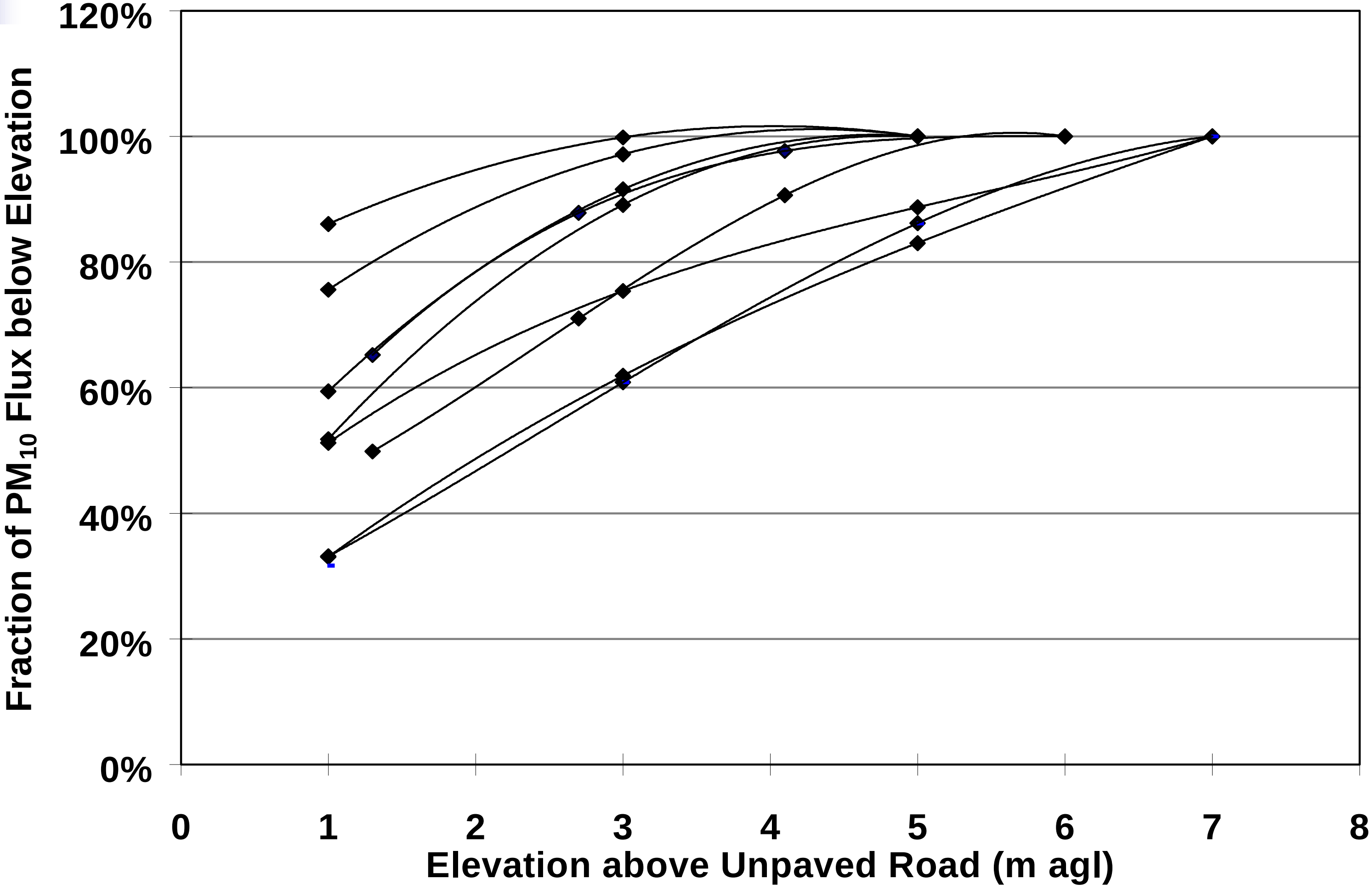
Objectives

- Summarize the findings and recommendations of a panel of air quality experts regarding the best methodology for estimating emissions of fugitive windblown and mechanically resuspended road dust applicable for regional scale air quality modeling
- Make recommendations for future research activities to generate improved fugitive dust emissions estimation techniques applicable for regional scale air quality modeling.

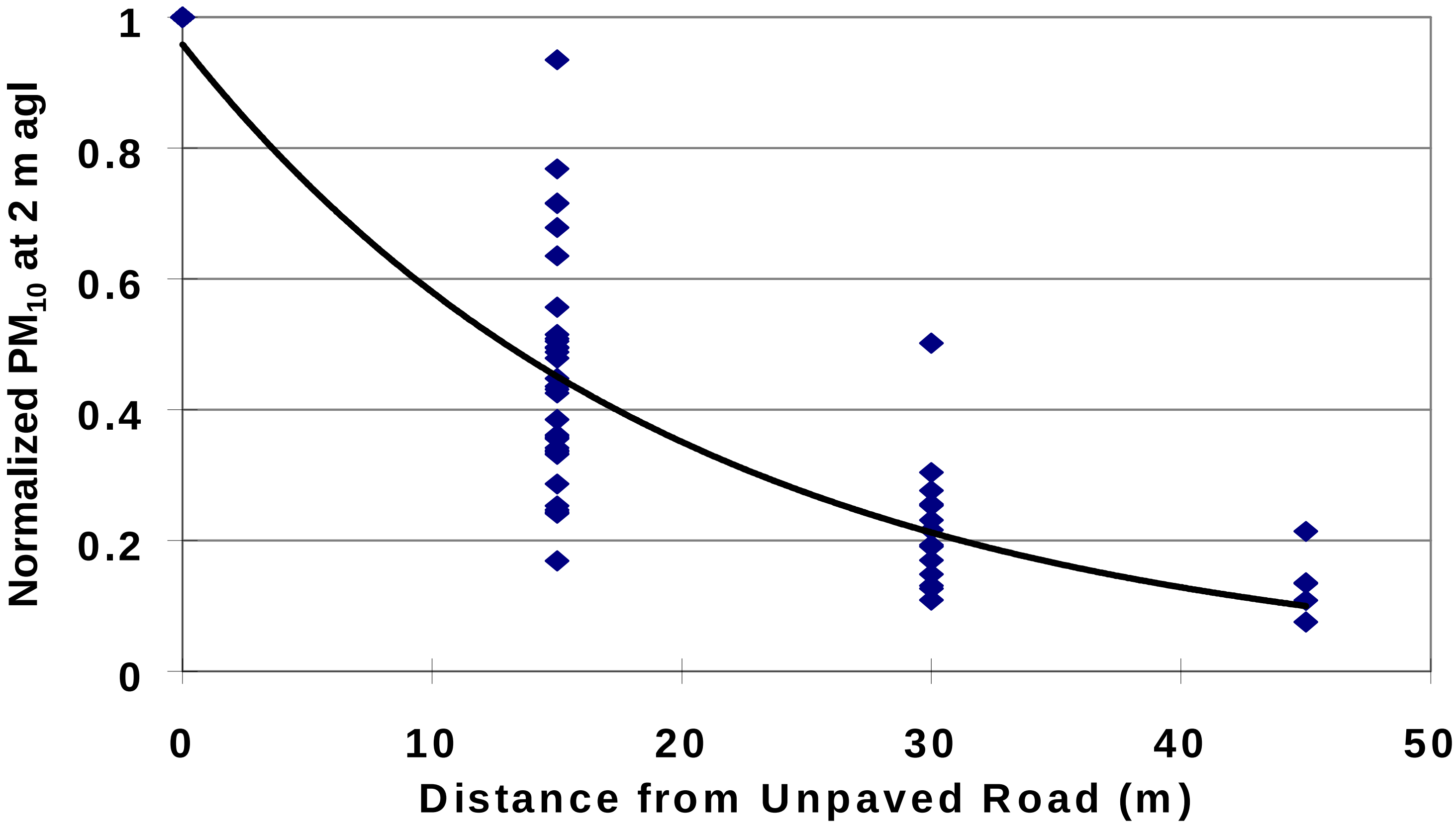
Expert Panel Findings: Suspension *vs.* Transport

- A large fraction of the suspended particles are not transported long distances
  - Particle losses due to impaction and deposition
- Regional-scale vertical flux is smaller than the local-scale fugitive dust flux
  - Particle loss affected by particle size, injection height, wind speed, terrain, obstacles

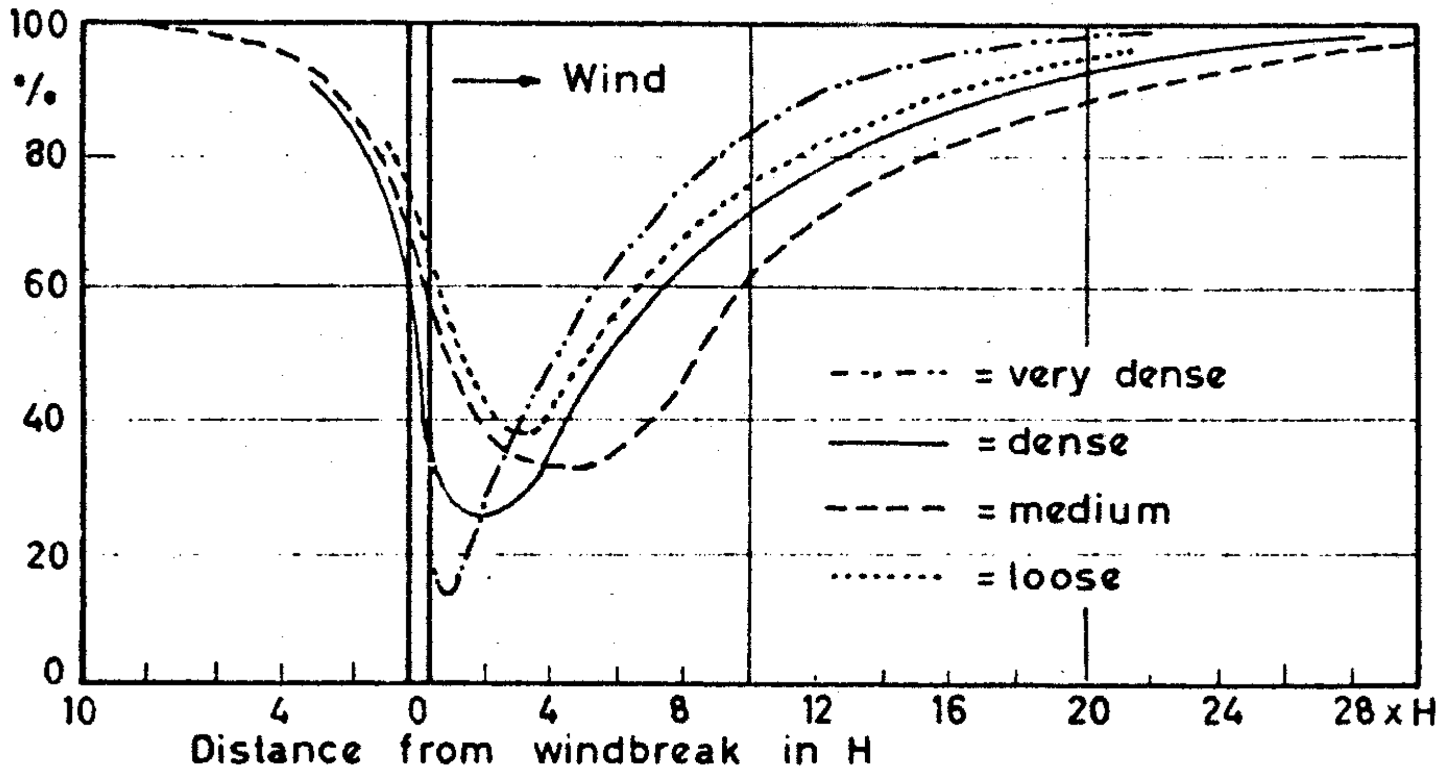
Horizontal PM_{10} Flux At Various Elevations Downwind of Unpaved Roads



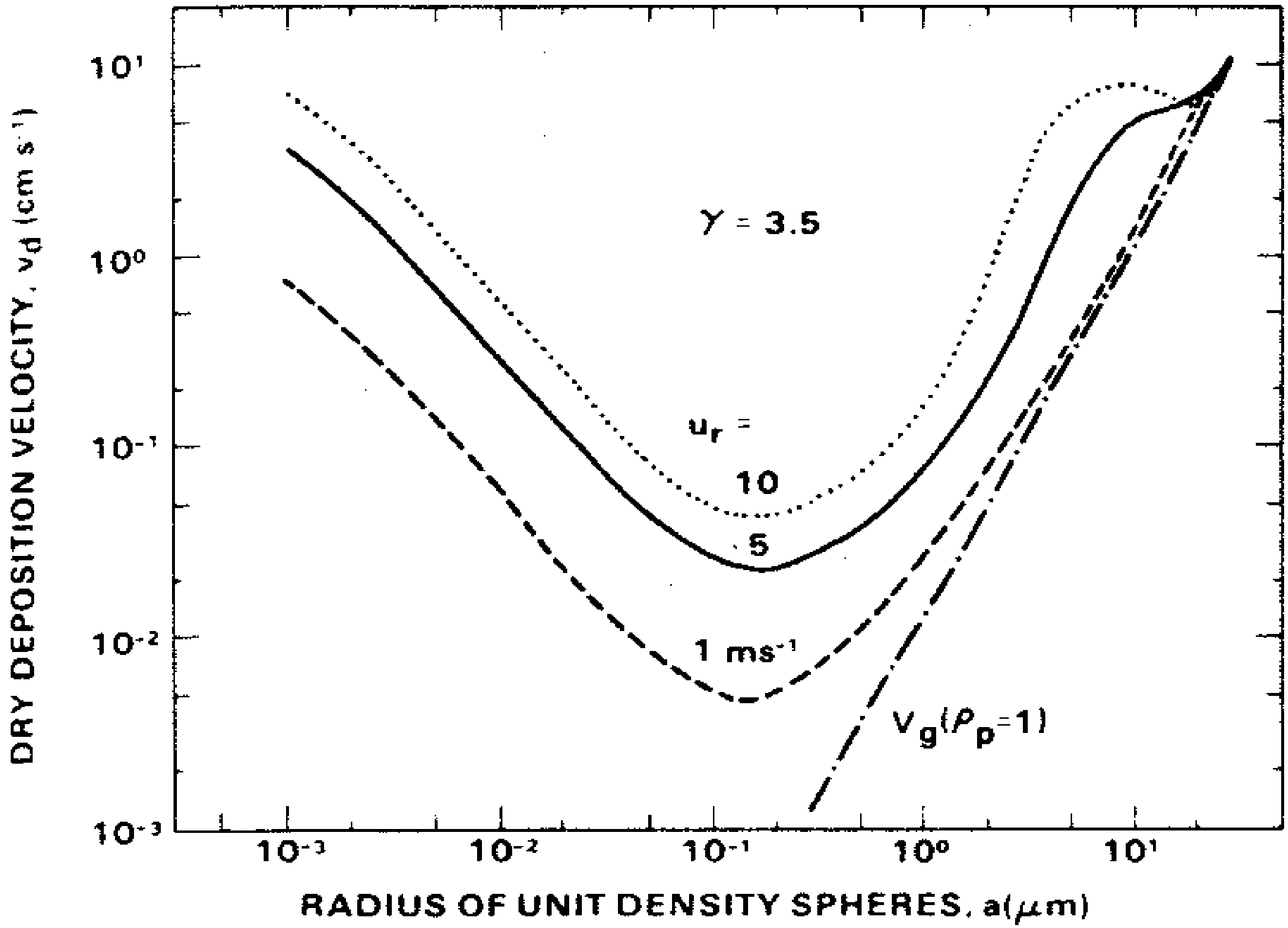
Attenuation of PM_{10} Concentrations Downwind of Unpaved Road



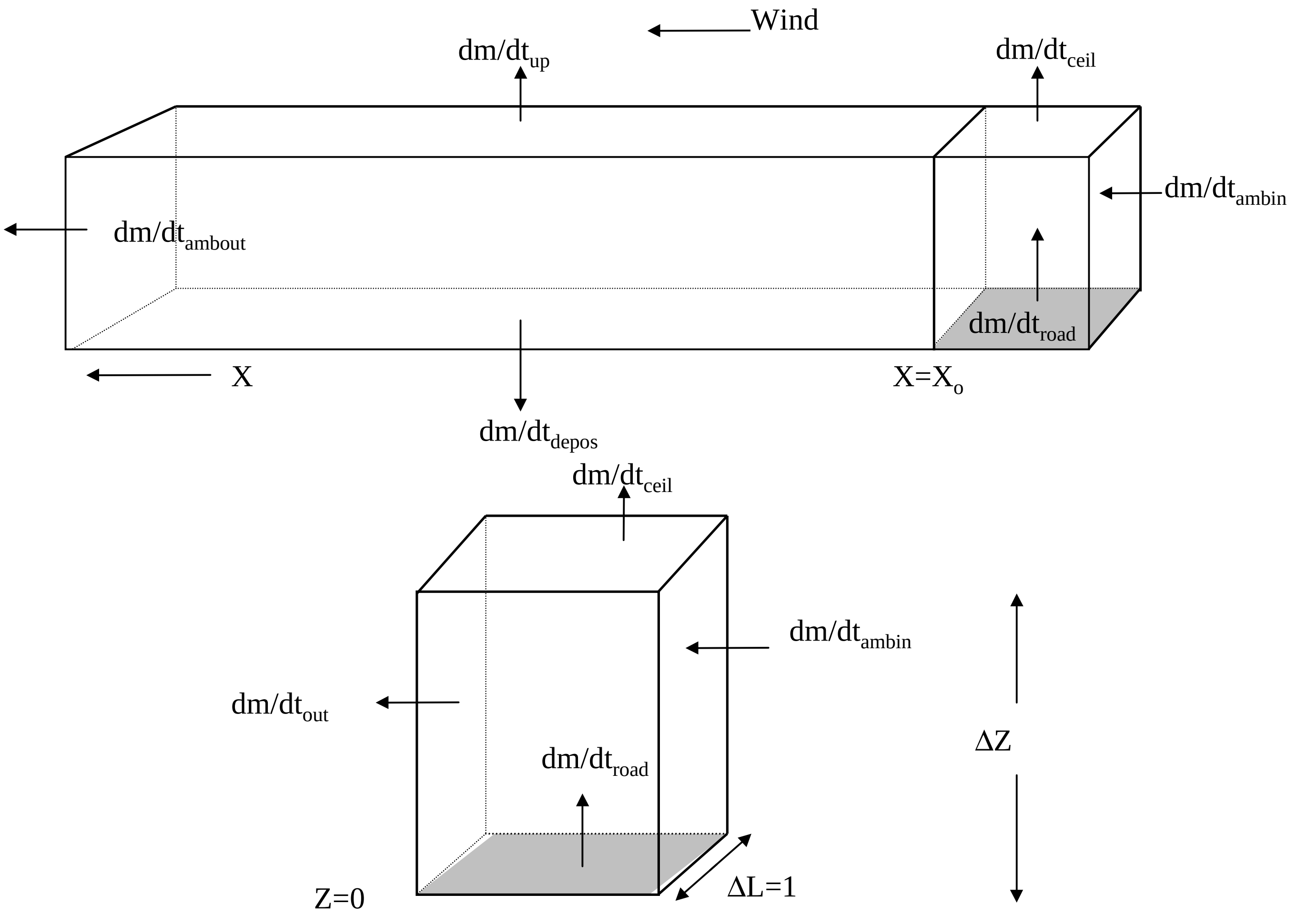
Wind Speed Attenuation Based On Vegetative Cover



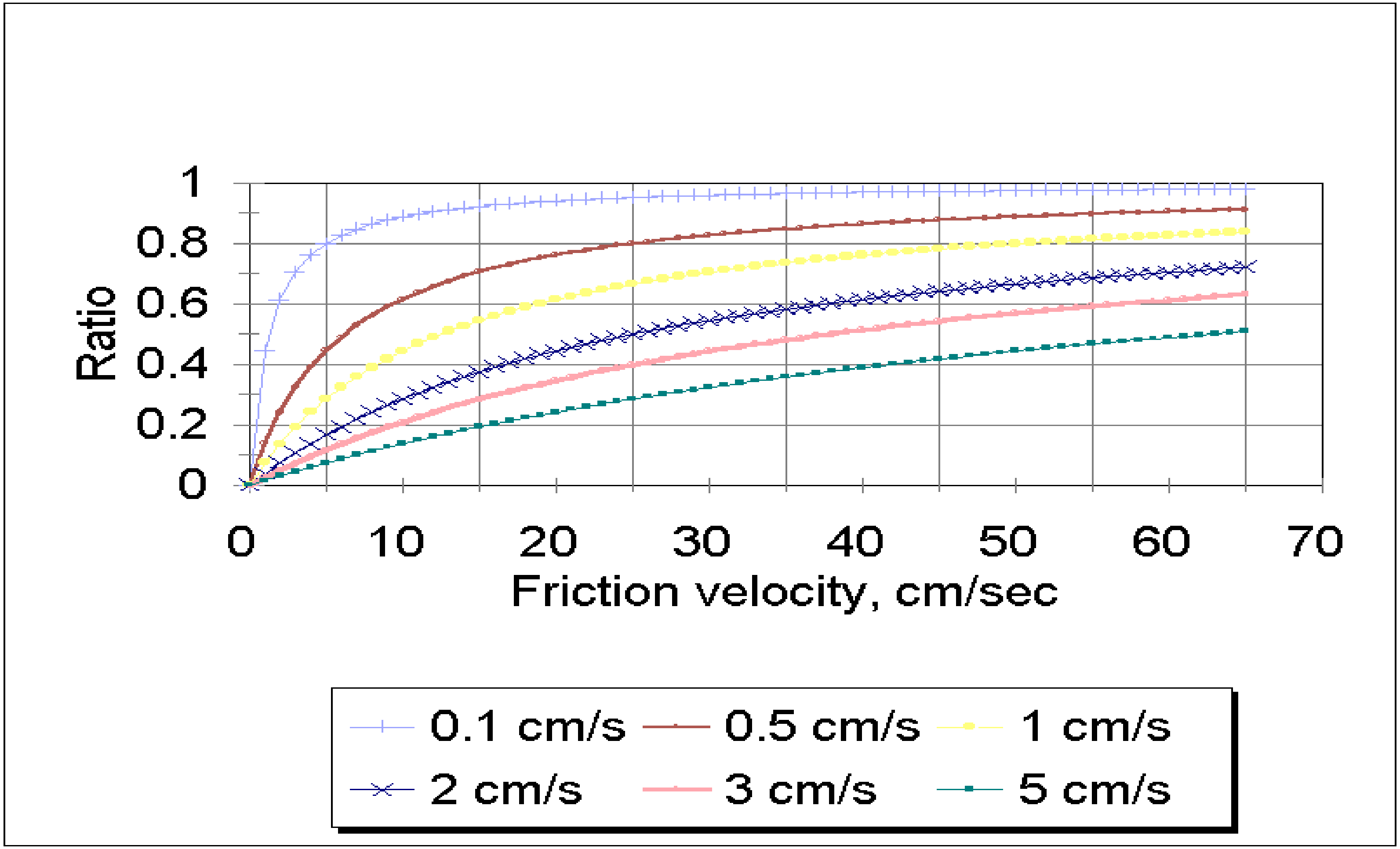
Downwind Deposition Based On Vegetative Cover



Gillette's Model Depicting Vertical & Horizontal Dust Flux



Ratio of Vertical Flux to Horizontal Flux

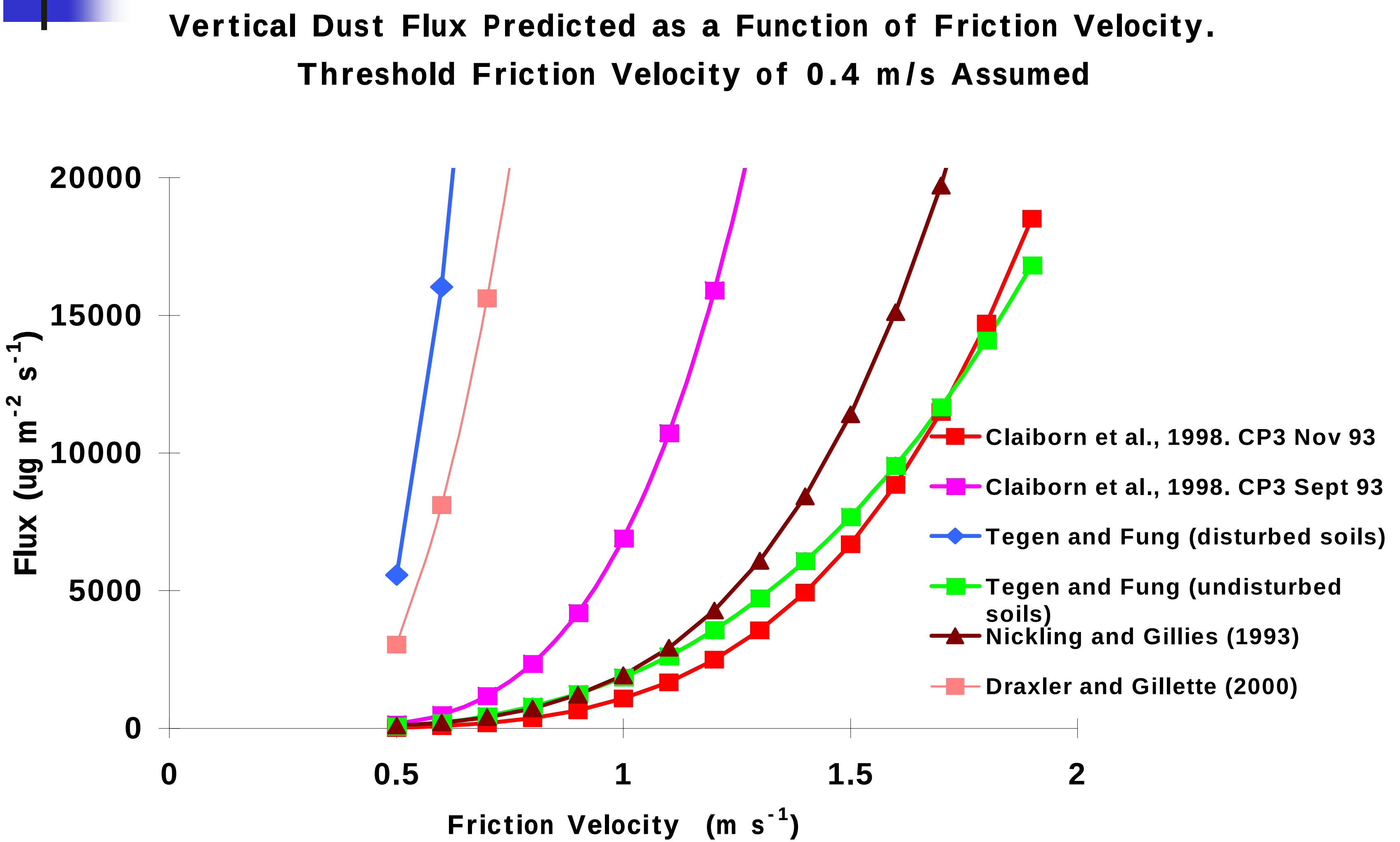


Findings: Emission Rates

Emission Rate = Emission Factor x Activity Level
(e.g.: pounds/day = pounds/mile x miles/day)

- Emission factors must be appropriate
  - ✓ Based on physically consistent model
- Activity levels should be accurate
  - ✓ Avoid default values
- Fine fraction needs to be characterized
  - ✓ Few direct measurements exist for $PM_{2.5}$

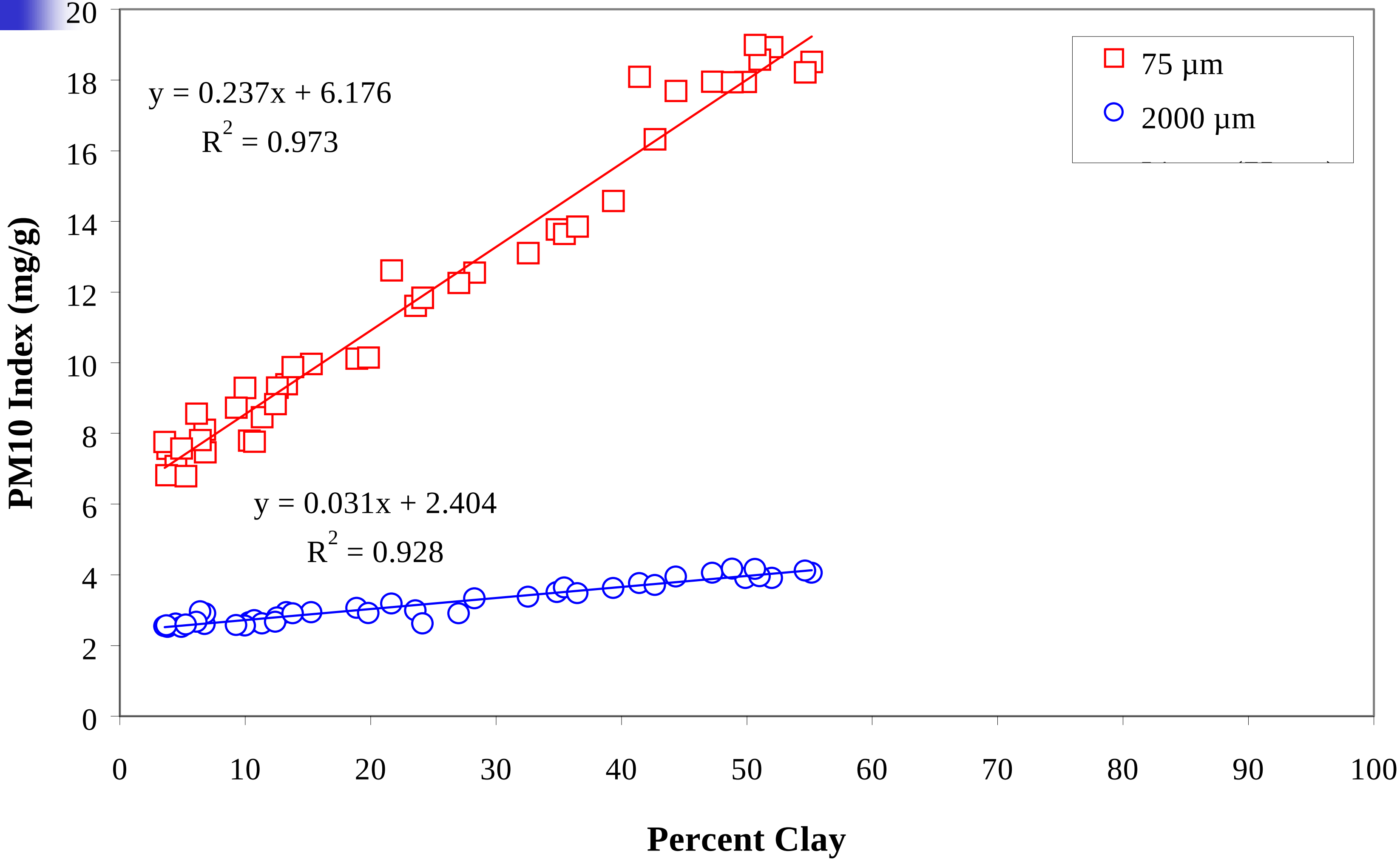
Apply Atmospheric Wind Suspension Rather Than Agriculture Based Wind Erosion Model



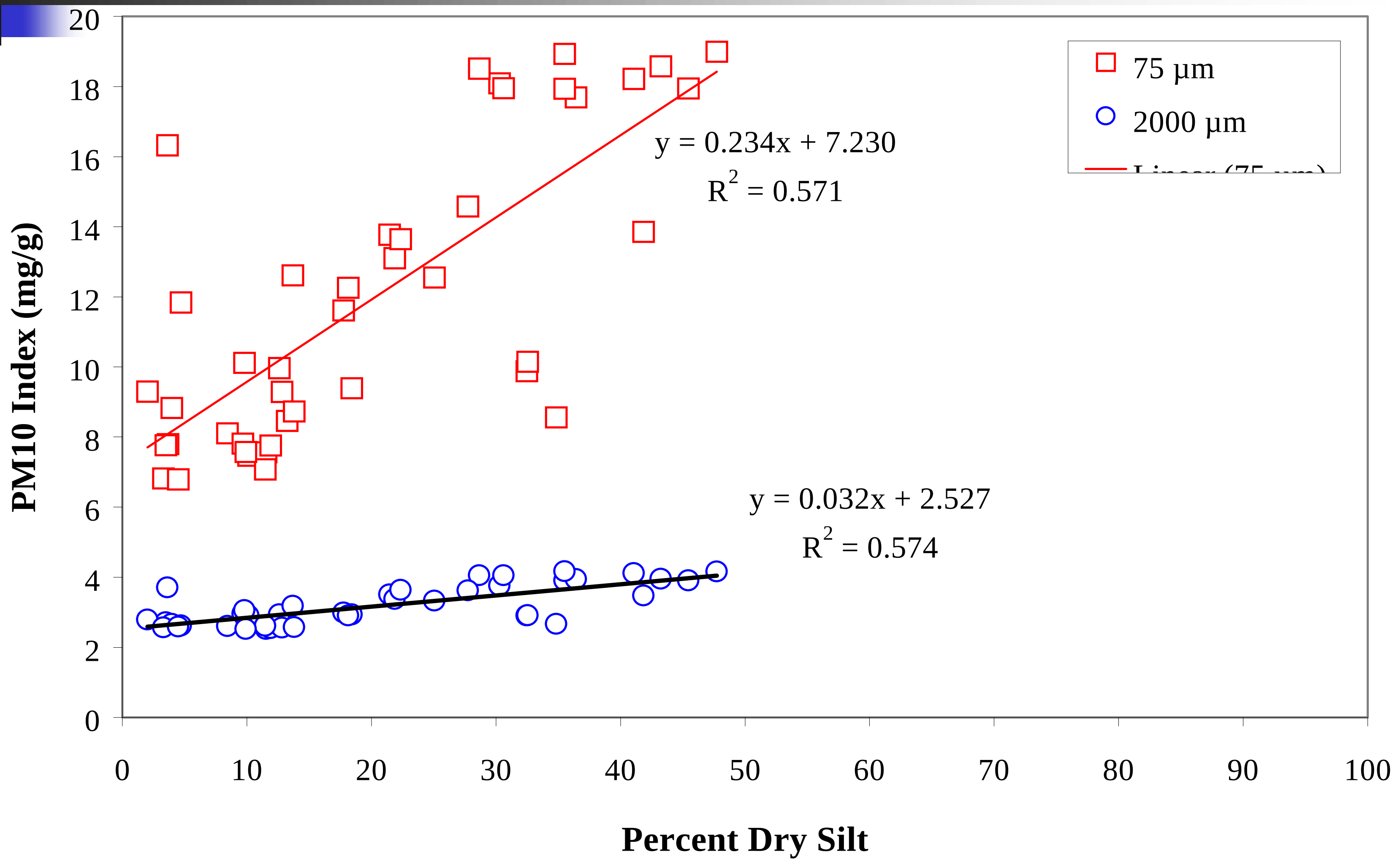
Findings: Emissions Vary Temporally and Spatially

- Emissions are not continuous processes
  - ✓ Wind erosion is of short duration & explosive in nature
- Annual inventories are not sufficient
  - ✓ Need to quantify short term variations in emissions to develop effective control strategy
- Spatial allocation of emissions is needed
  - ✓ Reservoirs and activities vary significantly spatially
  - ✓ Disturbed surfaces produce significantly more dust than undisturbed surfaces

PM_{10} Index *vs.* STATSGO Clay (Ashbaugh et al., 2000)



PM_{10} Index *vs.* AP-42 Silt



Findings: Models

- Air quality models need to integrate meteorology with the emissions generation processes
  - Previous modeling overestimated effect of emissions
- Receptor models can distinguish among different dust source categories
  - Identify contributions from specific dust sources (local *vs.* distant, paved road *vs.* windblown dust)

Recommendations for Generating a Fugitive Dust Emissions Inventory

- What do the experts say we need to do?
- What can we do based on available resources and funding?
- What are the priorities?
- What is the schedule for various tasks?

Experts' Recommendations

- Utilize physically consistent fugitive dust emissions model
- Quantify vertical PM_{10} & $PM_{2.5}$ emission rates
- Develop fugitive dust emissions inventory for the region
- Reconcile air quality dispersion model predictions with the inventory
- Apply receptor models to identify contributions from specific sources

Recommendations: Utilize Physically Consistent Emissions Model

- Test validity of assumptions of Gillette's model
  - ✓ Upgrade model to account for deposition and impaction
- Windblown dust
  - ✓ Field test USDA's Wind Erosion Prediction System
  - ✓ Alternatively, adopt Draxler's approach
  - ✓ Examine previous studies to determine proportionality constant between vertical and horizontal flux
- Mechanically suspended road dust
  - ✓ Evaluate alternative forms of EPA's emission factors

Recommendations: Quantify PM_{10} & $PM_{2.5}$ Vertical Flux Emission Rates

- Select unambiguous methodology to measure spatial and temporal variations in emissions
  - Few direct $PM_{2.5}$ measurements exist
  - Fewer measurements of PM_{10} & $PM_{2.5}$ vertical profiles
- Acquire accurate emission factors
  - Acquire information on parameters used in emission factor equations (silt loading, silt content, moisture content, threshold friction velocity, PM_{10} & $PM_{2.5}$ indices)

Recommendations: Quantify Vertical Flux Emission Rates (continued)

- Characterize temporal variability in emission rates taking into account:
  - ✓ Variability in threshold friction velocity
  - ✓ Variability in wind speed and the importance of wind gusts
  - ✓ Seasonal variations
  - ✓ Short duration events (e.g., analyze short term PM sampling results)

Recommendations: Quantify Vertical Flux Emission Rates (continued)

- Characterize spatial variability in emission rates
  - ✓ Determine availability of using existing spatially resolved data bases (land use, soil surveys) to improve inventories
  - ✓ Acquire samples of representative soils to determine their particle erosion potential (PM_{10} & $PM_{2.5}$ indices)
  - ✓ Develop practical method to obtain continuous roadway dust loadings
  - ✓ Develop GIS emissions modeling structure for acquiring and updating spatially resolved data for use in fugitive dust inventories

Recommendations: Quantify Vertical Flux Emission Rates (continued)

- Acquire accurate values of activity levels at sub-county level
  - Characterize spatial and temporal variability
- Quantify extent of particle reservoirs
  - Determine which surfaces have a limited *vs.* unlimited supply of particles
  - Examine effect of different types of disturbances
  - Quantify processes affecting particle reservoir replacement

Recommendations: Develop Fugitive Dust Emissions Inventory

- Develop inventory using best estimates of emission rates and quantify uncertainties
- Quantify effects of obstructions
  - Effect of upwind versus downwind obstructions on wind speed
  - Effect of attenuation of wind speed on residence time of suspended PM
- Determine variability in effectiveness of controls

Recommendations: Reconcile Dispersion Model Predictions with the Inventory

- Air quality models need to integrate meteorology with the emissions processes
  - Quantify impaction and deposition losses for different size particles
  - Quantify uncertainty of model inputs
  - Use "puff" type air dispersion model to characterize instantaneous emission rates from upwind/downwind exposure profiling studies

Recommendations: Apply Receptor Models to Identify Contributions From Specific Sources

- Utilize existing data bases (e.g., IMPROVE)
- Identify analytical methods with the potential to distinguish among different sources
- Implement a systematic source profile measurement program for the region
- Implement high temporal resolution ambient measurement program at selected IMPROVE sites

Inventory Approach

- Select emission factor equations
- Identify and assemble spatial data bases for soil properties, vegetative cover, roadway, and land use activity
- Quantify PM suspension potential, PM reservoir, shelterbelt attenuation of winds, and downwind deposition
- Determine temporal and spatial variations in dust-creating activities

Inventory Approach

- Determine wind directions and speeds for periods of interest
- Apply emissions factors to estimate suspension through vertical layers
- Apply Gillette vertical/horizontal flux inter-grid transport model to sub-grids
- Sum emissions into and out of sub-grids to obtain emissions out of the pre-sized emissions grid (10 to 50 km for regional inventories)

Activity Data Bases

- Ground cover (USGS, CALVEG)
- Soils (STATSGO, SSURGO)
- Agricultural fields and land use (California Water Resources, aerial photography)
- Roadways (FHWA, US Census Bureau)

Activity Types

- Where and when activities create, enhance, or reduce suspendable reservoirs (high winds, traffic, deposition, pollution controls, grazing, agriculture)
- Where and when activities inject surface dust into the atmosphere (winds, traffic)
- Size of reservoir and fraction that would suspend as PM_{10} or $PM_{2.5}$

Conclusions

- A theoretical framework exists to create more realistic regional fugitive dust inventories
- The data bases and computational capabilities are sufficient to implement further improvements
- Systematic surveys are needed to quantify representative samples of: PM potentials (replacing AP-42 silt); reservoir capacity; chemical/physical composition; and $PM_{2.5}$ emissions factors