DETERMINING FUGITIVE DUST EMISSIONS FROM WIND EROSION

Presented by

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April 29, 2003
PROJECT TEAM

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OUTLINE

• Project Background & Overview
• Literature Review
• Wind Tunnel Studies
• Agricultural Considerations
• Data Sources
• Estimation Methodology
• Program Development
• Summary
BACKGROUND AND OVERVIEW OF PROJECT

• WRAP Objectives

• Overall Objective to Compile PM10 and PM2.5 Emission Factors and Inventories From Windblown Dust for the Western Region

• Develop General Methodology to Facilitate Future Revisions and Control Strategy Development

• Develop Integrated SMOKE Processing Modules for PM10 and PM2.5 Emissions Modeling
BACKGROUND AND OVERVIEW OF PROJECT

- Develop PM10 and PM2.5 Emission Inventory Applicable to the Western Region
- Ensure Consistency With 36-km MM5 Meteorology and BELD3 Databases
- Develop General Methodology to Facilitate Future Revisions and Control Strategy Development
- Develop Integrated SMOKE Processing Modules for PM10 and PM2.5 Emissions Modeling
OVERVIEW OF TECHNICAL APPROACH

- Categorize Vacant Land Types
- Identify Wind Tunnel Emission Factors
- Develop Meteorological Data
- Develop Threshold Wind Velocities, Wind Events, Precipitation Events
- Develop Inventory Specific Emission Factors
- Apply Emission Factors to Vacant Land Categories
LITERATURE REVIEW

- Portable field wind tunnels have been used to investigate particle entrainment thresholds, emission potentials, and transport of sediment by wind.
- Key information has also come from dust emission modeling (e.g., Alfaro et al., 2003) and desert soil characterization studies (e.g., Chatenet et al., 1996).
Comparison between modeled relationship of threshold friction velocity and aerodynamic roughness length and wind tunnel data.

\[ u_t = 0.31e^{7.44x(Zo)} \]

\[ R^2 = 0.60 \]

\[ u_t = 0.30e^{7.22x(Zo)} \]

*(Gillette et al., 1980; Gillette et al., 1982; Gillette, 1988; Nickling & Gillies, 1989)*
The emission flux as a function of friction velocity predicted by the Alfaro and Gomes (2001) model constrained by the four soil geometric mean diameter classes of Alfaro et al. (2003).
WIND TUNNEL STUDY RESULTS: Emissions as a function of texture.

Relations between the soil types deduced from aggregate size distributions of various desert soils and soil textural categories (Chatenet et al. 1996). The “gray” highlighted textural classes indicate the 4 sediment types; the arrows indicate the pathways linking these types to the other textures. These can be linked to the North American soil texture triangle.
Comparison between model relationship for FS and CS sizes and the wind tunnel data of Nickling and Gillies (1989). Ten (out of 13) sites have a dust production potential similar to the FS model and one site (Mesa agricultural) is closely aligned with the CS model (after Alfaro et al., 2003).
AGRICULTURAL CONSIDERATIONS

• Non-climatic factors significantly decrease soil loss from agricultural lands
• Similar approach to CARB, 1997
• Seven “adjustment” factors simulate these effects:
  – Bare soil within fields
  – Bare borders surrounding fields
  – Long-term irrigation
  – Short-term irrigation
  – Crop canopy cover
  – Post-harvest vegetative cover (residue)
  – Post-harvest replanting (multi-cropping)
Canopy Cover and Residue Cover Adjustment Factors
AGRICULTURAL ADJUSTMENT FACTOR DEVELOPMENT

- New regional data collected for WRAP project:
  - Crop calendars with growth curves from Revised Universal Soil Loss Equation (RUSLE2) model
  - Residues remaining after harvest due to conservation tillage practices from Purdue’s Conservation Technology Information Center (CTIC)
  - Irrigation events from crop budget databases

- Factors applied by county/crop type, crop management zones (CMZs)
DATA SOURCES

• **Land Use/Land Cover (LULC)**
  – Biogenic Emission Landcover Database (BELD3)
  – North American Land Cover Characteristics (NALCC)

• **Soils Characteristics**
  – State Soil Geographic Database (STATSGO)
  – Soil Landscape of Canada (SLC_V2)
  – International Soil Reference and Information Centre

• **Meteorological Data**
  – 1996 MCIP 36-km (Friction Velocity, Precipitation)
**LAND USE/LAND COVER DATA**

- **BELD3 LULC Data**

<table>
<thead>
<tr>
<th>Summary</th>
<th>Total Area (Acres)</th>
<th>%</th>
<th>% excluding water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>6,781,771</td>
<td>0.26%</td>
<td>0.34%</td>
</tr>
<tr>
<td>Agriculture</td>
<td>531,231,552</td>
<td>20.54%</td>
<td>26.35%</td>
</tr>
<tr>
<td>Shrub/grassland</td>
<td>720,022,464</td>
<td>27.84%</td>
<td>35.71%</td>
</tr>
<tr>
<td>Forest</td>
<td>741,902,639</td>
<td>28.69%</td>
<td>36.80%</td>
</tr>
<tr>
<td>Barren</td>
<td>5,801,931</td>
<td>0.22%</td>
<td>0.29%</td>
</tr>
<tr>
<td>Wetlands</td>
<td>681,383</td>
<td>0.03%</td>
<td>0.03%</td>
</tr>
<tr>
<td>Tundra</td>
<td>9,096,875</td>
<td>0.35%</td>
<td>0.45%</td>
</tr>
<tr>
<td>Snow&amp;Ice</td>
<td>603,210</td>
<td>0.02%</td>
<td>0.03%</td>
</tr>
<tr>
<td>Water</td>
<td>569,829,853</td>
<td>22.04%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2,585,951,680</td>
<td>100.00%</td>
<td></td>
</tr>
<tr>
<td>Total excluding water</td>
<td>2,016,121,827</td>
<td>100.00%</td>
<td></td>
</tr>
</tbody>
</table>
## SOIL CHARACTERISTICS

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Soil Texture (from Chamley, 1987)</td>
<td>Groupings</td>
</tr>
<tr>
<td>sand</td>
<td>sand</td>
<td>CS</td>
</tr>
<tr>
<td>loamy sand</td>
<td>sand</td>
<td>CS</td>
</tr>
<tr>
<td>sandy loam</td>
<td>silty sand</td>
<td>MS</td>
</tr>
<tr>
<td>sandy clay loam</td>
<td>clayey sand</td>
<td>MS</td>
</tr>
<tr>
<td>sandy clay</td>
<td>clayey sand</td>
<td>MS</td>
</tr>
<tr>
<td>(medium) loam</td>
<td>clayey silty sand</td>
<td>MS</td>
</tr>
<tr>
<td>clay loam</td>
<td>clayey silty sand</td>
<td>MS</td>
</tr>
<tr>
<td>silty loam</td>
<td>clayey sandy silt</td>
<td>FS</td>
</tr>
<tr>
<td>silty clay loam</td>
<td>clayey silt</td>
<td>FFS</td>
</tr>
<tr>
<td>silt</td>
<td>silt</td>
<td>FFS</td>
</tr>
<tr>
<td>silty clay</td>
<td>silty clay</td>
<td>FFS</td>
</tr>
<tr>
<td>clay</td>
<td>sandy clay</td>
<td>FS</td>
</tr>
<tr>
<td></td>
<td>(10-50% sand, 75-50% clay)</td>
<td></td>
</tr>
<tr>
<td>clay</td>
<td>sandy silty clay</td>
<td>FS</td>
</tr>
<tr>
<td></td>
<td>(10-45% sand, 12-45% silt, 35-75% clay)</td>
<td></td>
</tr>
</tbody>
</table>
METEOROLOGICAL DATA

• **1996 MM5/MCIP**
  - 1996 Annual, hourly, gridded meteorology
  - 36-km horizontal resolution
  - Hourly friction velocities
  - Hourly precipitation rates
ESTIMATION METHODOLOGY

- **Wind Tunnel Studies**
  - Land use/Soil types
  - Surface Characteristics
  - Threshold $u^*$
  - Mass Flux
  - Representative $z_0$ values

- **Meteorological Data**
  - Hourly wind fields
  - Hourly precipitation fields
  - Hourly $u^*$ fields

- **Land-use/Soils Database**
  - Land-use/Land cover (LULC)
  - Soil characteristics (SC)
  - $z_0$

- **Agricultural Land Data**
  - Crop Production Database
  - Crop Calendars
  - Irrigation Schedules
  - Other Non-climatic Factors
START
Julian Day & Time

Cell I36, J36

METCRO3D
(mcip)

Met Information, Rain

Yes

DUST36 = 0

Rain

No

Table for X as a function of soil type, total rain or snow

Did it rain in the last X hours

Yes

DUST36 = 0

No

METDOT3D
(mcip)

Met Information, Wind Speed (UZ36), and Height of first layer (Z36)

Map I36, J36 to I12 and J12 (9 cells)

Next I12, J36 Cell

Next Time Step

Loop over I12, J12 cells

Soil Group Code (SGCD)

Grid12_soils table

SGCD = 0

Yes

DUST12 = 0

No

lu_wrap12

Table

Read Land Use Codes (LUCDAF), and Area Fractions (AF)

Loop over Area Fractions

Next AF

Next I12, J36 Cell
PROGRAM DEVELOPMENT

END

LUCDAF = 16 (water)

Read ZOAF for the area fraction (using LUCDAF) and calculate USTAR using UZ36 and Z36

Threshold velocity (USTARTH) from table or equation

ZO table

Next AF

Yes

DUSTAF = 0

No

DUSTAF = DUST12 + DUSTAF

DUST12 = DUST12 * AGF

Next AF

Yes

DUSTAF = EMSFAF * A12 * AF

No

Read EMSFAF for the area fraction (using USTAR and LUCDAF) and calculate DUSTAF = EMSFAF * A12 * AF

DUSTAF = 0

Is the AF an Ag land?

Yes

DUSTAF = DUST12 + DUSTAF

No

Agricultural Adjustment Factor AgF

DUSTAF = DUSTAF * AgF

DUST12 = DUST12 + DUSTAF

Next AF

Yes

DUST12 = DUST12 * AGF

DUST36 = DUST36 + DUST12

Next I36, J36 Cell

Next I12, J12 Cell

Next Time Step

END
SUMMARY

- Windblown dust emissions represent a significant portion of PM10 and PM2.5 emissions
- Applicable wind tunnel study results identified and evaluated
- Development of appropriate data sets
- Incorporation of non-climatic effects for agricultural lands
- Development of general emission estimation methodology
- Development of SMOKE compatible processing code