MOBILE SOURCE PARTICULATE AND SEMI-VOLATILE ORGANIC CARBON AMBIENT MODELING

Chris Lindhjem, ENVIRON International
Eric Fujita, Desert Research Institute
and Mark Janssen, LADCO

18th International Emission Inventory Conference
April 15. 2009
Baltimore, MD
Acknowledgement

This work is funded by the DOE Office of Vehicle Technologies through the National Renewable Energy Laboratory (NREL), Lake Michigan Air Directors Consortium (LADCO), and Mid-Atlantic Regional Air Management Association (MARAMA).
Review Potential Individual Adjustments to MOBILE6

- Current modeling air quality has consistently underpredicted the organic carbon particulate measured at ambient monitors.
- Likely future emission factors improvements in air quality modeling scenarios:
  - Light-duty gasoline vehicle (LDV): PM adjustments reflecting multi-sponsored test data in Kansas City.
  - Light-duty gasoline vehicle (LDV): Remote sensing study comparisons for high emitters sensitivity analysis.
  - Heavy-duty diesel vehicles (HDDV): in-use testing and realistic testing cycles.
- Inclusion of semi-volatile hydrocarbons.
Kansas City Study Light-duty Gasoline Vehicle PM Emissions

- Adjustments to MOBILE6 LDGV and LDGT PM emissions at 72°F

### LDGV – Passenger vehicles

<table>
<thead>
<tr>
<th>MDYgroup</th>
<th>DRI Adj.</th>
<th>Chicago</th>
<th>Cincinnati</th>
<th>Detroit</th>
<th>Milwaukee</th>
<th>LADCO Average</th>
<th>NYC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981-1990</td>
<td>4.36</td>
<td>6.1%</td>
<td>7.0%</td>
<td>10.1%</td>
<td>7.2%</td>
<td></td>
<td>10.3%</td>
</tr>
<tr>
<td>1991-1995</td>
<td>1.82</td>
<td>15.8%</td>
<td>18.3%</td>
<td>15.5%</td>
<td>18.5%</td>
<td></td>
<td>22.0%</td>
</tr>
<tr>
<td>1996+</td>
<td>0.54</td>
<td>78.1%</td>
<td>74.7%</td>
<td>74.4%</td>
<td>74.3%</td>
<td></td>
<td>67.6%</td>
</tr>
<tr>
<td>Average Adj.</td>
<td>0.97</td>
<td>1.04</td>
<td>1.12</td>
<td>1.05</td>
<td>1.044</td>
<td>1.21</td>
<td></td>
</tr>
</tbody>
</table>

### LDGV – Trucks

<table>
<thead>
<tr>
<th>MDYgroup</th>
<th>DRI Adj.</th>
<th>Chicago</th>
<th>Cincinnati</th>
<th>Detroit</th>
<th>Milwaukee</th>
<th>LADCO Average</th>
<th>NYC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981-1990</td>
<td>2.01</td>
<td>5.8%</td>
<td>8.3%</td>
<td>7.0%</td>
<td>21.0%</td>
<td></td>
<td>10.6%</td>
</tr>
<tr>
<td>1991-1995</td>
<td>2.02</td>
<td>12.3%</td>
<td>15.6%</td>
<td>7.9%</td>
<td>13.8%</td>
<td></td>
<td>12.2%</td>
</tr>
<tr>
<td>1996+</td>
<td>0.68</td>
<td>81.9%</td>
<td>76.1%</td>
<td>85.1%</td>
<td>65.2%</td>
<td></td>
<td>77.3%</td>
</tr>
<tr>
<td>Average Adj.</td>
<td>0.92</td>
<td>1.00</td>
<td>0.88</td>
<td>1.15</td>
<td>0.988</td>
<td>0.99</td>
<td></td>
</tr>
</tbody>
</table>
Light-duty Temperature Adjustment

- Very significant temperature adjustment outlined by EPA (Ed Nam 2008)
High Emitter Analysis
SEMCOG RSD and Atlanta CAFE RSD

• Results from ENVIRON study funded by EPRI
• Used RSD data for:
  – Atlanta: Continuous Atlanta Fleet Evaluation (CAFÉ), Release 18.

<table>
<thead>
<tr>
<th>Area</th>
<th>HC</th>
<th>CO</th>
<th>NOx</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LDGV</td>
<td>LDGT</td>
<td>LDGT1</td>
</tr>
<tr>
<td>Detroit – SEMCOG (CY 2007)</td>
<td>+32%</td>
<td>-8%</td>
<td>-</td>
</tr>
<tr>
<td>Atlanta - CAFE (CY 2006)</td>
<td>+26%</td>
<td>-</td>
<td>+24%</td>
</tr>
</tbody>
</table>
HDDV Approach

• Results from ENVIRON study funded by EPRI
• Vehicle types (normal and high)
  – High emitters (two types)
    • Snap-idle opacity failures
    • Others receiving repair based on mechanical review
• Test Cycles (ARB cycles and one other)
  – Creep3, Transient3, Cruise3, HHDDT short
  – Test D (simulated FTP cycle)
• Data Sources
  – West Virginia (CRC) Report E-55/59
  – Colorado School of Mines (EPA and other sponsors)
  – University of California Riverside
• Sample Size (mostly Class 8a (33k – 60k lbs. GVWR)
Comparison with MOBILE6 and EMFAC2007 for HDDV

Graphs showing the comparison of PM and THC emissions between MOBILE6 and EMFAC2007 for Class 8a 25% High Emitters and Class 8a 10% High Emitters. The graphs display emissions against average speed (mph) for each model.
Inclusion of Semi-Volatile Organic Carbon (SVOC)

- SVOC are missing from the speciation and perhaps in the emission estimates (~2 to 4% of TOG Emissions)
  - By weight are primarily C11 and C12 alkyl-benzenes and methyl-naphthalenes; minority sources have higher molecular weights
  - Not in the historic speciation profiles
  - These may adsorb or otherwise not be measured for light-duty gasoline vehicles as THC with the cold FID

- Mobile source SVOC usually ignored in PM modeling
  - CMU has added “IVOCs” to PMCAMx modeling
  - Intermediate species that after oxidation might condense

- These SVOCs are too volatile to condense under typical ambient conditions
  - Chemical aging rapidly lowers their volatility
  - The CMU “volatility basis set” methodology deals with aging and volatility
Introduction of Mobile Source Emissions into Volatility Basis Set (VBS)

- Pairs of condensable gas (CG) and organic aerosol (OA) exist in thermodynamic phase-equilibrium according to a partitioning coefficient.
- Chemical oxidation (aging) converts more volatile CGs to less volatile CGs.
- Example VBS with four volatility levels:

```
<table>
<thead>
<tr>
<th>Volatility</th>
<th>Condensable Gases</th>
<th>Organic Aerosol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CG1</td>
<td>OA1</td>
</tr>
<tr>
<td></td>
<td>CG2</td>
<td>OA2</td>
</tr>
<tr>
<td></td>
<td>CG3</td>
<td>OA3</td>
</tr>
<tr>
<td></td>
<td>CG4</td>
<td>OA4</td>
</tr>
</tbody>
</table>
```

- SVOC emissions go into CG1.
- POA emissions go into OA4.
Source Apportionment with the VBS

- **CAMx PM source apportionment technology (PSAT)**
  - can be used to separate the source contributions, e.g., gasoline vs. diesel vehicles
  - Figure shows PSAT methodology for apportioning four source category contributions (a-d) within a volatility basis set with four volatility levels (1-4)
Modeling Plan

- MOBILE6 adjustments
  - LGV (mostly temperature adjustments especially important for winter conditions)
  - HDDV (speed adjustments)
  - Sensitivity for LGV high emitters
- SVOC inclusion (mass and chemistry)
- Comparison of modeled and monitor data