Studies of Resuspended Road Dust and In-Basin vs. Out-of-Basin Transport

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Outline

- Resuspended Road Dust
  - Flux tower methodology
  - Deicer, sanding/salting emission factors
  - Impact of street sweeping

- In-Basin vs. Out-of-Basin Sources
  - DRI
    - Measurements
    - Models
  - USFS
  - UC Davis
How?

PM Flux Measurements

- Tower-mounted DustTraks for measuring PM$_{10}$ and PM$_{2.5}$ mass concentrations simultaneously at 1 Hz.
- Medium-volume samplers to collect time-integrated samples for chemical analyses.
- Particle size distributions measured with Grimm 1.108.
- Wind speed and wind direction with combination anemometer / wind vane.
- 3-dimensional wind speed data with sonic anemometer.
- Video record of vehicles passing the monitoring sites.
- Road tube counter for vehicle class.
- Radar gun for vehicle speed.
The flux perpendicular to the roadway can be calculated from:

$$ Flux(mg/m) = \sum_{i=1}^{n} \sum_{j=1}^{4} u_i \left( \frac{m}{s} \right) \cos(\theta_i) C_{ij} \left( \frac{mg}{m^3} \right) \Delta z_j (m) \Delta t_i (s) \$$

Where: \( \theta \) is the angle between the wind direction and a line perpendicular to the road, \( u \) is the measured wind speed in m/s, \( C_{ij} \) is the \( i \)th PM concentration, \( \Delta z \) in m is the vertical interval, \( \Delta t \) in s is the time between data points.

The emission factor can be calculated from the flux:

$$ EF(g/km) = \frac{Flux(mg/m)}{TrafficVolume(vehicles)} (1g/1000mg)(1000m/1km) $$
Time Series Analysis – Multi-Lag Regression Approach

\[ PM(t) = BG + w + \sum_{i=0}^{n} \alpha_i PM(t - i) + \sum_{i=0}^{n} \beta_i cars(t - i) + \sum_{i=0}^{n} \gamma_i LDTrucks(t - i) + \sum_{i=0}^{n} \delta_i HDTrucks(t - i) + \ldots \]

Where:
- \( t \) = time (s)
- \( BG \) = background
- \( W \) = white noise
- LD Trucks = light-duty trucks
- HD Trucks = heavy-duty trucks
- \( n \) = number of lags
- \( \alpha, \beta, \gamma, \delta, \ldots \) = regression coefficients.

Road Sand/Salt Results – Lake Tahoe
Roadside PM Flux Measurements

- PM$_{10}$ Concentration Profile 1 m Downwind of Paved Road (mg/m$^3$)

- PM$_{10}$ Flux Perpendicular to Road (mg/m s)

- Wind Direction (degrees)

- Time on 2003/03/31
## Roadside Flux EMF Results

<table>
<thead>
<tr>
<th>Sampling Period</th>
<th>Condition</th>
<th>PM$_{2.5}$ EMF (mg/km)</th>
<th>PM$_{10}$ EMF (mg/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Baseline</td>
<td>76</td>
<td>229</td>
</tr>
<tr>
<td>2</td>
<td>After salting</td>
<td>99</td>
<td>310</td>
</tr>
<tr>
<td>3</td>
<td>1$^{\text{st}}$ dry day after storm</td>
<td>112</td>
<td>612</td>
</tr>
<tr>
<td>4</td>
<td>2$^{\text{nd}}$ dry day</td>
<td>133</td>
<td>660</td>
</tr>
<tr>
<td>5</td>
<td>After sweeping</td>
<td>211</td>
<td>735</td>
</tr>
</tbody>
</table>

Resuspended Road Dust
Summary and Conclusions

- Flux tower measurements:
  - Abrasive material significantly increases road dust resuspension
  - The use of a liquid deicer resulted in a smaller increase in the rate of re-entrainment
  - Street sweeping to remove the deposited material increased the observed emission rate
In Basin vs. Out of Basin?

- DRI
  - Measurements
    - Spatial distributions
    - Inter-site correlations
    - Development of isopleths
    - Air mass age
  - Models
    - Back trajectory
    - Air quality modeling
- USFS
- UC Davis
Sampling Locations

(View from above Incline Village, at the north end of the Lake Tahoe Basin)

Measured HNO₃, NH₃, and NH₄NO₃
Methods: Integrating Bigleaf with a GIS

**Estimated Flux**

<table>
<thead>
<tr>
<th>Nitrogen species</th>
<th>Lower limit $(10^6 \text{ g})$</th>
<th>Upper limit $(10^6 \text{ g})$</th>
<th>Estimate $(10^6 \text{ g})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>HNO$_3$</td>
<td>26.7</td>
<td>33.7</td>
<td>30.2</td>
</tr>
<tr>
<td>NH$_3$</td>
<td>2.9</td>
<td>22.1</td>
<td>14.6</td>
</tr>
<tr>
<td>NH$_4$NO$_3$</td>
<td>0.1</td>
<td>4.9</td>
<td>4.6</td>
</tr>
<tr>
<td>TOTAL</td>
<td>29.7</td>
<td>60.8</td>
<td>49.4</td>
</tr>
</tbody>
</table>

Note: Based on summer only data, does not include NO/NO$_2$ deposition.

2000 Results – HNO$_3$

Most sites similar, with So Lake higher $\rightarrow$ Regional + local source
2000 Results – NH₃

Major differences → Local source
Higher values at Echo Summit (day) imply aged air mass, while lower values at SLT and Echo Summit (night) point to the presence of fresh emissions.
Two case studies coinciding with the field study by Tarnay (2001).
- CALMET/CALPUFF system using MM5 predicted fields as the first guess.
- 85 hours forecast for each simulation.
Emissions

- Developed emissions estimates for the Tahoe basin: 7.3 NO\textsubscript{x} (tn/day).

- Data from 42 surface, 2 upper air, and 49 ozone stations.
• Regional background ~0.4 µg/m³
• Accounted for 81 to 98% of the observed HNO₃
• Local sources responsible for 70% of the observations
Lake Tahoe Basin Air Pollution Monitoring (summer 2002) - Bytnerowicz et al.
HNO$_3$ – Bytnerowicz et al.
O<sub>3</sub> – Bytnerowicz et al.
P – Cahill et al.

South Lake Tahoe Aerosols, Winter, 2002
Phosphorus

Maximum P in largest size fraction → resuspended geological material (in-basin source)
Transported sources:
- Asian dust: 0.6 – 1.0 tonnes/yr
- Sacramento valley dust: 0.12 – 0.6 tonnes/yr
- Oregon forest fire smoke (2002): 0.2 – 0.3 tonnes/yr

Local sources:
- Highway road dust (winter): 3.5 – 5.0 tonnes/yr
- Local soils (spring to fall): 1.5 – 4.5 tonnes/yr
- Vehicle exhaust: 1.2 – 1.8 tonnes/yr
- Local wood smoke: 0.3 – 0.5 tonnes/yr

In-basin vs. Out-of basin Summary and Conclusions

- **DRI Studies:**
  - **Measurement Component:**
    - HNO$_3$ is regional with a significant local component.
    - The sources of NH$_3$ are local.
  - **Modeling Component:**
    - Backward trajectory analysis showed a transport potential from the California valley; however, the possibility of significant pollutant transport was weak.
    - For the high concentration period, local sources dominated.

- **USFS Studies:**
  - The mountain range west of Lake Tahoe Basin creates a barrier that prevents air masses from California Central Valley and the Bay Area from entering the Lake Tahoe Basin.
  - Local pollutant generation appears to be the main cause of elevated O$_3$ and HNO$_3$ concentrations.

- **UC Davis Studies:**
  - DRUM measurements of P coupled with other data indicate that for a typical year local sources dominate the airborne P by about a factor of 10.

- **Bottom line:**
  - To reduce the atmospheric contribution of N, P, and sediment to the lake, local sources must be controlled.
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Resuspended road dust
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