Overview of the Lake Tahoe Atmospheric Deposition Study (LTADS)

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LAKE TAHOE
Annual Average Secchi Depth ± 1 s.d.

Meters

Feet


TAHOE RESEARCH GROUP
UC DAVIS

r = 0.89
n = 36
p < .001
Presentation Outline

- Study Design
- Activities
- Results
LTADS Objectives

Quantify direct atmospheric deposition of nutrients and aerosols to Lake Tahoe

Characterize atmospheric processes and the nature of emission sources
LTADS Monitoring Network

1. Big Hill
2. Echo Summit
3. Tahoe Airport
4. SL T-S Sandy Way
5. SL T-S SOLA
6. DL Bliss SP
7. Ward Creek
8. Tahoe City
9. Lake Forest
10. Incline Vlg - AQ
11. Incline - Met
12. Thunderbird Ldg
13. Cave Rock SP
14. Stateline - Harvey
15. Buoys/Piers
16. Grass Valley

- AQ - gas & PM
- AQ - PM
- AQ - single gas
- Deposition
- On-Lake
- Meteorology aloft
**Primary Instruments**

- **winds aloft**
  - RWP/RASS also provides temperature aloft

- **TSP**
  - and PM species
  - on buoys & piers

- **TSP, PM10, & PM2.5**
  - & PM species, and
  - NH₃ & HNO₃
  - at land sites

**Mini-Sodar**

**Mini-Volume Sampler**

**Two-Week Sampler**
Special Measurements

- UCD Carroll – aircraft & boat
- UCR Fitz – wood smoke & MV fleet
- DRI Kuhns – residential wood smoke & road dust
- UCB Cohen – reactive nitrogen & transport
- UCSD Michalski – isotopic fingerprints
- DRI/UCD Kohl/Cliff&Green – XRF/s-XRF & ICP-MS
- DRI Dana – heat and momentum flux
- TRG Schladow & JPL Hoek – met on buoy & piers
- ARB Tony/Jim/Ash – Optical Particle Counters
- ARB Leon – surrogate surface comparison
LTADS Complexities

- AQ Measurements
  - Siting
  - Atmospheric conditions
  - Clean air
- Meteorology
- Emissions
LTADS Activities

Characterizing Emission Sources

- **Source profiles**
  - Smoke (residential, neighborhood, prescribed burns)
  - Road dust
  - Fleet composition

- **Source Activity**
  - Wood burning survey
  - Driving patterns

To model, more investigation needed of Tahoe-specific emission factors
LTADS Activities

Characterizing Atmospheric Processes

• Air flow
• Vertical temperature profiles
• Precipitation

To model, more investigation needed:

• Atmospheric processes aloft
• Microscale processes @ lake/air interface
• Meteorological model that replicates seasonal patterns and is constrained by pollutant patterns
LTADS Results

Hierarchy of Air Quality during LTADS

Atmospheric Deposition Estimates

- Nitrogen
- Phosphorus
- Particulate Matter
Mean Values during orbits at 7800' & 6800' over Lake Tahoe - Sept. 2003

- T (°C)
- RH (%)
- O₃ (ppb)
- PC1 (millions)
- NO, NOy, HNO₃, NH₃ (ppb)
- PC2 (10,000s)

Legend:
- O₃
- PC1 (d>0.3u)
- Δ NO
- Δ NOy
- + PC2 (d>3.0u)
- × NH₃
- - HNO₃
Annual Mean Total Suspended Particulate Matter during LTADS

[TSP] (ug/m³)

Big Hill  Buoy TB1 (east)  Buoy TB4 (west)  Lake Forest  LF - Coast Guard  SLT-Sandy Way  SLT-SOLA  Thunderbird Lodge  Timber Cove  Wallis Pier  Wallis Tower  Zephyr Cove
Annual Mean Particulate Matter by Size during LTADS
Annual Mean Ammonium Ion during LTADS

[Graph showing annual mean ammonium ion concentrations for various locations, with TWS and MVS labels for comparison. Locations include Big Hill, Buoy TB1 (east), Buoy TB4 (west), Lake Forest, LF_Coast Guard, SLT-Sandy Way, SLT-SOLA, Thunderbird Lodge, Timber Cove, Wallis Pier, Wallis Tower, and Zephyr Cove.]

[TSP_NH4] (ng/m³)
Annual Mean Nitrate Ion during LTADS

NOTE: TWS samples had back-up filter for volatilized nitrate but MVS samples did not
Annual Mean Ammonia during LTADS

[Comparison of ammonia concentrations at various locations: Big Hill, Lake Forest, SLT-Sandy Way, SLT-SOLA, Thunderbird Lodge]
Annual Mean Nitric Acid during LTADS

[HNO₃] (ng/m³)

- Big Hill
- Lake Forest
- SLT-Sandy Way
- SLT-SOLA
- Thunderbird Lodge
## Estimate of Total Atmospheric Deposition Directly to Lake Tahoe
(Metric Tons/Year)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Dry</th>
<th>Wet</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSP_NH₄</td>
<td>9.8</td>
<td>16.8</td>
<td>26.6</td>
</tr>
<tr>
<td>TSP_NO₃</td>
<td>8.0</td>
<td>15.0</td>
<td>23.0</td>
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<tr>
<td>NH₃</td>
<td>68.2</td>
<td>31.0</td>
<td>99.2</td>
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<tr>
<td>HNO₃</td>
<td>19.1</td>
<td>8.9</td>
<td>28.0</td>
</tr>
<tr>
<td>Total N</td>
<td>105.2</td>
<td>71.8</td>
<td>177.0</td>
</tr>
<tr>
<td>P</td>
<td>1.2 (1.8)*</td>
<td>2.1 (4.2)*</td>
<td>3.3 (6.0)*</td>
</tr>
<tr>
<td>TSP</td>
<td>718 (587)+</td>
<td>946</td>
<td>1664 (1533)+</td>
</tr>
</tbody>
</table>

* # within () indicates update associated with new P measurement correction factors and on-lake depletion factor
** # within () indicates update associated with new P measurement correction factors
+ # within () indicates update associated with on-lake depletion factor
Estimate of Total Atmospheric Deposition Directly to Lake Tahoe (Metric Tons)

Direct Atmospheric Deposition in metric tons (nitrogen compounds as N)

Notes:
1) The wet dep estimates are from a simple model with unvalidated assumptions. As such, the dry dep estimates are considered to be more reliable than the wet dep estimates.
2) The P values assume basin mean 40 ng/m³.
3) The actual PM numbers are 20 times the axis label while the actual P numbers are one-tenth the axis label.
Meteorological Processes
LTADS Results

Emission Source Indications

• Default MV assumptions inappropriate
• PM – in-basin road dust
• Reactive N – in-basin
• NH$_3$ is primary contributor to total N
Extensive database for Tahoe can help address outstanding issues

Additional data analysis needed

Additional research needed
Acknowledgements

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• ARB PTSD (Hsu & Fitzgibbon)
• ARB RD (Taylor & management)
ARB’s LTADS Survivors