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.

PM Emission Factor Calculation

- 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: θ 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 ith PM concentration, Δz in m is the vertical interval, Δt 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

$$PM(t) = BG + w + \sum_{i=0}^{n} \alpha_i PM(t-i) + \sum_{i=0}^{n} \beta_i cars(t-i) +$$

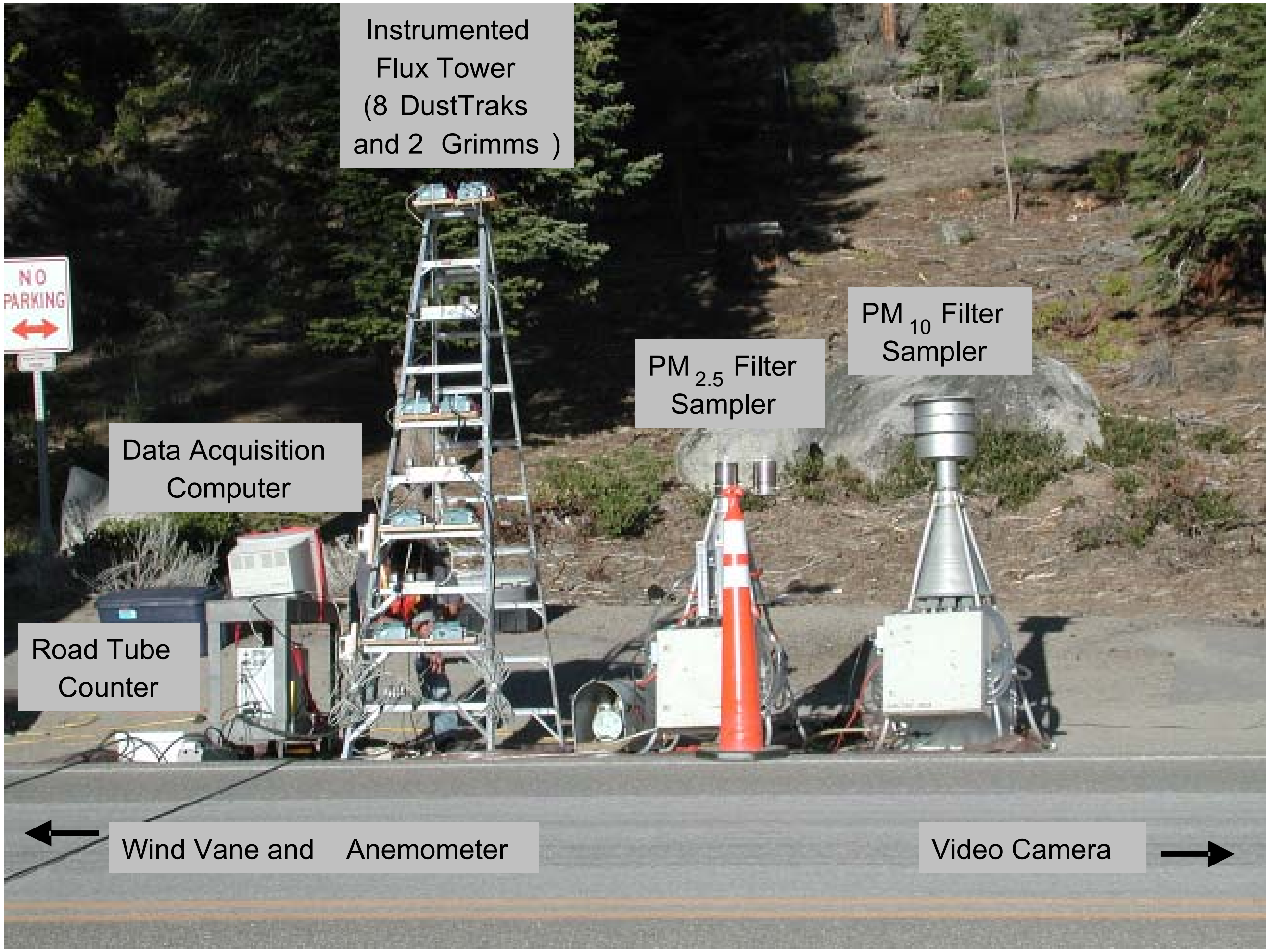
$$\sum_{i=0}^{n} \gamma_i LDTrucks(t-i) + \sum_{i=0}^{n} \delta_i HDTrucks(t-i) + \cdots$$

Where:

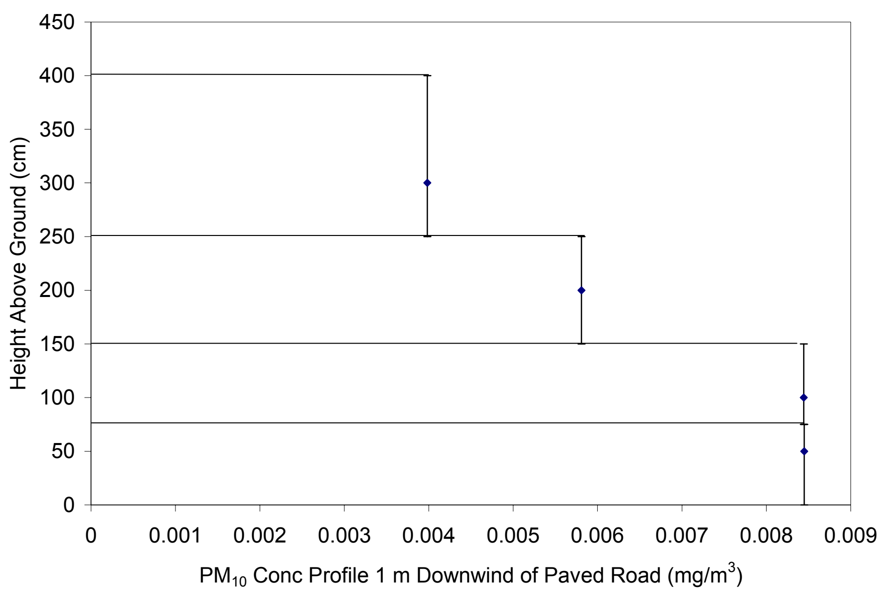
t = time (s)
BG = background
W = white noise
LD Trucks = light-duty trucks
HD Trucks = heavy-duty trucks
n = number of lags
α, β, γ, δ, … = regression coefficients.

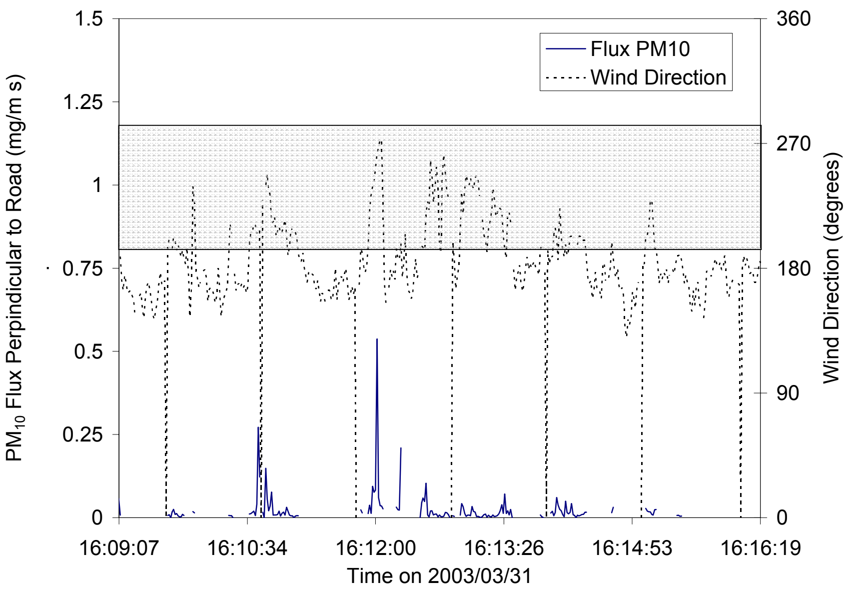
Abu-Allaban, M., J.A., Gillies and A.W. Gertler (2003). Application of a Multi-Lag Regression Approach to Determine On-Road PM10 and PM2.5 Emission Rates. *Atmos. Environ.*, **37**, 5157-5164.

Road Sand/Salt Results – Lake Tahoe



Roadside PM Flux Measurements





Roadside Flux EMF Results

Sampling Period	Condition	$PM_{2.5}$ EMF (mg/km)	PM_{10} EMF (mg/km)
1	Baseline	76	229
2	After salting	99	310
3	1st dry day after storm	112	612
4	2nd dry day	133	660
5	After sweeping	211	735

Gertler, A., Kuhns, H., Abu-Allaban, M., Damm, C., Gillies, J., Clayton, R., and Proffitt, D. (2005). The Impact of Winter Road Sand/Salt and Street Sweeping on Road Dust Re-Entrainment, *Atmos. Environ.*, submitted.

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)

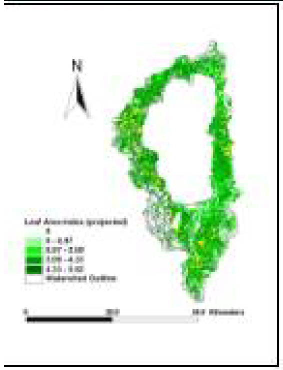
Measured HNO_3, NH_3, and NH_4NO_3

Methods: Integrating Bigleaf with a GIS

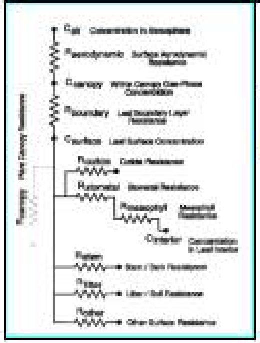
Meteorology

+

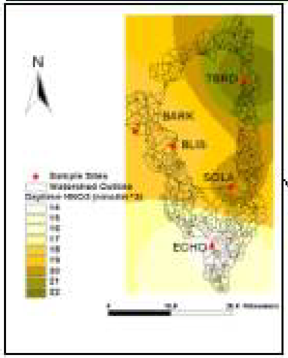
Leaf Area Index/Land cover



Bigleaf Model

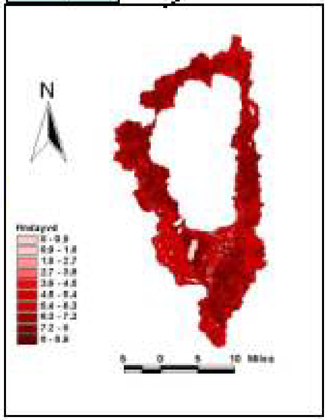


Pollutant Concentration

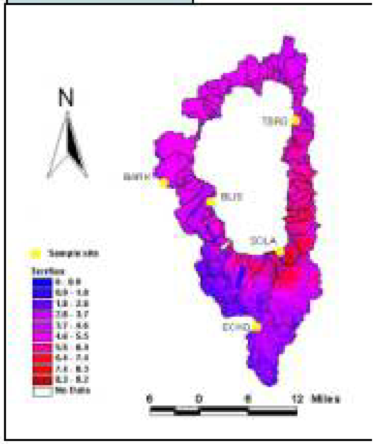


X

V_d



Flux



Tarnay, L.W., A.W. Gertler, and G.E. Taylor (2002). An Inferential Model for HNO3 Deposition to Semi-arid Coniferous Forests. *Atmos. Environ.*, **36**, 3277-3287.

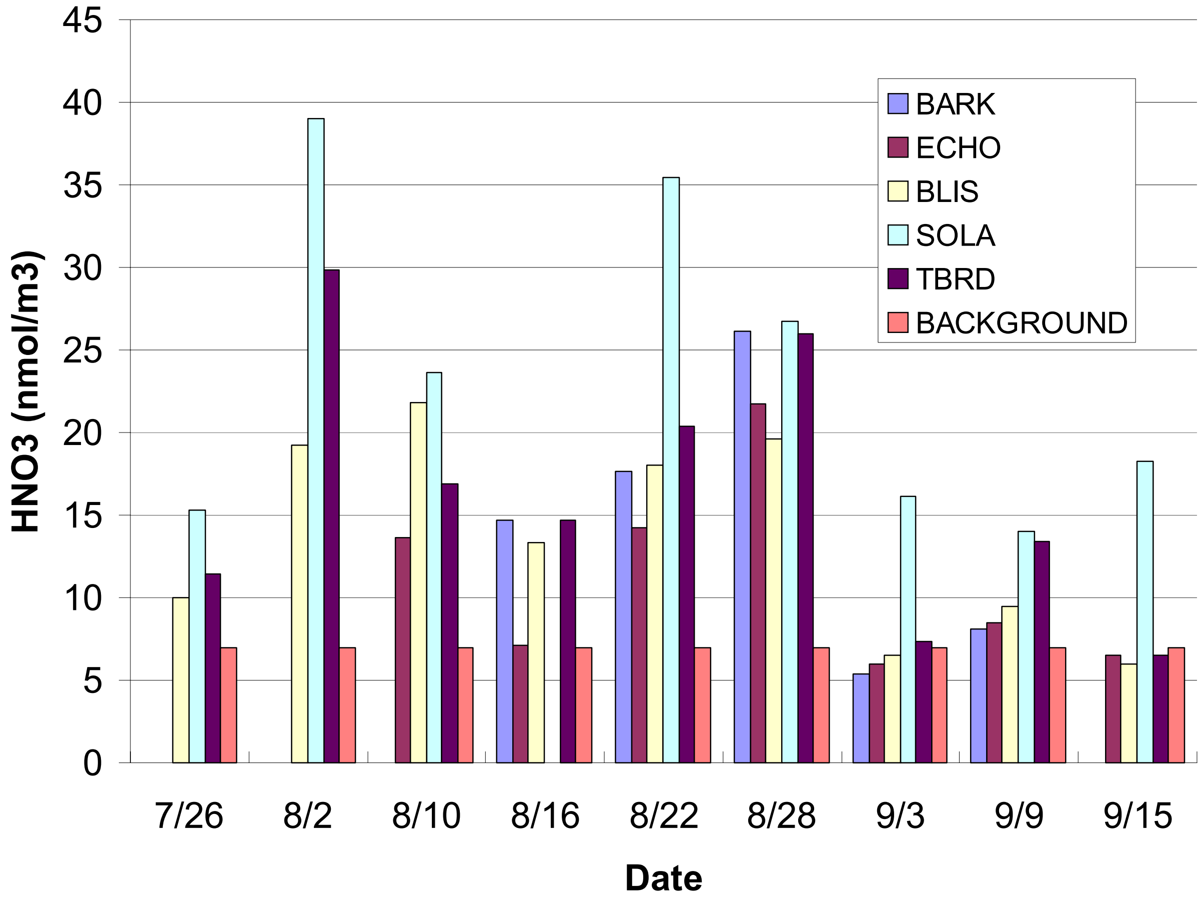
Estimated Flux

Nitrogen species	Lower limit (10^6 g)	Upper limit (10^6 g)	Estimate (10^6 g)
HNO_3	26.7	33.7	30.2
NH_3	2.9	22.1	14.6
NH_4NO_3	0.1	4.9	4.6
TOTAL	29.7	60.8	49.4

Note: Based on summer only data, does not include NO/NO_2 deposition.

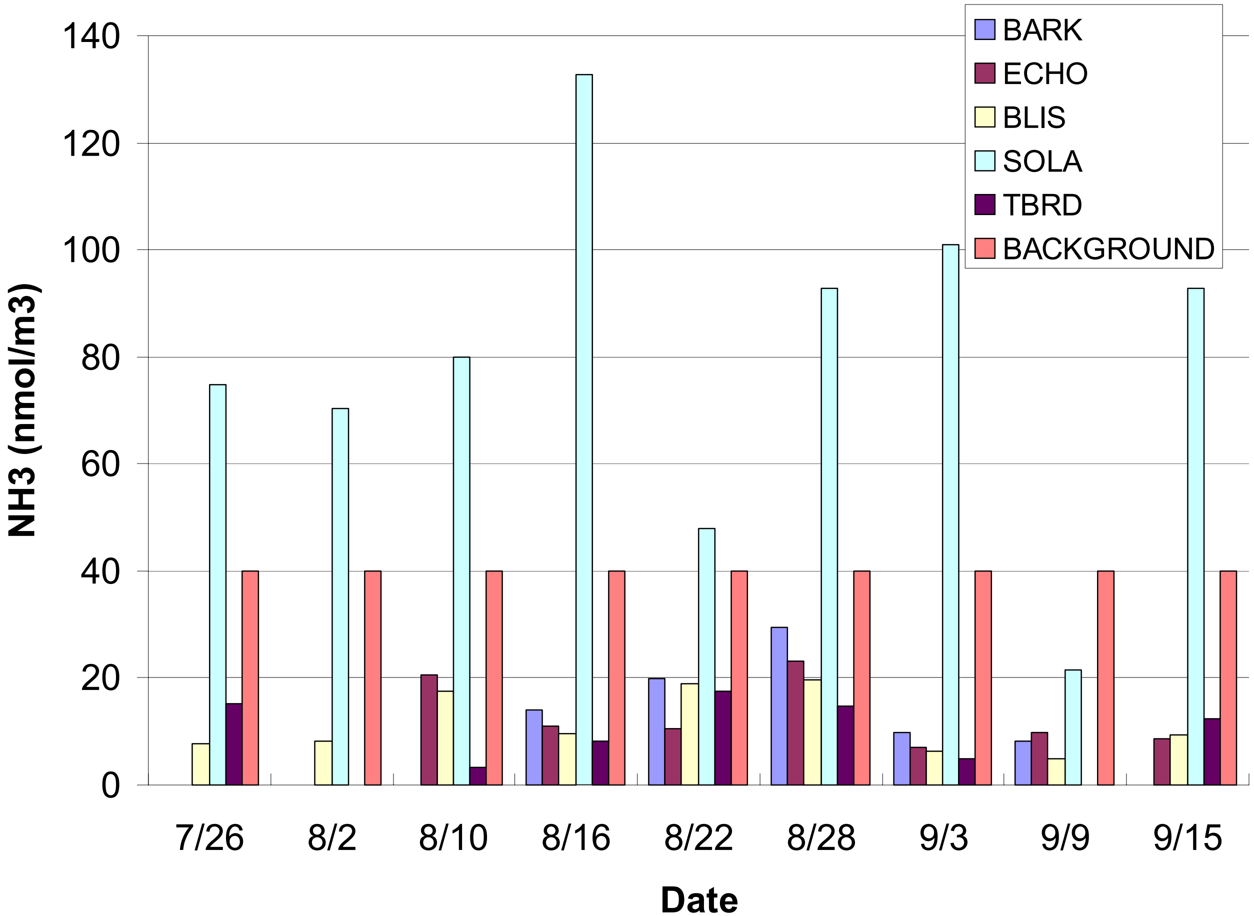
Tarnay, L., A.W. Gertler, R.R. Blank, and G.E. Taylor Jr. (2001). Preliminary Measurements of Summer Nitric Acid and Ammonia Concentration in the Lake Tahoe Basin Airshed: Implications for Dry Deposition of Atmospheric Nitrogen. *Env. Poll.*, **113**, 145-153.

2000 Results – HNO_3



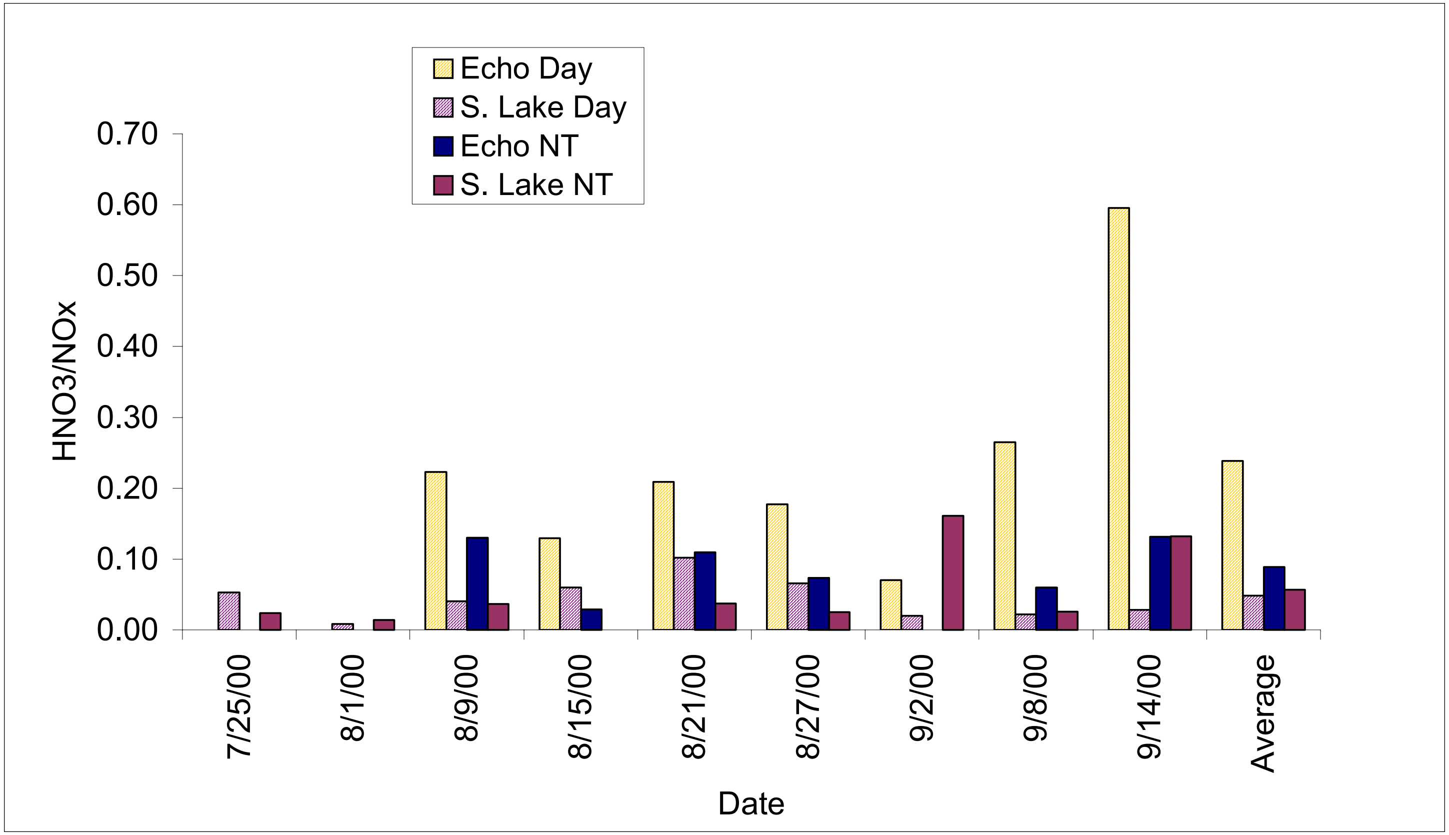
Most sites similar, with So Lake higher → Regional + local source

2000 Results – NH_3



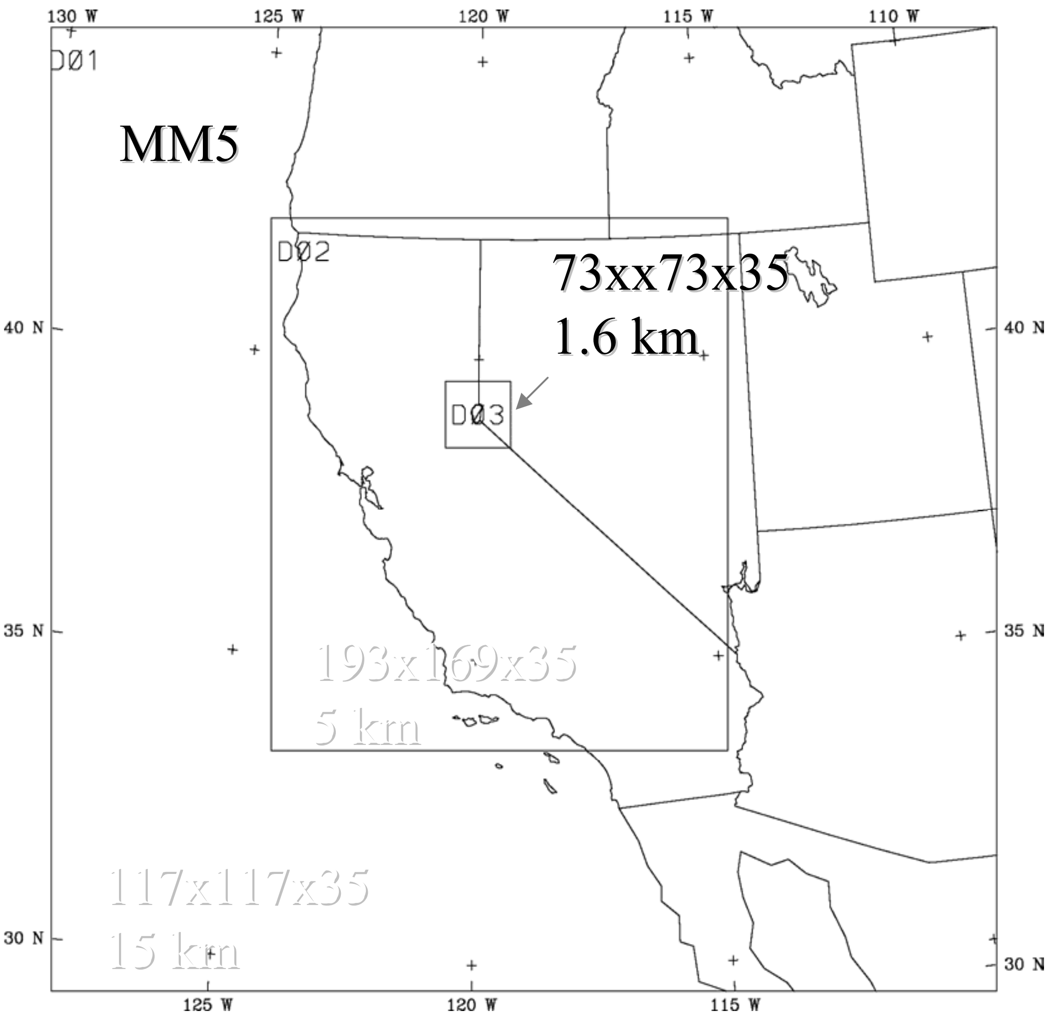
Major differences → Local source

Air Mass Age



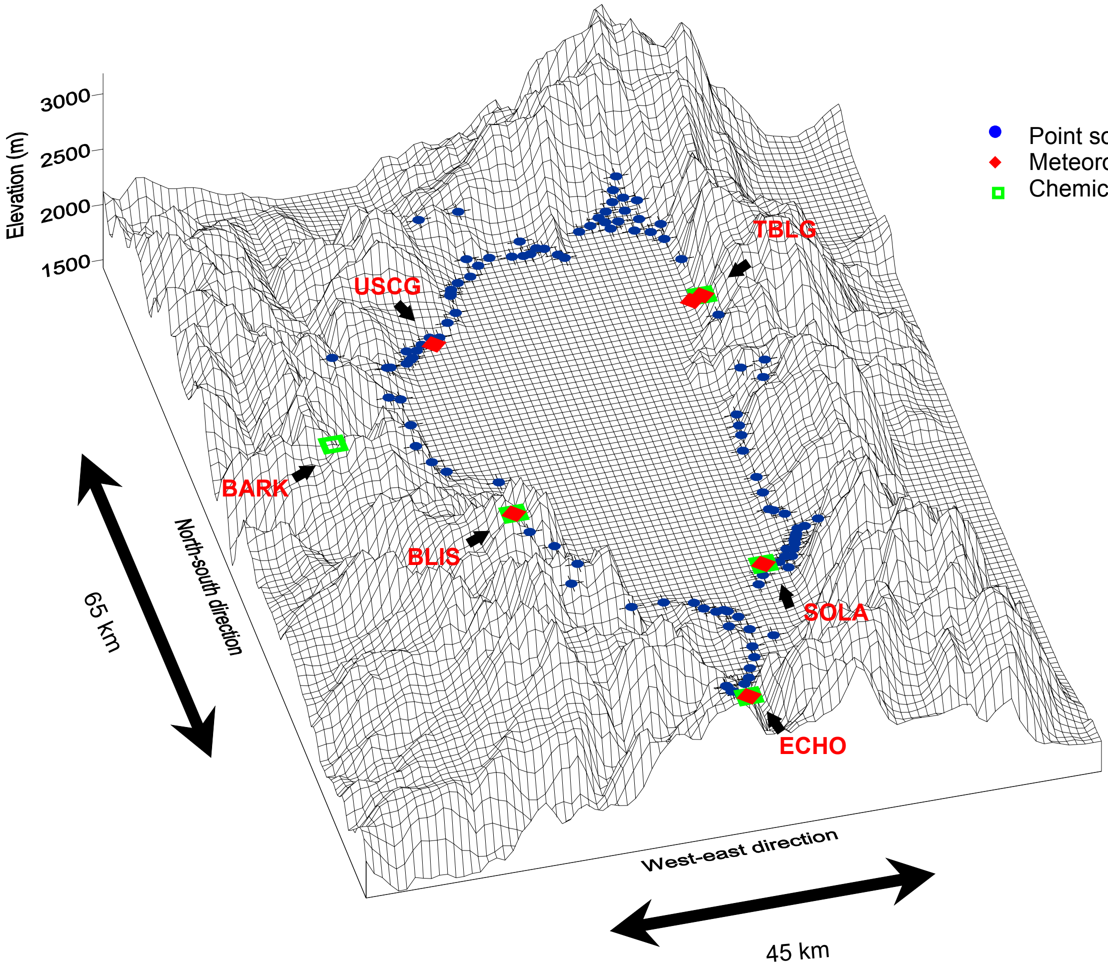
Higher values at Echo Summit (day) imply aged air mass, while lower values at SLT and Echo Summit (night) point to the presence of fresh emissions.

Modeling System



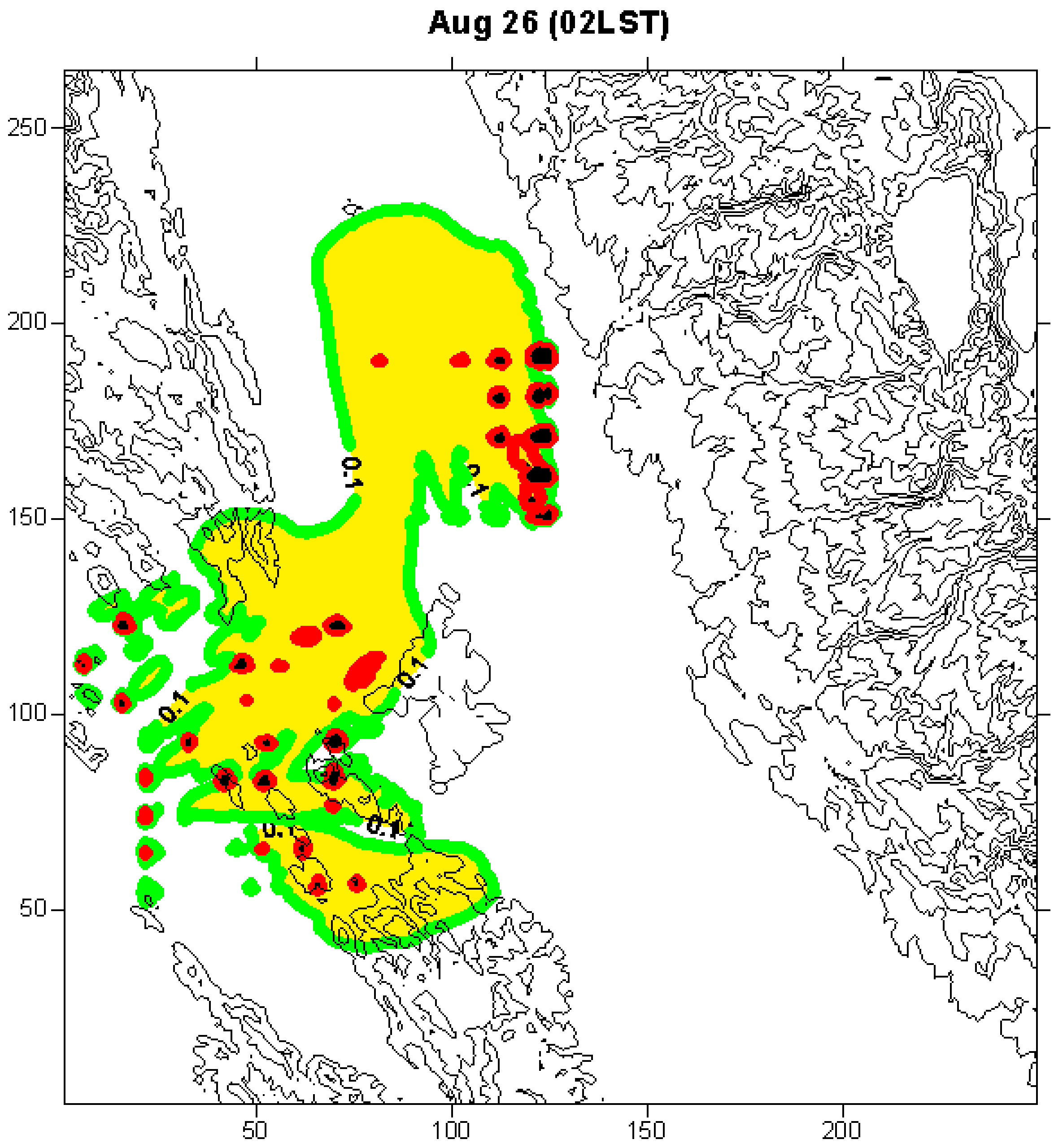
- Two case studies coinciding with the field study by Tarnay (2001).
- Cases on August 22 and September 3, 2000.
- CALMET/CALPUFF system using MM5 predicted fields as the first guess.
- 85 hours forecast for each simulation.

Emissions



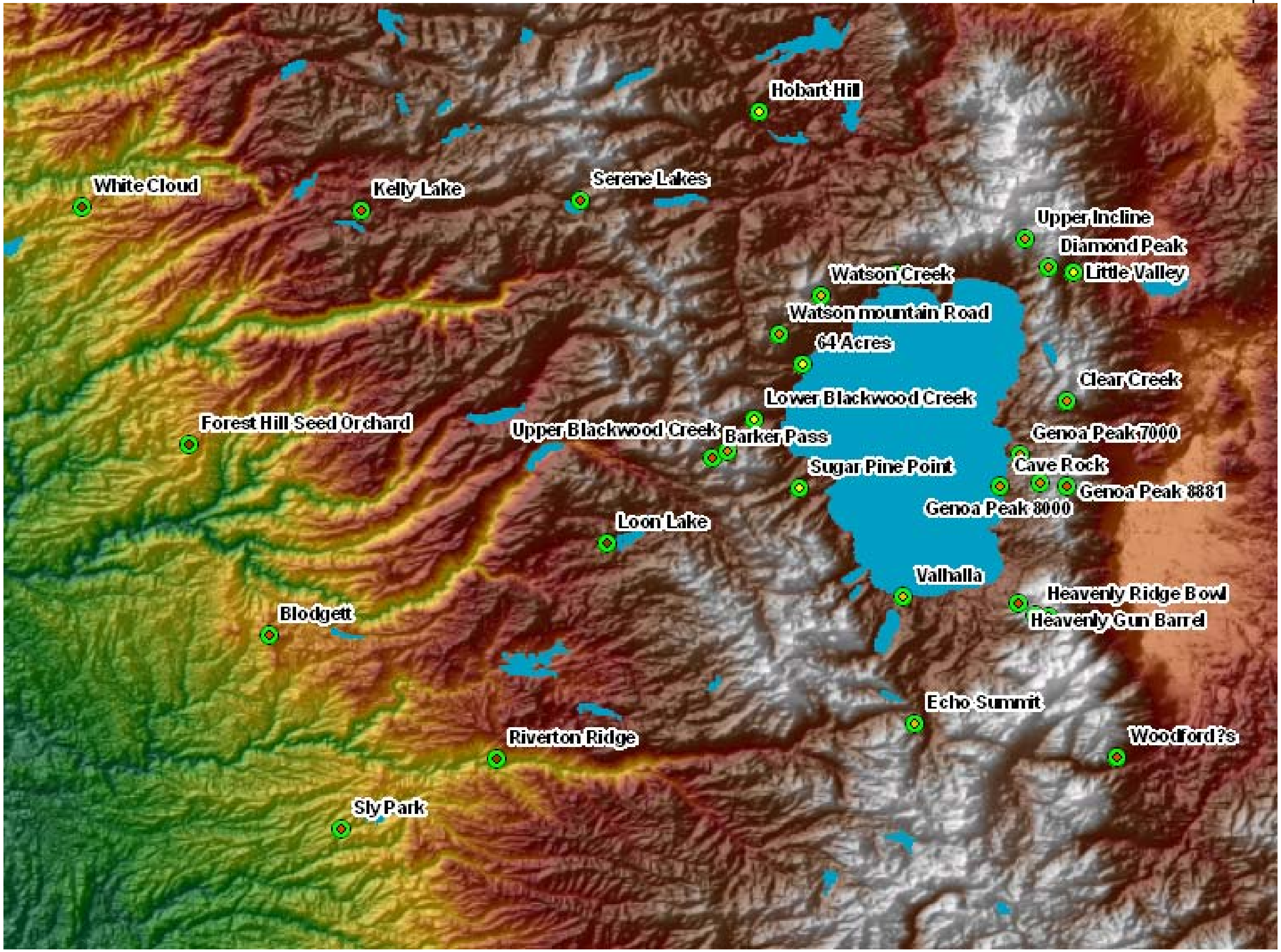
- Developed emissions estimates for the Tahoe basin: 7.3 NO_x (tn/day).

- Data from 42 surface, 2 upper air, and 49 ozone stations.

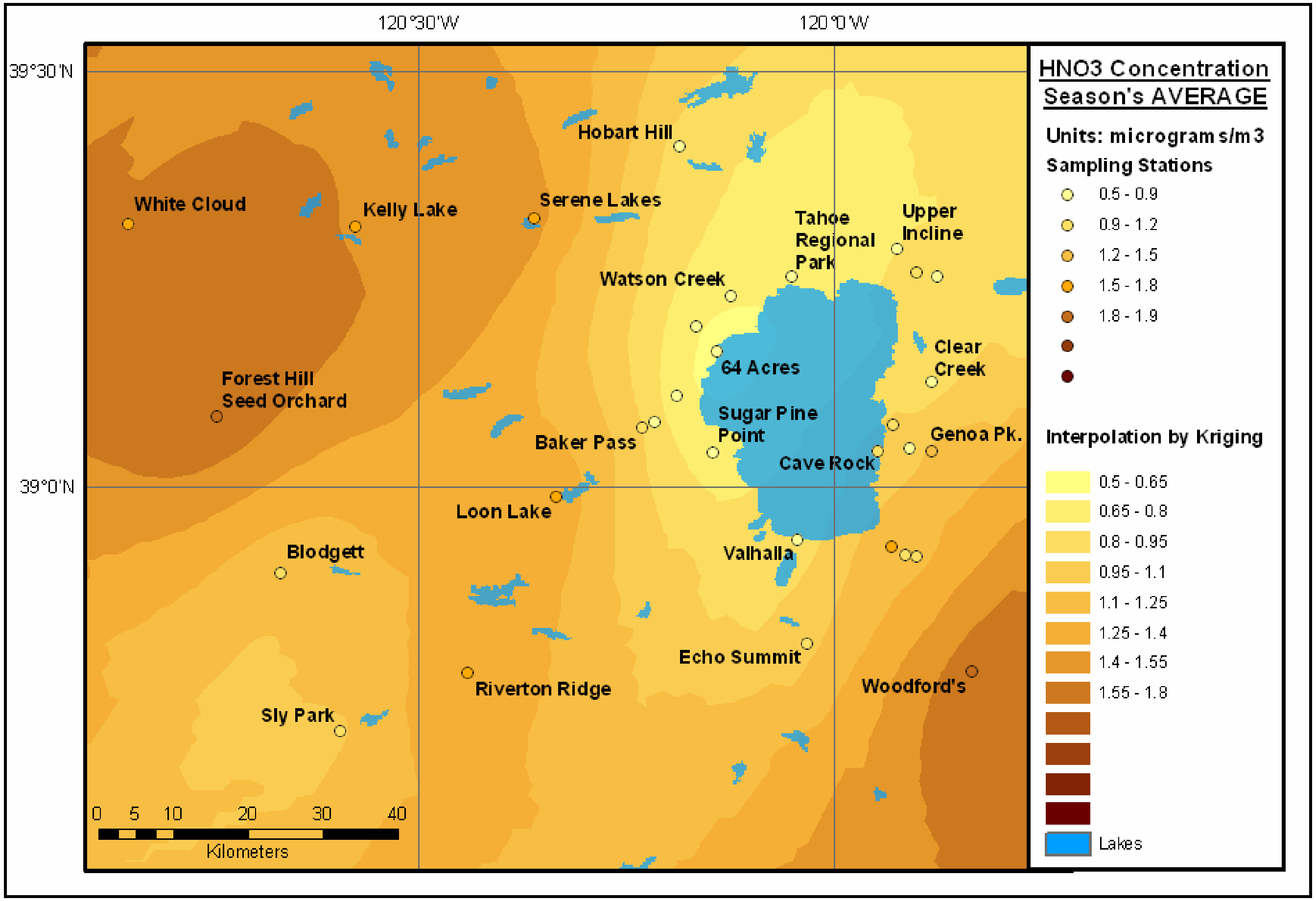


- Regional background ~0.4 μg/m^3
- Accounted for 81 to 98% of the observed HNO_3
- Local sources responsible for 70% of the observations

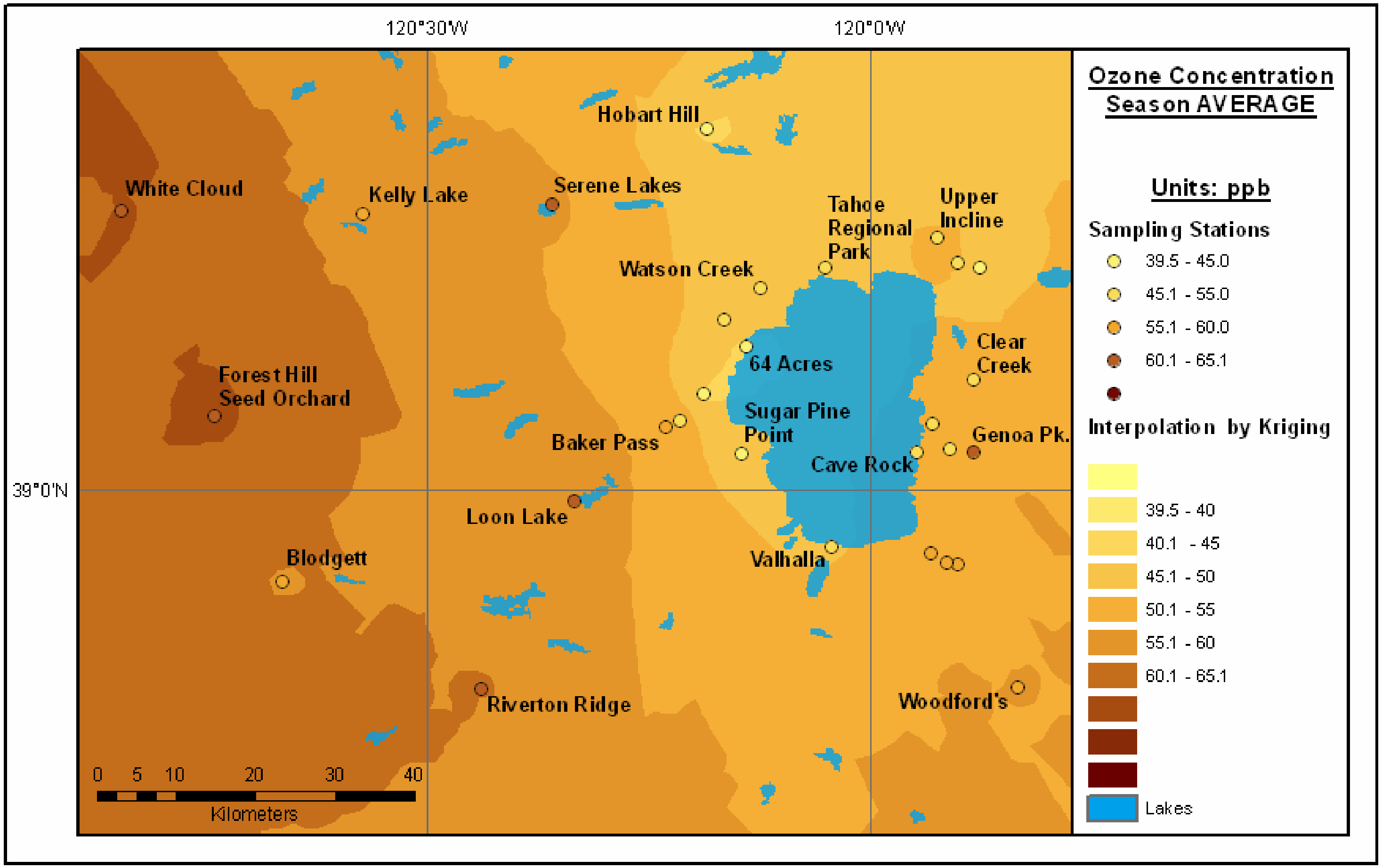
Lake Tahoe Basin Air Pollution Monitoring (summer 2002) - Bytnerowicz et al.



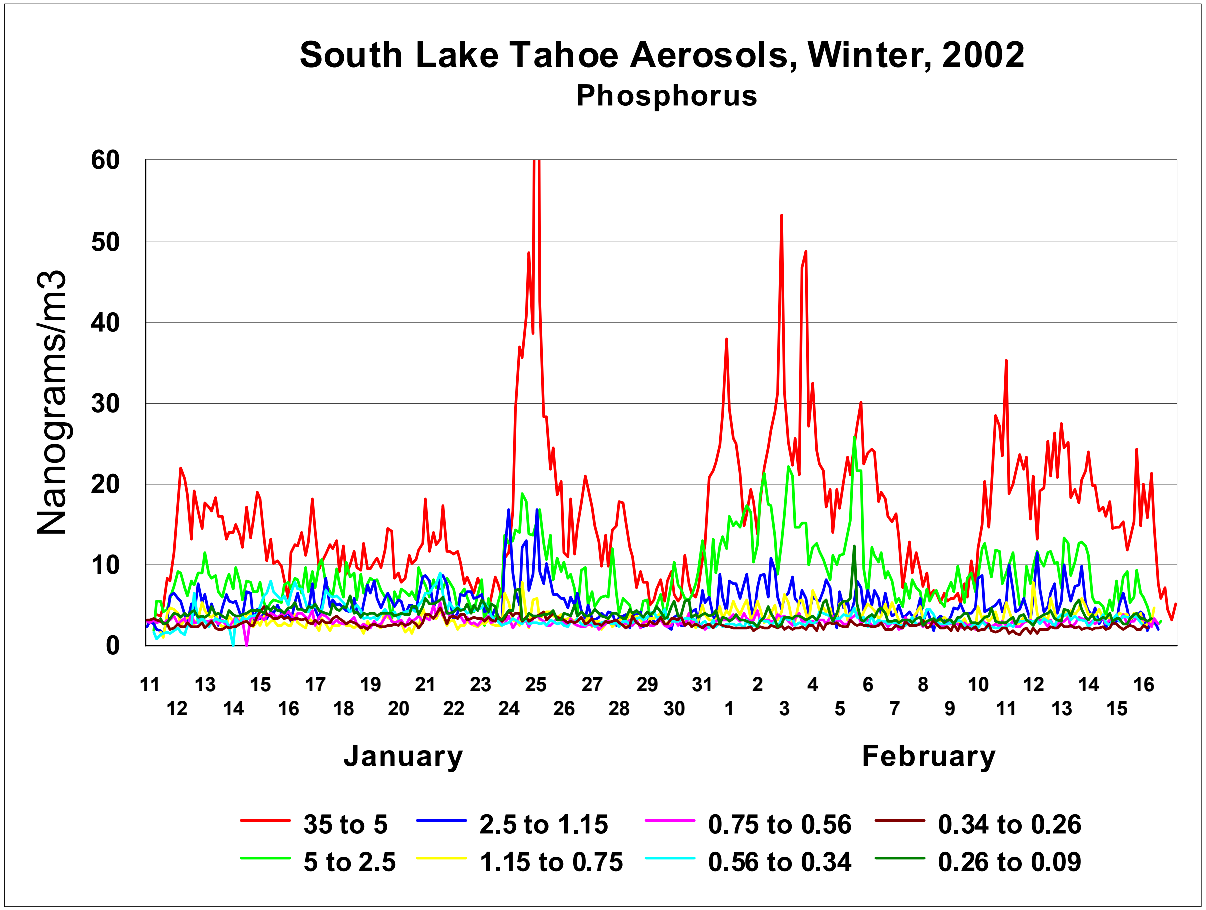
HNO_3 – Bytnerowicz et al.



O_3 – Bytnerowicz et al.



P – Cahill et al.



Maximum P in largest size fraction → resuspended geological material (in-basin source)

P – Cahill et al.

- 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: Gertler, A.W., A. Bytnerowicz, T.A. Cahill, M. Arbaugh, S. Cliff, J.K. Koračin, L. Tarnay, R. Alonso, and W. Frączek (2005). Sources of Atmospheric Pollutants in the Lake Tahoe Basin, *California Agriculture,* accepted.

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.

Acknowledgements

Resuspended road dust

- DRI:
  - Jack Gillies
  - Hampden Kuhns
  - Mahmoud Abu-Allaban
  - Gayathri Parthasarathy
- Sierra Nevada College
  - Chris Damm
- Funding:
  - NCHRP project 25-18

DRI In-basin vs. Out-of-basin Studies

- DRI:
  - John Lewis
- Hebrew University:
  - Menachem Luria
- University of California, Davis
  - Geoffrey Schladow
- California Air Resources Board
  - Paul Allen
  - Vernon Hughes
- Funding:
  - Nevada NSF- EPSCoR
  - NSF Advanced Computing in Environmental Sciences (ACES)
  - DRI – Center for Watersheds and Environmental Sustainability