Lake Tahoe Visibility Impairment Source Apportionment Analysis

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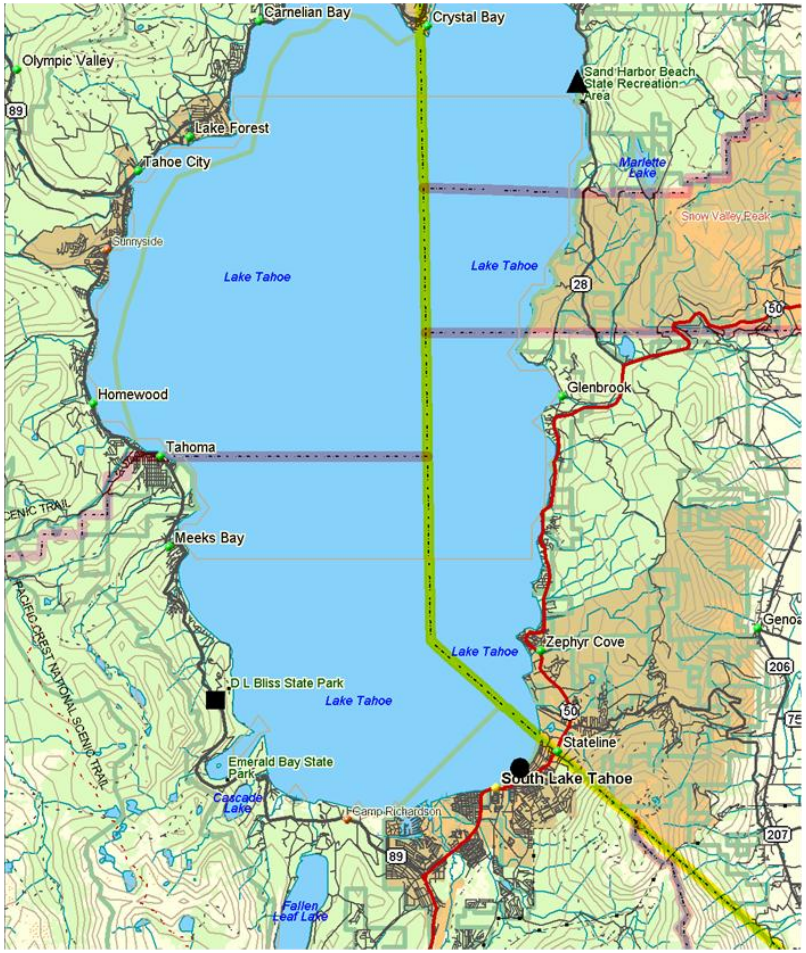
Background

- Aerosol and optical data collection in the Lake Tahoe Basin for many years but little data analysis
- Tahoe Regional Planning Agency (TRPA) interested in visibility conditions and trends
- Used 20 years of chemically speciated aerosol data to understand seasonal patterns and long-term trends in visibility in the Lake Tahoe Basin.
- Receptor modeling to provide insight into contributions to haze by source type
- Study funded by Southern Nevada Public Lands Management Act (SNPLMA) Round 10
- Provides support information for another Round 10 project- Visibility Monitoring and Standards for Lake Tahoe Basin: Assessment of Current and Alternative Approaches

History of visibility related monitoring in the Lake Tahoe Basin



- SOLA1- Speciated aerosol 1989-2004, light scattering 1989-2000- site located at Lake level
- BLIS1- speciated aerosol 1990-present, light scattering 1990-2005, light extinction 1990-2000 (BLIS1 to Zephyr Cove)- site about 230m above Lake Tahoe
- TBLG1- speciated aerosol 2000-2004 every 6th day only- Lake level location

What causes haze?

- Haze caused by scattering and absorption of light by atmospheric gases and particles
- Light extinction coefficient

  $b_{ext} = b_{sp}+b_{sg}+b_{ap}+b_{ag}$

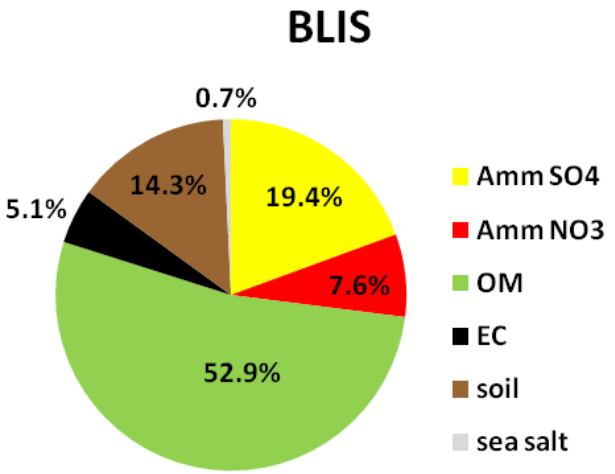
Usually b_{sp}, scattering by particles (aerosol), largest component. On clear days, scattering by gases greatest contributor to b_{ext}

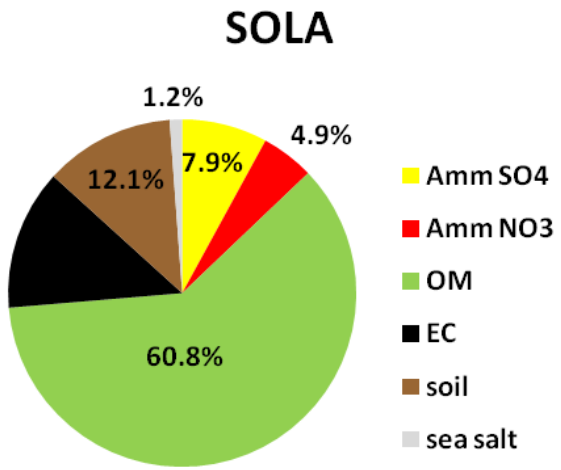
Soot absorbs significant amount of light

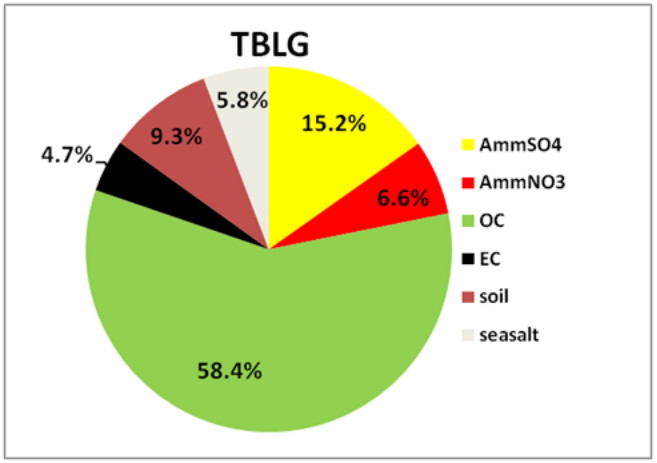
In general larger particles cause more light extinction than smaller particles per particle, but less per unit mass concentration

Some particles such as sulfate, nitrate and sea salt absorb water at high humidity and scatter increased amounts of light at high RH.

Component contributions to reconstructed fine mass (used IMPROVE algorithms)



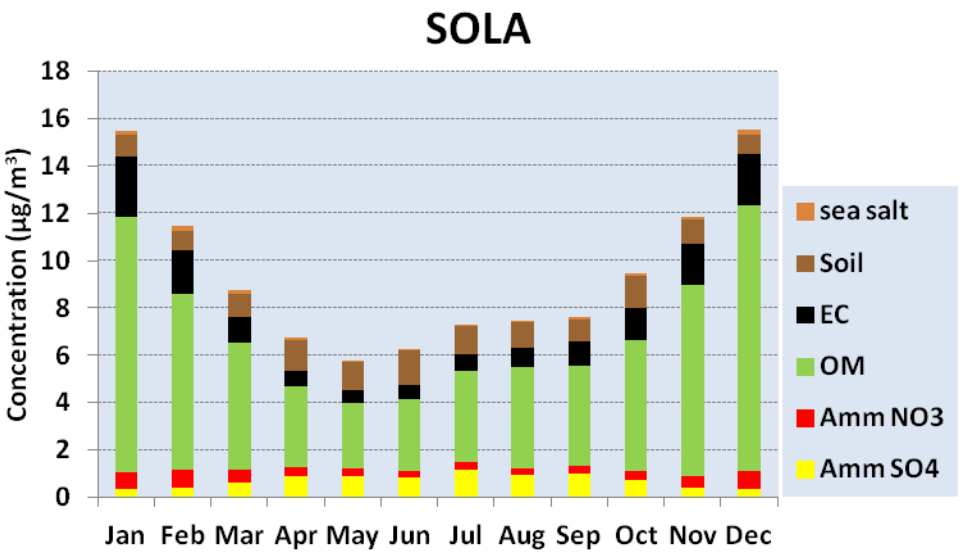


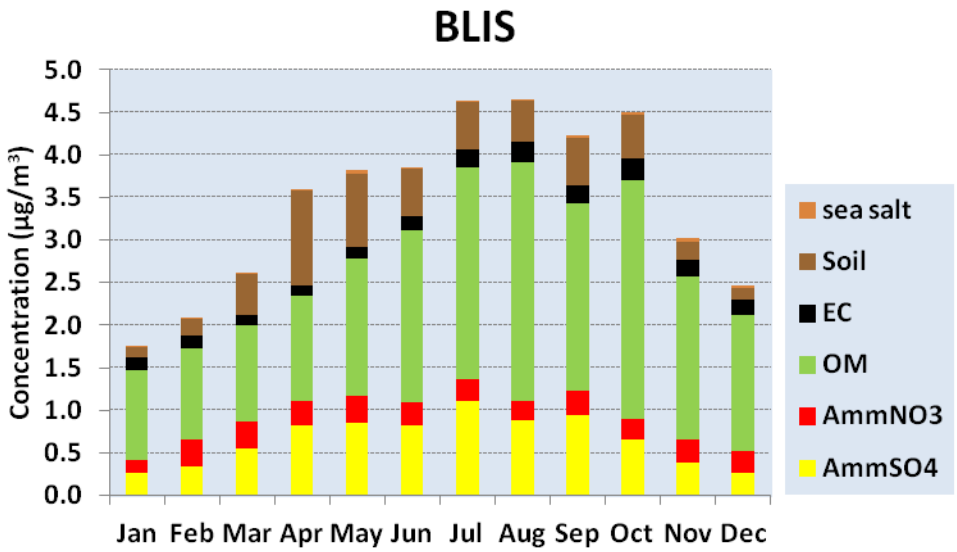


Organic carbon dominates fine mass at all sites

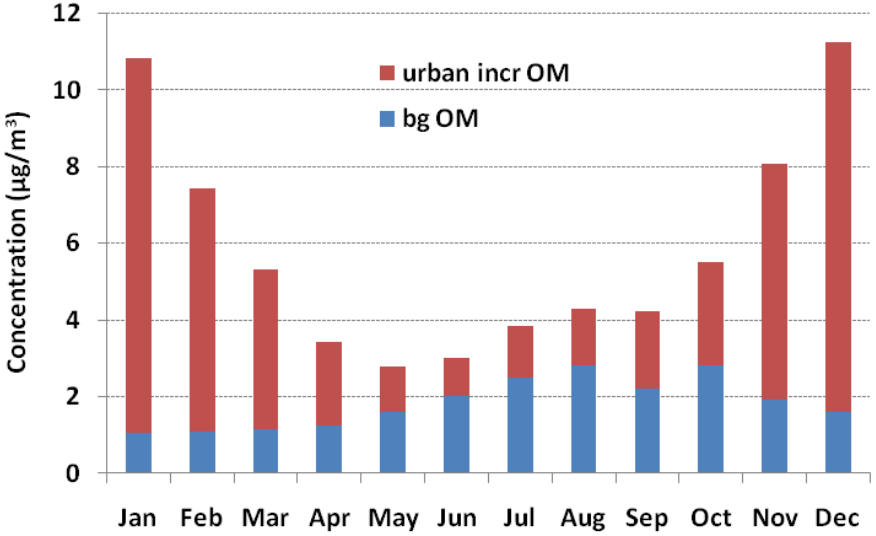
South Lake Tahoe winter peak in $PM_{2.5}$, Bliss State Park summer peak in $PM_{2.5}$

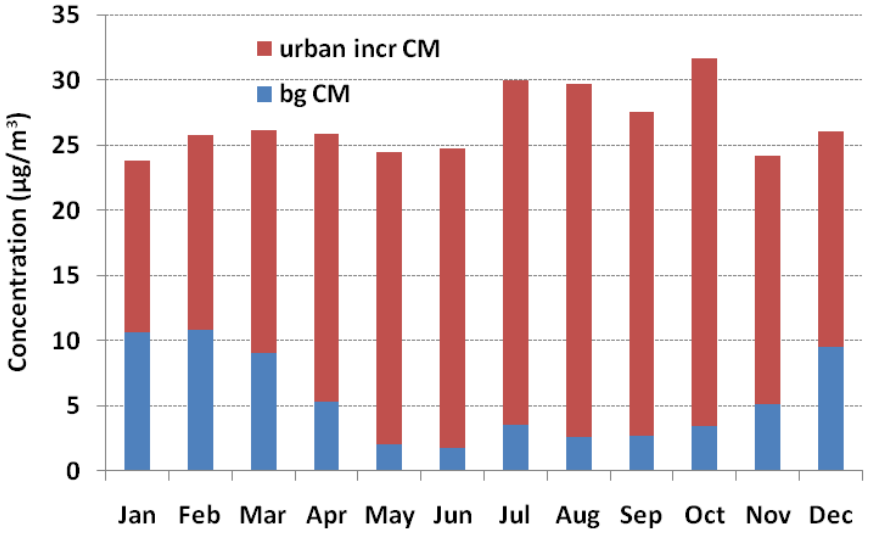
Note much higher concentrations at South Lake Tahoe

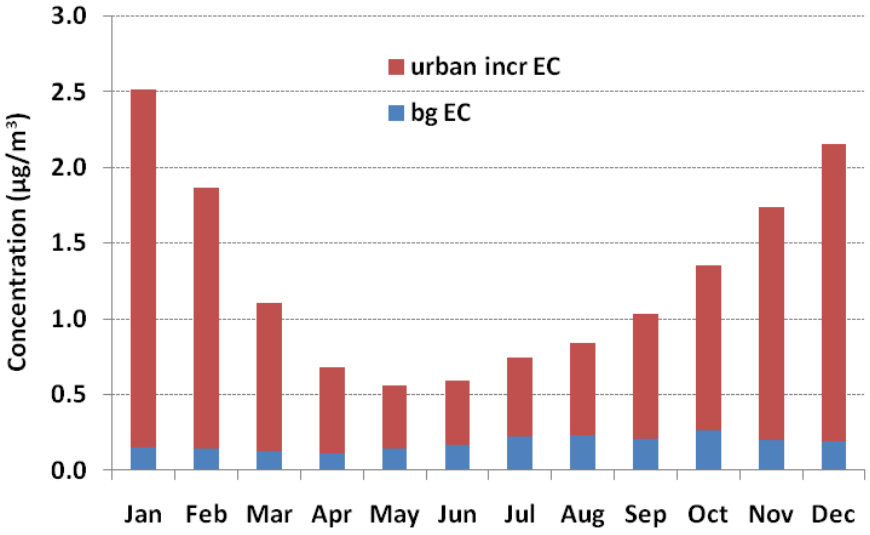


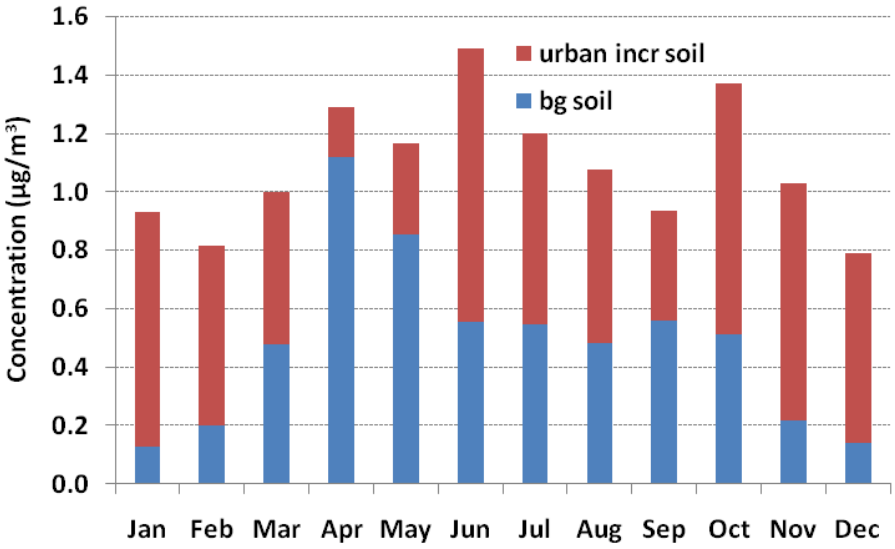


Large urban increments for carbon, soil, and coarse mass

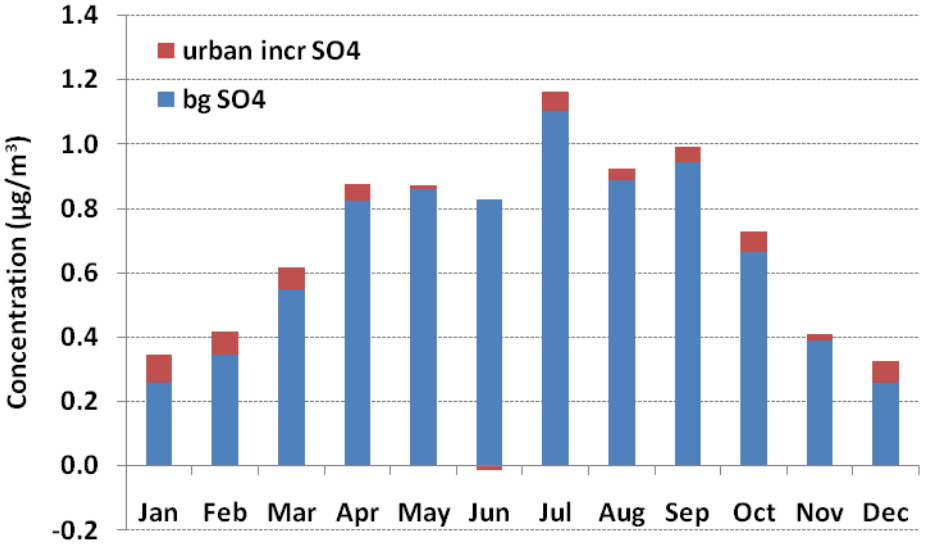




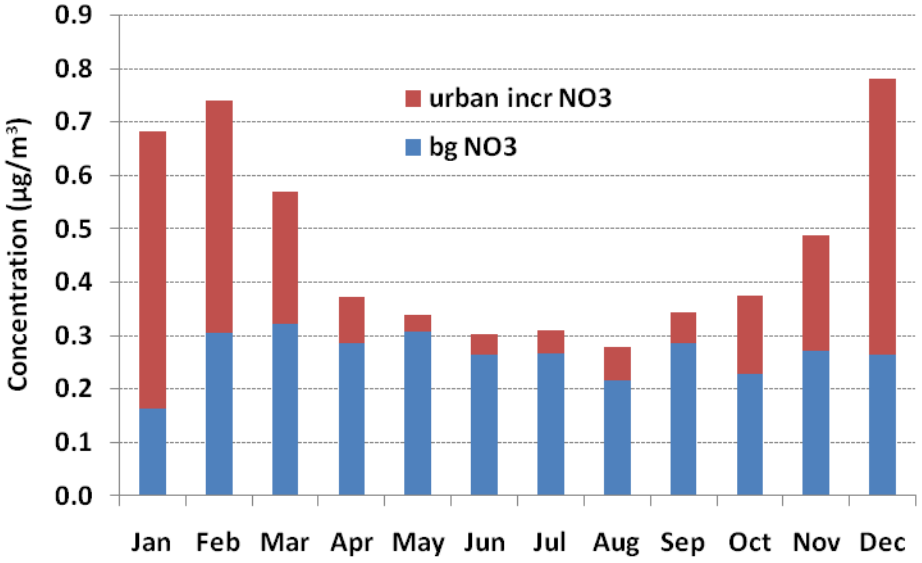




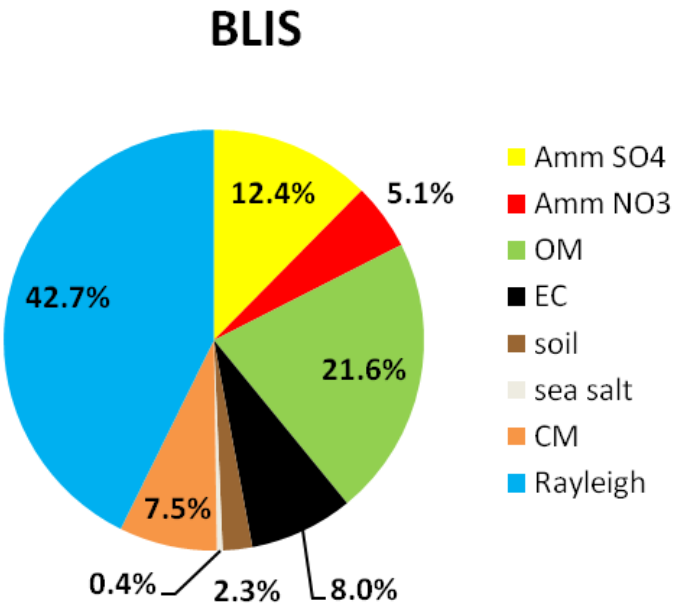
Sulfate regional in nature, little urban enhancement

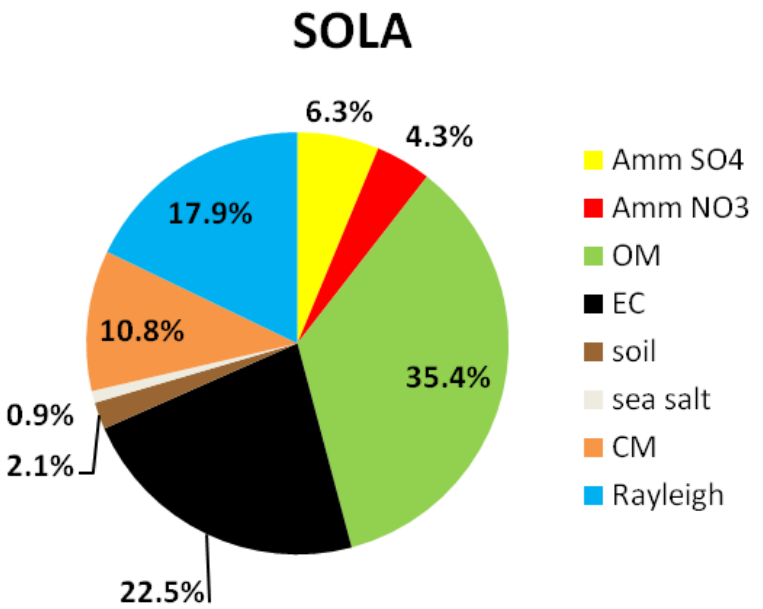


Nitrate produced locally and more urban enhancement

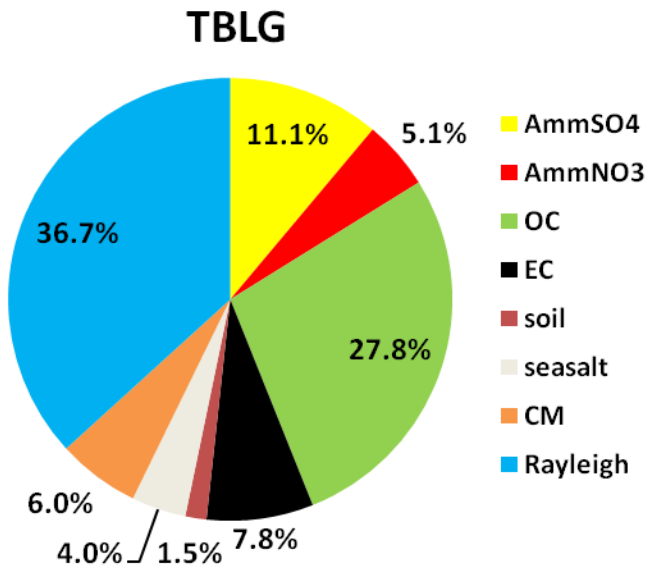


Reconstructed total light extinction (includes Rayleigh)

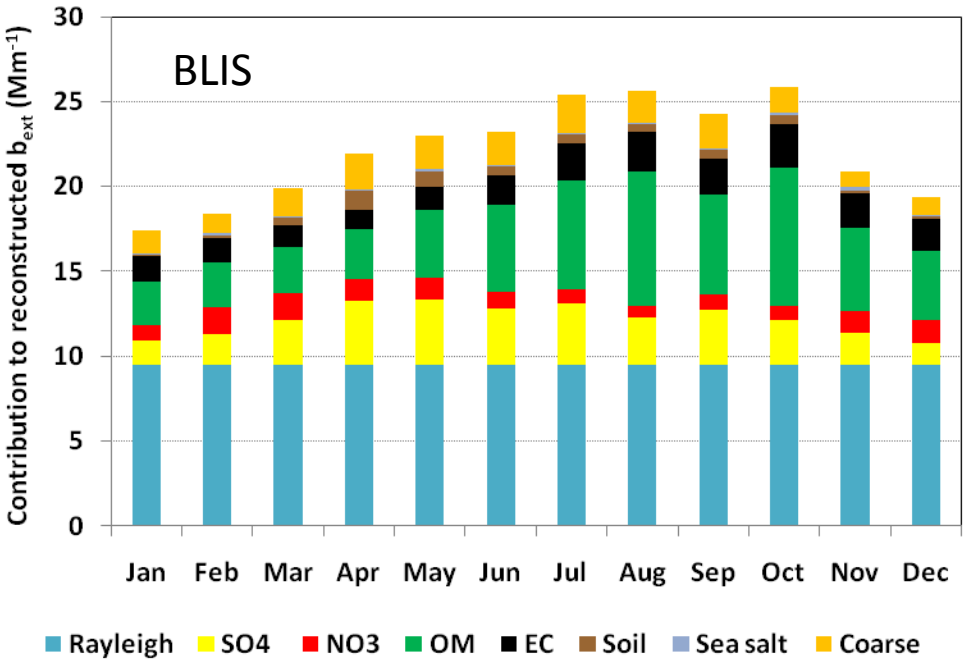


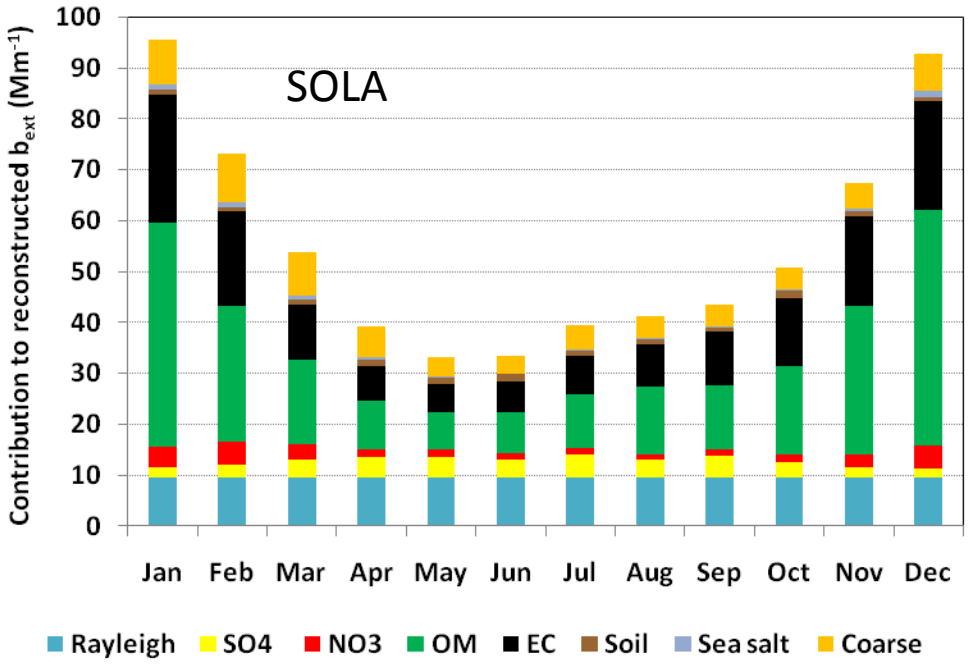


Rayleigh contributes 43% to b_{ext} at Bliss but only 18% at South Lake Tahoe



In winter natural (Rayleigh) scattering >½ of light extinction at Bliss State Park, ~10% at South Lake Tahoe

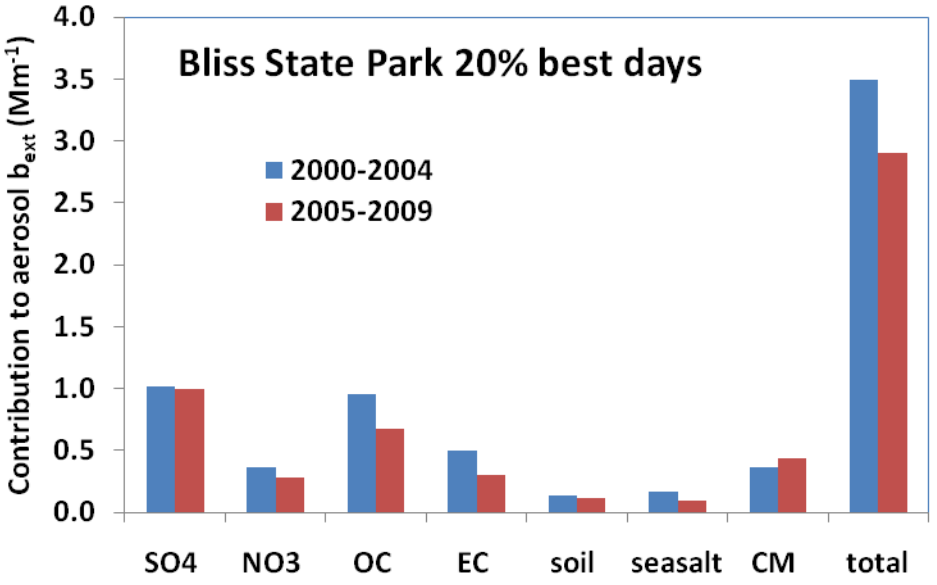


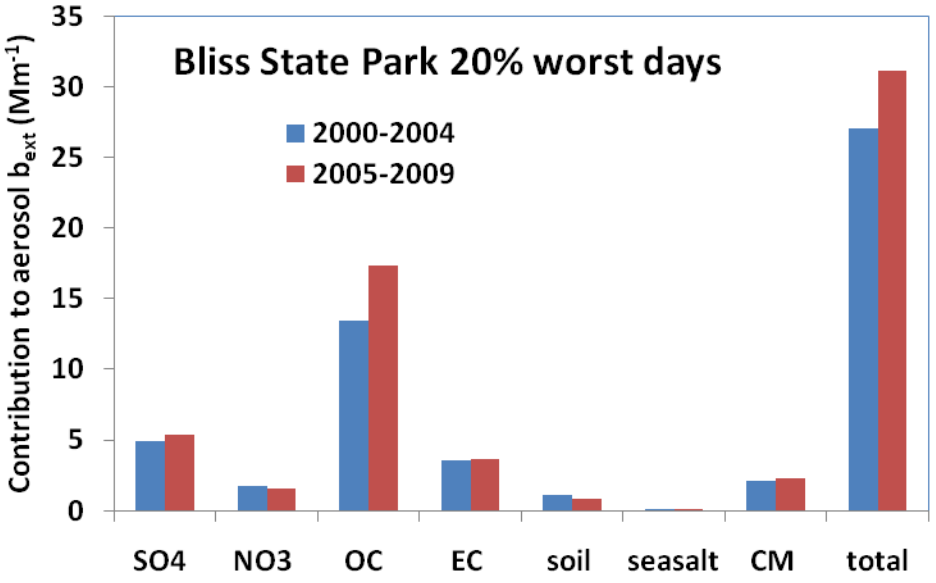


Regional haze rule for Class I areas requires improvement on worst 20% days, no backsliding on 20% best days

Clean days got cleaner at Bliss, mainly due to decreased carbon (OC and EC)

Hazy days got hazier at Bliss mainly from increased OC, slight increase in SO_4.





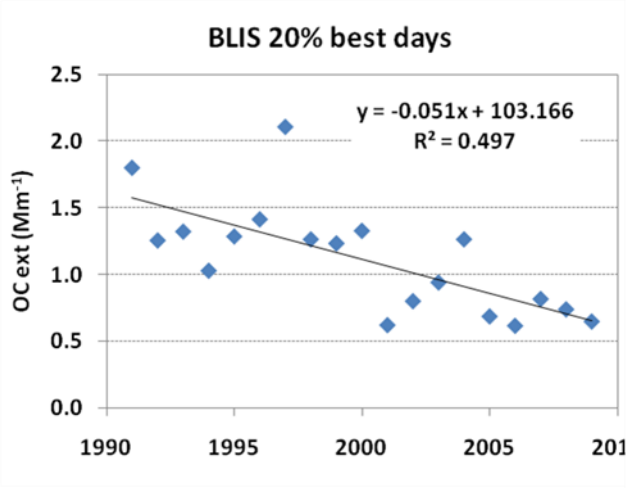
Bliss State Park Thiel regression results

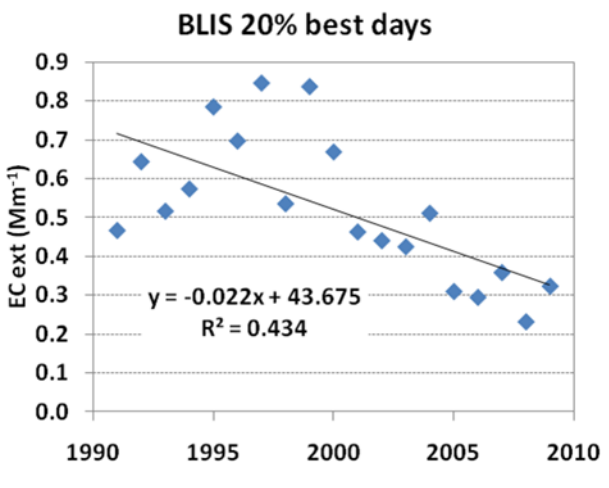
20% best days		SO4 ext	NO3 ext	OMC ext	EC ext	Soil ext	CM ext	Recon b_{ext}
1991-2009	Slope	-0.019	-0.012	-0.049	-0.020	-0.003	-0.038	-0.138
	P-Value	0.062	**0.003**	**0.001**	**0.001**	0.093	**0.000**	**0.000**
1991-1999	Slope	-0.093	-0.034	-0.009	0.043	0.008	-0.082	-0.209
	P-Value	**0.038**	**0.006**	0.381	**0.038**	0.179	**0.022**	**0.022**
2000-2009	Slope	-0.025	-0.023	-0.038	-0.034	-0.003	0.013	-0.081
	P-Value	0.242	**0.014**	0.146	**0.005**	0.146	0.300	**0.023**

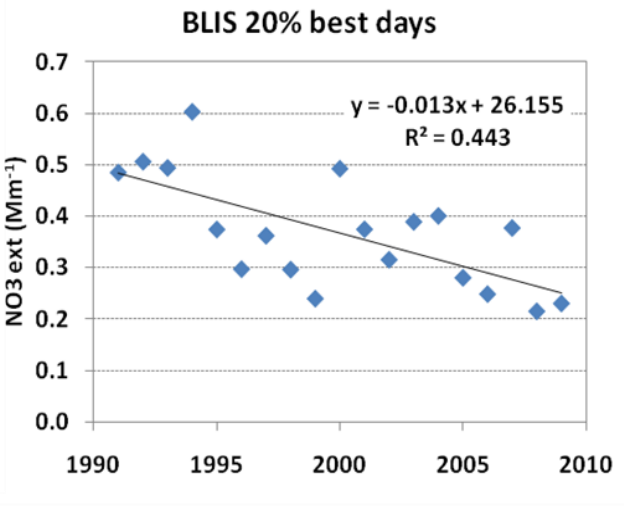
Middle 60% days		SO4 ext	NO3 ext	OMC ext	EC ext	Soil ext	CM ext	Recon bext
1991-2009	Slope	-0.002	-0.018	-0.067	-0.038	-0.001	-0.031	-0.170
	P-Value	0.473	**0.004**	0.006	**0.002**	0.365	**0.040**	**0.000**
1991-1999	Slope	-0.170	-0.083	0.113	0.021	0.003	0.003	-0.173
	P-Value	**0.000**	**0.001**	0.090	0.090	0.460	0.460	0.060
2000-2009	Slope	0.010	-0.047	-0.039	-0.042	0.010	0.052	-0.091
	P-Value	0.500	**0.005**	0.300	**0.036**	0.300	**0.023**	0.300

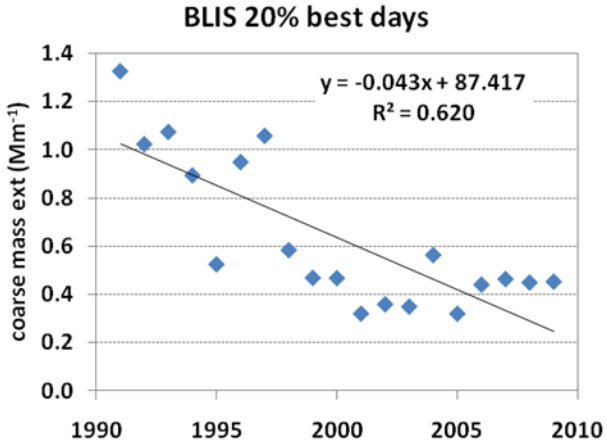
20% worst days		SO4 ext	NO3 ext	OMC ext	EC ext	Soil ext	CM ext	Recon bext
1991-2009	Slope	0.061	-0.062	0.328	-0.010	0.007	-0.034	0.175
	P-Value	0.082	**0.012**	**0.012**	0.418	0.203	**0.025**	0.184
1991-1999	Slope	-0.232	-0.101	0.441	0.088	0.004	-0.079	0.370
	P-Value	0.130	0.179	**0.012**	0.179	0.460	0.179	0.060
2000-2009	Slope	0.112	-0.070	0.425	0.010	-0.046	0.038	0.788
	P-Value	0.190	0.146	0.190	0.431	0.364	0.364	0.300

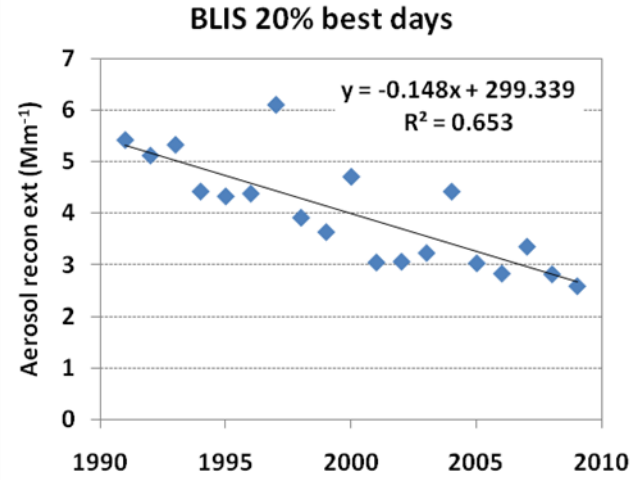
Slope in Mm^{-1} per year



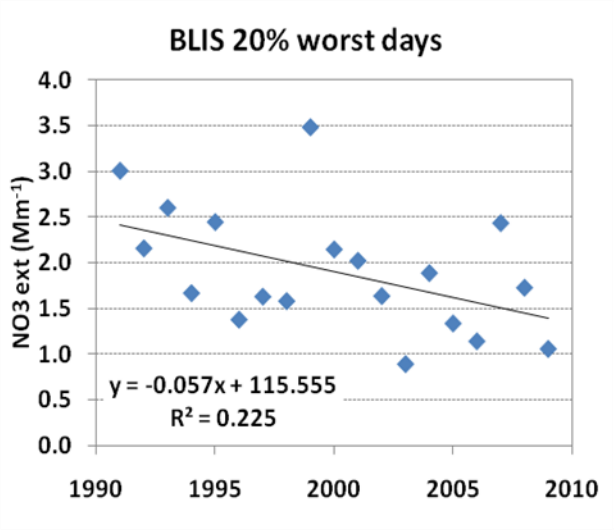


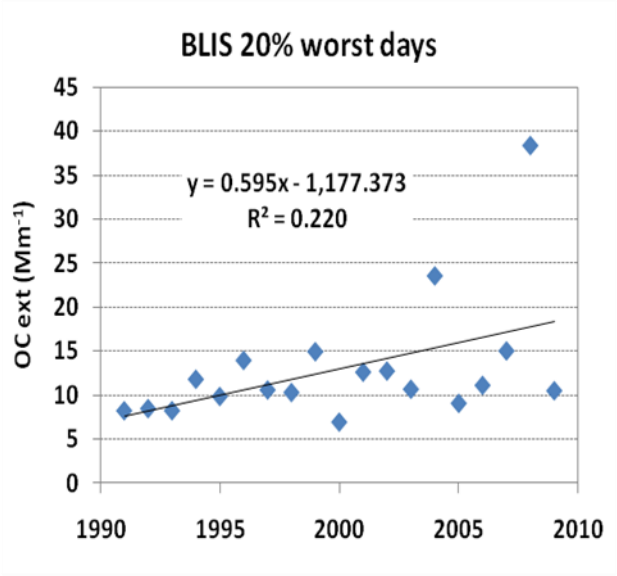


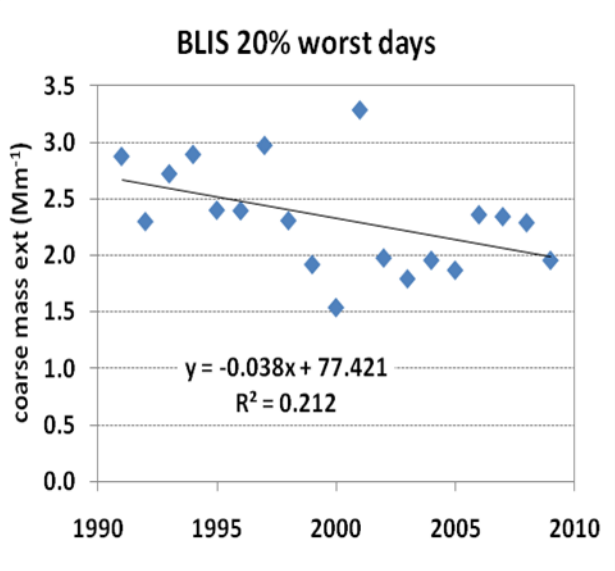




OC, EC, NO_3, coarse mass and total aerosol extinction statistically significant decreases 20% best days at Bliss from 1990-2009.







20% worst days statistically significant decreases in NO_3 and coarse mass extinction, increased OC extinction at Bliss State Park

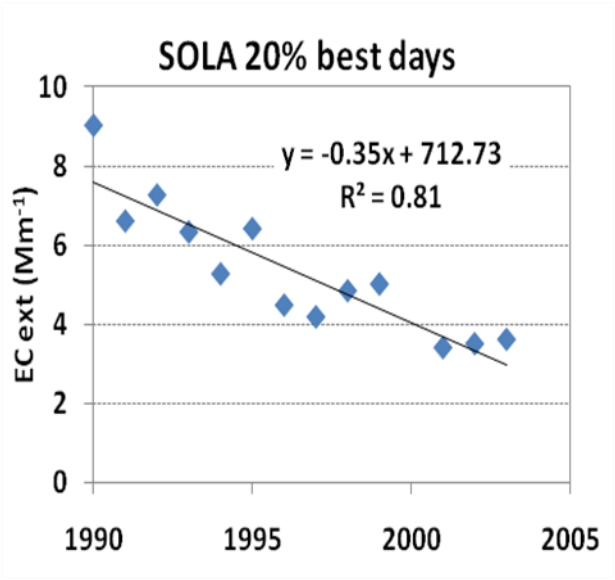
South Lake Tahoe Thiel regression results 1991-2003

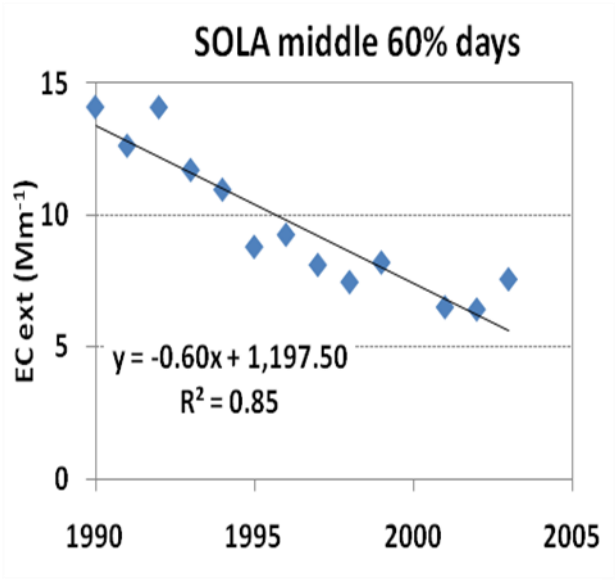
20% best days		SO4 ext	NO3 ext	OMC ext	EC ext	Soil ext	CM ext	Recon bext
1991-2003	Slope	-0.096	-0.049	-0.134	-0.341	-0.013	-0.053	-0.680
	P-Value	**0.011**	**0.005**	0.126	**0.000**	0.218	0.038	**0.003**

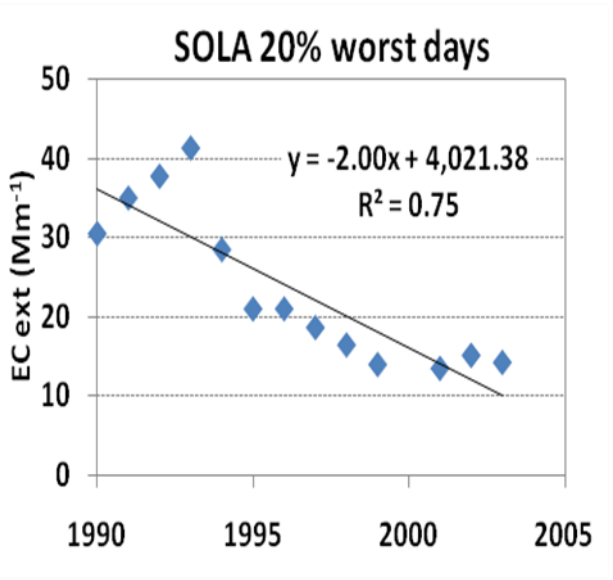
Middle 60% days		SO4 ext	NO3 ext	OMC ext	EC ext	Soil ext	CM ext	Recon bext
1991-2003	Slope	-0.126	-0.073	-0.312	-0.604	0.021	-0.094	-1.468
	P-Value	**0.001**	**0.003**	0.082	**0.000**	0.064	0.082	**0.001**

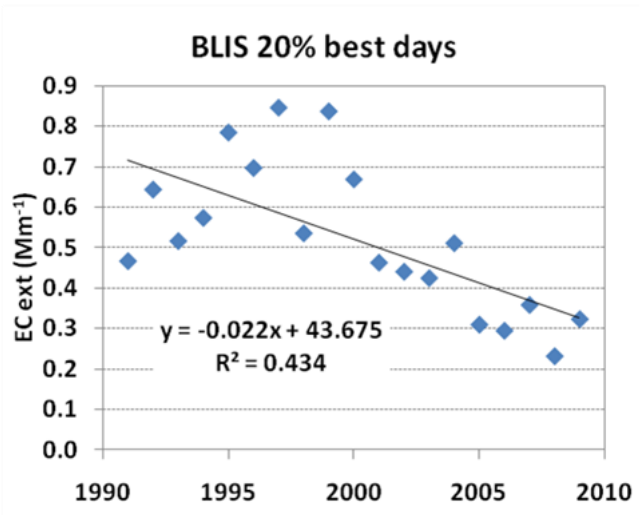
Worst 20% days		SO4 ext	NO3 ext	OMC ext	EC ext	Soil ext	CM ext	Recon bext
1991-2003	Slope	-0.053	-0.318	-2.623	-1.816	-0.002	-0.205	-4.737
	P-Value	0.102	**0.005**	**0.029**	**0.000**	0.383	0.218	**0.005**

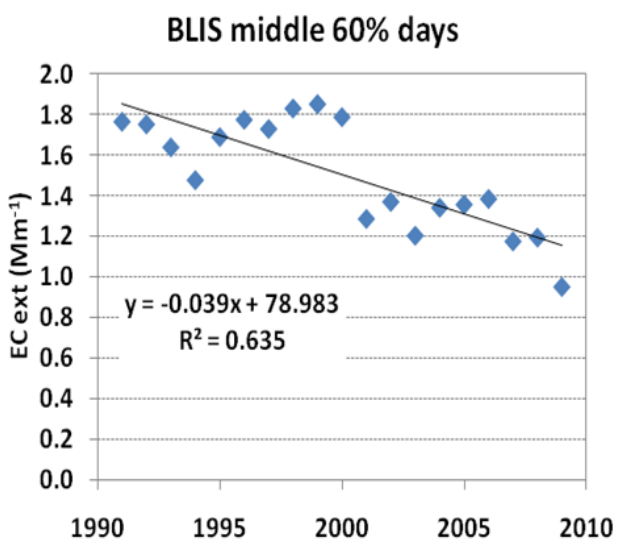
Nitrate, EC, reconstructed extinction at South Lake Tahoe statistically significant declines for best, middle, and worst days.

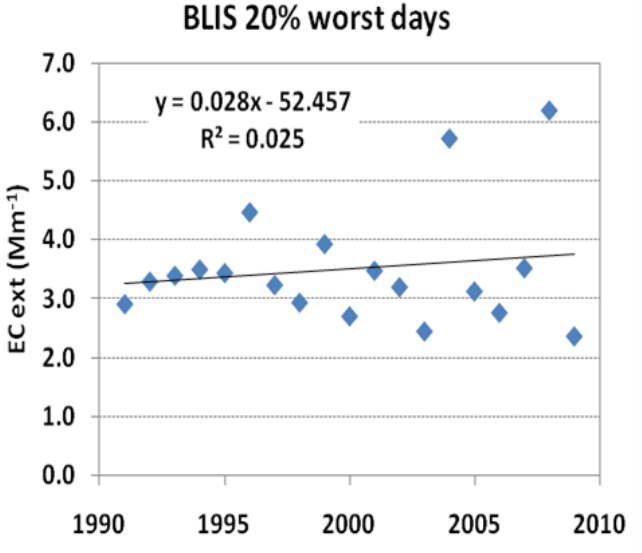








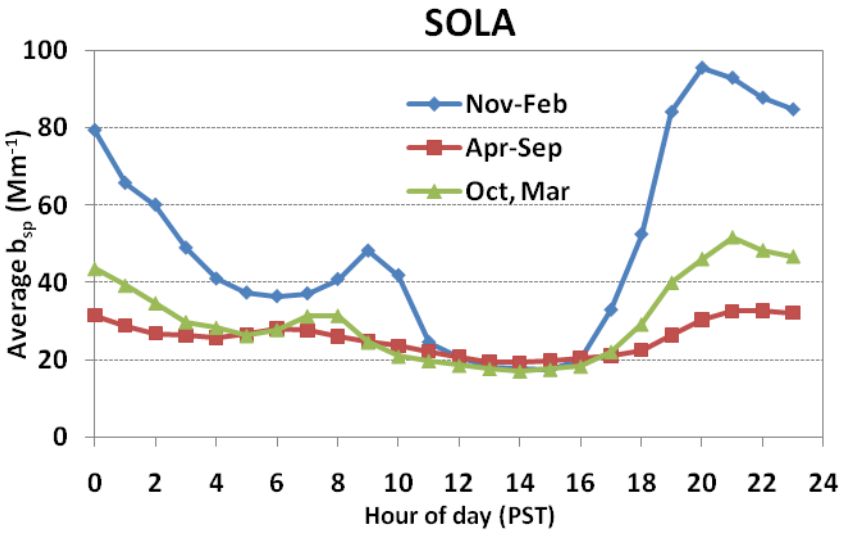




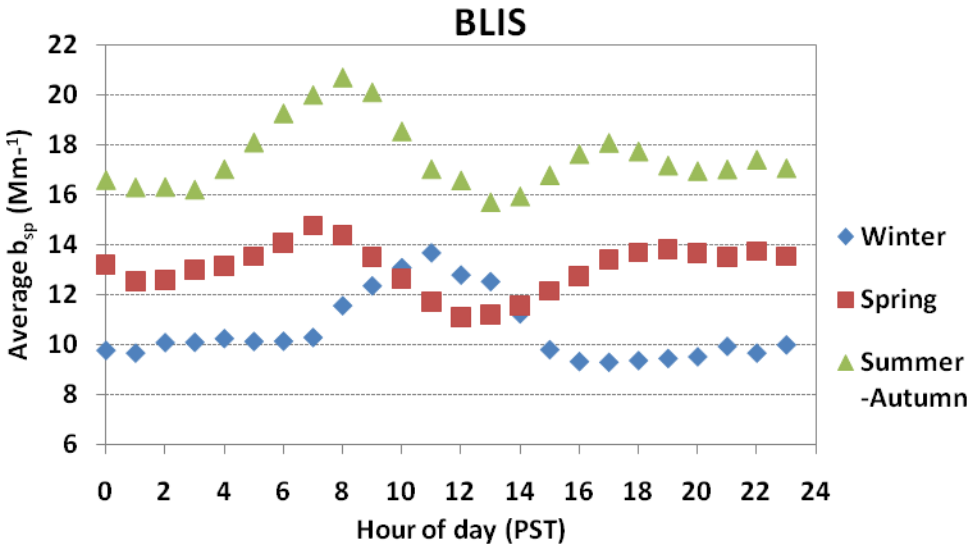
Large declines in EC at South Lake Tahoe for all day categories. EC levels off starting in about 2000

Diurnal patterns in light scattering

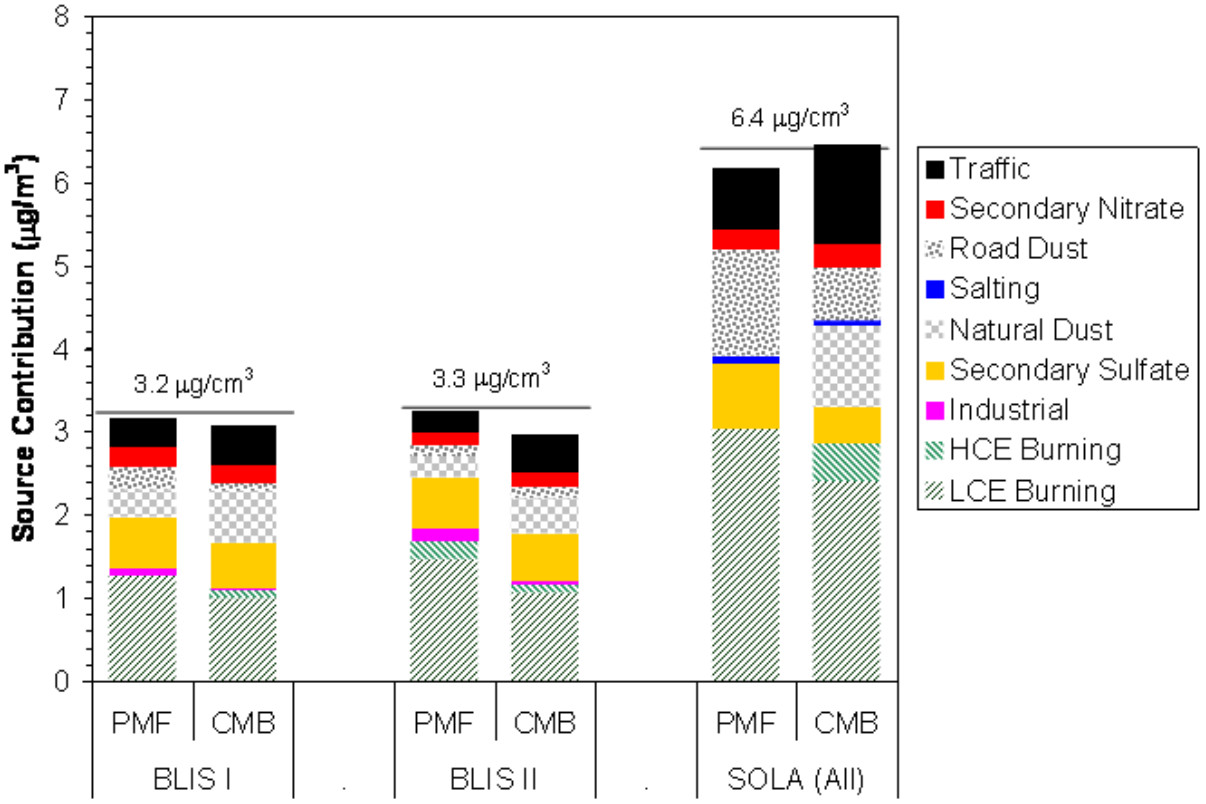
Urban SOLA site large evening winter peak in b_{sp}



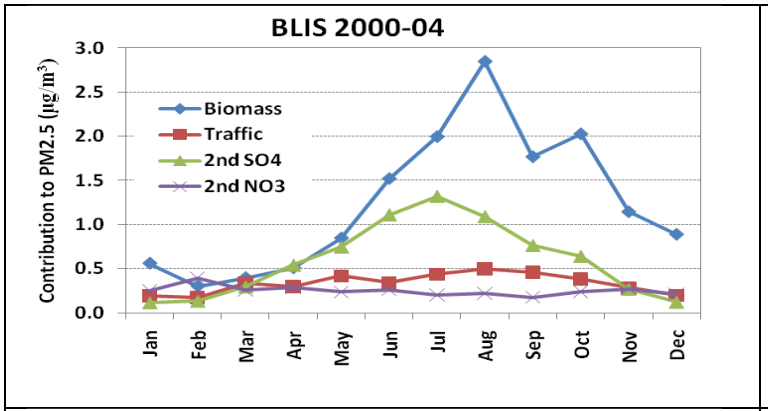
Remote BLIS site small diurnal variations in b_{sp} winter peak about 11 am (mixing from below?)

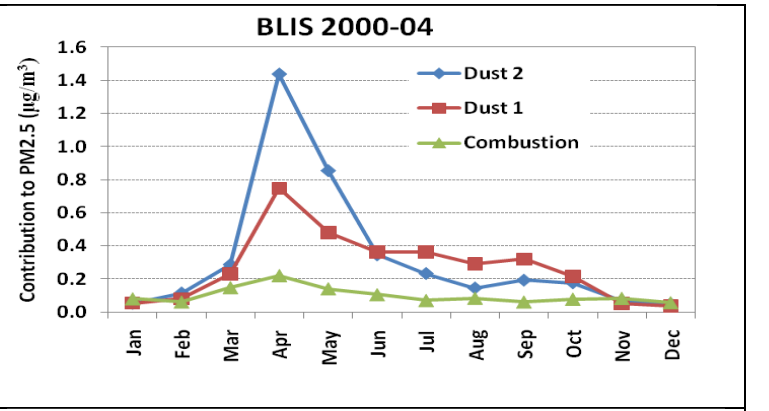


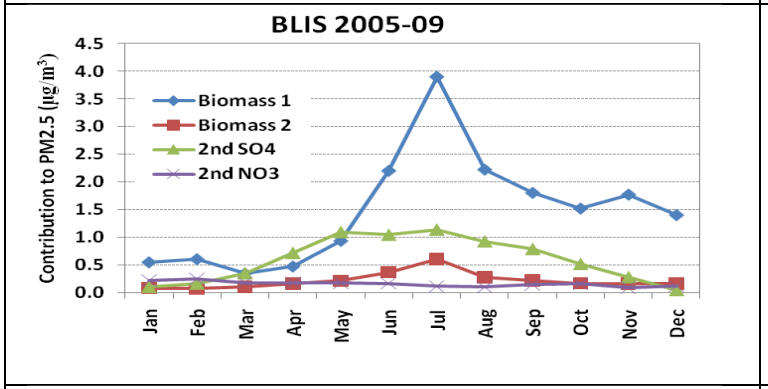
PMF and CMB source apportionment at BLIS and SOLA

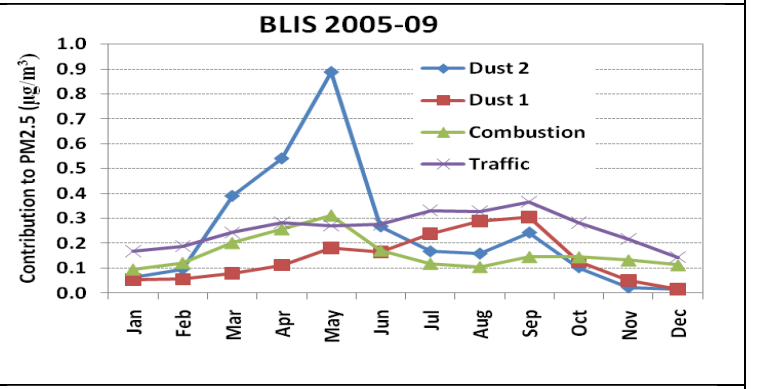


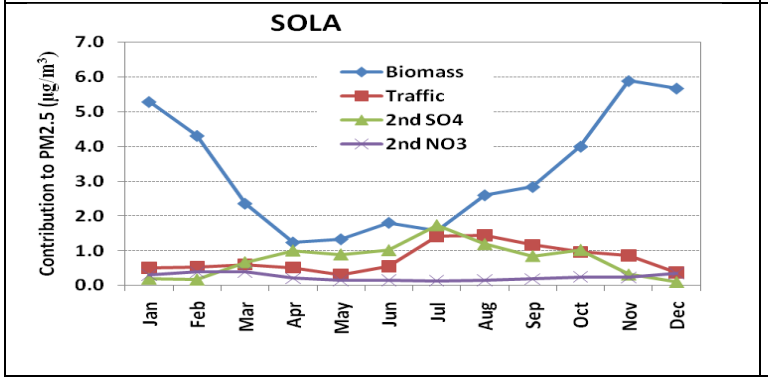
Seasonal variation of PMF factor contributions to $PM_{2.5}$

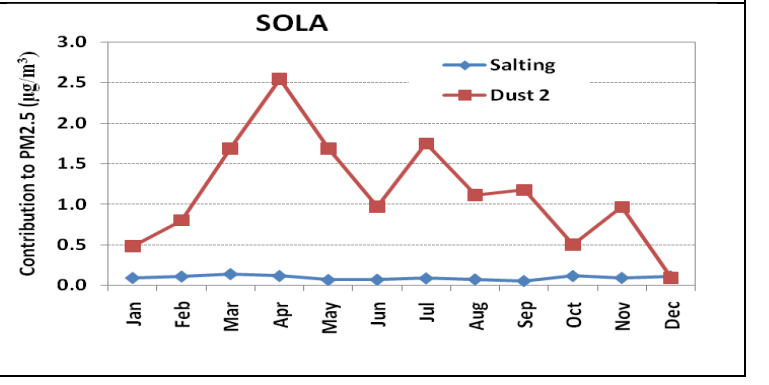






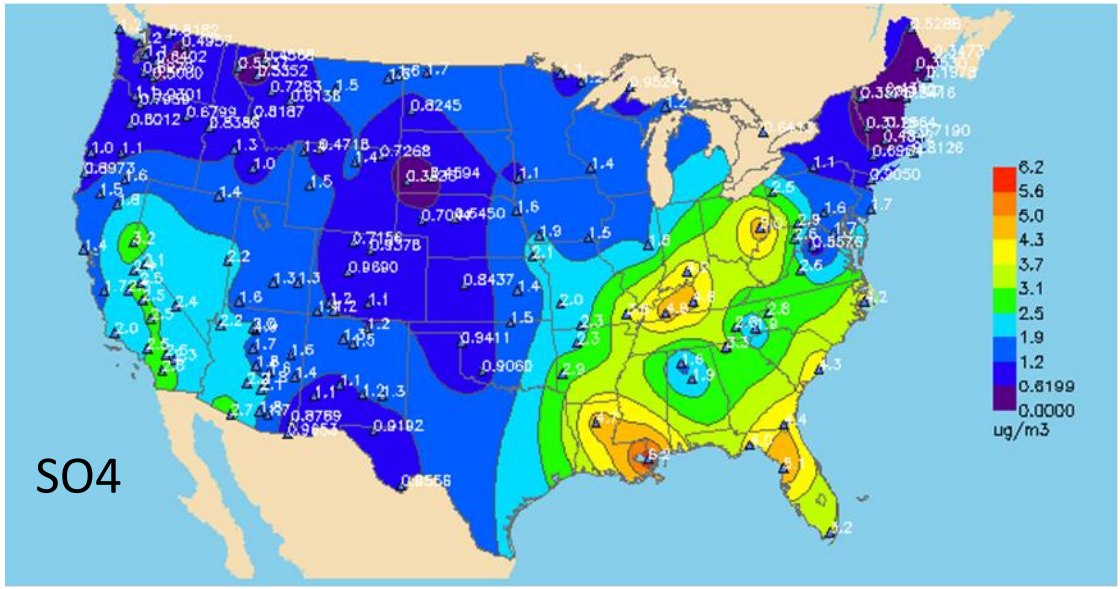


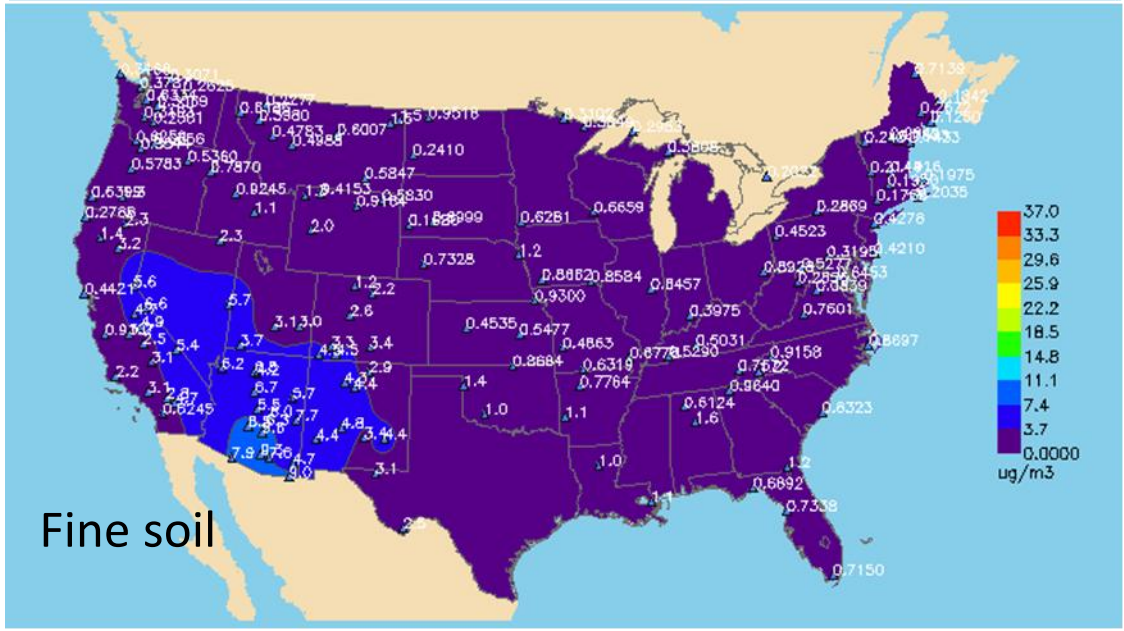


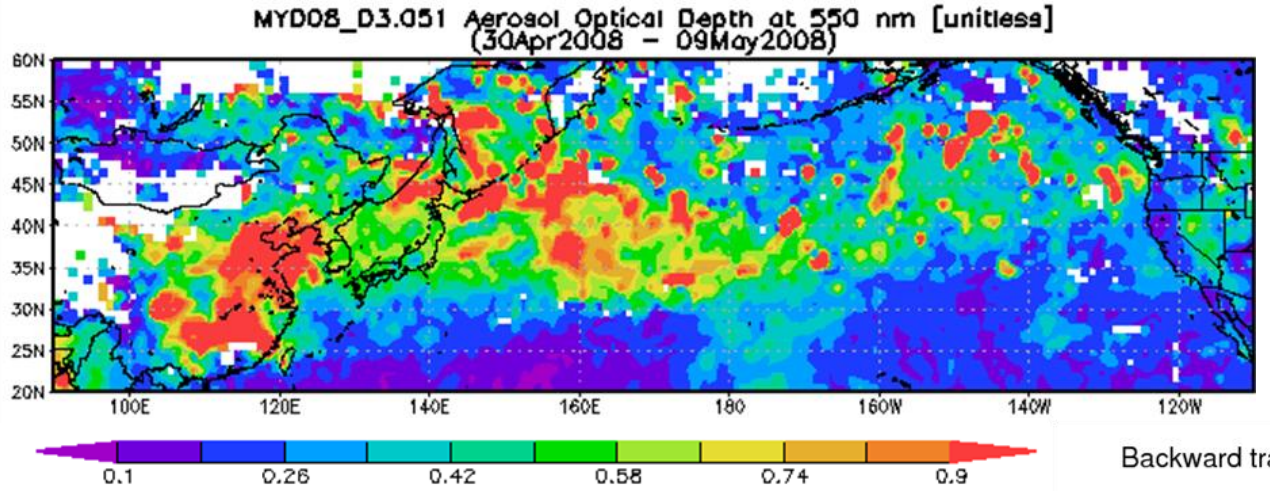


May 9, 2008: Highest sulfate and 5th highest reconstructed fine soil, 98%ile reconstructed b_{ext}

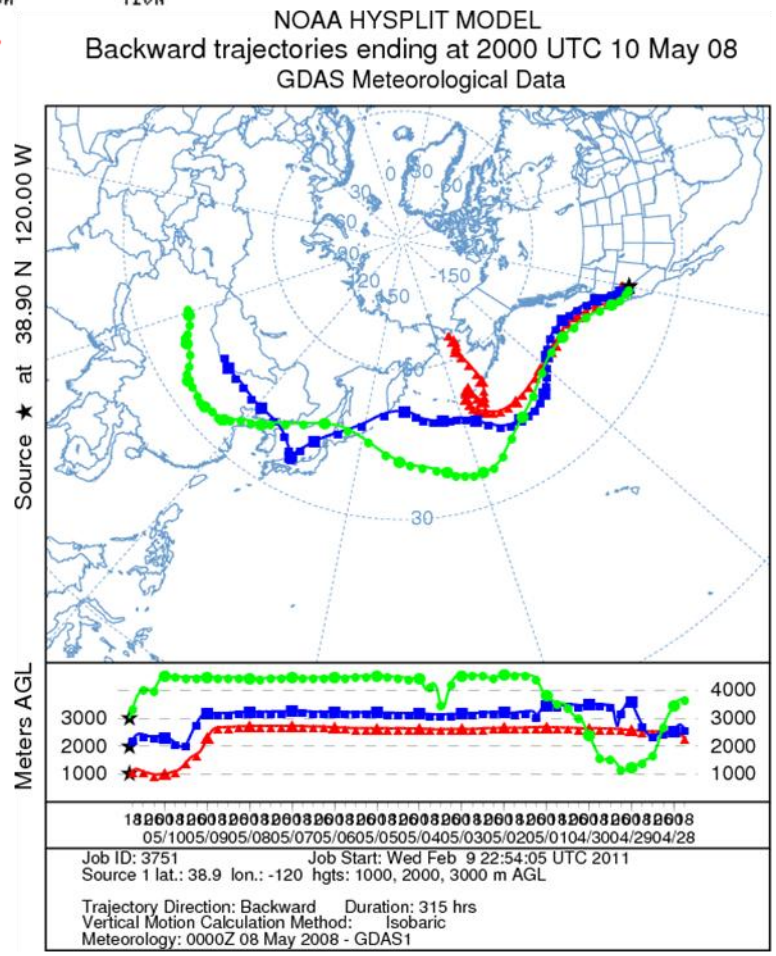
SO_4 and fine soil highest at elevated monitoring sites, indicating transport aloft



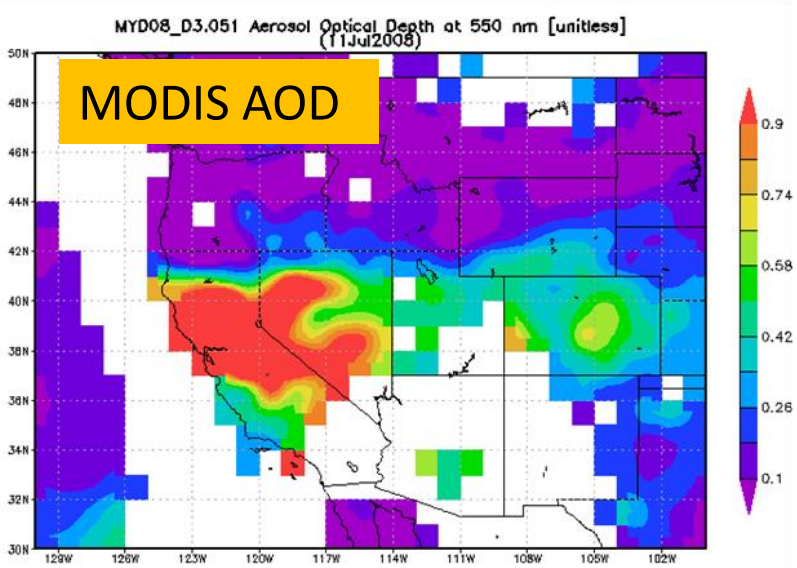


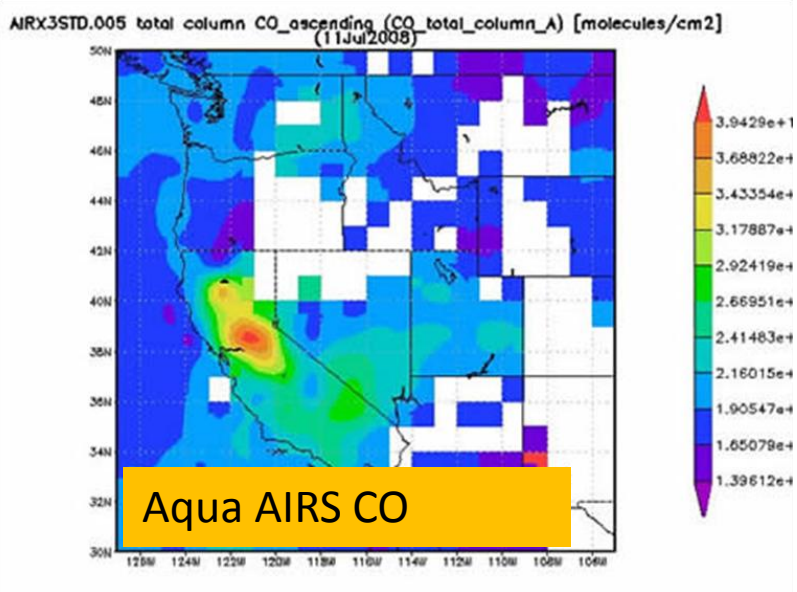


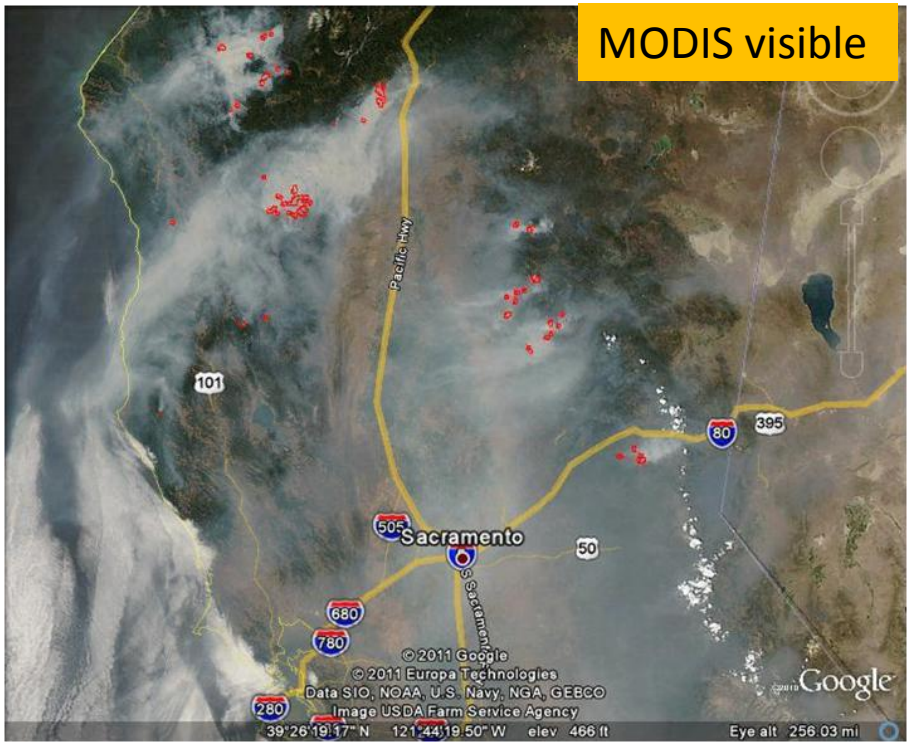
MODIS AOD and backtrajectories consistent with transport of dust and sulfate from China



July 11, 2008: Highest reconstructed light extinction at Bliss State Park, highest OC

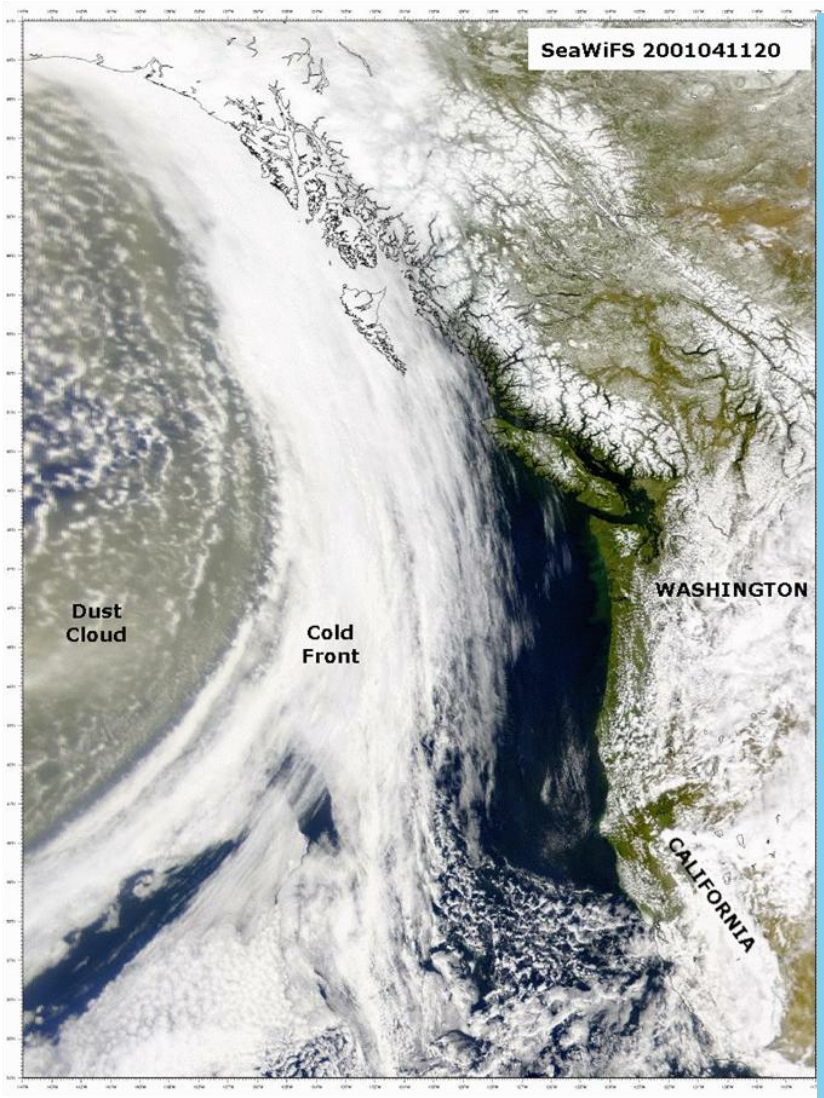


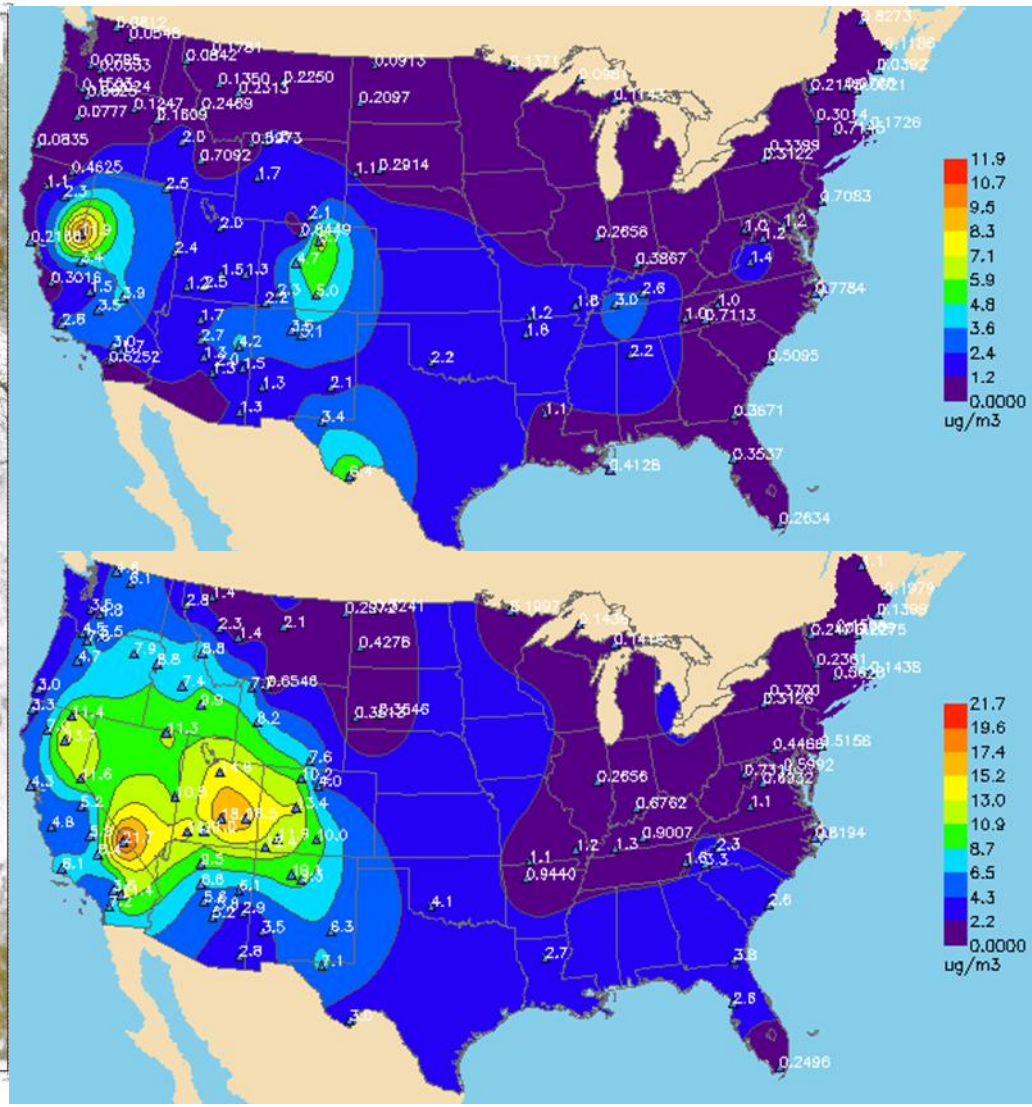




>6000 lightning strikes June 20-21 in Northern California started >2000 fires

Asian dust episode of April 2001- April 13, 2001 highest fine soil





Satellite photo April 11, 2001 showing dust on it's way

IMPROVE fine soil for April 13 (top) and April 16 (bottom), 2011

Summary

- Background visibility in the Lake Tahoe basin, represented by the Bliss State Park site, is generally excellent
- Urban visibility at South Lake Tahoe is significantly impaired in winter but improved over the period 1989-2004 for which data is available- trend since then is unknown due to lack of monitoring
- Clean days have gotten cleaner at Bliss, but dirty days are hazier due to increased wildfire impacts
- Carbonaceous aerosol responsible for a majority of $PM_{2.5}$ and haze in the Lake Tahoe Basin due to residential wood combustion and mobile sources in winter and wildfires and prescribed burning in summer
- Long range transport of dust and sulfate from Asia occasionally contributes to haze in the Lake Tahoe Basin, especially in spring