

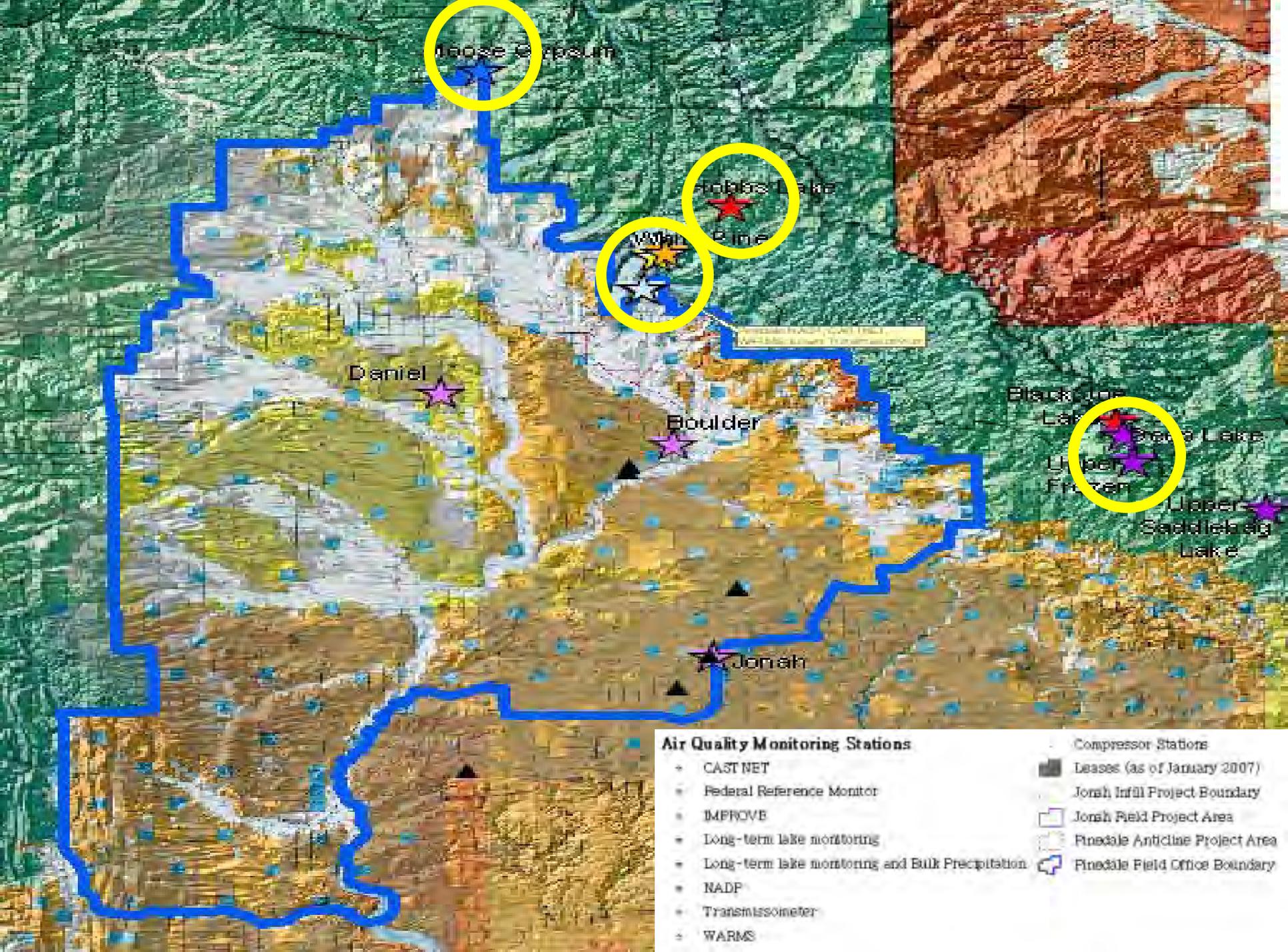
Bridger-Teton NF Analysis of Lake, Bulk, NADP, and IMPROVE N and S data



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Available datasets for analysis

- Four Lakes in the Bridger Wilderness (annual, seasonal, inlet, outlet, hypolimnion, and epilimnion), 1984.
- Two bulk deposition sites in the Bridger Wilderness (annual deposition-includes snow and rain), 1985.
- Five NADP sites (annual and seasonal concentrations and deposition), GC and PI since 1982.
- Three IMPROVE sites (annual and seasonal), 1988.



Moose

Hobbs Lake

White Pine

Daniel

Boulder

Jonah

Blackfoot Lake
Upper
Frozen

Upper
Saddlebag
Lake

Air Quality Monitoring Stations

- + CAST NET
- + Federal Reference Monitor
- + IMPROVE
- + Long-term lake monitoring
- + Long-term lake monitoring and Bulk Precipitation
- + NADP
- + Transmissometer
- + WARMS

- Compressor Stations
- Leases (as of January 2007)
- Jonah Infill Project Boundary
- Jonah Field Project Area
- Pinedale Anticline Project Area
- Pinedale Field Office Boundary

Statistics

- SAS Institute statistical software was used to run analyses following draft USFS Data Analysis Protocol (DAP) recommendations in coordination with Lori Porth, RMRS Statistician
- Non-parametric tests because we are working with non-normal distributions that have errors, gross outliers, or missing data in the data set.
- Our designated alpha level for trend detection was $\alpha = 0.1$, we also reported α levels of 0.05, 0.01, 0.001. A significant p-value does not speak to the magnitude of a trend.

Raw data preparation and exploratory analysis

**Mann –Kendall
Sen slope estimator**

**Kruskal-Wallis
Seasonal Mann-Kendall
Sen slope estimator**

**p-values
Slope estimates**

INTERPRETATION

Statistical Tests Used

- Mann-Kendall – calculated each elemental variable over the years to see if there were statistically significant increasing or decreasing trends.
- Kruskal-Wallis -- to see if seasons in the data set were statistically different
- Seasonal Mann-Kendall-run to look for trends while taking seasonality into account
- Sens slope estimator- magnitude of slope.

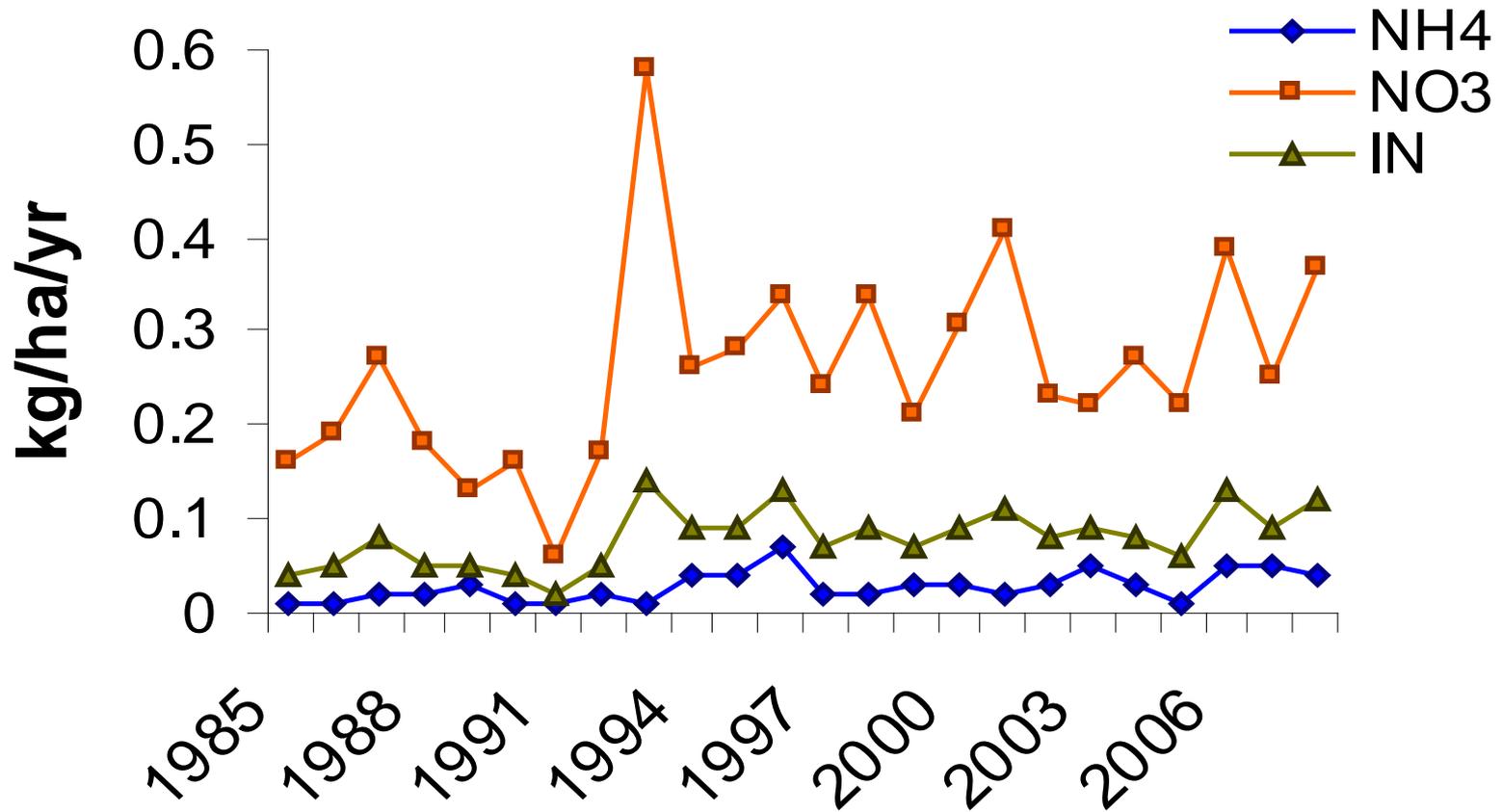
Gypsum Creek and Pinedale NADP sites

Seasonal Trends

	Winter		Spring		Summer		Fall	
	GC	PI	GC	PI	GC	PI	GC	PI
NH_4^+	↑ ***	---	---	---	↑ **	↑ *	↑ ****	↑ ***
NO_3^-	↑ **	---	---	---	---	---	↑ **	↑ *
IN	↑ ***	---	---	---	↑ **	---	↑ ***	↑ **
SO_4^{2-}	---	↓ ***	---	↓ **	---	↓ ***	---	↓ *

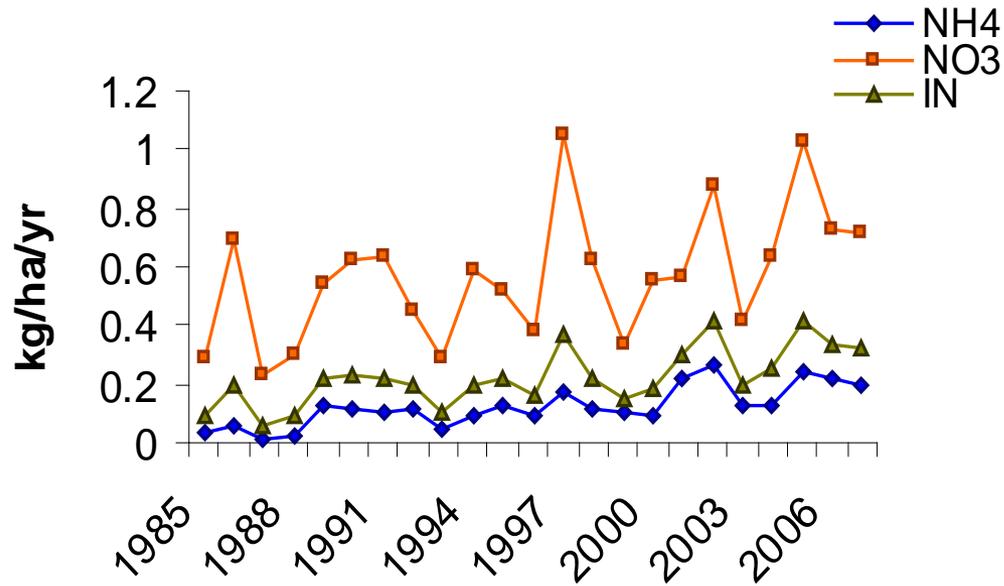
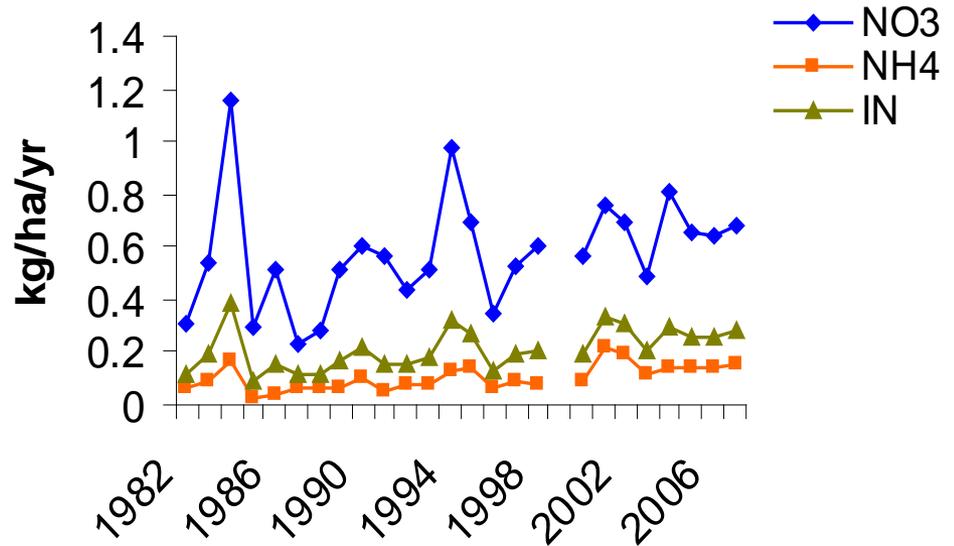
* = $p < 0.1$, ** = $p < 0.05$, *** = $p < 0.01$, **** = $p < 0.001$

Gypsum Creek NADP site winter nitrogen deposition



Fall Nitrogen wet Deposition NADP

Pinedale



Gypsum Creek

Trends in Annual Lake Concentrations ($\mu\text{eq/L}$)

	Black Joe		Deep		Hobbs	
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
NH_4^+	---	↑ *	---	---	↑ **	↑ *
NO_3^-	↑ ***	↑ **	↑ **	---	↑ *	---
SO_4^{2-}	↑ *	---	---	---	---	---

* = $p < 0.1$, ** = $p < 0.05$, *** = $p < 0.01$, **** = $p < 0.001$

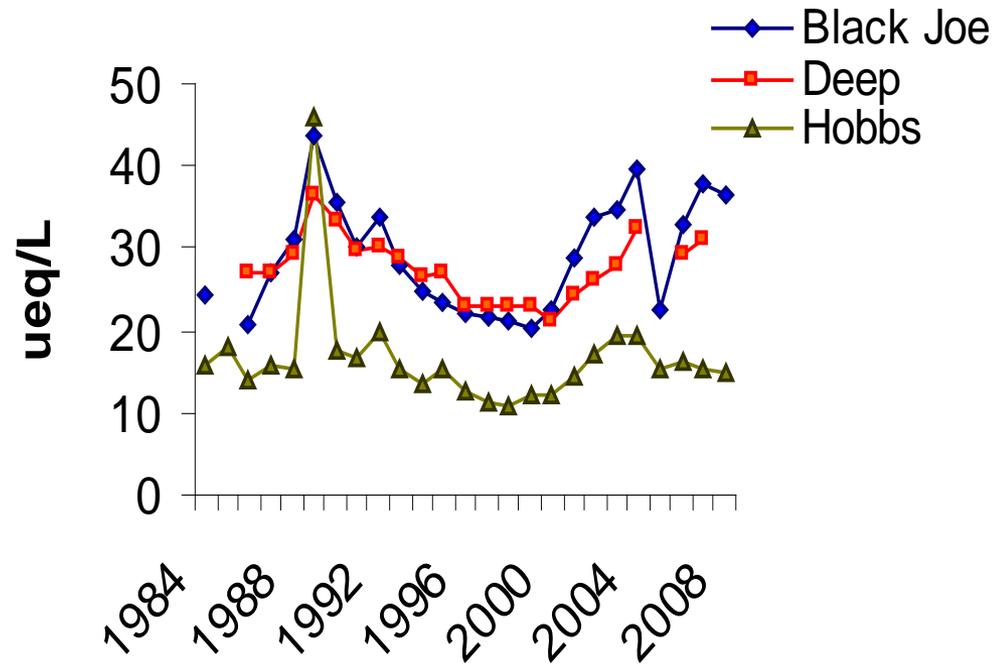
Trends in Seasonal Lake Conc. ($\mu\text{eq/L}$)

(at inlets unless stated otherwise)

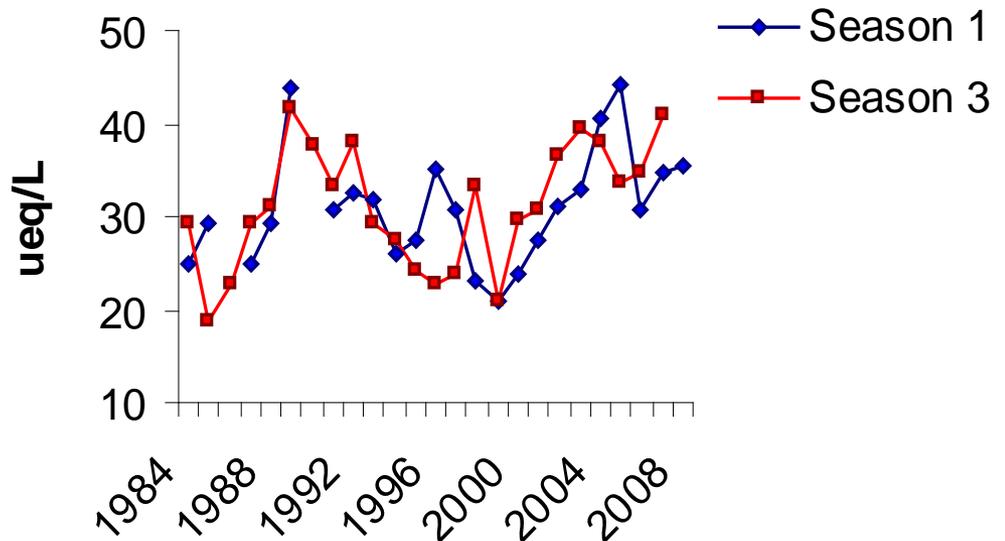
	Black Joe			Deep			Hobbs		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
NH_4^+	---	---	---	---	---	---	↑**	↑*	---
NO_3^-	---	↑**	↑***	---	↑**	↑*	---	↑**	---
SO_4^{2-}	---	↑**	---	---	---	---	---	↓**	---
Outlet NO_3^-	---	↑**	---	---	---	---	---	---	---
Outlet SO_4^{2-}	↑*	---	↑*	---	---	---	---	---	---

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Annual sulfate conc. From the hypolimnion



Seasonal sulfate concentrations From Black Joe Outlet

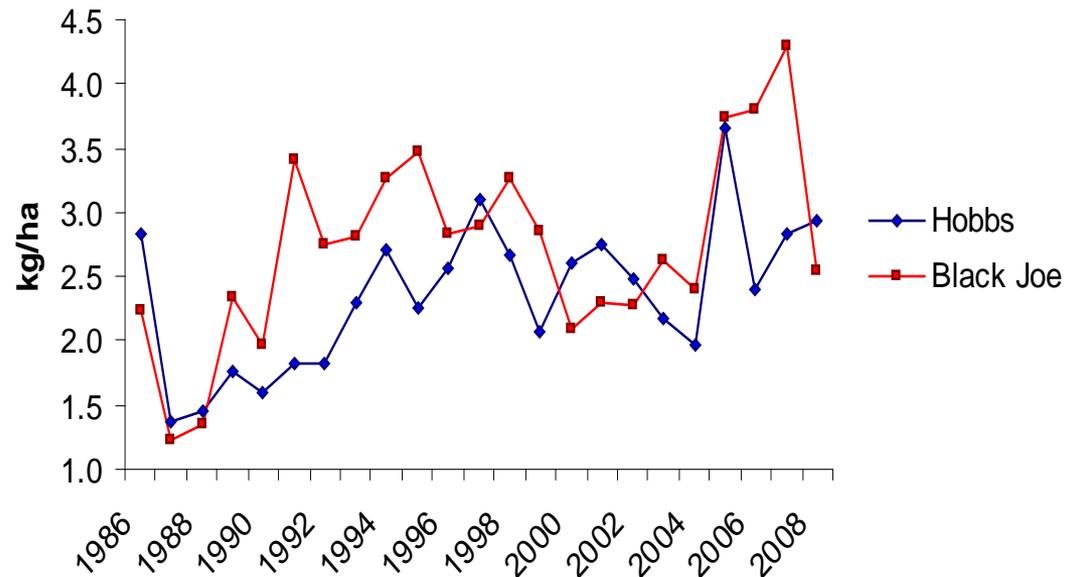


Black Joe and Hobbs Bulk Deposition

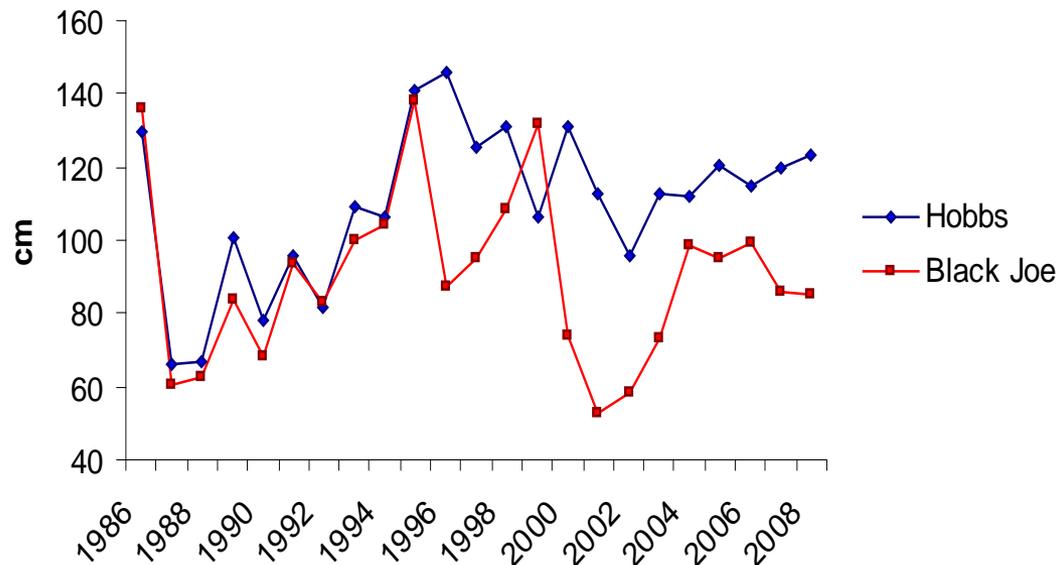
Variable	Black Joe	Hobbs
NH_4^+	↑ **	↑ ***
NO_3^-	↑ **	↑ ***
Total N	↑ *	↑ ***
Precipitation	↑ **	↑ **
SO_4^{2-}	---	---

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Annual Nitrogen Bulk Deposition (Total)



Annual precipitation at Bulk Deposition sites



Yell2 IMPROVE site on a clear day and on a hazy day



Spectrum Series

dv=0 Bext=10 SVR=390

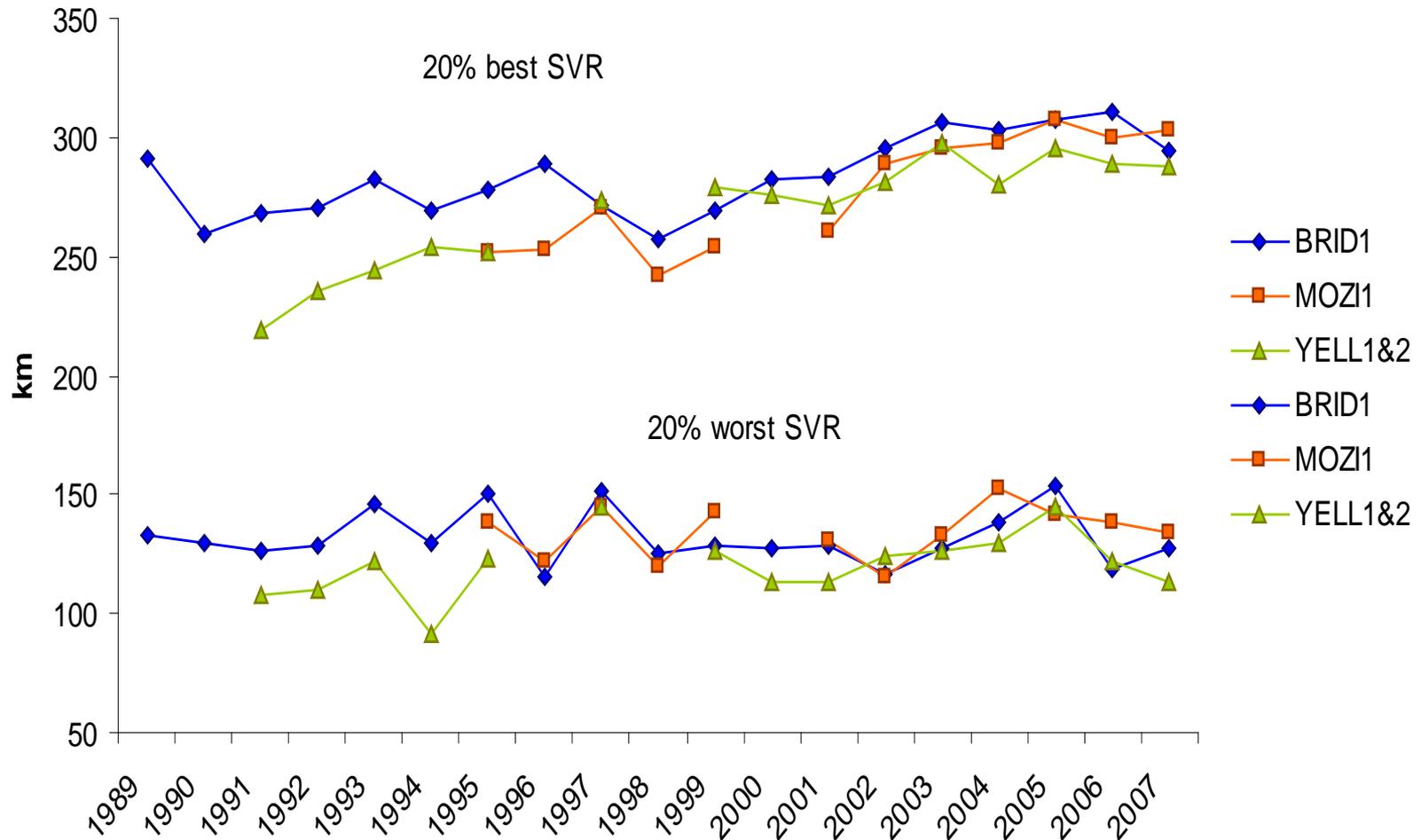
Spectrum Series

dv=17 Bext=52 SVR=75

Visibility

- ◎ **SVR** = Standard Visual Range – measured in km. The measured distance one should be able to see.
- ◎ **dv** = deciview – official unit for regional haze. The increment corresponding to the minimum change in visibility detectable to the human eye.

SVR at IMPROVE sites



Trends at BRID1 and YELL1&2 IMPROVE sites

- BRID1 ↑ in nitrate—winter *
↓ in sulfate—annual**, summer**, fall**
- YELL1&2 ↑ in nitrate—annual*
↑ in sulfate—spring*
↓ in sulfate—fall*

(R1 IMPROVE sites had no ↑ in nitrate or sulfate)

* = $p < 0.1$, ** = $p < 0.05$, *** = $p < 0.01$, **** = $p < 0.001$

Brief Summary

- General decrease in sulfate (but increase in some of the lakes)
- General increase in visibility (IMPROVE site was just installed at Boulder which is projected to be the deposition hotspot).
- Increase in ammonium (agrees with the general increase occurring across the western US).
- Increase in nitrate this trend was also found in the CO Front Range.

Where do we go from here?

- Analyze the Bulk deposition sites for seasonality.
- Quantify the deposition for each of the data sets and compare total deposition for N and S between data sets.
- How much of an increase or decrease is there?
- Compare N and S deposition in R4 to R1 and R2.
- What are the repercussions for increase in N and S?
- Critical loads?

N deposition and Critical Loads

- Total N deposition at the Hobbs and BJ bulk sample sites average 2.35 and 2.66 kg/ha⁻¹year⁻¹ respectively and range from 1.23 to 4.3 kg/ha⁻¹year⁻¹
- Baron (2006) suggest CL for high alpine lakes in CO ~1.5 kg/ha⁻¹year⁻¹
- Fenn et al. (2008) suggest CL for lichens communities in mixed conifer forests of CA to be around 3.1 kg/ha⁻¹year⁻¹

THANK YOU

- Laurie Porth
- Scott Copeland
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