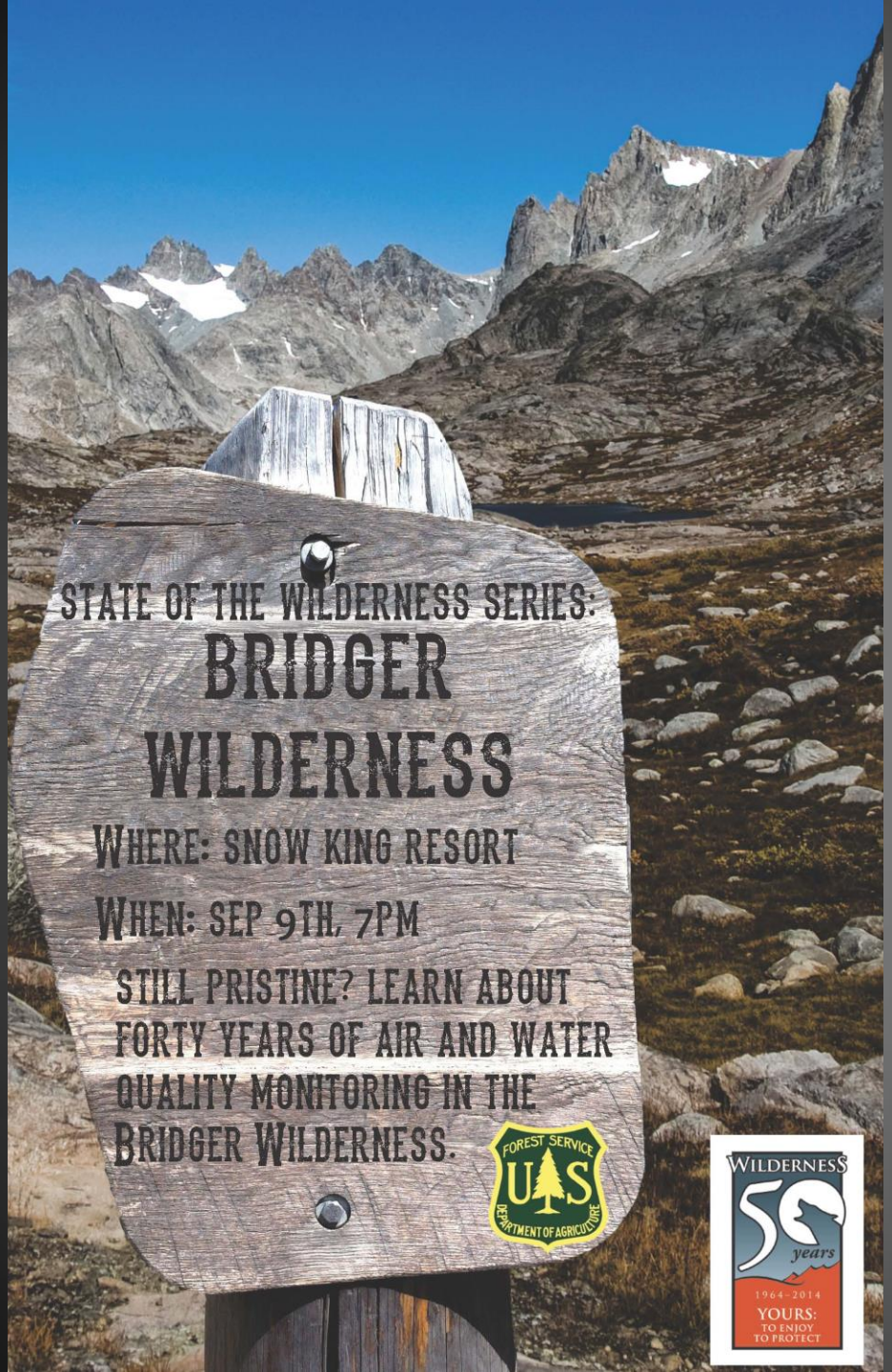


Wilderness 50th Anniversary
Speaker Series

Bridger Wilderness: 40 Years of Air and Water Quality Monitoring

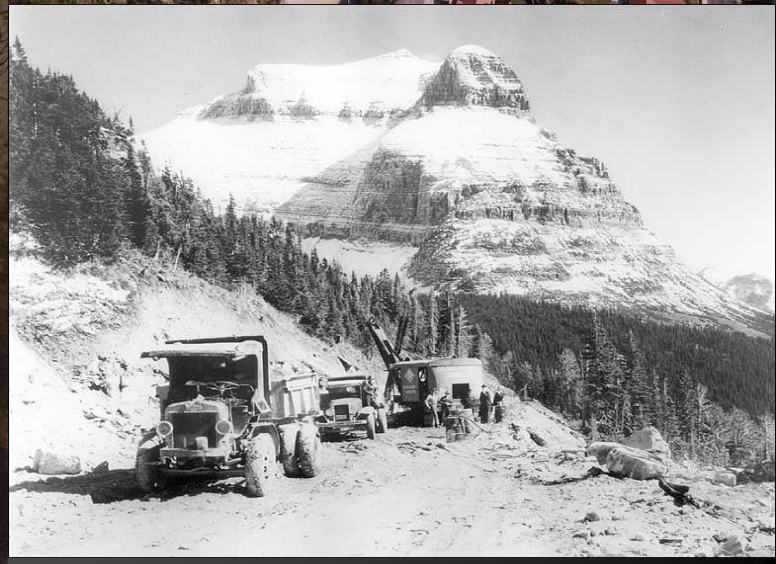
Introduction: Linda Merigliano
Air and Water Quality Monitoring: Ted Porwoll
Special Guest: Al Galbraith (retired)

Bridger Wilderness

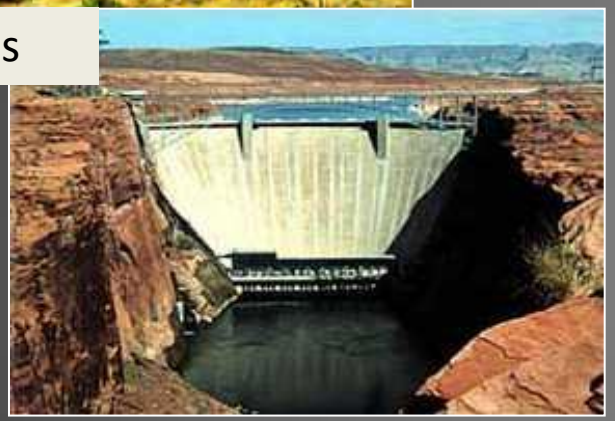
40 years of air and water quality monitoring

Ted Porwoll, Andrea Davidson,
Linda Merigliano

The Wilderness Act
A brief history



Versus



"Wilderness protection is paper thin, and the paper should be the best we can get — that upon which Congress prints its Acts." David Brower, 1956

"Let's be done with a wilderness preservation program made up of a sequence of threats and defense campaigns! Let's make a concerted effort for a positive program … where we can be at peace and not forever feel that the wilderness is a battleground." Howard Zahniser 1951

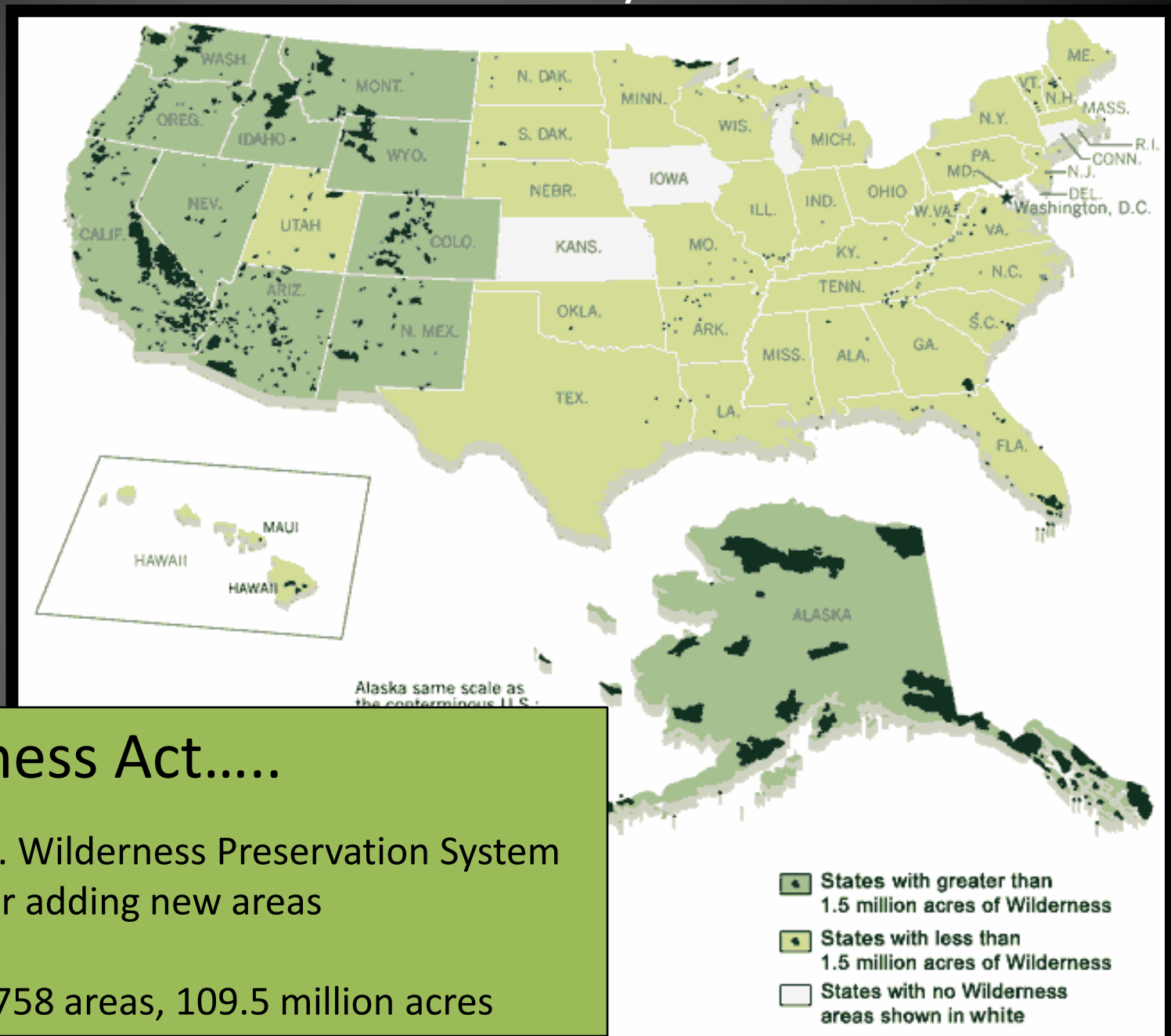
President Johnson signing the Wilderness Act Sept. 3, 1964

"If future generations are to remember us with gratitude rather than contempt, we must leave them more than the miracles of technology. We must leave them with a glimpse of the world as it was in the beginning, not just after we got through with it". Lyndon B. Johnson

Purpose of the Wilderness Act

"In order to assure that an increasing population, accompanied by expanding settlement and growing mechanization, does not occupy and modify all areas within the United States and its possessions, leaving no lands designated for preservation and protection in their natural condition, it is hereby declared to be the policy of the Congress to secure for the American people of present and future generations the benefits of an enduring resource of wilderness."

The National Wilderness Preservation System



The Wilderness Act…..

1. Created a Natl. Wilderness Preservation System and process for adding new areas

The 2014 NWPS = 758 areas, 109.5 million acres

The Wilderness Act..

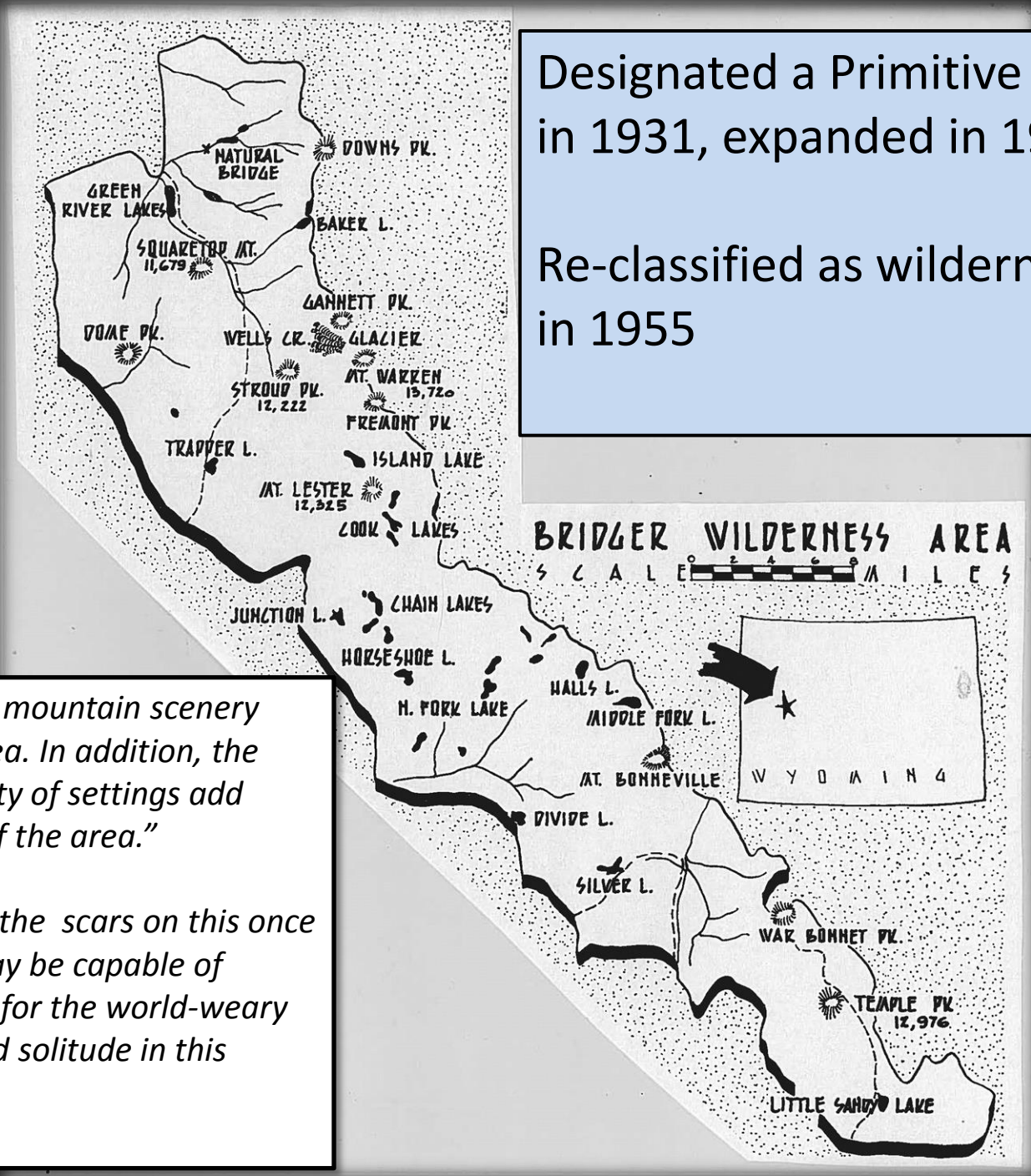
2. Defined Wilderness
3. Set direction for managing wilderness

Wilderness is:

- Where the earth and its community of life are untrammeled by man; Affected primarily by the forces of nature
- Undeveloped federal land retaining its primeval character and influence, without permanent improvements, with the imprint of man's work substantially unnoticeable ….
- Protected and managed so as to preserve its natural conditions….
- Has outstanding opportunities for solitude or a primitive and unconfined type of recreation
- May also contain ecological, geological, or other features of scientific, educational, scenic, or historical value

Designated a Primitive area in 1931, expanded in 1937

Re-classified as wilderness in 1955



Excerpts from reports and brochures 1950s

"Unparalleled panoramas of mountain scenery can be viewed within this area. In addition, the many lakes with their diversity of settings add much to the attractiveness of the area."

"Nature has healed many of the scars on this once harried land. Perhaps she may be capable of performing a similar miracle for the world-weary traveler who seeks peace and solitude in this magnificent wilderness"

Bridger Wilderness
428,087 acres

Designated by Congress in 1964, expanded in 1984

Bridger Wilderness – Key values

- Exceptionally wide variety of recreation opportunities (rich mountaineering history)
- Outstanding scenery – over 2900 lakes and numerous granite peaks (incl. Gannett Peak)
- Abundant snowfall and high water yield; large glaciers
- Wildlife viewing, hunting, fishing opportunities

Air and Water Quality in Wilderness
September 9, 2014

Ted Porwoll, Bridger-Teton National Forest

Air Quality Related Mandates

"…conserve [natural and cultural resources]…as will **leave them unimpaired** for the enjoyment of future generations." (NPS Organic Act)

"Wilderness areas…shall be administered…in such a manner as will **leave them unimpaired** for future use and enjoyment as wilderness…" (Wilderness Act of 1964)

"… **preserve, protect and enhance the air quality** in national parks, national wilderness areas, national monuments, national seashores…" (Clean Air Act as amended in 1977)

"In cases of doubt the land manager should err on the side of protecting the air quality-related values for future generations." (Senate Report No. 95-127, 95th Congress, 1977)

"…National Forest wilderness resources shall be managed to promote, perpetuate and, where necessary, restore the wilderness character of the land…" (FS Regs Implementing the Wilderness Act, 1997)

Air Quality Protection

- **National Parks and National Forests**
  - Class I and Class II Wilderness Areas Status
  - Established by the Clean Air Act (CAA)

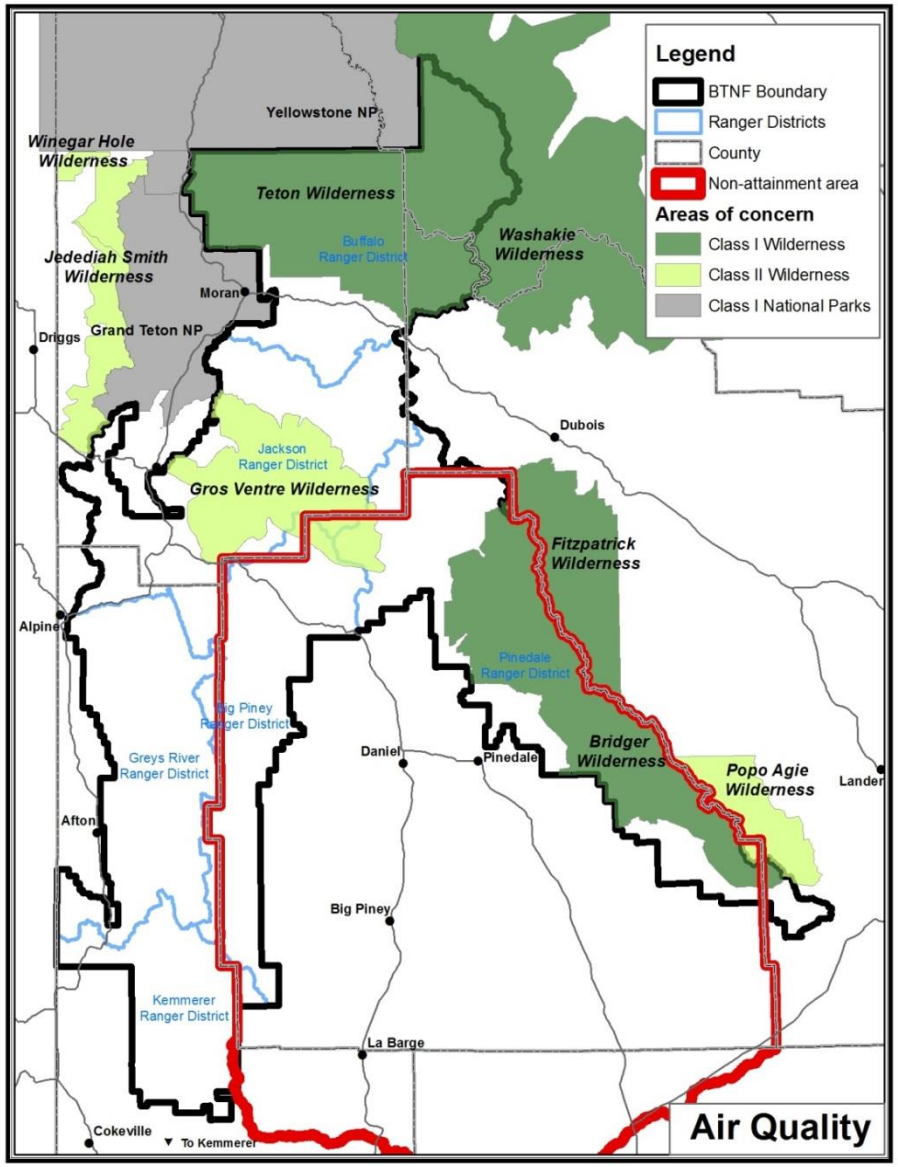
- **National Ambient Air Quality Standards**
  - Established and updated regularly to protect human health and the environment

- **National Environmental Policy Act**
  - Development plans must adhere to CAA and
  - Wilderness Act regulations

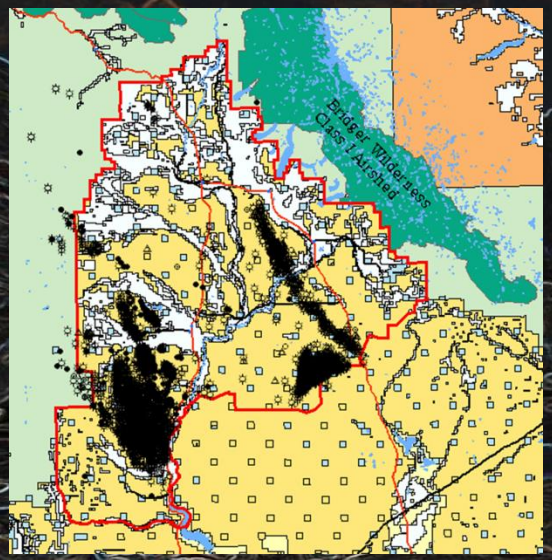
Area Designations

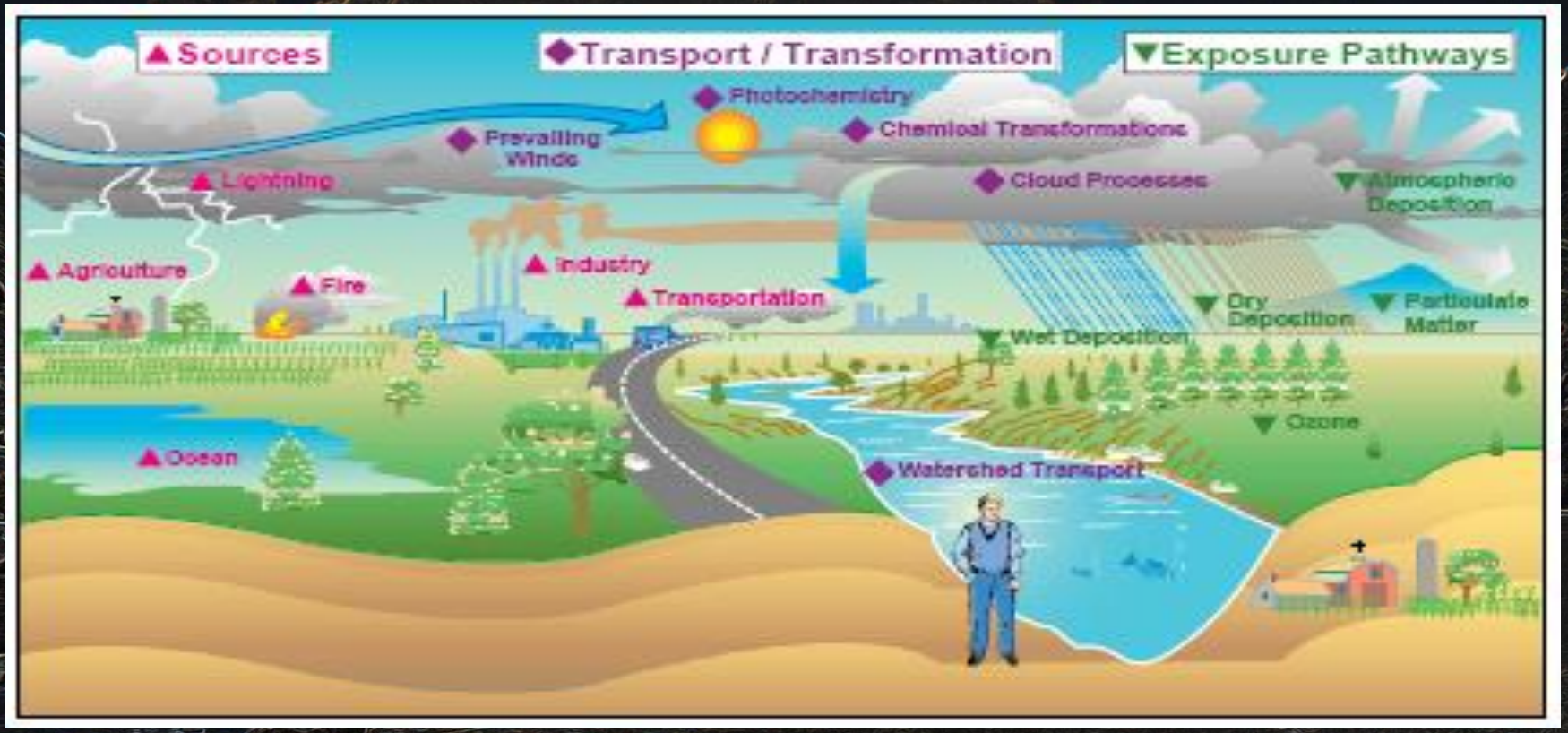
Class I Areas are those Wilderness Areas (over 5,000 acres) and National Parks and Monuments (over 6,000 acres) which had been established as of 1977. This designation provides these areas special protection from the degradation of air quality by human-caused air pollution.

Class II areas are all lands not designated as Class I. The Forest Service manages Class II Wilderness Areas under mandates found in the Wilderness Act. These mandates provide for more conservative management of air quality than those lands that are simply designated as Class II.



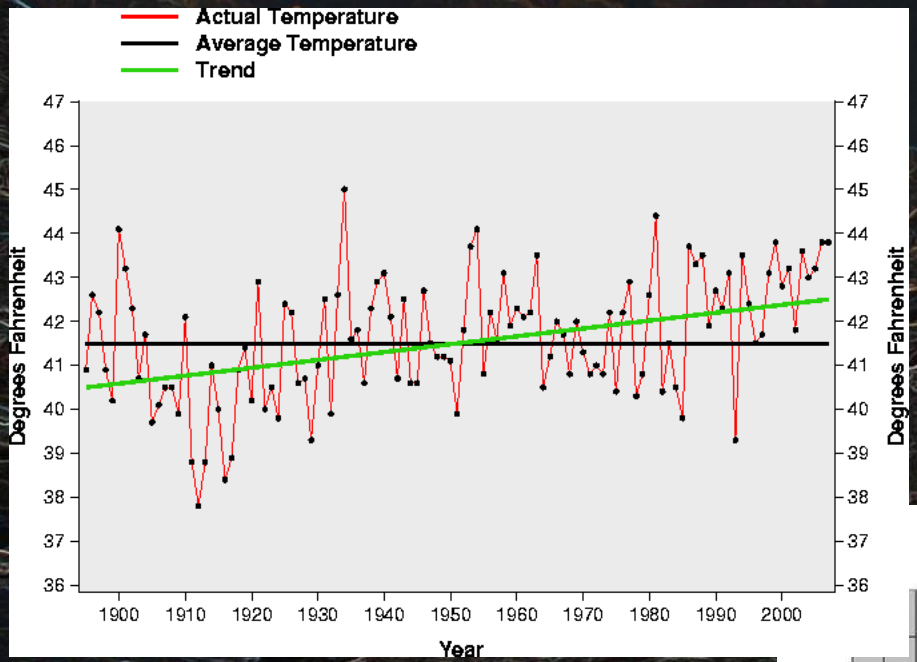
It’s All Connected

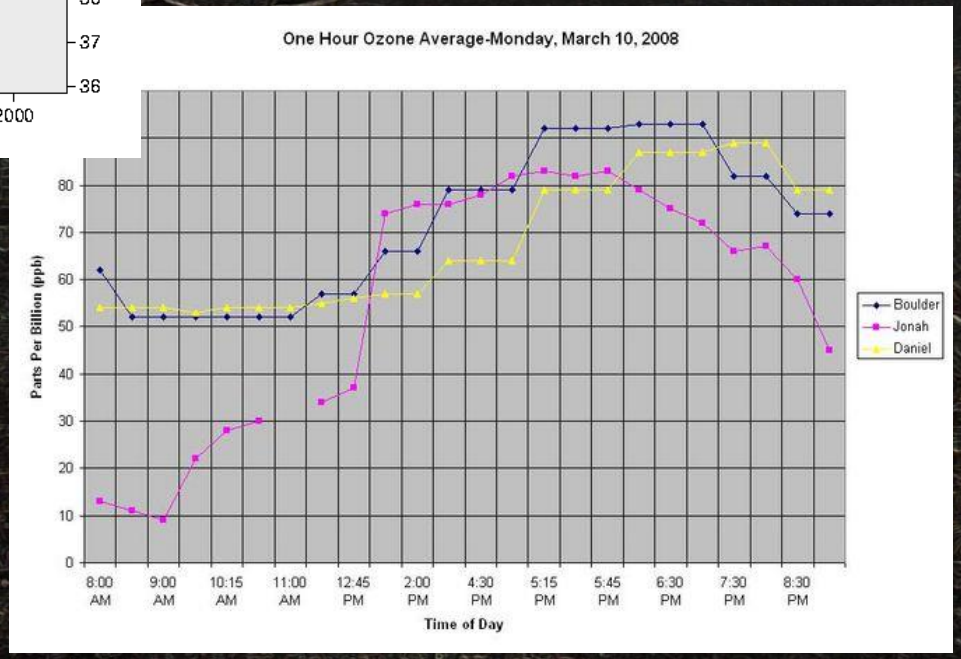




Source	Emissions	Deposition
Combustion: Vehicles Energy development Energy production	**NO_x** **SO** **VOCs**	**NO_3^-** **HNO_3**
Agriculture: Livestock production Crop production	**NH_3**	**NH_4^+**

If you don’t like the Air Quality, just wait 15 minutes





Wilderness Air Quality Concerns

- **Nitrogen and Sulfur deposition**
  - Water, soil and vegetation changes
  - From agricultural and transport sources
    - Enhanced sensitivity in particular high altitude lakes

- **Air Toxics**
  - Mercury and BTEX emissions
  - From natural and various man-made sources
    - i.e. forest fires, geothermal, snowmobiles, traffic, natural gas processing, condensate tanks, pipelines, fracking

- **Visibility**
  - Standard Visual Range of 180 miles reduced to less than 70 miles on high pollution days
  - Haze from particles inorganic and organic
    - Smoke and oil and gas sources contribute

- **Ozone**
  - Vegetation and people are sensitive to elevated ozone pollution
  - New phenomenon of winter ozone
    - From oil and gas emissions in the UGRB

State of the Science in the GYA: What is the problem?

- Nitrogen deposition is increasing in many regions of the GYA
- Some GYA lakes are likely experiencing eutrophication
- Some GYA lakes are beginning to show signs of acidification
- Lake sediment cores show increasing influence of anthropogenic Nitrogen
- Critical loads of deposition established for other areas suggest that additional effects on lichen, soils, alpine vegetation may soon occur in GYA

Air Quality Impact Thresholds

Pollutant Load

SO4, NH4, NO3
Hg, POPs
NOx, SO2

Annual averages
Seasonal patterns

Chemical Variables

ANC, pH, Nitrogen,
Base Saturation, Ca/Al

Annual averages
Seasonal extremes

Biological Responses

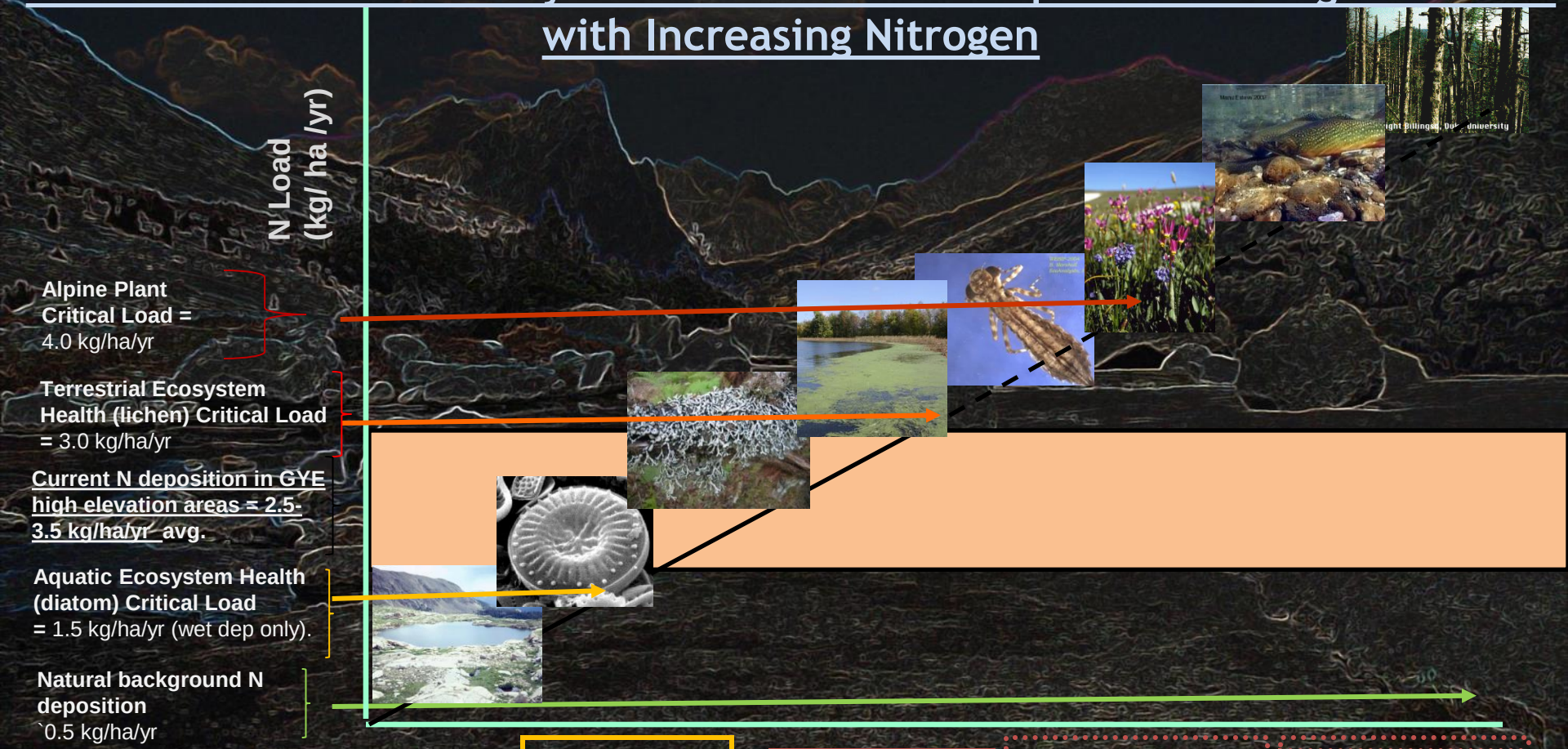
Death of Indicator species, Decline in Condition of individuals
Decreased Reproductive Success

Loss of species
Change in biodiversity

"Critical Load"-
deposition loading at which something happens in an ecosystem

"Ecological Threshold" -
Chemical or biological limit defining when "something happens" in an ecosystem

Greater Yellowstone Ecosystem: Continuum of Impacts to Ecological Health with Increasing Nitrogen



Changes in water chemistry

Increase in "weedy" lichen species

Change in macroinvetebrate diversity

Effects on aquatic animals (episodic acidification)

Forest decline (acidification effects on trees)

Increase in "nitrogen loving" aquatic diatom species

Surface water N saturation (NO3 at lake outlet)

Change in alpine plant diversity

Lethal effects on fish, other aquatic animals (chronic acidification)

Good ecosystem science can be used to develop a sound basis for pollution reduction strategies

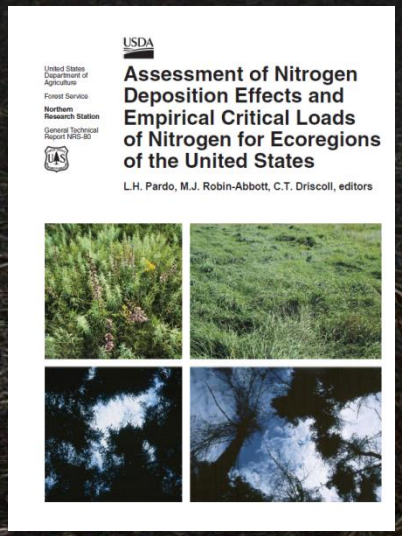
Critical loads are established by scientists by determining cause and effect (how much deposition causes change to some part of an ecosystem)

Target loads are goals that can be established by FLMs, states or other stakeholders to designate how much or how fast we want ecosystem recovery to occur

Establishing Critical Loads For The GYA

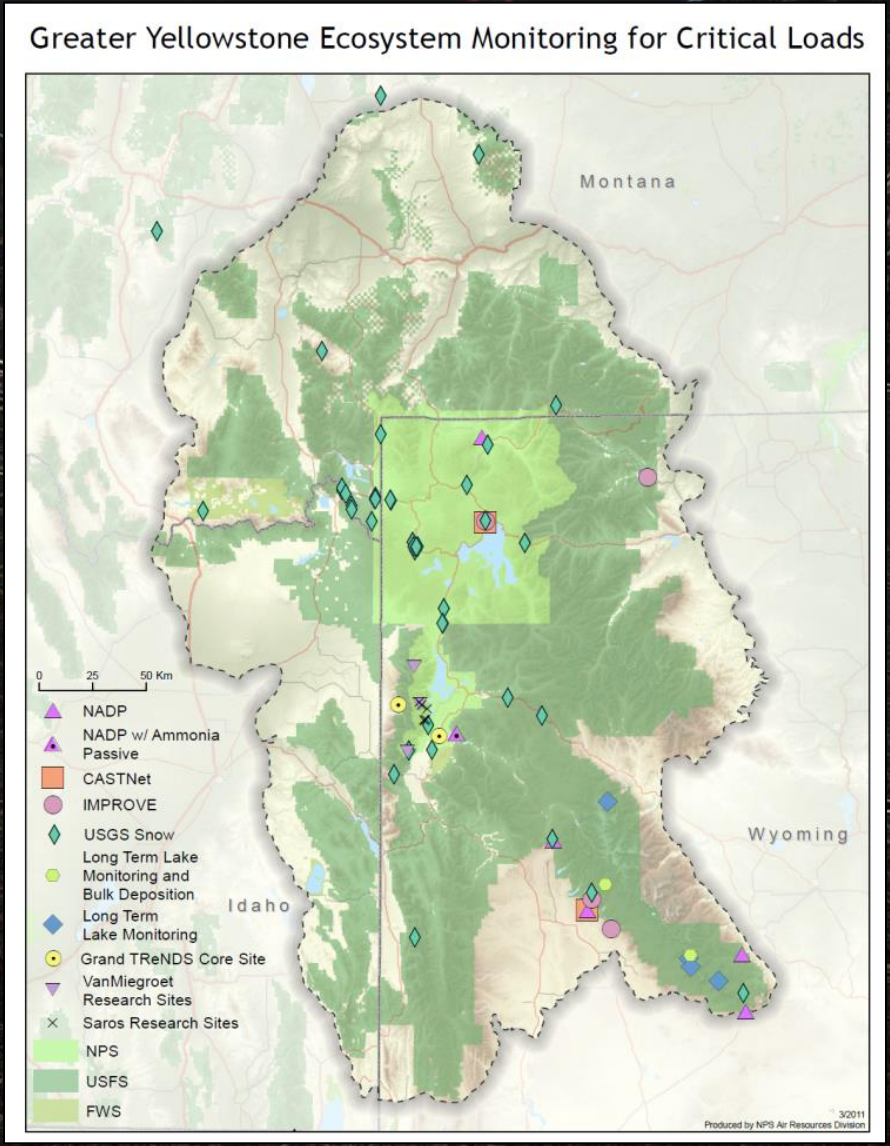
Table 8.1—Observed and modeled responses to N inputs for the Northwestern Forested Mountains ecoregion. Reliability rating: ## reliable; # fairly reliable; (#) expert judgment

Ecosystem	Site	N deposition $kg\ ha^{-1}\ yr^{-1}$	Reliability	Response	Comments	Study
Coniferous forest	Alaska	1.2-3.7	(#)	Lichen community composition	Application of western Oregon and Washington model	Geiser et al. 2010
Alpine lake	S. Rockies/Loch Vale RMNP	1.5	##	Diatom assemblages	Wet deposition estimate	Baron 2006
Coniferous forest	Northwestern Forested Mountains, non-Alaska	2.5-7.1	##	Lichen community composition	Application of western Oregon and Washington model, Sierra thresholds	Geiser et al. 2010
Alpine	S. Rockies/ Rocky Mountain National Park	3-4	(#)	Soil chemistry		Baron et al. 1994
Coniferous forest	Sierra Nevada	3.1-5.2	##	Lichen community composition	N measured as canopy throughfall	Fenn et al. 2008
Subalpine Forest	S.Rockies/12 stands of paired high and low N deposition	<4	##	Foliar chemistry, mineralization, nitrification, initial increases in N leaching below the organic layer	Effects are cumulative over time	Rueth and Baron 2002
Subalpine Forest	S. Rockies/fertilized plots in Fraser and Loch Vale	<4	##	Foliar chemistry, mineralization, nitrification	Effects are cumulative over time	Rueth et al. 2003
Alpine vegetation	S. Rockies/ Niwot Ridge	4	##	Species composition ; individual species responses		Bowman et al. 2006
Alpine lake	S. Rockies/Niwot	4.0	#	Episodic freshwater acidification		Williams and Tonnesson 2000
Hardwood and coniferous forests	Columbia River Gorge	4-5	#	Lichen community composition	N measured as canopy throughfall	Geiser et al. in 2010
Alpine stream	S. Rockies/Loch Vale RMNP	5	(#)	Episodic freshwater acidification		Baron and Hartman[a], model results
Alpine and subalpine lakes and streams	Sierra Nevada	> 5	##	NO_3^- leaching	Increased NO_3^- leaching not observed at the highest deposition (5 kg ha^{-1} yr^{-1})	Sickman et al. 2001

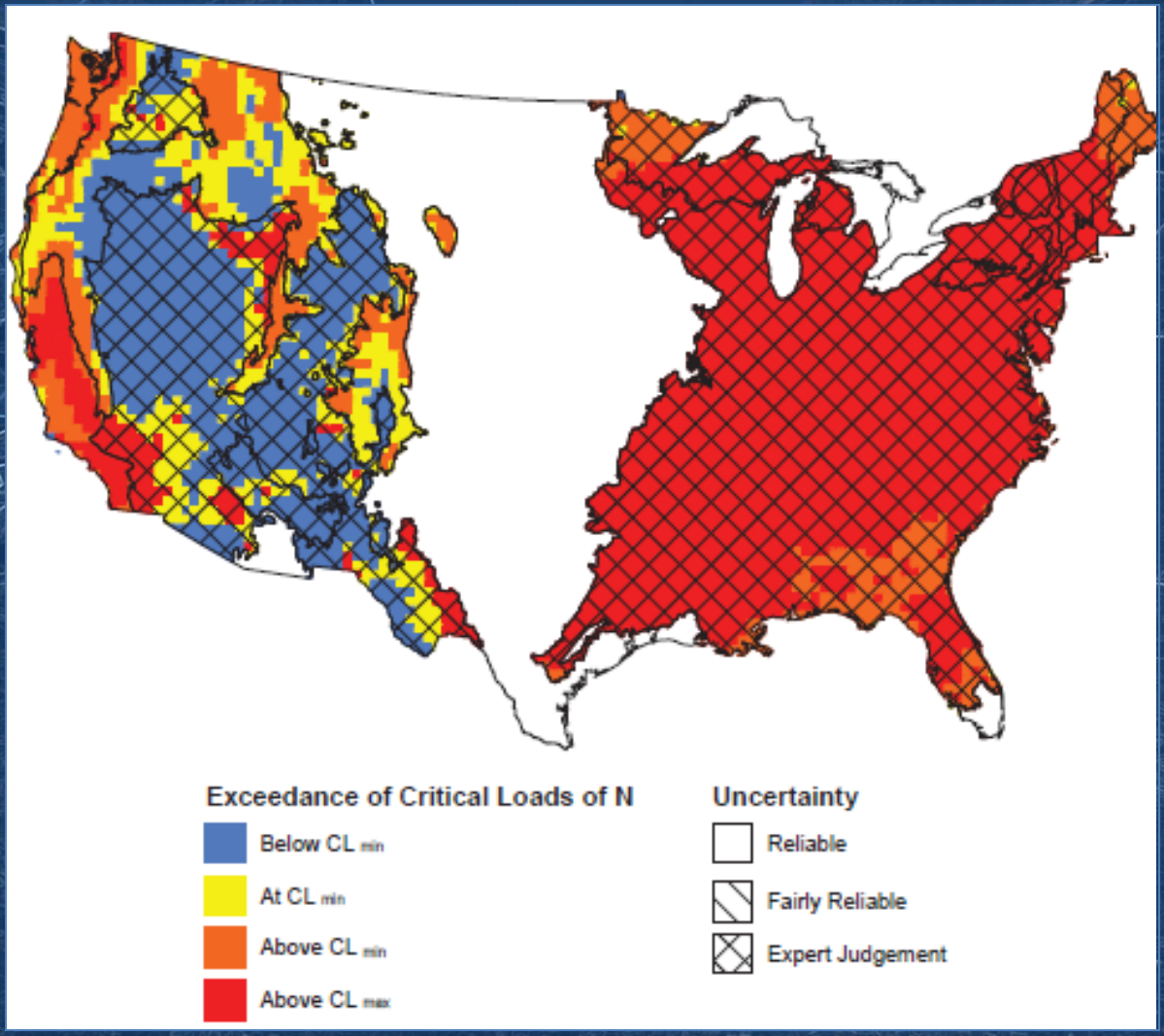


Methods for Estimating Deposition

- Deposition Monitoring
  - NADP
  - CASTNet
  - Passive Ammonia
  - Bulk sampling
    - Snow surveys (USGS)
    - Containers
    - Ion exchange resins
    - Lichens
- Deposition Models
  - Using PRISM (a precipitation model)
  - CMAQ emission-based model



Nitrogen deposition exceedance of critical loads for lichen



Studies in the Rocky Mountains indicate:

3-4 kg/ha/yr is N critical load for faster growth of alpine grasses:

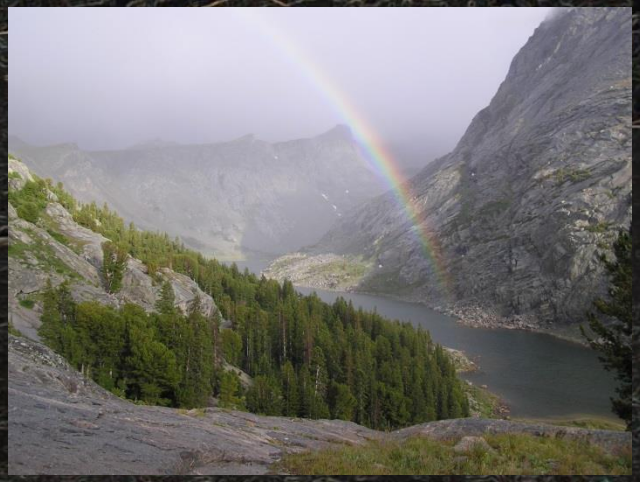
Since current GYA deposition is at or greater than this amount, alpine plants may be affected now…

Air Quality Monitoring in the Bridger Wilderness

1984 - 2014

In March of 1984 a workshop was held at Colorado State University. A diverse group of scientists and stakeholders was assembled to identify AQRVs (Air Quality Related Values) in the Wind River Mountains and to suggest possible long term monitoring strategies to track trends in the health and function of these systems.

With the help of this group, the Forest Service took on the challenge by establishing baseline conditions in the Bridger, Fitzpatrick and Popo Agie Wilderness Areas and began long term monitoring of several of these sensitive resources. At the outset of this monitoring the main concern was the effect of Acid Rain on a landscape that has very little buffering capacity, due to its granitic geology, poorly developed soils and sensitive aquatic systems.



Over the past 30 years the Forest Service has been monitoring the deposition of pollutants and their corresponding effects on aquatic systems, vegetation and visibility, among other things. This work has taken place in all seasons and conditions using minimum tools and primitive transport in remote portions of the Wind River Wilderness Areas.

In those 30 years new threats have emerged. Roughly 10,000 new natural gas wells have been completed directly upwind of the Wind River Mountains with another roughly 8,000 proposed and currently being analyzed.

Increased deposition of atmospheric Nitrogen has the potential to alter systems which have been Nitrogen limited, and studies indicate it is already affecting Wilderness resources.

Localized increases in SO2 deposition buck national and regional trends of decreasing sulphur emissions. The larger air quality issue of climate change threatens to alter natural processes and confound current conditions and trends.

As part of our Long Term lake sampling we continue to sample aquatic organisms. Macro invertebrates and zooplankton are sampled on an annual basis.

Synoptic Lake Sampling

The Bridger-Teton N.F. has sampled approximately 165 lakes as part of our synoptic and long term lake sampling programs. In addition there were 10 lakes sampled on the Wind River Reservation. Since 1996, we have identified 22 sensitive lakes with ANC's less than 50 ueq/l in the Wind River Range.

Bridger Wilderness Air Quality Related Values Monitoring

USFS Monitoring

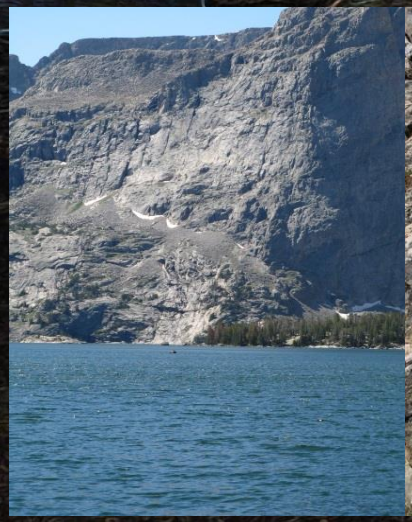
- **Deposition**
  - NADP (4 monitors)
  - Bulk Deposition (2 Monitors)
- **Lake Chemistry** (6 long-term lakes)
  - Inlet
  - Outlet
  - Hypolimnion
  - Epilimnion
  - Macroinvertebrates
- **Visibility**
  - Aerosol (2)
  - Transmissometer
  - Camera

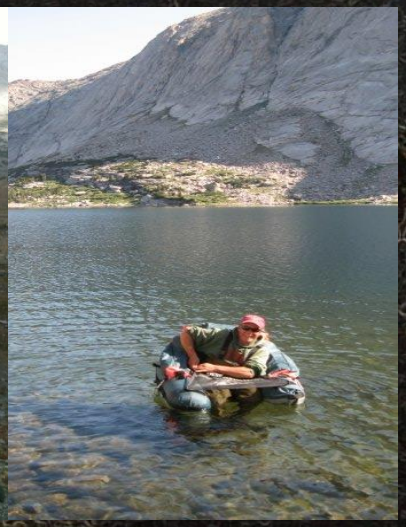
Why are high elevation areas in GYA at risk? Why should we care?

- Shallow soils
- Granitic bedrock
- Scant vegetation
- Higher precipitation/deposition

Significant Trends for Long-Term Lakes (1984-2010)

	Black Joe (BTNF)			Hobbs (BTNF)			Deep (BTNF)			Ross (SNF)			Lower Saddlebag (SNF)		
	Inlet	Outlet	Hypo	Inlet	Outlet	Hypo	Inlet	Outlet	Hypo	Inlet	Outlet	Hypo	Inlet	Outlet	Hypo
ANC	–	–	–	–	↓	–	–	–	–	↓	↓	↓	↓	–	–
NH4	–	↑	↑	↑	↑	↑	–	–	↑	ND	ND	ND	ND	ND	ND
NO3	↑	–	–	–	–	↓	–	–	↑	↑	–	–	↑	–	↑
SO4	↑	–	–	–	–	–	–	–	–	–	↓	↓	–	–	–
ND=Not Determined															





Summary of Nitrogen concentration and ANC changes in GYA lakes

Impact to Lakes:	Location	# Sites
Lake water N ↑ (Eutrophication)	Wind River Range – (Ross, L. Saddlebag, Black Joe, Hobbs)	4/6
Lake water ANC↓ (Acidification)	Wind River Range (Ross, Hobbs & L. Saddlebag lakes)	3/6
Sediment N source change from natural to man-made	Grand Teton NP (high-elev. Lakes)	7/7

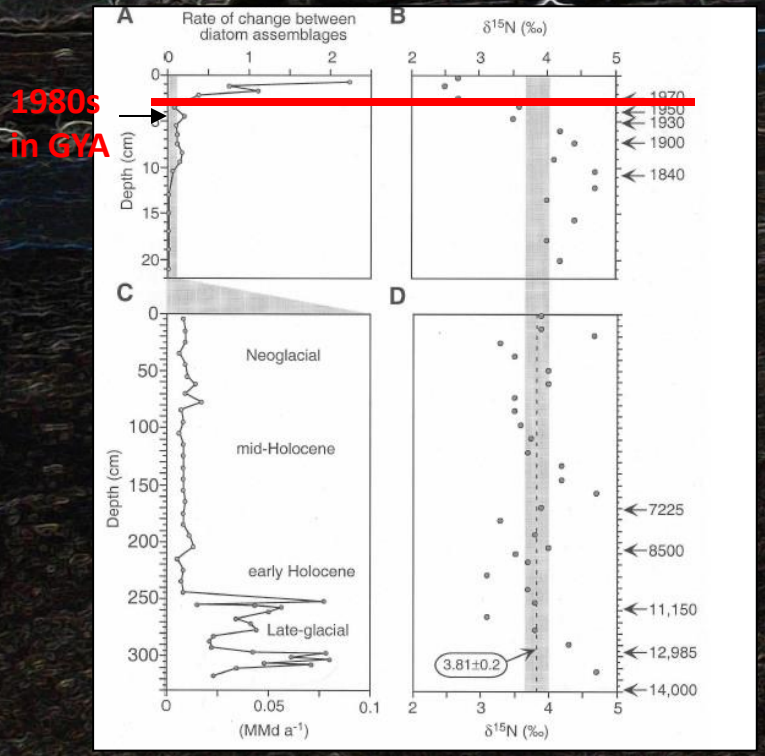
Lichen, aquatic plants, alpine grasses: at CL soils are likely affected also…

Diatom Species

Lake Sediments: Time machines to see Past Environmental Changes

Changes in aquatic plant species represent biological evidence that some high elevation lakes have shifted from undisturbed to disturbed (weedy) systems- which are unnatural–

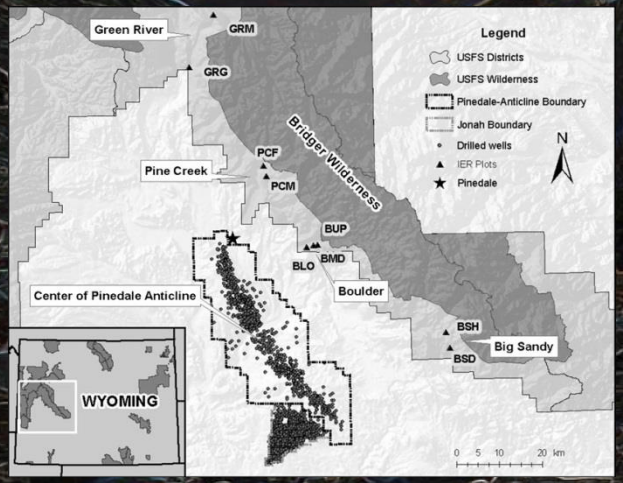
Sediment Cores Show sensitive Rocky Mountain lakes have Changed More in past few decades than Previous 14,000 Yrs



- Species shift to 2 disturbance species: *Asterionella formosa* and *Fragilaria crotonensis.* (indicators of nutrient-rich waters)
- GYA data supporting this is from Absaroka-Beartooth wilderness

Wolfe et al 2003; Baron, 2006: Saros 2003

Bridger-Teton Lichen Monitoring



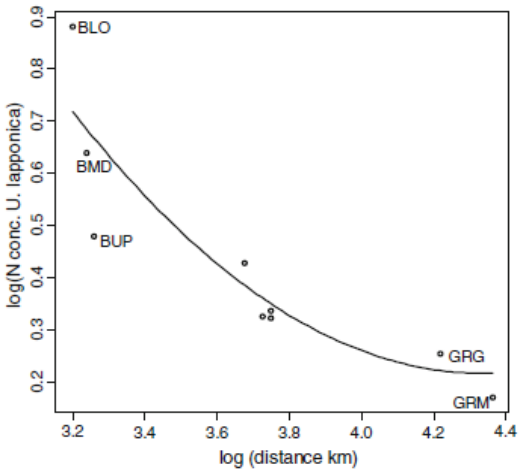


Fig. 4 Log transformation of both nitrogen concentrations in *U. lapponica* and distance from the center of the Pinedale Anticline natural project area. $R^2=0.76$, $p=0.006$. Curve$=7.54-3.38x+0.39x^2$. *GRM* Green River Moose Creek, *GRG* Green River Gypsum Creek, *BLO* Boulder low, *BMD* Boulder middle, *BUP* Boulder up. The three points in the center of the graph are not co-located

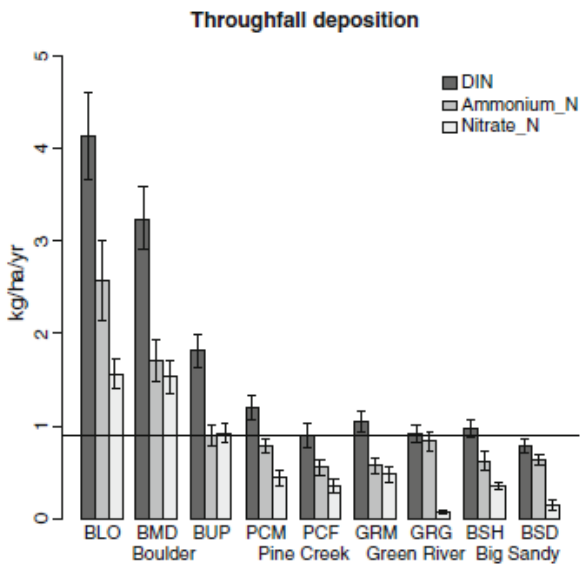
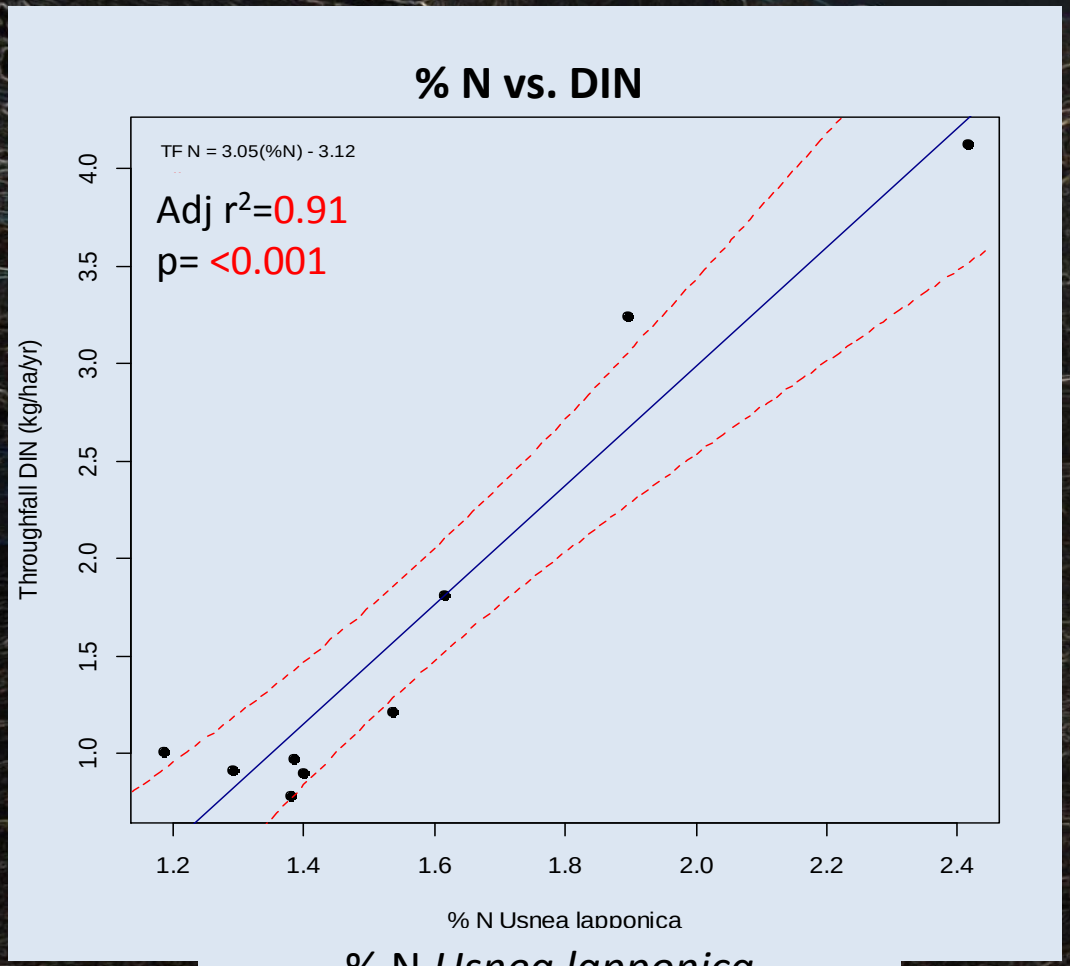


Fig. 5 Annual throughfall N deposition from four drainages in the Wind River Range. DIN refers to total dissolved inorganic N (ammonium N plus nitrate N). The horizontal line represents background levels of N deposition in the Northern Rockies as estimated by Sverdrup et al. (2012)

Good correlation of DIN between through fall deposition and Lichen tissue



% N *Usnea lapponica*

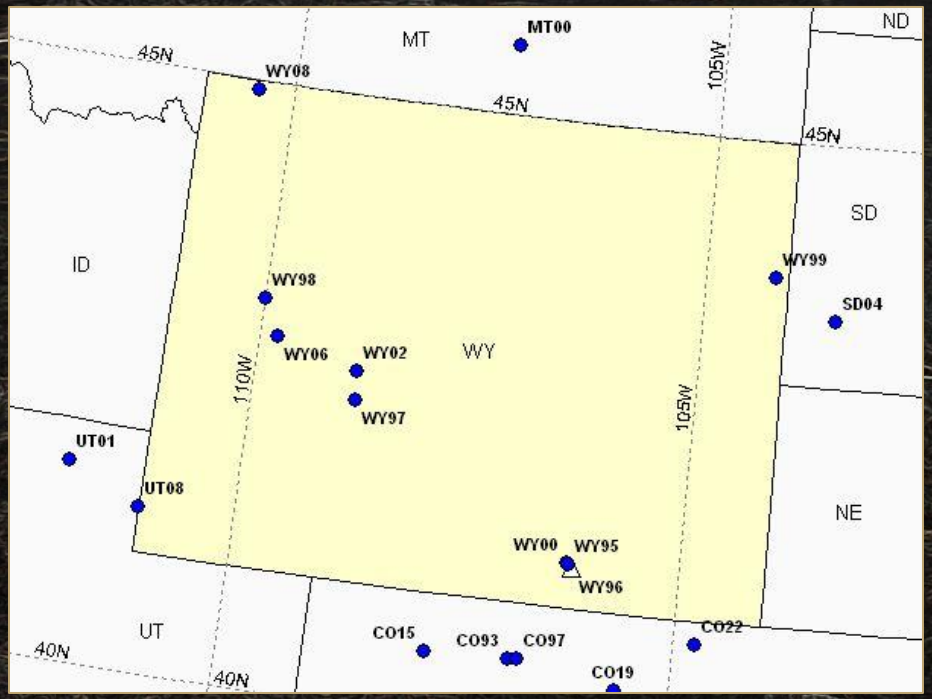
Annual Bulk Deposition Trends at Hobbs and Black Joe Collectors (1984-2010)

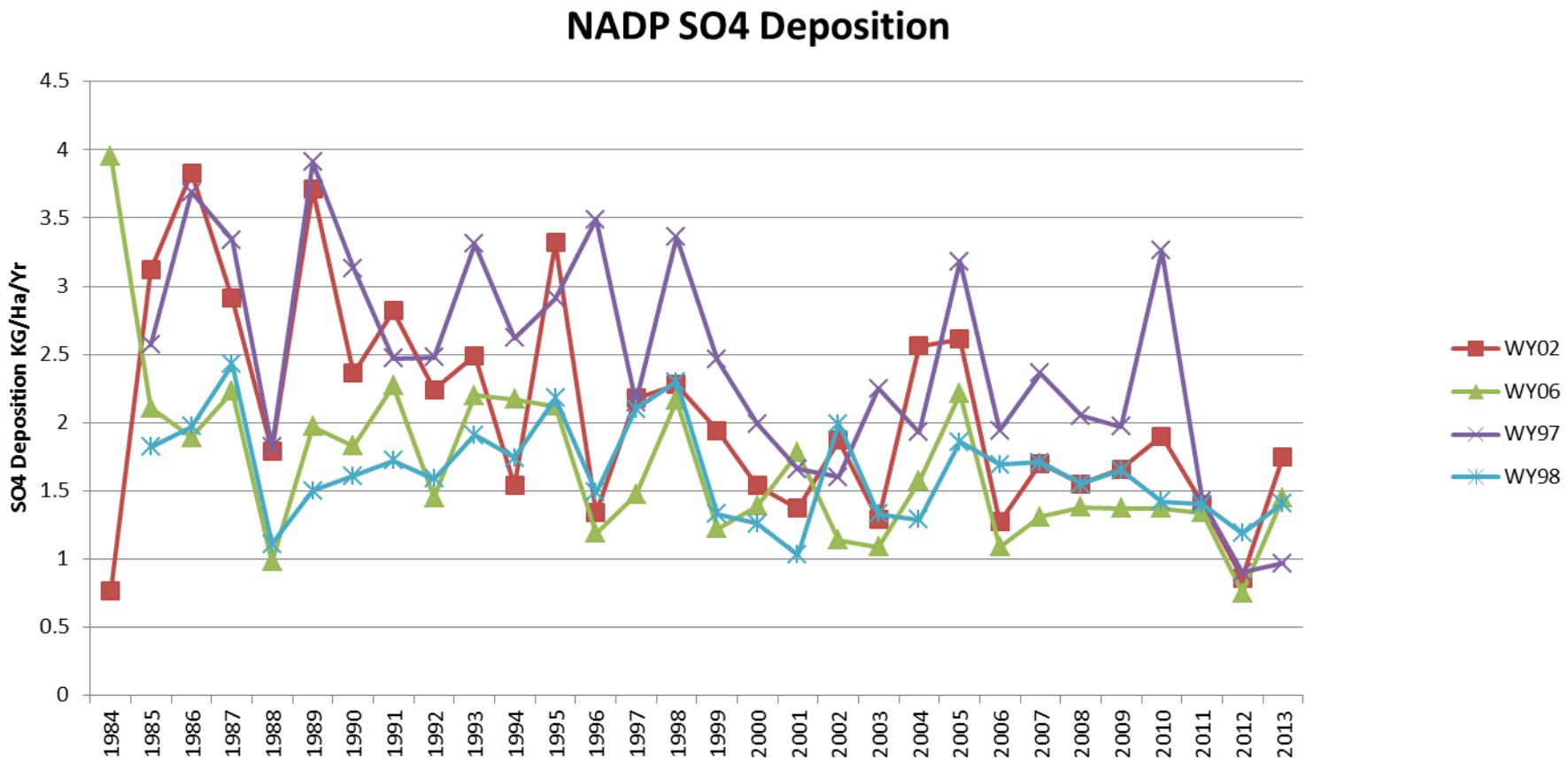
Variable kg/ha	Hobbs (BTNF)	Black Joe (BTNF)
NH_4^+	*** ↑	** ↑
NO_3^-	*** ↑	* ↑
Total N	*** ↑	** ↑
SO_4^{2-}	---	---
Precipitation	** ↑	---

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

NADP Annual Trends (1986-2010)

Variable	Yellowstone (NPS)	Gypsum Creek (BTNF)	Murphy Ridge (BLM)	Pinedale (BLM/BTNF)	Sinks Canyon (BLM)	South Pass (BTNF/SNF)
NH4	↑	↑	↑	↑	↑	↑
NO3	–	–	–	–	–	↑
SO4	↓	↓	↓	↓	↓	↓




NADP SO4 Deposition
SO4 Deposition KG/Ha/Yr
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
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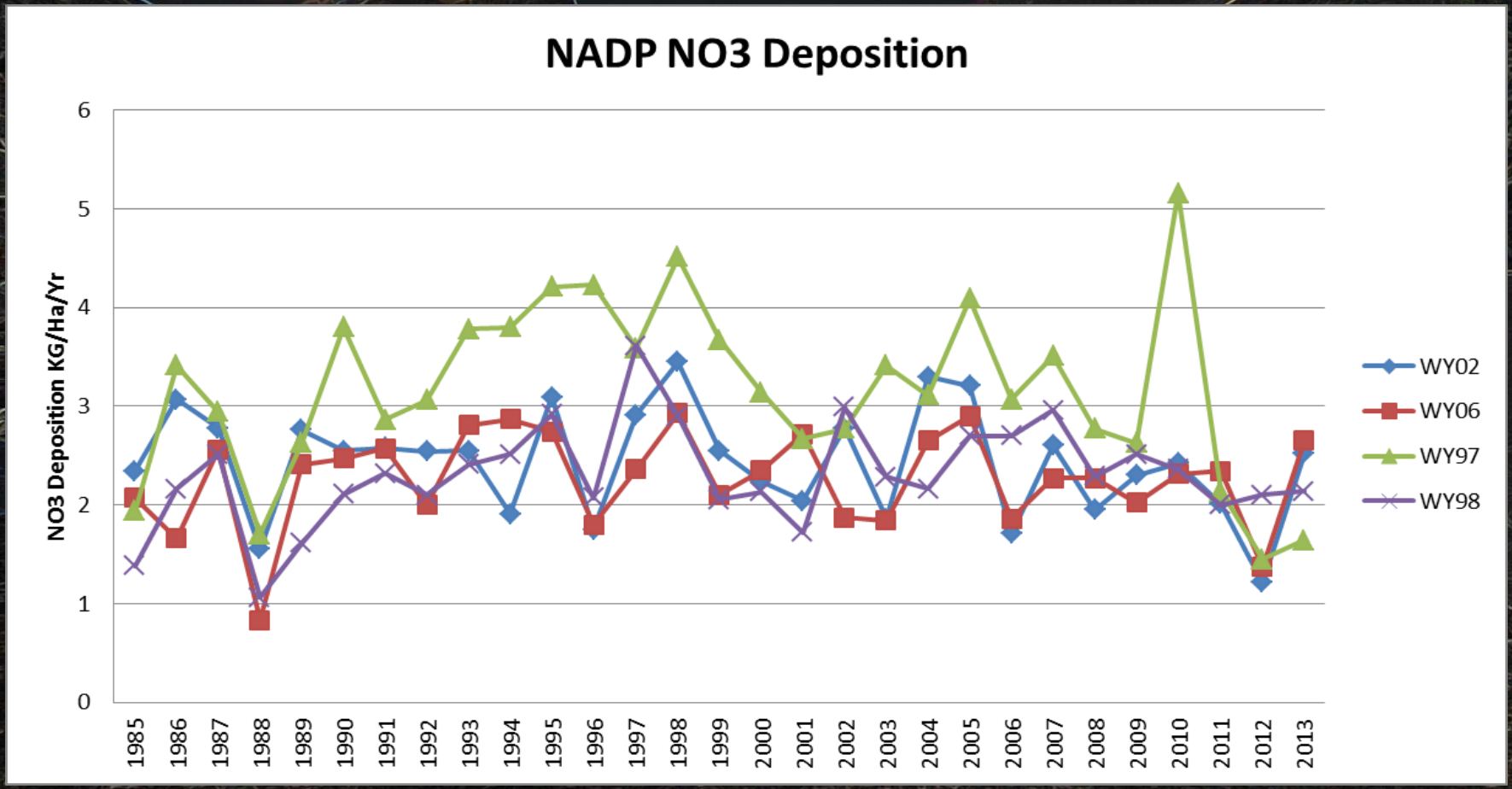
2009
2010
2011
2012
2013
WY02
WY06
WY97
WY98


NADP NO3 Deposition
NO3 Deposition KG/Ha/Yr
0
1
2
3
4
5
6
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
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2006
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2008
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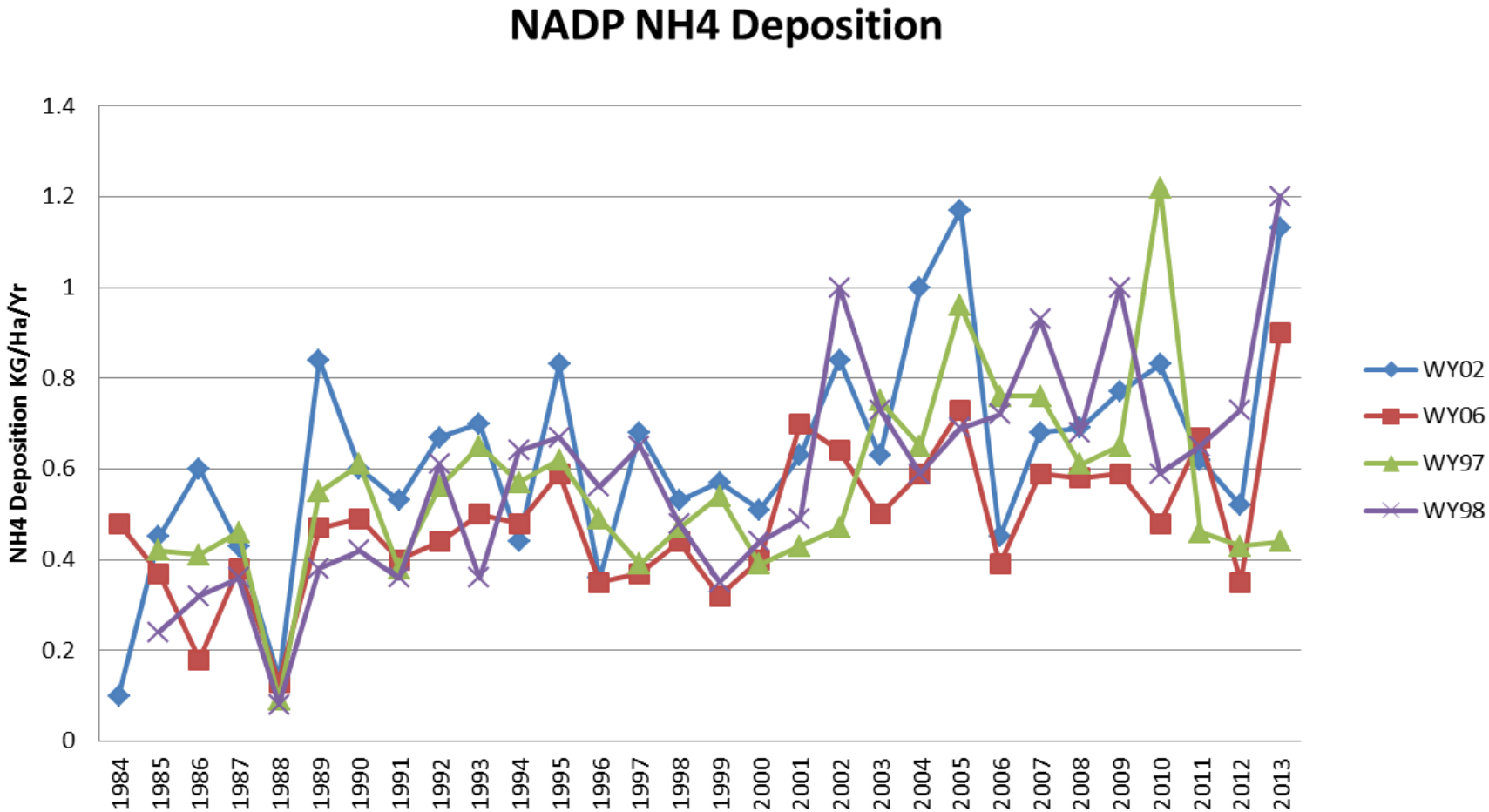
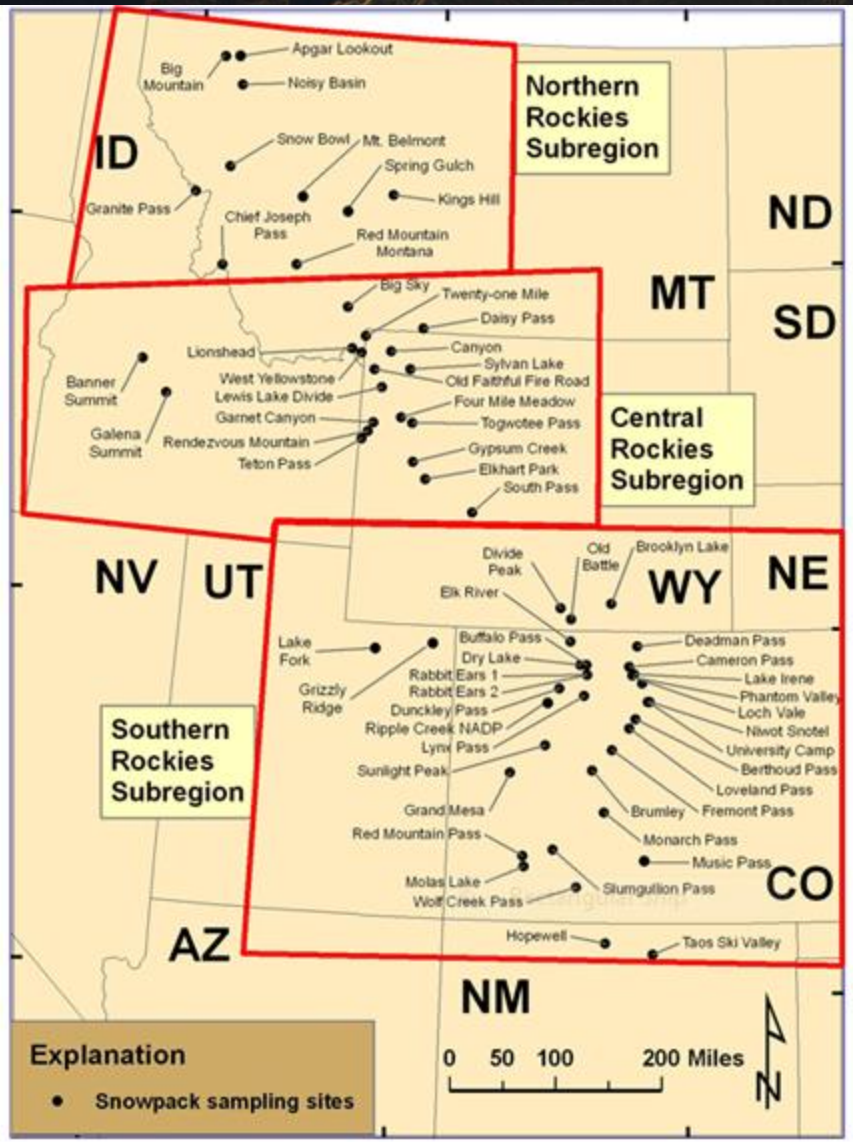
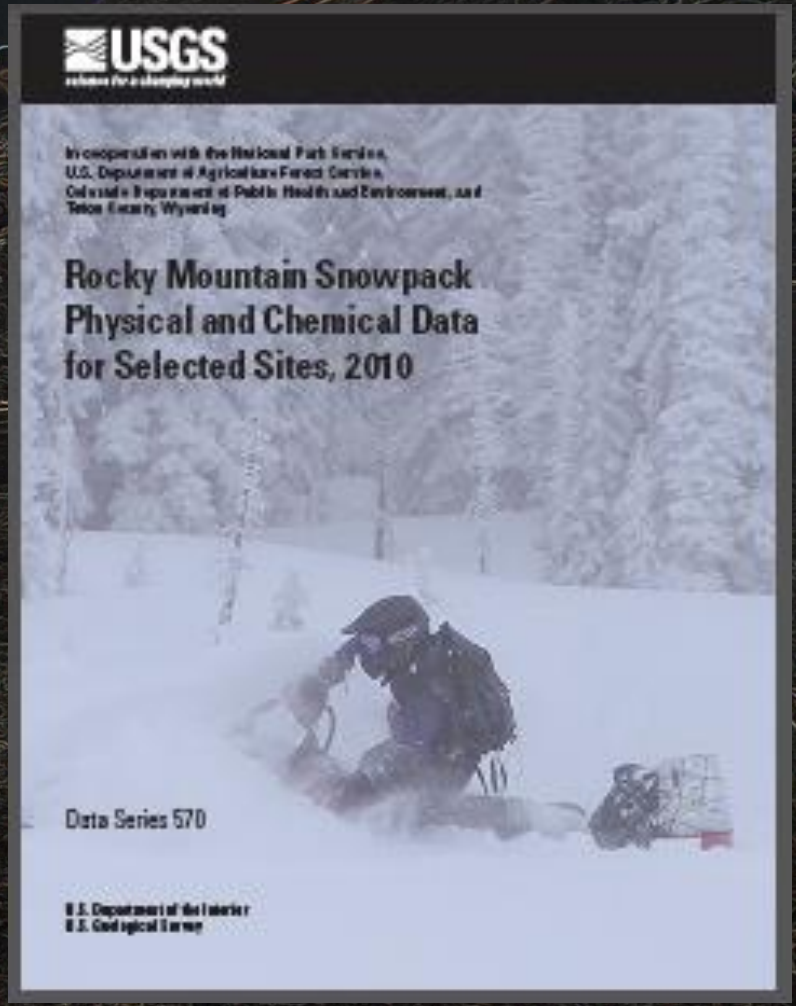
WY02
WY06
WY97
WY98

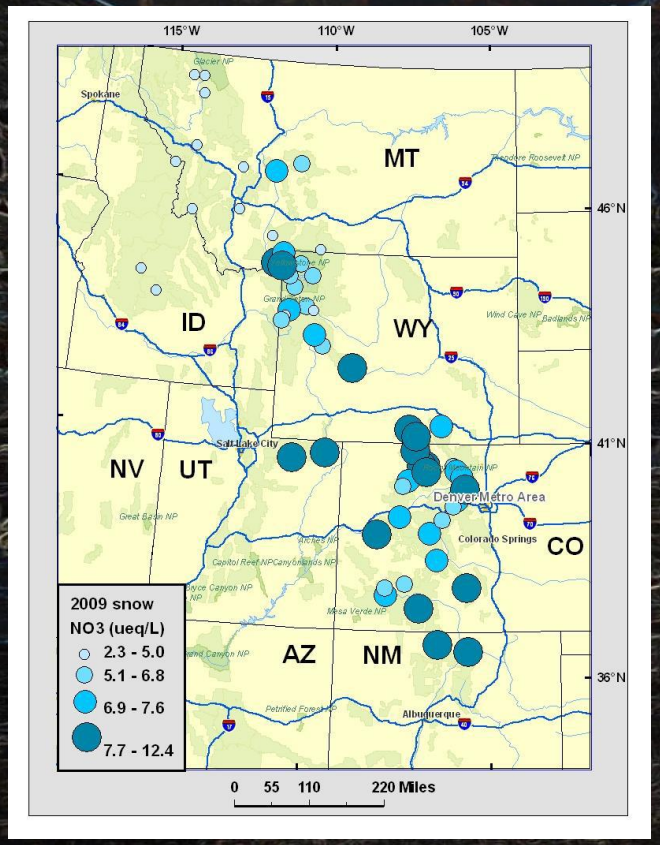

NADP NH4 Deposition
NH4 Deposition KG/Ha/Yr
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
WY02
WY06
WY97
WY98

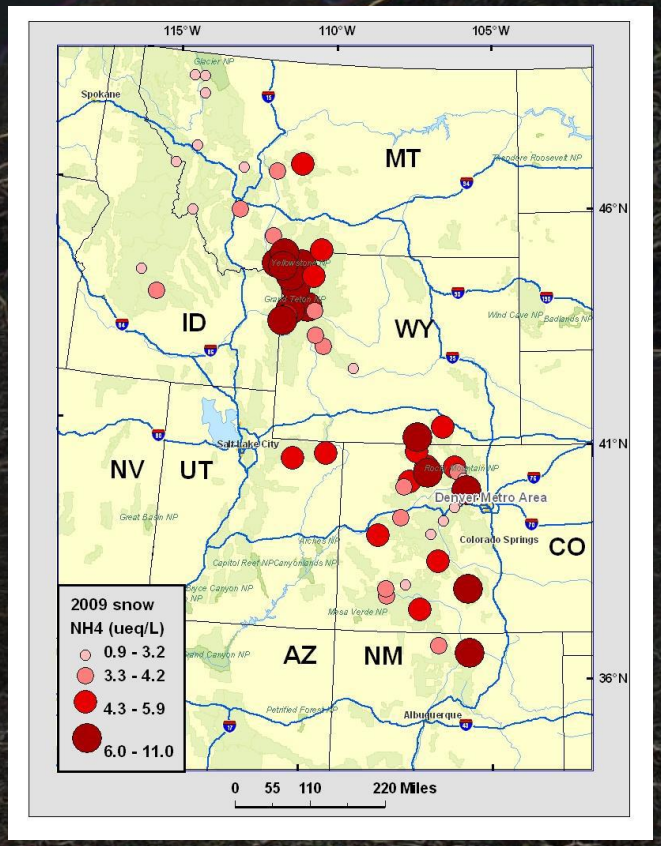
USGS Snowpack Chemistry Monitoring


Northern Rockies Subregion
Central Rockies Subregion
Southern Rockies Subregion
ID
MT
ND
SD
NV
UT
WY
NE
CO
AZ
NM
46°N
41°N
36°N
Apgar Lookout
Big Mountain
Noisy Basin
Snow Bowl
Mt. Belmont
Spring Gulch
Kings Hill
Granite Pass
Chief Joseph Pass
Red Mountain Montana
Big Sky
Twenty-one Mile
Daisy Pass
Lionshead
Canyon
Sylvan Lake
Old Faithful Fire Road
Banner Summit
West Yellowstone
Lewis Lake Divide
Four Mile Meadow
Garnet Canyon
Togwotee Pass
Galena Summit
Rendezvous Mountain
Gypsum Creek
Teton Pass
Elkhart Park
South Pass
Divide Peak
Old Battle
Brooklyn Lake
Elk River
Lake Fork
Buffalo Pass
Deadman Pass
Dry Lake
Cameron Pass
Rabbit Ears 1
Lake Irene
Grizzly Ridge
Rabbit Ears 2
Phantom Valley
Dunckley Pass
Loch Vale
Ripple Creek NADP
Niwot Snotel
Lynx Pass
University Camp
Sunlight Peak
Berthoud Pass
Loveland Pass
Grand Mesa
Brumley
Fremont Pass
Red Mountain Pass
Monarch Pass
Music Pass
Molas Lake
Slumgullion Pass
Wolf Creek Pass
Hopewell
Taos Ski Valley
0 50 100 200 Miles
N
Explanation
Snowpack sampling sites


USGS
Rocky Mountain Snowpack Physical and Chemical Data for Selected Sites, 2010
Data Series 570

USGS Snowpack Surveys





- Measures concentrations of sulfate, nitrate, and ammonium in snowpack and snow water equivalence
- Represents winter bulk deposition to high-elevation sites

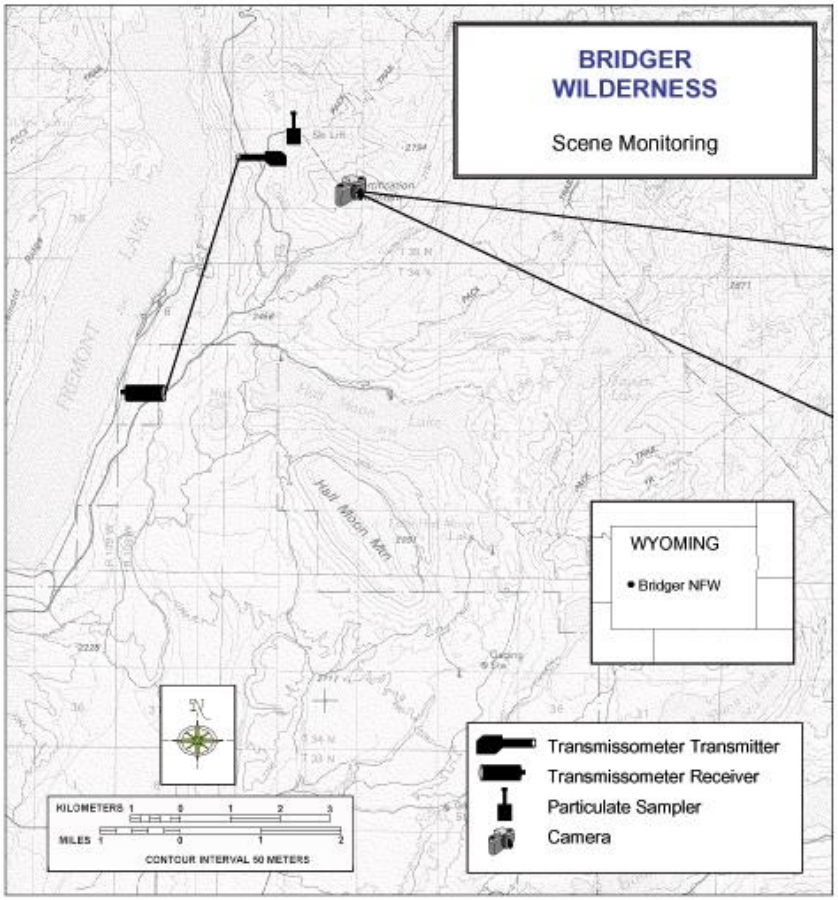
GYE = 0.3-1.8 kg/HA/YR Bulk N Deposition (Winter Season only)

Summary of N-Deposition Trends in the GYA:

Type of Monitoring	Location & Impact	# Sites	Source Implications?
N deposition in rain & snow	↑ GYA-wide	6/8	Effects are widespread in GYA
Ammonium (NH4) conc. in rain & snow	↑ GYA-wide	11/11	Agriculture likely contributor
Wet nitrate (NO3) conc.	Local increases at some GYA sites	3/11	Combustion local contributor
Air conc. of nitrate (NO3)	↑ Bridger (winter) ↑ Yellowstone (all year)	2/2	?
Bulk deposition of Total N, NH4, and NO3	↑Wind River Range	2/2	Emissions are reaching sensitive ecosystems

Weight of evidence approach

Interagency Monitoring of Protected Visual Environments (IMPROVE)



SITE SPECIFICATIONS

Site Abbreviation:	BRID
Instrument:	Automatic 35mm camera with 135mm lens
Elevation:	2860 m
Longitude:	109° 44' 50"
Latitude:	42° 58' 05"
Bearing:	107°
Map Reference:	Pinedale, Wyoming 1:100,000
Target/Vista:	Mount Bonneville
Target Distance:	35.8 km
Monitoring Period:	9/22/86 - 4/17/94

SCENE MONITORING HISTORY

35mm Camera Automatic:	9/22/86 - 4/17/94
Time Lapse:	None
Period Reviewed:	9/22/86 - 4/17/94

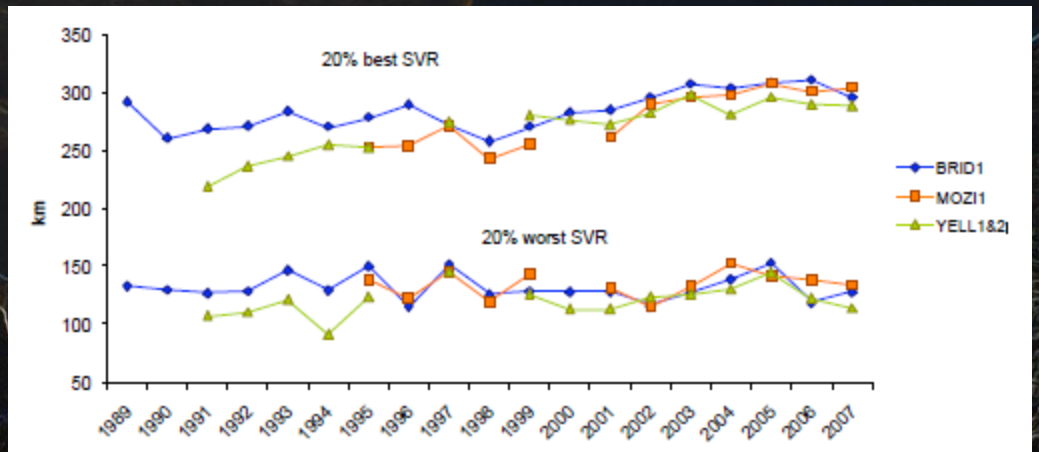
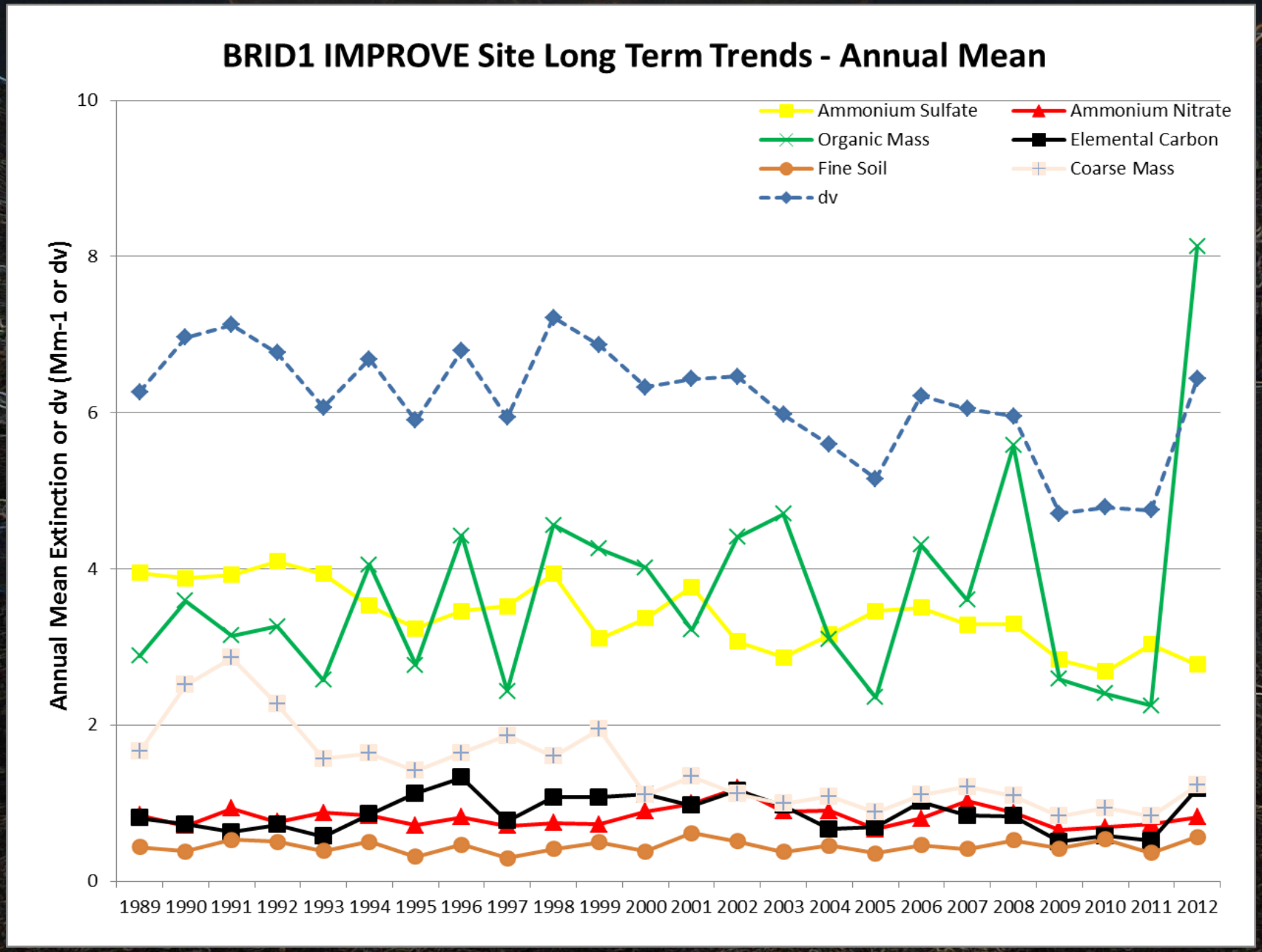
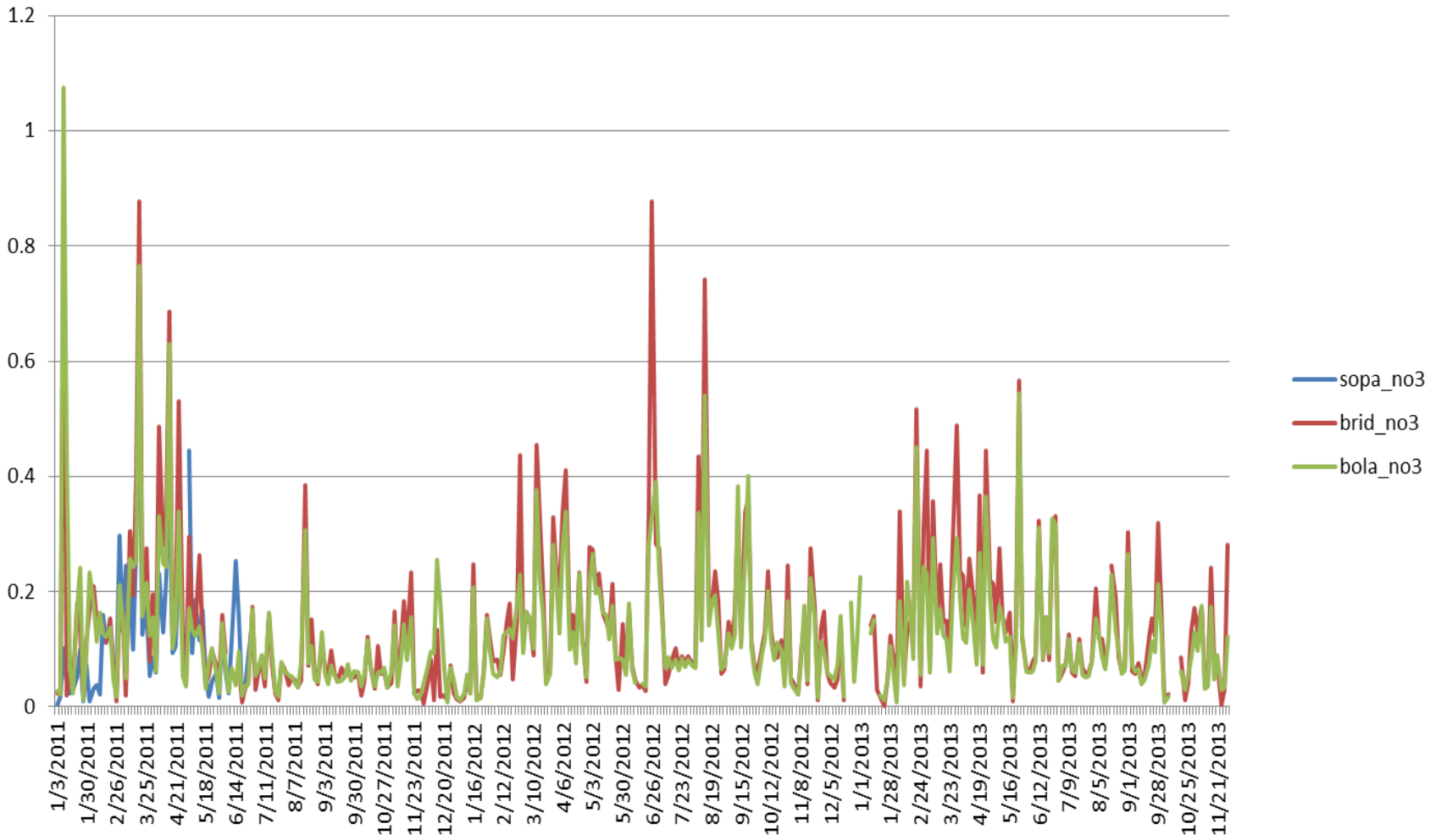


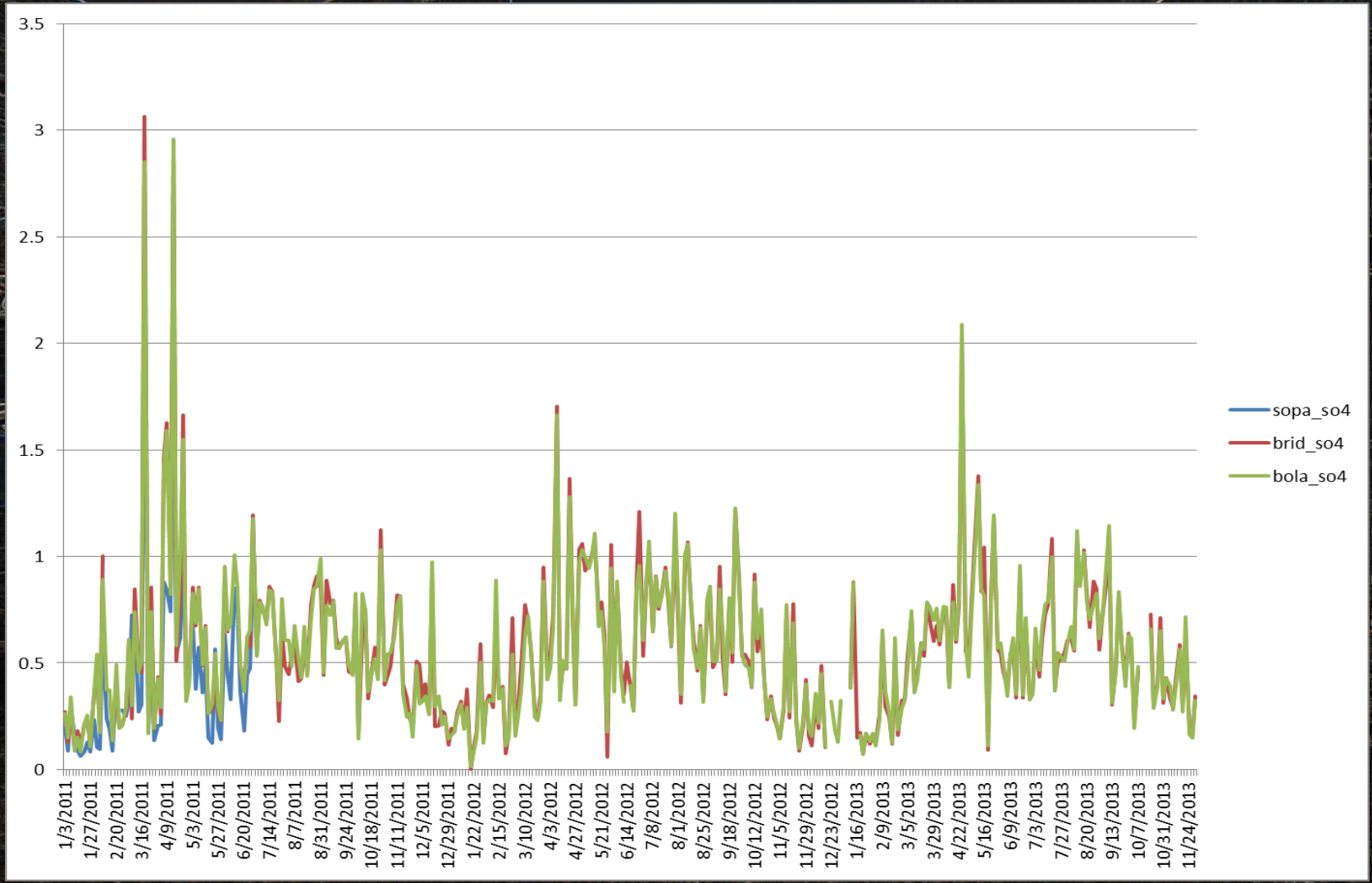
Figure 49—The 20% best and 20% worst annual average SVR at BRID1, MOZI1, and YELL1&2 IMPROVE sites.

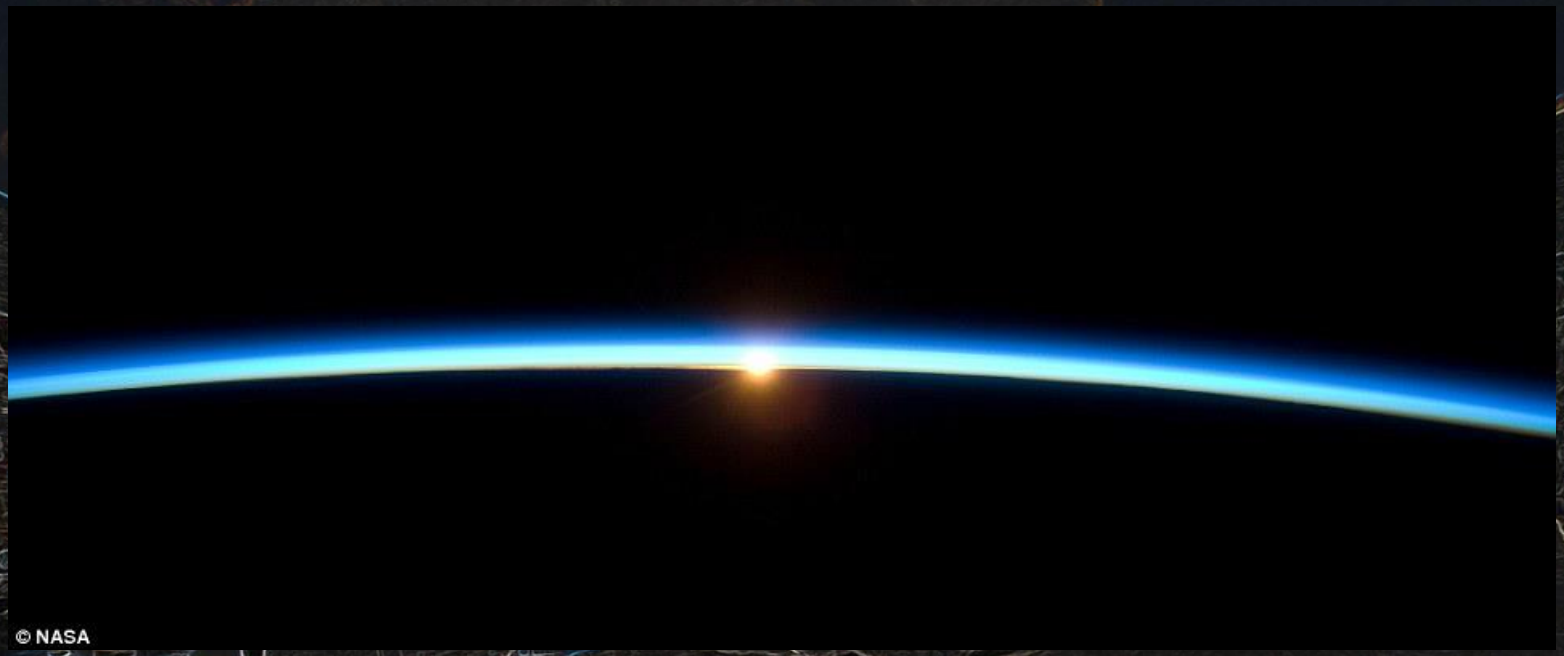

BRID1 IMPROVE Site Long Term Trends - Annual Mean
Annual Mean Extinction or dv (Mm-1 or dv)
10
8
6
4
2
0
Ammonium Sulfate
Ammonium Nitrate
Organic Mass
Elemental Carbon
Fine Soil
Coarse Mass
dv
1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012

NO3 at 3 IMPROVE Monitors



SO4 at 3 IMPROVE Monitors





The **troposphere** is the lowest portion of Earth's atmosphere and is about 7-9 miles in depth. This is about the same distance as the trip from downtown Jackson to the airport. It contains approximately 80% of the atmosphere's mass and 99% of its water vapour and aerosols.

Questions?