Effect of power-plant emission reductions on the Mount Zirkel Wilderness Area in northwestern Colorado

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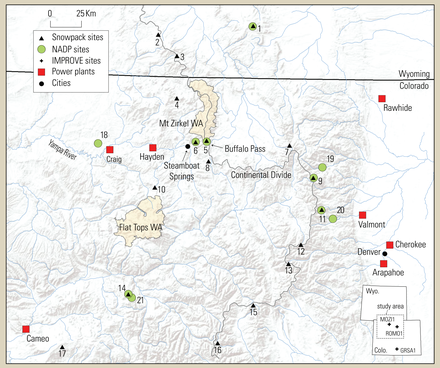
Introduction

In the early 1990s, there were concerns that sulfur dioxide (SO2) and nitrogen oxide (NOx) emissions from the Hayden and Craig power plants were contributing to air- and water-quality impairment in the Mount Zirkel Wilderness Area (MZWA) and an agreement was made between the power plants and the Forest Service, State of Colorado, Sierra Club, and U.S. Environmental Protection Agency to install emission control equipment. At Hayden the upgrades were completed in 1999 and at Craig in 2004. The emission controls resulted in a decline in SO2 emissions of 75% in just over 5 years (1999-2004). This large reduction provides a unique opportunity to investigate source-receptor relationships between SO2 emissions and air and water quality in a sensitive mountain environment directly downwind of the power plants. Because SO2 emissions have been declining across the Rocky Mountain region over the past 15 years, one of the major challenges of the study was separating out the effects of local (Hayden/Craig) from regional emission sources.

Hayden Power Plant located 30 km west of MZWA



Lake Elbert in MZWA

Seven Lakes in MZWA

Ned Wilson Lake in Flat Tops Wilderness

Snow Sampling on Buffalo Pass

Buffalo Pass NADP Station

Monitoring Data

Environmental data collected by several long-term monitoring networks in and near the MZWA during the periods before and after installation of emission controls were examined including:

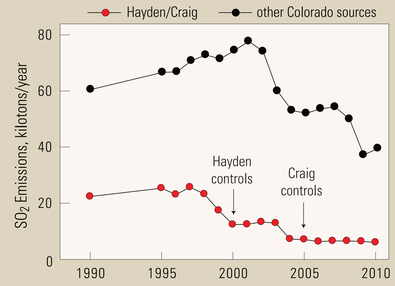
1. Chemically speciated aerosol concentrations and optical data (particle scattering) monitored at the IMPROVE station (MOZI1) on Buffalo Pass (http://vista.cira.colostate.edu/improve/)
2. Annual snowpack chemistry data at 15 stations monitored as part of the USGS Rocky Mountain Snowpack Network (http://co.water.usgs.gov/projects/RM_snowpack/)
3. Weekly wet deposition chemistry from 10 high-elevation NADP stations (http://nadp.sws.uiuc.edu/)
4. Surface-water chemistry for 28 lakes and ponds monitored during snowfree season by a long-term USGS monitoring program.

Emissions

SO_2 emissions from Hayden/Craig peaked in 1997, accounting for 27% of SO_2 emissions in Colorado.

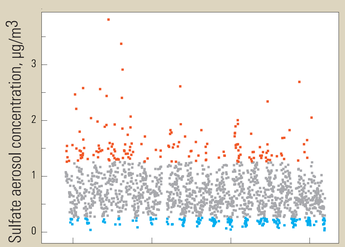
Controls resulted in a 75% reduction in SO_2 emissions at Hayden/Craig.

Regional declines of 55% in SO_2 emissions also occurred over the same period.



IMPROVE Aerosol Data

	Before (1994-1998)			After (2005-2009)					
	MOZI1	ROMO1	GRSA1	MOZI1	ROMO1	GRSA1	MOZI1	ROMO1	GRSA1
	Sulfate aerosol (μg/m³)						*% change*		
20% clearest	0.40	0.32	0.40	0.23	0.26	0.35	-42%	-19%	-13%
20% haziest	1.38	1.60	1.48	1.11	1.36	1.29	-20%	-15%	-13%
all data	0.87	0.92	0.89	0.69	0.80	0.79	-20%	-12%	-11%
	Nitrate aerosol (μg/m³)						*% change*		
20% clearest	0.07	0.05	0.08	0.08	0.05	0.08	11%	13%	-3%
20% haziest	0.20	0.54	0.28	0.26	0.70	0.28	26%	30%	-2%
all data	0.15	0.26	0.17	0.17	0.31	0.18	17%	19%	10%
	Haze Index (deciview)						*difference*		
20% clearest	2.95	3.56	4.26	0.68	2.03	3.56	-2.27	-1.53	-0.69
20% haziest	10.34	12.77	11.93	9.72	12.62	11.44	-0.63	-0.15	-0.48
all data	6.64	8.13	7.84	5.15	7.17	7.41	-1.49	-0.96	-0.43



Daily sulfate aerosol concentrations at MOZI1

Sulfate aerosol concentrations declined at MOZO1 in the after period with the largest declines on the clearest days (-42%).

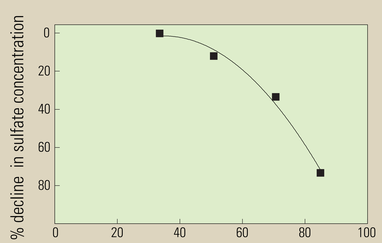
Nitrate aerosols increased in the after period despite a 30% decline in powerplant NOx emissions.

Visibility (haze index) improved most on the clearest days but changed relatively little on the haziest days.

The overall reduction in sulfate aerosols was 20% despite a 75% decline in SO_2 emissions.

A possible explanation is the slow rate at which SO_2 is converted to sulfate, particularly in dry, cloud free environments.

The % change in sulfate concentrations decreased with increasing RH suggesting this explanation is reasonable.

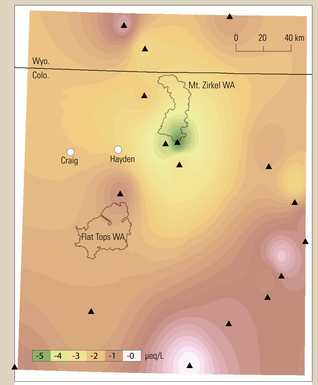


NADP Chemistry

Temporal trends in sulfate, nitrate and hydrogen ion concentrations for 1993-2010. Statistically significant trends shown in bold (p<0.05). Trend slopes in units of μeq/L/yr and elevation in meters.

No.	NADP site	Elevation	Sulfate	Nitrate	Hydrogen
1	Snowy Range (WY00)	3,286	**-0.19**	-0.15	**-0.32**
5	Buffalo Pass (CO97)	3,234	**-0.48**	-0.12	**-0.48**
6	Dry Lake (CO93)	2,538	**-0.53**	-0.15	**-0.68**
18	Sand Springs (CO15)	1,998	**-0.39**	-0.02	**-0.45**
19	Beaver Meadows (CO19)	2,490	**-0.30**	-0.19	**-0.36**
9	Loch Vale (CO98)	3,159	**-0.19**	-0.05	**-0.33**
11	Niwot Saddle (CO02)	3,520	**-0.25**	-0.12	**-0.25**
20	Sugarloaf (CO94)	2,524	**-0.47**	-0.27	**-0.46**
14	Sunlight Peak (CO92)	3,218	**-0.21**	-0.08	**-0.28**
21	Four Mile Park (CO08)	2,502	**-0.19**	-0.05	**-0.28**

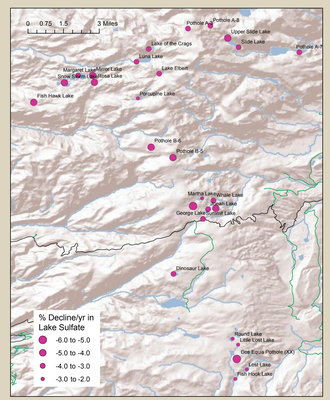
Snowpack Chemistry

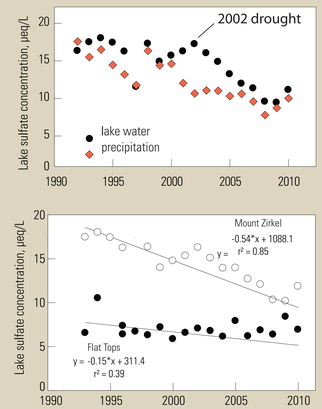


Change in snowpack sulfate concentrations after emission reductions at 17 sites in NW Colorado

Percent decline in sulfate deposition attributed to emissions controls at Hayden/Craig at 3 deposition sites in the Yampa River Valley

Lake Chemistry





Since 1993, sulfate concentrations in late summer have decreased in all 28 lakes and ponds.

The average rate of decrease in lakes was -0.51 μeq/L/yr, which is remarkably similar to the decrease of -0.48 μeq/L/yr in wet deposition at the Buffalo Pass NADP station.

The average sulfate trend of the MZWA lakes was substantially higher than the trend in backgroung lakes (Flat Tops) providing evidence that MZWA lakes have responded to both local and regional SO_2 emission reductions.

Mast, M. Alisa; Ely, Daniel (2013) Effect of power plant emission reductions on a nearby wilderness area: a case study in northwestern Colorado: Environmental Monitoring and Assessment, v. 185, p. 7081 - 7095.