Statement of problem. Coal burning power plants in the American Southwest produce a variety of airborne pollutants and combustion products, which fall to the ground via precipitation processes. These pollutants often land on the surface of an area known as the Great Basin and the Colorado Basin. Sulfur and nitrogen deposition in excess of the natural historic quantities may result in ecological change. The purpose of this study was to explore this issue and to determine if there may be any ecological changes and if there is indeed any need for concern.

1. Introduction

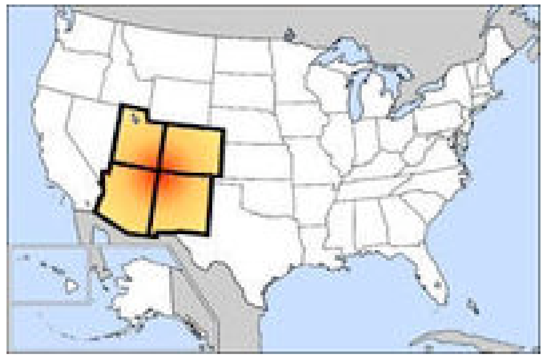
The area of interest for this project was the Desert Southwest consisting mainly of Arizona, New Mexico, parts of Nevada and Utah, Western Texas, Southern California, and the Southwestern Colorado. This report centered mainly on the Four Corner states, consisting of Utah, New Mexico, Colorado, and Arizona. A great portion of the geography in the Southwest forms the Colorado Plateau, which is enclosed by deserts and mountains. Deserts are geologic features in which rainfall has to average a maximum of 250 mm (10 in) annually. Deserts in the areas such as the Great Basin, Nevada and Utah are largely rain shadows. The Colorado Basin consists of the area west of the Continental Divide. The rain shadows are largely attributed to being leeward of a mountain in respect to wind direction. Further, it should be noted that the Great Basin is not associated with the Rocky Mountains.

These deserts are created when tall mountain ranges prevent clouds from covering a specific area in the direction the air mass is going. The air cools down as it moves over the mountains; the moisture will condense and cause precipitation on the side the wind is blowing. The air is dry on the leeward side since the air has lost its moisture by now. This results in a desert. The warm air of the desert sucks up moisture (a process known as evapotranspiration) because it has compressed and warmed. These factors contribute to the climates of the deserts and their dry conditions. The desert humidity is minimal with dew points in the 30-40 degree F range most of the time. The Colorado Plateau is comprised of plateaus 6,500 feet in elevation on average. These plateaus are rounded on the top and are separated by large canyons.

A lot of the landscape of the Southwest is primarily the result of erosion, which cause bridges, towers and other geological features. In Utah we find the Great Basin Desert, which comprises many watersheds making it more than just a single Basin. The Great Basin and Colorado Basin are in rain shadows of mountains. As moist air arriving from the Pacific rises over the mountains to the west of these basins the air cools and once dew points are exceeded the moisture precipitates as rain, snow, or ice. (this removes 540 calories/g of moisture that turns water vapor into rain and snow). As the drier air now descends on the eastern side of the mountain the air mass is compressed and heats up (Chinook effect). This dryer and hotter air forms the semi-arid regions of the southwestern desert. Death Valley is a true desert getting an average of around 3" of rain a year. Utah also has the Uinta Mountains, the tallest mountain range in the state surpassing 13,000 feet at some peaks. Another notable mountain range found in Colorado is the San Juan Mountains range. To the east of the San Juan Mountains are the eastern plains, which comprise some of the lowest elevations in Colorado.

Interestingly, the Southwest has some of the hottest as well as some of the coldest areas in the country. This varying temperature is due to the great range in elevation in this region of the country. The Southwest is also known for it's volatile weather in the fall and spring, often bringing snowfall, rainstorms and rapid climate changes.

The Four Corner states have had much change in population distribution and growth in the last decade. The following map depicts the Four Corner states designated in red

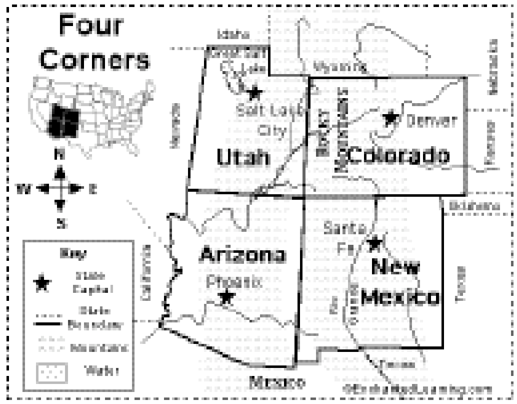


(Fig 1. Location of the Four Corner states)

2. Population

The U.S Census Bureau (http://www.census.gov/) shows that the Population growth varied significantly by region in the 1990s, indicating higher growth in the West (19.7 percent) and South (17.3 percent) and much lower rates in the Midwest (7.9 percent) as well as the Northeast (5.5 percent). In assessing the growth of our Four Corner states from 1990 to 2000, the U.S. Census shows a 40 percent increase for Arizona, 20 percent increase for New Mexico, 29 percent increase for Utah, and a 30 percent increase for Colorado. These are indeed very significant increases in population relative to the rest of the United States. Furthermore, the only state to surpass the Four Corner states during this time is Nevada with a 66 percent increase. It should also be noted that Nevada is also somewhat in the Colorado Basin – the River does flow by it although I do not think run off from anywhere in NV finds its way into the river – often, yet it takes an awful lot of electricity from the Hoover Dam generating station – which of course produces no air pollutants anyway. Furthermore, we aren't particularly concerned with Nevada, but mention some change in that area that might be of interest.

As of 2005, Utah's population was considered to be the fifth fastest growing in accordance with U.S. Census Bureau estimates. Furthermore, Nevada and Arizona were also some of the fastest growing states, coming in first and second respectively as of 2005.The U.S. Census indicates that the southwest seems to be the fastest growing area of the U.S. It can be seen that some of this increase is from some of the urban areas, including San Juan, Phoenix and others. Phoenix alone increased by 787,000, making it one of the top fastest-growing metro areas in the country. St. George Utah was the fastest-growing metro area in the entire country with a total population of 126,000 as of 2006. Maricopa County, Arizona had a rapid numeric increase in population between 2000 and 2006 with 696,000 residents. Moreover, out of the 20 counties with the greatest increase in population, only one was outside the southwest.



(Fig 2. Four-Corner area)

This dramatic increase in population necessitated the development of infrastructure to support it. As energy use increases with population, there has been a great increase in demand for energy in this area over the period studied. This demand was met by a combination of fossil, nuclear and hydropower generation. This report is mainly concerned with fossil fuel power plants and specifically coal burning plants, their location and possible effects of their emission on the environment.

The increase in population implies an increase in energy use and so is substantial in our investigations. Despite the U.S. having slower population growth than other countries, the U.S. is the leader in energy consumption.

3. Coal Plants in the Southwest

The operation of coal burning power plants in the American southwest was central to our investigation of the possible changes caused from an increase of energy use. Our primary reference for information on the content of emissions from coal plants is the Oak Ridge National Laboratory (ORNL). The ORNL (http://www.ornl.gov/info/ornlreview/rev26-34/text/colmain.html) states that U.S. 1000 MW coal-fired plants burn 4 million tons of coal annually and this number is steadily increasing. The ORNL makes U^{235} for nuclear power plant use (and for bombs too, but no longer builds bombs), so they are likely to supply Nuclear and not so much coal. It is estimated with the given increase in population and energy consumption in the U.S. that it is expected that 2516 million tons of coal will be burned in the year 2040. What is emitted by fossil fuel burning power plants, especially coal plants and oil burning plants in the American southwest is important in accessing the potential environmental damage. This report is concerned with coal since its combustion products are emitted in large quantities and coal is considered the most impure of fuel according to the ORNL. The main fuel used to generate electricity in the United States is coal; the close second is nuclear energy. At the same time there are many alarming facts about coal combustion and the effects it has on the ecosystems.

4. Products of Coal Combustion

Coal combustion produces large amounts of carbon dioxide as well as other chemicals responsible for global warming. Nitrous oxides and sulfur oxides for example, are also a result of combustion and when released into the atmosphere produces acid precipitation.

The trace metals found in coal are significant contributors to impurities found to contaminate drinking water and air quality. Combustion of coal results in the production of ash, which is composed of many harmful oxides. Coal ash constitutes the oxides of magnesium, sodium, mercury, and many others which form a deadly concoction when combusted and emitted into the atmosphere. Fly ash is a mineral residue produced from coal combustion and is composed mostly of silicon compounds. Often when dealing with fly ash it is effective to employ a particulate capture system (electrostatic precipitator) to retain the fly ash from being emitted into the atmosphere. Dating back to the 1960's, particulate precipitators have been employed in many of the U.S. coal burning power plants.

Naturally radioactive elements in coal include uranium and thorium, which are less toxic than some other coal constituents such as arsenic and selenium. Coal combustion causes both uranium and thorium to leave the coal matrix and be distributed in the gaseous phase. These two elements are used as fuel for nuclear reactors. Uranium is a metallic element that is considered only weakly radioactive but more dense than lead. It is also known that uranium is the heaviest of all naturally occurring elements often found in soil and rocks in low concentrations.

Thorium is also a metallic element that is slightly radioactive and occurs in low concentrations in soil and rocks. Despite it being radioactive, thorium decays very slowly and its radiation isn't strong enough to penetrate skin. A harmful form of thorium is aerosolized thorium, which is known to cause cancer (http://www.cleartheair.org/proactive/newsroom/release.vtml?id=17320).

In terms of volume and variety of contaminants emitted, no other single industry comes close to matching the negative impact from electric power plants. They are the single largest industrial source of some of our worst air pollutants, including sulfur dioxide, nitrogen dioxides, carbon dioxide and mercury. Among power plants, the dirty old coal-fired facilities produce the most pollution.

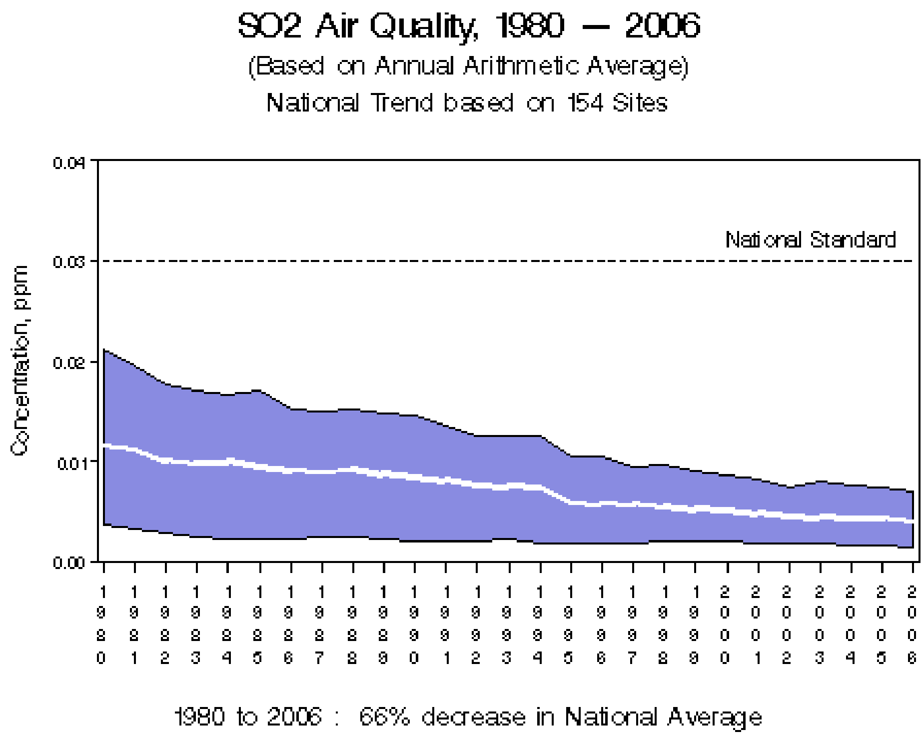
5. Composition of Coal

The composition of coal is important since it can mean the difference between a clean or unhealthy atmosphere. The primary mineral in coal that affects acid rain levels is sulfur. The chemical compounds pyritic sulfur (S_2), sulfate sulfur ($S0_4$), and monosulfide (S) make up total sulfur concentrations and are determined in coal samples. Iron sulfide or pyrite is the primary sulfur mineral in coal. Low sulfur content in coal is generally considered to be 0.4% between 0.06% total, depending on location. Further, there is some variation in different areas of the U.S., being slightly higher at the east coast. Low sulfur coal is mined in Montana and Wyoming. High sulfur coal is generally in the 2-4% range and is mined in Ohio, Kentucky, West Virginia, and other states. The price of coal generally falls in the range of $20.00 to $30.00 per ton. The prices of coal have actually risen in recent years because of pressure on coal productive capacity. Despite the harmful effects of high-sulfur coal, new technology and pollution-control equipment is a viable option to utilize high-sulfur coal. This upgrade in technology is due to the strict guidelines of the Clean Air Act Amendments of 1990. It is clear that using low sulfur coal would reduce sulfur oxide emissions, but one downside is the higher cost for transportation.

6. Sulfur Dioxide

One of the worst air pollutants emitted from coal burning power plants is sulfur dioxide. Sulfur dioxide has severe impacts on the human nervous system and respiratory system. Specifically, large quantities suffice to block nerve signals that are important to pulmonary receptors in smooth muscle of the lungs. Sulfur dioxide is a colorless gas with a strong odor that is often described as overwhelming. It deteriorates when mixed with organic materials and forms sulfurous acid when dissolved in water. Sulfur dioxide is one of the main components of particulate matter pollution in the United States. This chemical compound can be inhaled easily because of its gaseous nature, which is why it causes respiratory disease. It forms a gas but when it hits the ground the acid is neutralized usually by calcium carbonate forming calcium sulfite. If the SO_2 has oxidized in the air to SO_3, the anhydride of sulfuric acid, then it forms calcium sulfate. However, in the Northeast (like upstate NY) the acids fall but have no carbonate mineral to neutralize them so they enter the water as acids and cause acidification of the water, dropping the pH substantially. This drop in pH kills fish and especially fish eggs preventing of course hatching and eventually decreasing the fish population. Even though sulfur dioxide has played a central role in particulate matter pollution its concentration levels in the atmosphere have actually decreased in recent years.

However, this isn't to suggest sulfur dioxide is nothing to worry about. The National Pollutant Inventory (NPI) ranked SO_2 as the 4^{th} most hazardous substance out of four hundred other chemicals. Recently, the EPA has implemented a plan called the Acid Rain Program, which resulted in a reduction in sulfur dioxide emissions. The Acid Rain Program was set into motion for the sole purpose of reducing annual SO_2 emissions to 10 million tons below 1980 levels. This was accomplished by setting restrictions on the coal and facilities of the coal-burning power plants. The main purpose of this program is to utilize technology to chemically restrict sulfur dioxide in power plants. The EPA mandates how sulfur dioxide emission reductions are achieved. In particular, it is required that low-sulfur coal is to replace the high-sulfur coal that was previously used. And since using low-sulfur coal implies reduced SOx emissions, this change in coal reduces SO_2 emissions as well. In 1970, 31,161 short tons of sulfur dioxide was being emitted into the atmosphere. This program brought this harmful level down to 18,867 short tons by 1999. (^ National Trends in Sulfur Dioxide Levels, Environmental Protection Agency.) The following figure depicts the national trends in Sulfur Dioxide levels over the period of two decades.



(Fig. 3 Sulfur Dioxide trend)

7. Nitrous Oxide

Other chemical compounds that play a crucial role in the stratosphere to provide support of the ozone are oxides of nitrogen, also called NOx emissions. If the concentration of these chemical compounds increase then the ozone level will decrease due to increased chemical reactions. Oxides of nitrogen don't immediately cause harmful effects on humans but may over time produce superfluous fluid in the lungs, which can be fatal. Industrial emissions do contribute to low concentration in the atmosphere, but volcanic eruptions can produce greater concentrations in the local area. These oxides of nitrogen are also produced from combustion in coal burning power plants. When these compounds are combined with hydrocarbons, smog is readily produced. Nitrous oxide can be found in sewage, animal manure, and microbial action. Naturally, nitrous oxide is produced in the soil from microbial processes known as nitrification and denitrification. The most relevant human-related inorganic nitrogen source for this report however is mobile and stationary combustion of fossil fuel. Nitrous oxide emission levels are sometimes difficult to assess because they can vary from region to region depending on climate, industrial production, and waste management.

The nitrogen oxide removal from coal is much like that of SOx's. Coal is composed of nitrogen molecules as well as other elements. These nitrogen molecules are released from coal when exposed to high temperatures. Thermal NOx's are formed from a process known as combustion. When nitrogen molecules combined with oxygen under high temperatures, we obtain thermal NOx's. Heat combustion also causes nitrogen molecules from the atmosphere break apart producing the same chemical reaction. New coal burners were produced in the 1970's and 80's that restricted oxygen levels, and were named low-NOx burners. Excess air, the amount not needed to burn the fuel but must be present to maximize the burn and produce carbon dooxide and a minimum of carbon monoxid, is usually around 20%. They have since reduces NOx emissions by 40 to 60 percent. Recently "selective catalytic reduction" systems were employed in coal burning power plants to reduce NOx emission in much the same way a catalytic converter is used for car emissions. Another interesting method that is now being used is injecting ammonia into the coal surface. Coal-fired power plants in the Southwest emit large amounts of nitrogen oxides. About 25% of all nitrogen emissions are produced by coal-fired power plants from the U.S.

Nitrogen oxides play an intimate role in sustaining and reducing the tropospheric ozone. This occurs because of catalytic cycles that are involved in balancing certain reactions. Nitrogen monoxide or nitric oxide (NO) can be obtained from nitrogen dioxide (NO_2) by being broken down by sunlight. At this point NO_2 can be obtained again when NO is oxidized. Unstable oxygen compounds as well as ozone are also involved in this cycle. Incidentally the Acid Rain Program has the goal of reducing NOx emissions as well as SOx emissions. However, the primary concern was SOx and reduction of sulfur in coal has proven successful in reducing acid precipitation since its inception in 2000.

8. Inorganic Nitrogen

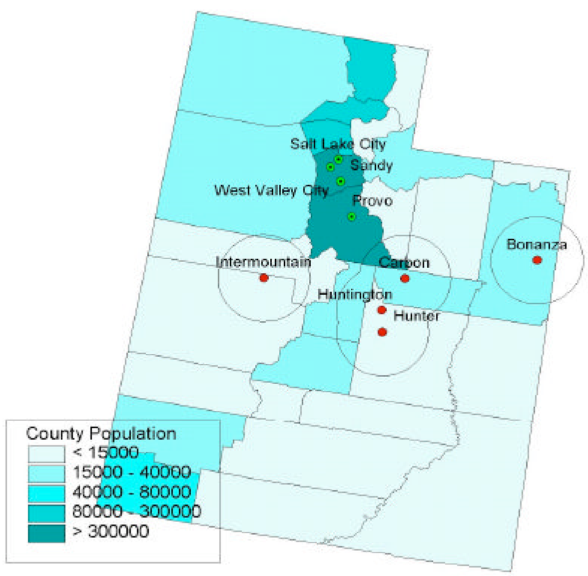
Inorganic nitrogen has its origins from minerals (not of biological origin), and is used for fertilizers. This is done to help plants grow and remain healthy. Plants cannot use organic forms of nitrogen. This is ameliorated when microbes in the soil convert organic N into inorganic forms for plants to use. One primary form of inorganic N that is used in the soil is ammonium (NH_4^+). The other inorganic N forms can't be held by soil particles (such as nitrate NO_3^-, and nitrite NO_2^-). This results in these forms of inorganic N leaking out of the soil through water or even volatilize. Inorganic N usually transforms into either N_2, NO, NH_3 or N_2O nitrogen gases when it volatilizes. There are many interesting processes that change organic nitrogen to inorganic nitrogen and vise versa, for instance ammonification, which transforms organic N into ammonium. Immobilization counters this reaction, making organic N from ammonium and nitrate N. These cycles create an equilibrium (as well as a general balance) of organic N and inorganic N in the soil and atmosphere.

9. Mercury

Mercury is one of the harmful components of coal burning power plant emissions but has a low concentration in coal. Humans imbibe mercury mostly in their diet from fish. It is currently being debated as to how much mercury in our diet can contribute to heath problems. If taken in high doses, mercury can severely damage the central nervous system, brain as well as other areas of the human body. According to TVA, 40% of worldwide mercury emissions are attributed to volcanic eruptions and emissions from the ocean. The remaining 60% of mercury air emissions are due to human-made sources. Moreover, coal-fired electric power plants are considered the largest source of mercury pollution in the United States. In fact, coal-fired plants contribute 99% of total mercury emissions from power plants. The EPA claims coal-fired power plants mercury emissions have increased by 10% from 1990 to 1994 alone. However, half of the emissions from man-made sources are from Asian countries and only 5 percent are from the United States. While mercury seems to be a minimal problem for the United States, small amounts stay circulating in the environment from centuries ago. This is primarily due to the fact that mercury doesn't break down into other elements. Mercury has the potential to drift throughout the atmosphere to great distances until it is deposited into the earth in rainfall or in a gaseous form.

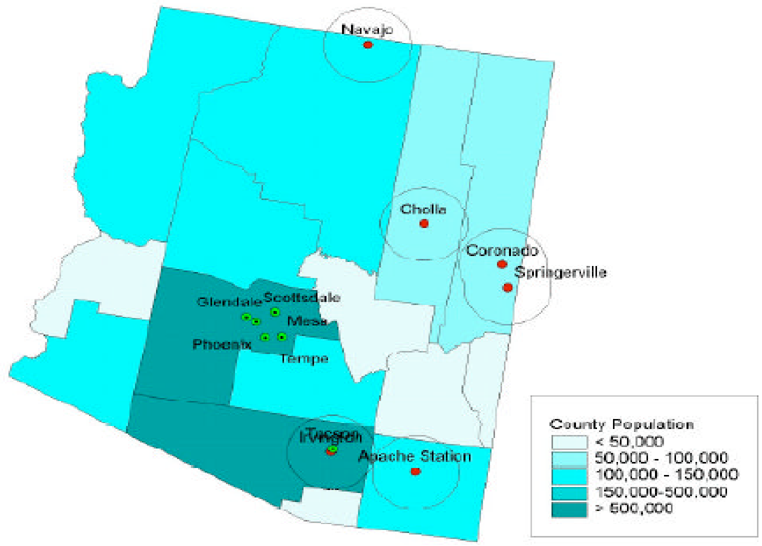
EWG has estimated mercury air pollution from coal burning power plants of the states we are investigating in the southwest. Total emissions that we give are calculated by applying total mercury released to plant specific emission modification factors.
The state estimated emissions for mercury air pollution in Nevada is 416 (pounds), New Mexico 1,323, Utah 660, and Arizona 1035. These large figures don't vary much in comparison with states in the northeast or southeast. However, New Mexico does have an overwhelming amount of mercury air pollution.

The following are maps of the locations of coal burning power plants of the four corner states.

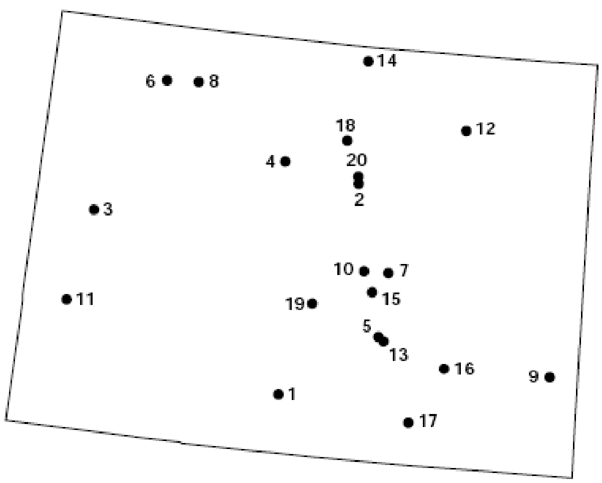


(Fig.4 Coal Burning Power Plants in Utah)

Arizona State Profile of Exposure to Coal-Fired Power Plants



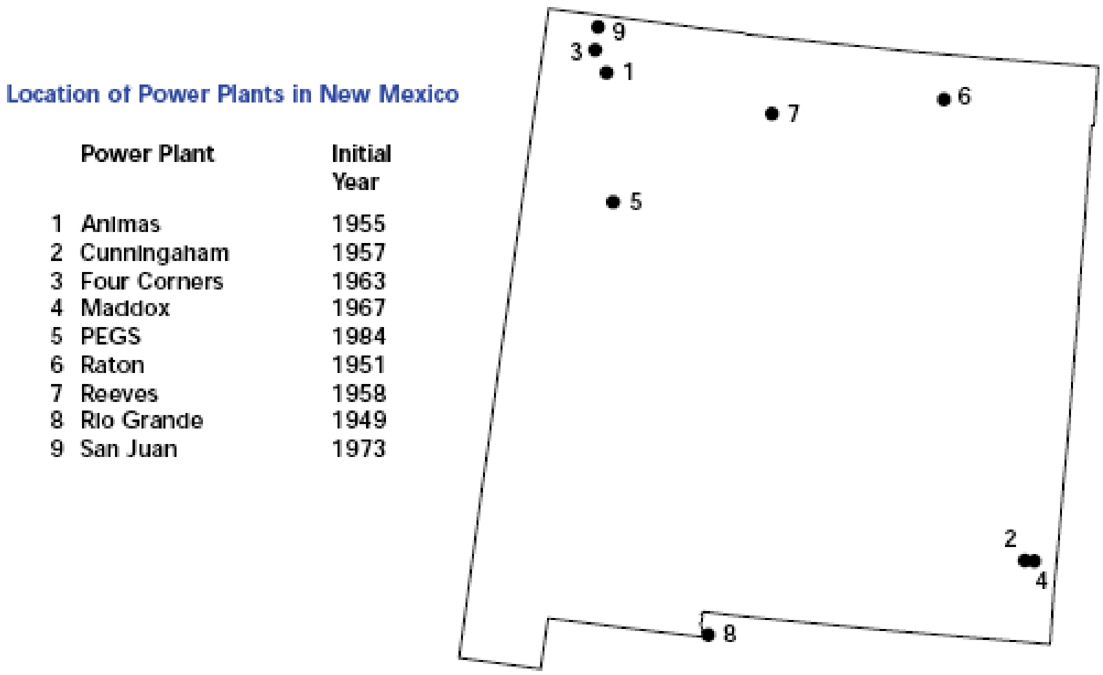
(Fig.5 Coal Burning Power Plants in Arizona)



Location of Power Plants in Colorado

	Power Plant	Initial Year		Power Plant	Initial Year
1	Alamosa	1929	11	Nucla	1987
2	Arapahoe	1950	12	Pawnee	1981
3	Cameo	1957	13	Pueblo	1922
4	Cherokee	1965	14	Rawhide	1983
5	Comanche	1973	15	Ray D. Nixon	1979
6	Craig	1979	16	Rocky Ford	1951
7	George Birdsall	1979	17	Trinidad	1950
8	Hayden	1965	18	Valmont	1924
9	Lamar Pit	1972	19	W N Clark	1955
10	Martin Drake	1945	20	Zuni	1948

(Fig.6 Coal Burning Power Plants in Colorado)



(Fig.7 Coal Burning Power Plants in New Mexico)

10. Oxidation Processes Forming Stronger Mineral Acid Anhydrides

Nitric and Sulfuric acids have intimate chemical reactions that are considered very harmful to the atmosphere. NOx is converted to nitrous and nitric acid and SOx is converted to sulfurous and surfuric acids. These acids lower the pH of rain and fall directly on the plants and soils. The soils may have lots of calcium carbonate in them and thus can be protected from the increased acidity. On the other hand any ammonia or nitrate or nitrite serves as fixed N for plants. More N means different plants may be able to populate the region replacing naturally occurring native species.

11. New Power Plant Construction

There have been many new coal fired power plants appearing over the last few years. New Mexico has recently (2006) built a 1500 MW sized coal fired power plant in Farmington along with a 300 MW in Milan. The 1500MW plant is the San Juan Generating Station. In Front Range (mountain range), Colorado a 1000 MW coal fired power plant has been built as well as a 750 MW in Pueblo. To the west we find two 400 MW coal burning power plants in Springerville, Arizona. To the north of Arizona one can find 850 MW and 950 MW plants in Emery and Delta, Utah, respectively.

Perhaps the plant of most concern is the Four Corners Power Plant that resides in Fruitland, N.M. This coal-fired power plant provides the electricity for over 300,000 homes in the four corner states. The Four Corners Power Plant has five coal-burning generating units that contribute a large amount of the emissions of nitrogen oxide, carbon dioxide, mercury and sulfur dioxide emissions in the four-corner region. This power plant was among the fifty dirtiest power plants in the nation from Environmental Integrity Project's list. It was claimed in 2004, that Four Corners was the No.1 emitter of nitrous oxide. Moreover, it can also be found that Four Corners was No. 37 emitter of Mercury and in the top fifty in sulfur dioxide emissions. Interestingly, these high emission rates occurred after Four Corners reduced its nitrogen emissions in the 1980's.

Another notable power plant is the Afton Generating Station, located a few miles from Las Cruces, New Mexico. The Afton plant produces 135 megawatts of electricity optimally and was operational by late 2002. The plant's main purpose is to provide power to the western area and a backup for emergency electricity in New Mexico.

A nearby coal-fired power plant, and the seventh largest in the southwest, is the San Juan Generating Station. The purpose of this plant in New Mexico is to serve as a primary source of power for the four-corner region. This plant has kept within the federal regulations for sulfur dioxide, nitrous oxide and all other emissions. The San Juan plant is a zero-discharge facility to recycle water and make sure water is only evaporated if released.

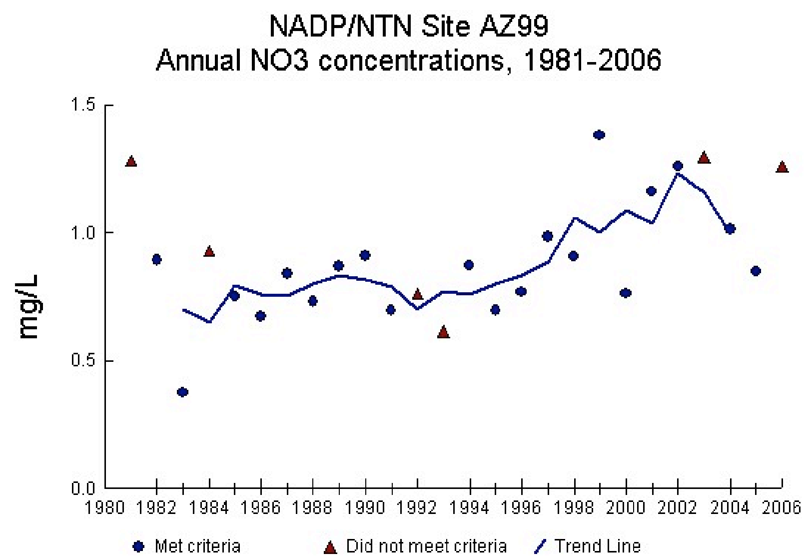
The 750 MW power plant In Pueblo is of particular concern since it releases 6.5 million tons of carbon dioxide a year. It is unfortunate that this plant is being built in Colorado because it will only increase mercury concentrations of already widely contaminated reservoirs. In fact, it is estimated that the coal-fired plant in Pueblo releases 100 pounds of mercury annually. The Pueblo coal-fired plant would also consume large amounts of water out of the Arkansas River Basin. The prospects of the basin already look dim, with a predicted shortfall in 2030. The location of the plant is to the east of the Colorado Basin, which cannot ever impact Colorado. It is projected that this plant consumes 5 million gallons of water from the Arkansas River daily.

12. Deposition Data Acquisition

In this section, the deposition levels and various figures of recent trends of inorganic N and SO_4^{-2} from the sites of interest are compared. This is accomplished by analyzing trend plots (http://nadp.sws.uiuc.edu/sites/ntnmap.asp), and looking for any outstanding variation in deposition levels of the significant chemical compounds. Comparing these deposition levels over time relative to recently built (as well as older) plants is important in assessing any possible influence these coal fired plants have on the atmosphere. The annual deposition (kg/ha) changes of inorganic N and SO_4 in the past decade suggest that there has been a great influence from some source. It is important to get the various deposition amounts in the southwest to determine any possible change that has occurred in the atmosphere in the last few decades. The following is a table of the various stations that offer deposition levels of the chemical compounds that are investigated in this paper. The following table offers locations, and dates of operation for the plants under consideration in this report.

Station	Location	Dates of Operation
Bandelier National Monument (NM07)	Los Alamos County, New Mexico	6/22/1982 - Present
Green River (UT98)	Emery County, Utah	4/25/1985 - Present
Oliver Knoll (AZ99)	Graham County, Arizona	8/25/1981 - Present
Grand Canyon National Park-Hopi Point (AZ03)	Coconino County, Arizona	8/11/1981 - Present
Ripple Creek Pass (CO18)	Rio Blanco County, Colorado	5/13/2003 - Present

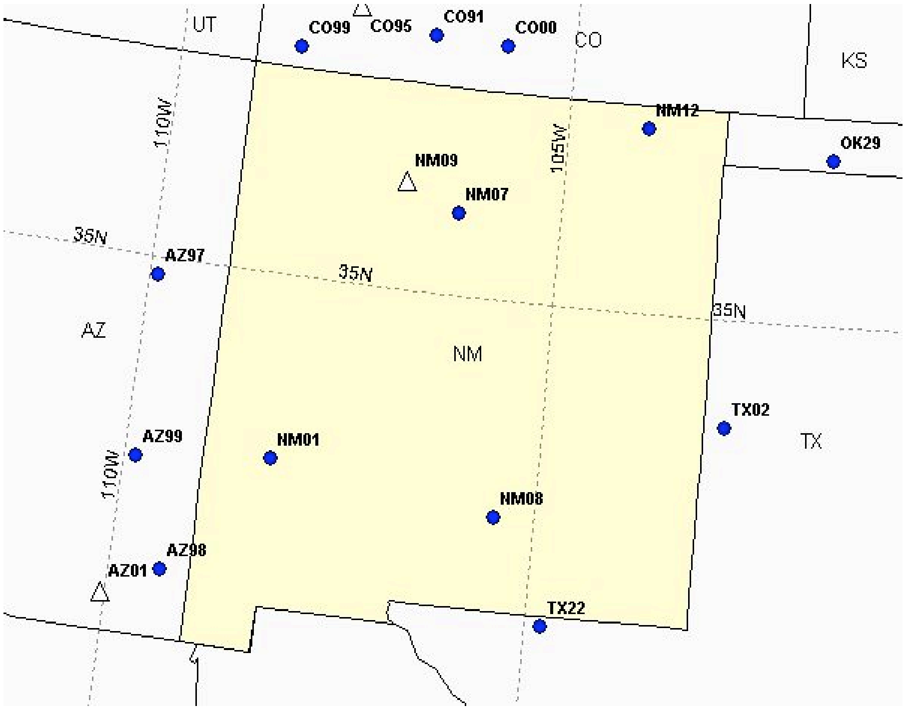
A trend plot is a figure that depicts possible variation of something over time. It will be important to assess whether the trends of deposition amounts mean anything relevant to recent developments of coal-fired power plants. This report needs trend plots of the concentrations of various chemical compounds to assess possible changes in the atmosphere. The following figure depicts $N0_3$ deposition from the 1980's to present in Arizona.



(Fig.8 Annual NO3 concentrations for site AZ99)

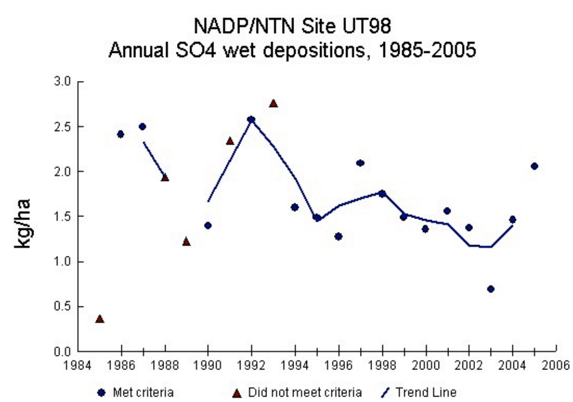
In Fig.8 the concentration (mg/L) for NO_3 of 1981 should be compared with 2005, which present two very different levels of NO_3 deposition. The higher levels of NO_3 deposition imply that there has been a great change of some sort in the last decade. High levels of nitrate cause severe damage to ecosystems. Nitrate levels over 30 ppm could potentially inhibit growth, kill fish as well as cause stress to a variety of ecosystems. The sites NW07, AZ03, CO18, and AZ97 all indicate increases in deposition of NO_3, Ca, K,

NH_4, InN, but not SO_4^{-2}. The following map depicts the various sites that reside near new power plant construction from the previous section.



(Fig. 9 New Mexico (and surrounding) sites)

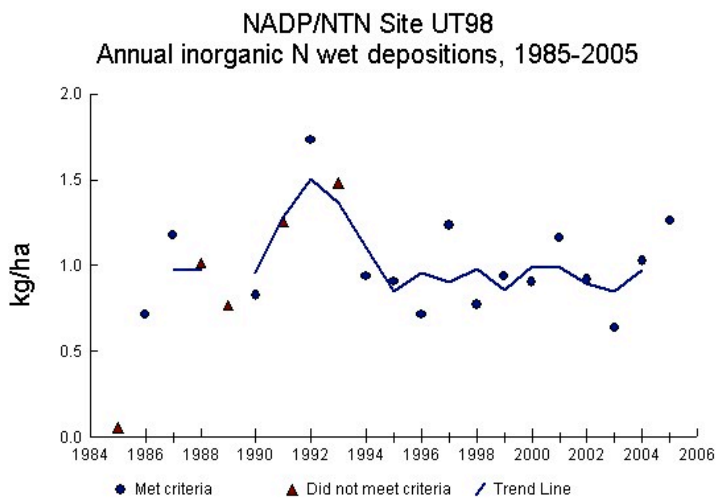
Where CO18 is taken to be further north in Colorado, AZ03 further west. These chemical compounds are some of the many constituents of coal fired power plant effluents. However, the wet deposition increases seem to have declined slightly since 2005. For instance below is an annual trend plot for wet deposition of SO_4^{-2} at the site NW07.



(Fig. 10 Sulfate Wet Deposition for site UT98)

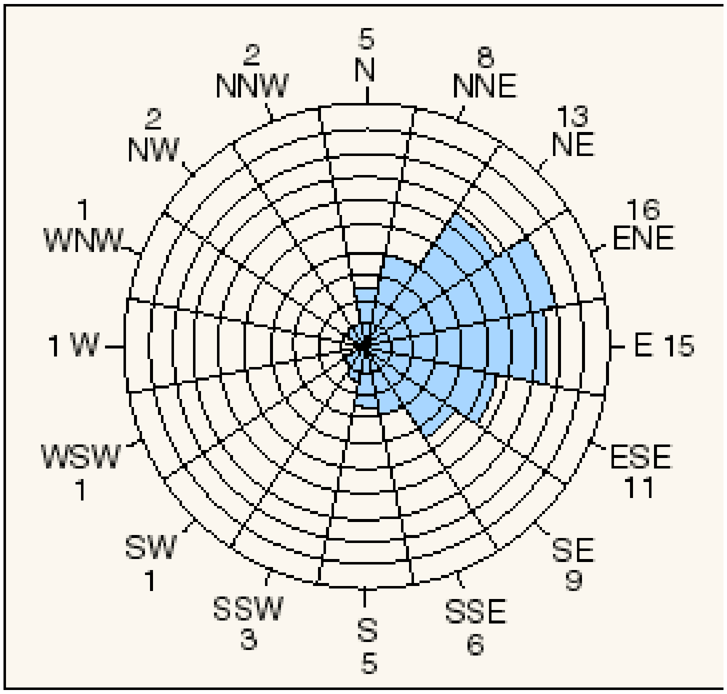
This trend plot is quite similar to the trend plots offered at the sites CO18, AZ03, NW07, and others, all indicating a decline in SO_4^{-2} after 2000. It is in the interest of this investigation to verify this since it would imply a correlation with the Acid Rain Program as well as the emissions of the coal-fired power plants that have been mentioned. However, the trend plot might be difficult to use to accurately assess the decline after 2005. The annual wet deposition for SO_4^{-2} in 2005 is 2.71 (kg/h) and 1.59 (kg/h) in 2006 (for NM07). It would be hard to verify that there is a clear trend here since in 2001 NM07 had a wet deposition of 2.17 (kg/h) for SO_4^{-2}. However the trend shows an overall decrease in annual SO_4^{-2} wet deposition since the 1990's.

Shown below is a trend plot for total inorganic N (the composite of nitrate and ammonium) in Utah.



(Fig. 11 Annual Wet Inorganic N Deposition for UT98)

Since wind direction determines effluent direction and downwind deposition it is important to look for trends in the areas of interest. The USGS long valley observatory (see http://www.wrcc.dri.edu/htmlfiles/westwinddir.html) offers an annual wind directions graph from 1992-2002 in the following.



(Fig. 12 Wind Direction)

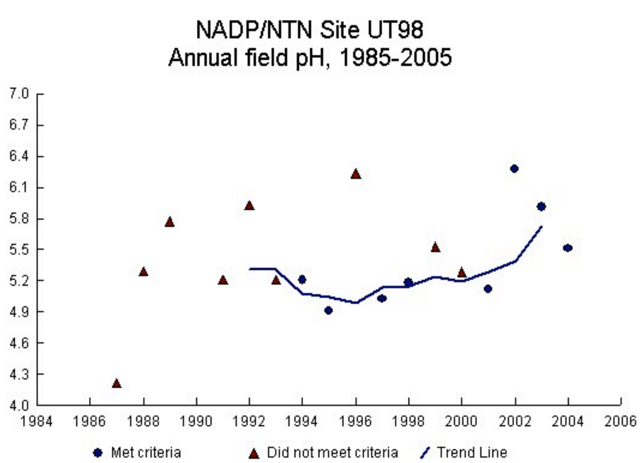
This graph implies the direction of the darkened zones have a high probability of being hit by a tephra fall. A tephra is the material which falls from the atmosphere from a volcanic eruption. The Air Weather Service indicates the winds in the Long Valley-Las Vegas area blow toward the area between N. 45˚ E. and S. 45˚ E. Moreover, the wind from Long Valley arrives in this area more than 50 percent of the time annually. It is also stated by the U.S. Air Force that the majority of the winds blow to the east at least 80% of the time.

It can be found at (see http://www.wrcc.dri.edu/htmlfiles/westwinddir.html) the Western Regional Climate Center the general wind directions for the areas of interest at the four corner states. This is offered in a table of prevailing wind directions over the course of a year. The finding of the general wind direction is done by choosing a few critical sites over a full year (12 readings). The following is a table of the sites of interest and their prevailing wind directions.

Station	Prevailing Wind Direction (12 months)	Ann
RYCE CANYON AP, UT	W W W W W W W W W W W W	W
CANYONLANDS AP-MOAB, UT	NW W W W W SW SE E W W W NW	W
DEMING AP, NM	W W W W W W E E E W W W	W
GUNNISON AIRPORT, CO	N N N W N N N N N N N N	N
PHOENIX-DEER VALLEY AP, AZ	E E SW SW SW SW SW SW E E NE NE	SW

Table I. Wind Direction

Bryce Canyon has a compass with one needle with an arrow pointing eastward since it seems that all of the time the wind is out of the west. For Canyonlands, there are several arrows with one large arrow of 8 units pointing to the east, two to the SE (opposite the two from the NW). In Deming, NM it is seen that the prevailing wind is out of the west as well. Deming, NM is very southwest New Mexico and is located in the Basin and Range Province. Gunnison Airport has a compass with an arrow pointing south since the wind is coming from the north. It is now clear that the overall general wind direction is coming from the west.



(Fig. 13 Field pH for site UT98)

The above figures show the rise in pH, which in all likelihood may be attributable to the decrease in SO_4^{-2} which leads to the production of sulfuric acid. It should be noted that these plots are in kg/hectare per year. A hectare is a unit of area equal to 10,000 square meters and or 2.4710439 U.S. survey acres.

13. Conclusion

NMO7 in midwest New Mexico and will affect the Basin of interest. The annual wet deposition for SO_4^{-2} in 2005 was 2.71 (kg/h) and 1.59 (kg/h) in 2006 at NM07. This could be the direct influence of recent restrictions on effluents of coal burning power plants. In particular it has been mentioned that the Acid Rain Program has already been implemented at many plants in the four-corner region. It would be hard to verify this as the primary cause though considering in 2001 NM07 had a wet deposition of 2.17 (kg/h) for SO_4^{-2}. The decrease in is most likely related to the increase in pH in the past decade. It is given by the EPA that the coal burning power plants mentioned were required to implement low-sulfur coal as part of the Acid Rain Program. Interestingly, NO_3 was not a primary concern for the Acid Rain Program and seems to be steadily increasing. It is most likely that the concentration increase in NO_3 is attributed to the new coal fired plants that have been mentioned. For instance, the area of Springerville, Arizona is actually where AZ099 is located and where the deposition levels for NO_3 were found to increase. Moreover, it should be noted that two 400 MW coal burning power plants were located in this area. This allows us to conjecture that these increases are most likely attributed to these plants. Likewise, It can be seen by (Fig. 13) that the increase in pH precipitation in the region UT98 is most likely attributable to the low-sulfur coal being used. The site UT98 is actually quite close to the 850 MW and 950 MW coal fired plants in Emery, and Delta, Utah respectively. These areas all reside in the middle of Utah, suggesting that the pH as well as deposition trends of UT98 must give a fairly accurate assessment of the affects of these plants. Moreover, these plants were included in the Acid Rain program, which implies that our assessment is most likely true.

The Clean Air Act Amendments require reductions in sulfur dioxide in every locality of the U.S.A. If a utility emits more than the allowed amounts then that utility will be fined. Hypothetically, if a utility were willing to pay these allowances while emitting large amounts of sulfur dioxide, the amendments require all states to restrict emission limits to ensure a healthy atmosphere. The Acid Rain Program also stresses that cost-effective strategies are an important part of the program. The program also enforces an allowance trading system that creates low-cost rules of exchange that minimizes government intrusion. This ensures that the program doesn’t result in debt problems and to make allowance trading an effective way of reducing SO_2. The allowance trading system provides a way to maximize economic efficiency without mitigating economic growth. The Acid Rain program is to be implemented on the most recently built power plants as well as the older plants.

14. References

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