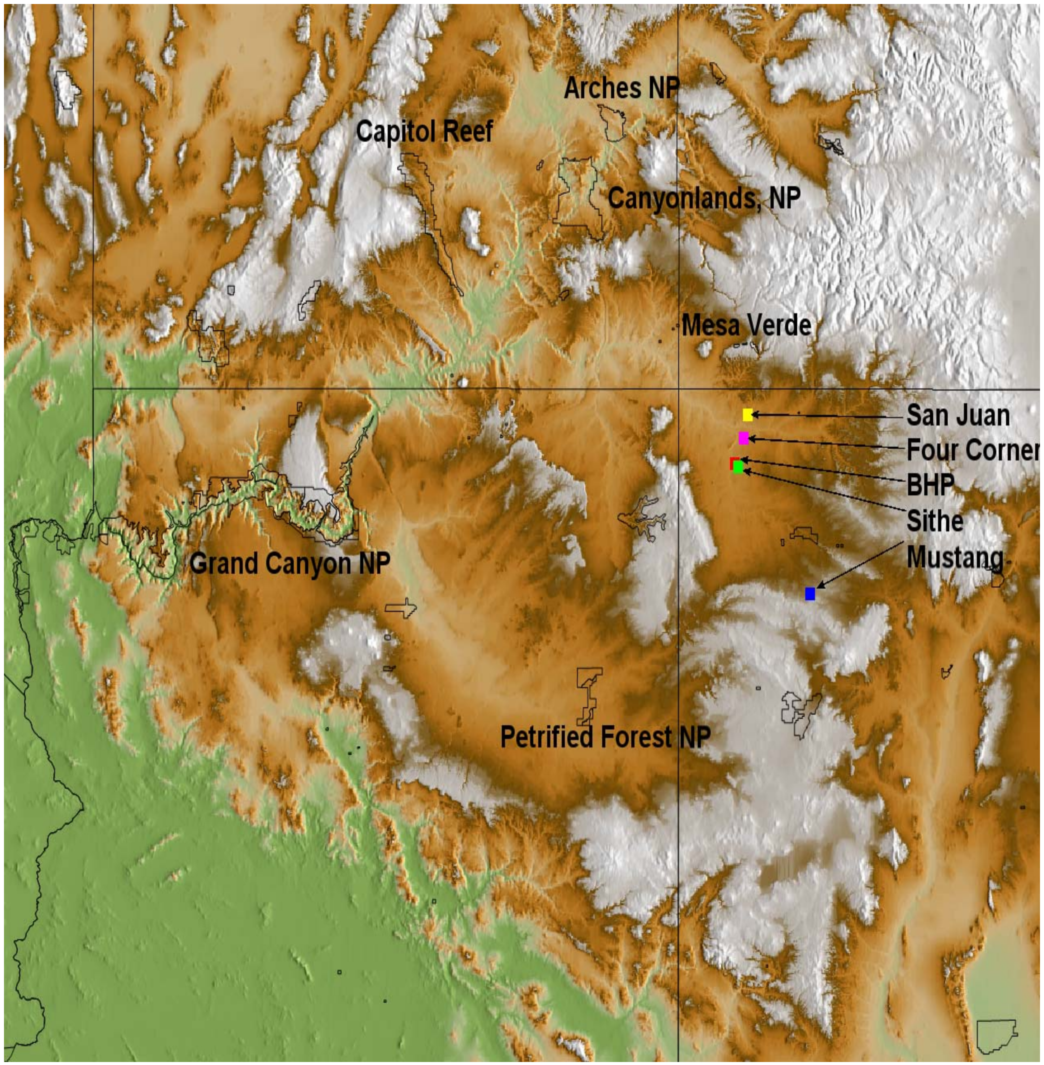
Evidence of the Proposed Sithe Power Plant's SO_2 Emissions Contributing to Haze in the Grand Canyon NP and other Class I Areas

Four Corners and Surrounding Terrain



Four Corner region is surrounded by mountains extending more than km above and can act as effective barriers to airmass transport allowing PP emission to accumulate.

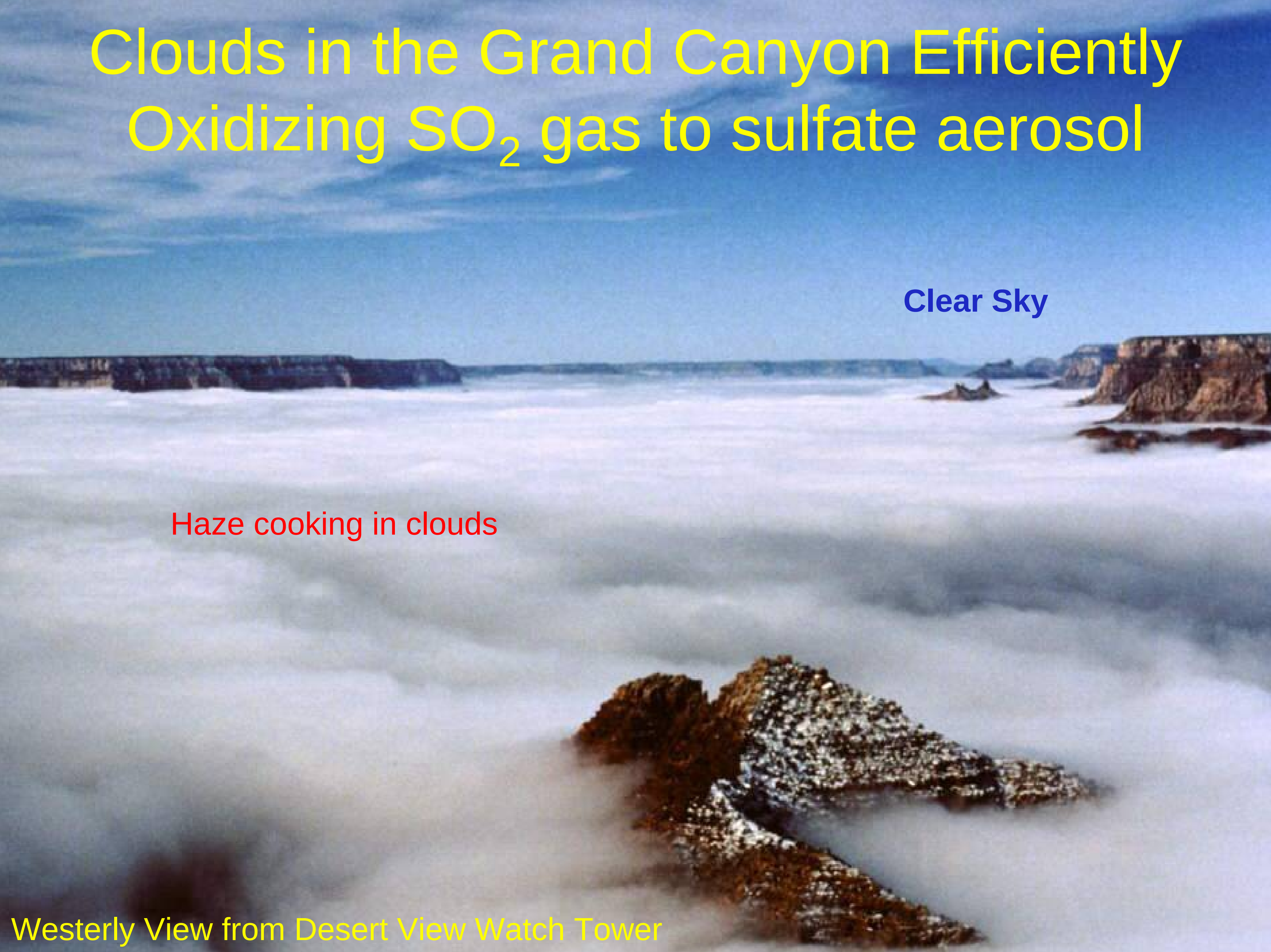
Three passes exist in which trapped air in the four corner region can escape

1) Northwest along the San Juan river valley to Lake Powel and Grand Canyon
2) Southwest through the ?? Pass to the Painted Desert and Petrified Forest. These airmasses could then be channeled along the Little Colorado River basin to GC
3) Southeast to Albuquerque NM

Grand Canyon Filling Up With Clouds

Easterly View of Grand Canyon from Desert View Watch Tower

Clouds in the Grand Canyon Efficiently Oxidizing SO_2 gas to sulfate aerosol

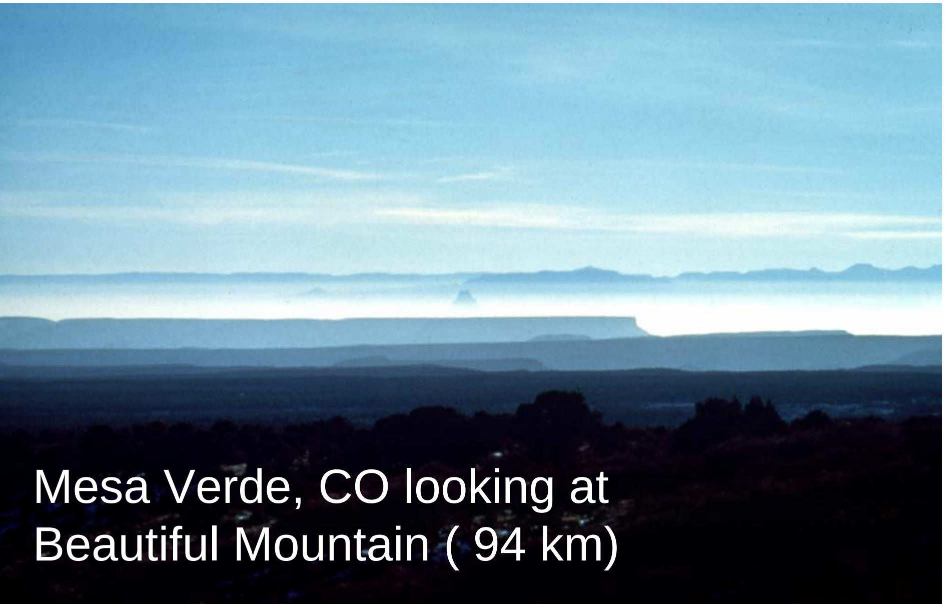


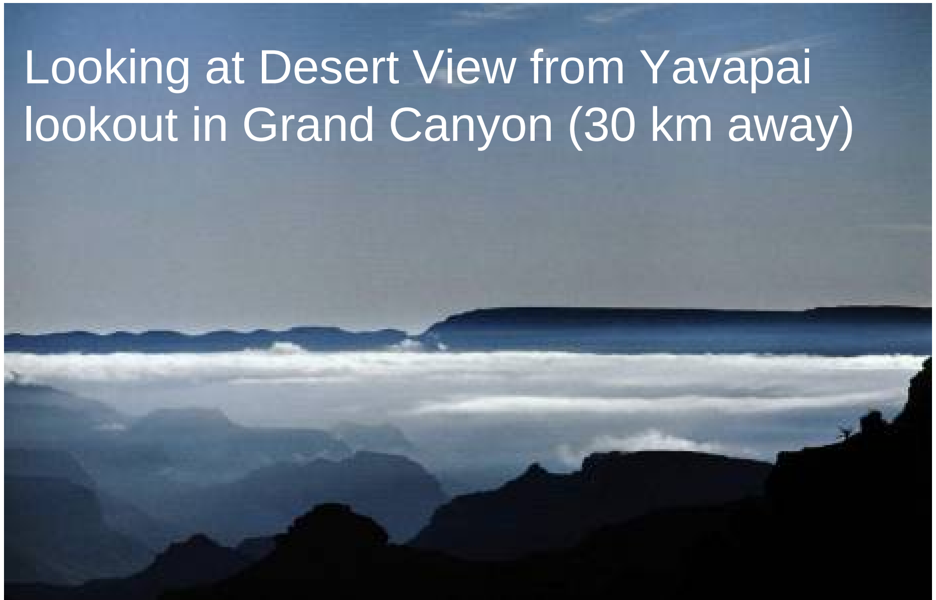
Clouds Evaporate Leaving Behind a Sulfate Haze

Clouds Evaporated Leaving Sulfate Haze

Next Day After Haze is Blown Out

Layered Hazes at Multiple Parks





Elevated Nitrogen Dioxide Layers

Conceptual Model for Wintertime Haze in the Grand Canyon Due to Power Plants

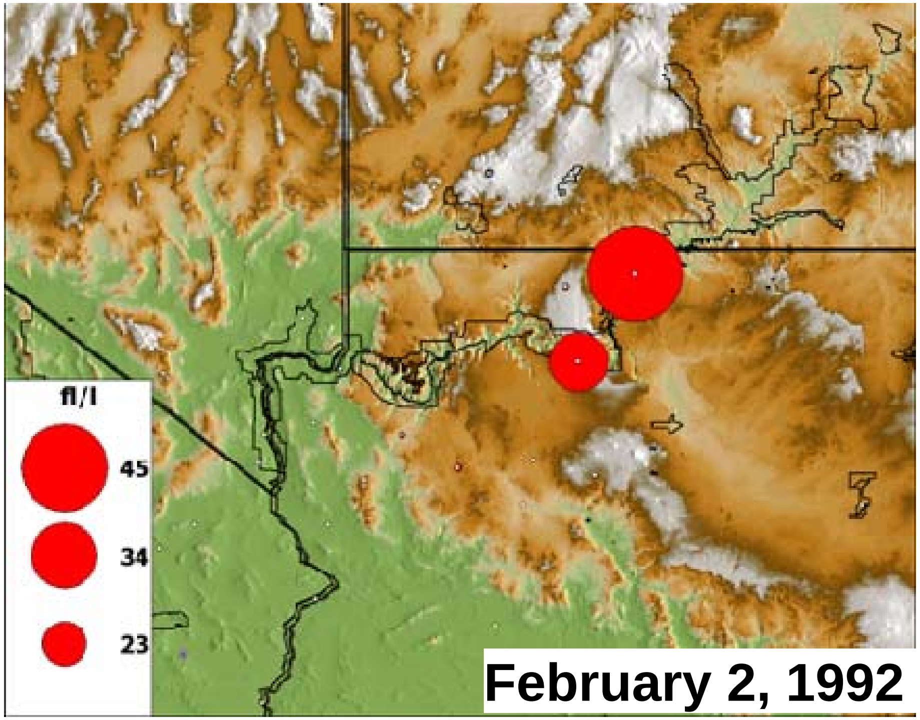
- Pollutants are transported to the rim of the canyon or Lake Powell Region
- Drainage flow bringing the pollutants into the canyon from the rim or from the entrance at Lake Powell and can be transported throughout the length of the Grand Canyon
- Over one or two days sulfur dioxide gas is converted to particulate sulfate efficiently through wet phase chemistry in clouds.
- The clouds evaporate, leaving behind the in-canyon sulfate haze with clear sky above the canyon.
- Human observers are particularly sensitive to the sharp changes in contrast between the boundary of the haze layer and clear sky or terrain.

Can emissions from the Steag Power Plants be transported to Lake Powell and into the Grand Canyon?

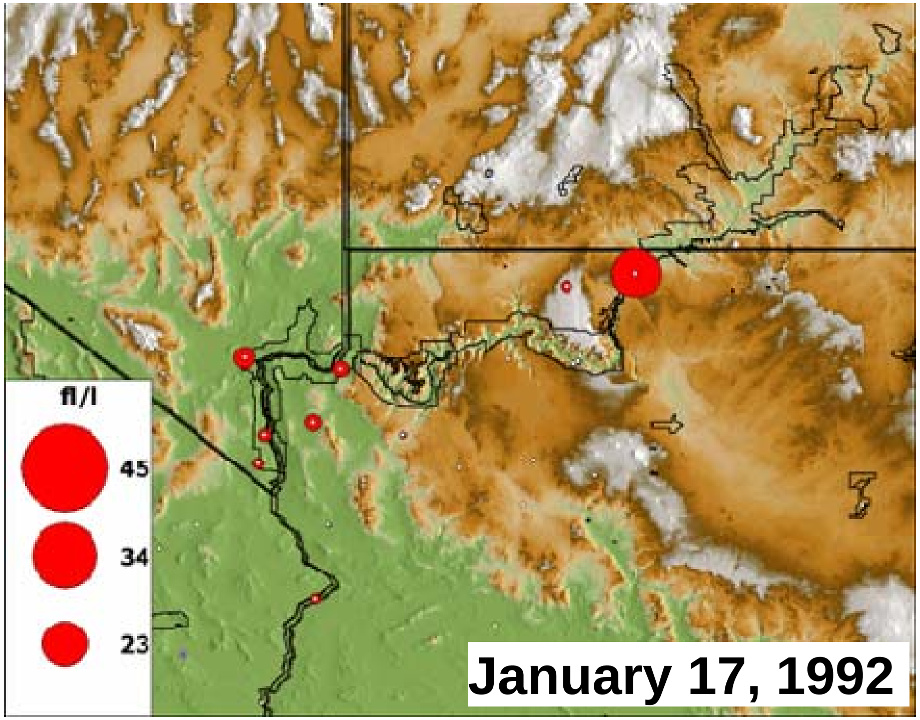
Perfluorocarbon Tracers Release During Project MOHAVE

Jan-Feb 1992, tracer was released from Dangling Rope on shore of Lake Powell

Dangling Rope Tracer Measured in Canyon



High concentrations in canyon at Marble Canyon (47 fl/l) and Indian Gardens (29 fl/l). Low concentrations at Hopi Point



Concentrations throughout the canyon along the Colorado River from Lake Powell to Mohave PP

CAN THESE TYPE OF TRANSPORT, DISPERSION, AND CHEMICAL PROCESSES BE MODELED?

CMC Simulation

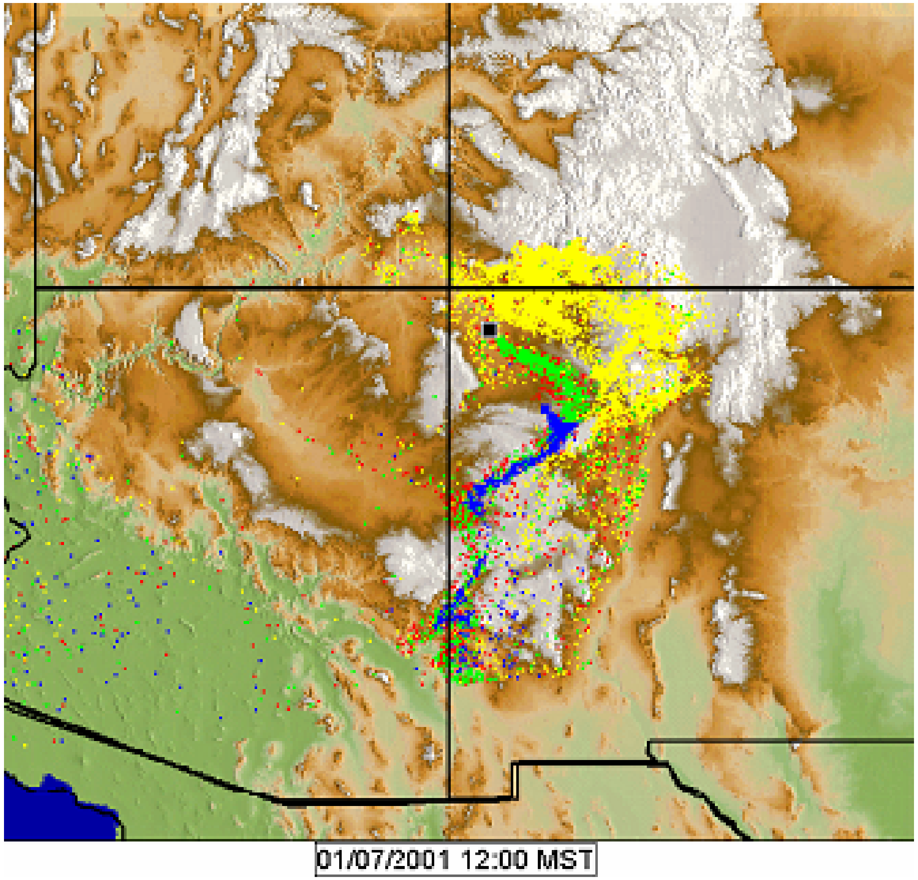
- CMC is a particle dispersion model that directly simulates the transport and diffusion of the power plant plume.
  - 150 particles are released every hour and advected and diffused based upon input met fields
- Met data: MM5 4km nested in 12 km every one hour – Thank-you Tim
- Plume release at
  - One simulation at stack height
  - Second at stack height plus ~150 m

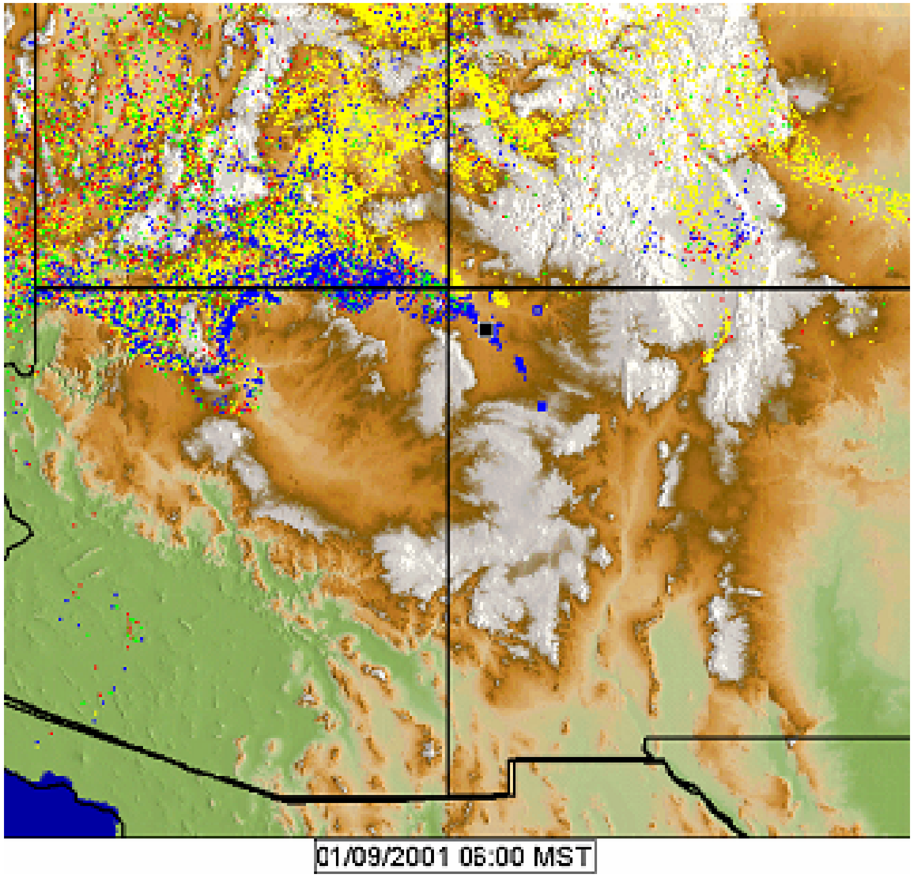
Episodes where Four Corner power plants impacted Grand Canyon NP in January 2001

	Time Period	Duration (Days)
Event 1	1/8 12:00 – 1/10 12:00	2
Event 2	1/15 16:00 – 1/18 06:00	1.6
Event 3	1/22 12:00 – 1/24 12:00	2
Event 4	1/26 20:00 – 1/28 00:00	1.16

- But is it real?
  - Match transport of existing power plants in Four Corners region into the Grand Canyon with pictures

See animations

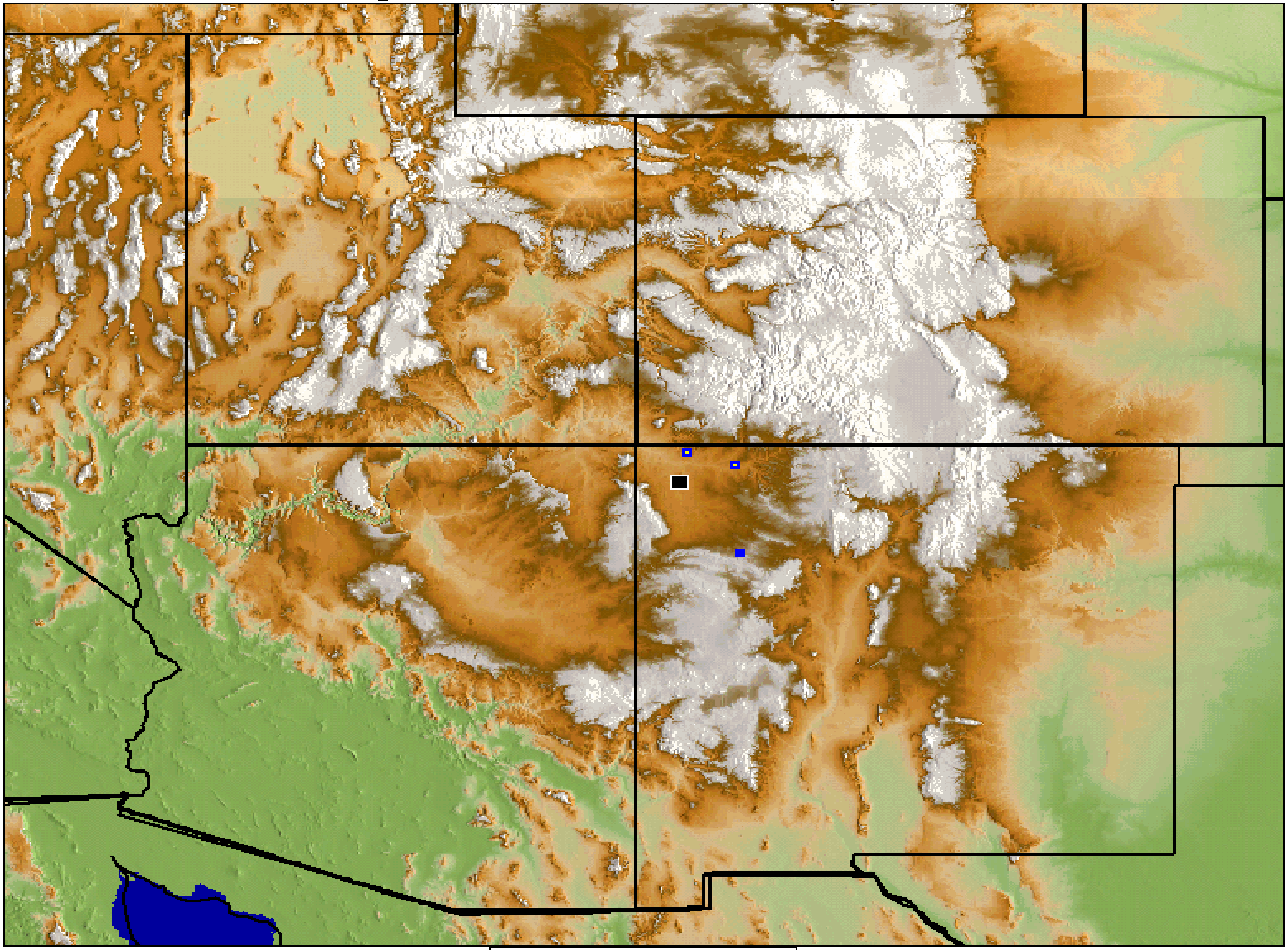




Multi-day stagnation events

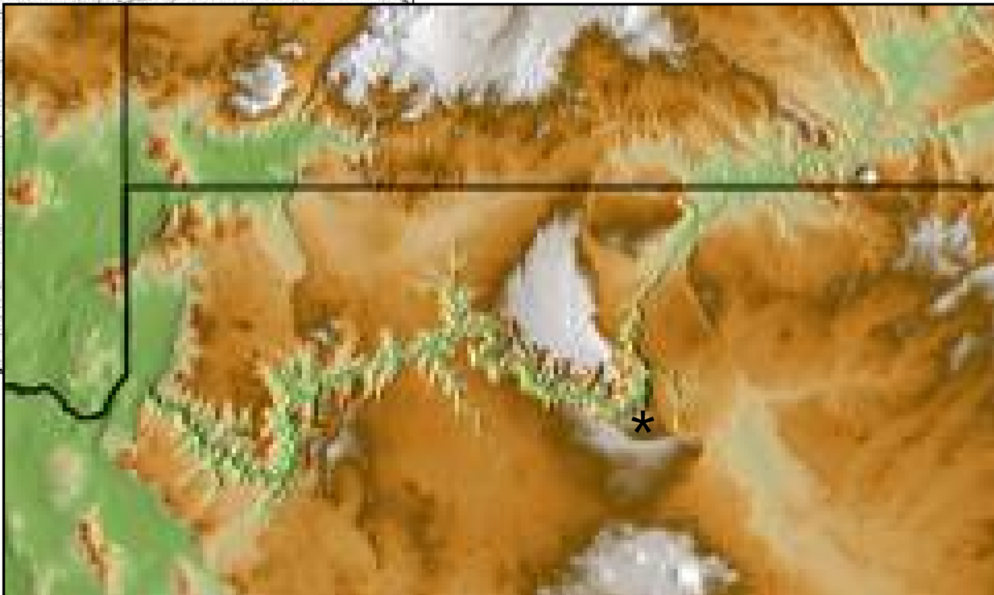
Accumulated emissions transported to Lake Powell and Channeled down the Grand Canyon

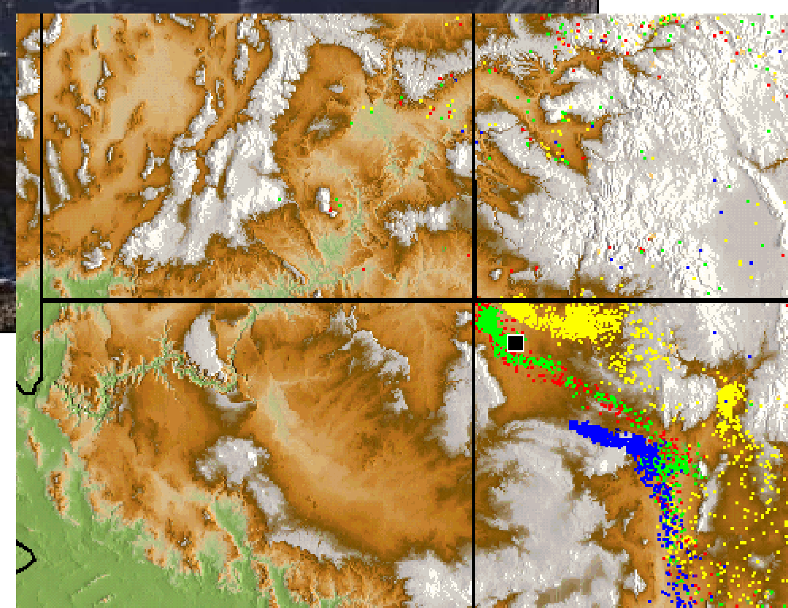
Plume Dispersion Simulation from Power Plants in Four Corner Region
Yellow - Existing; Blue, Green, Red - Proposed Power Plants



01/02/2001 18:00 MST

Field of view of the camera at Desert View point

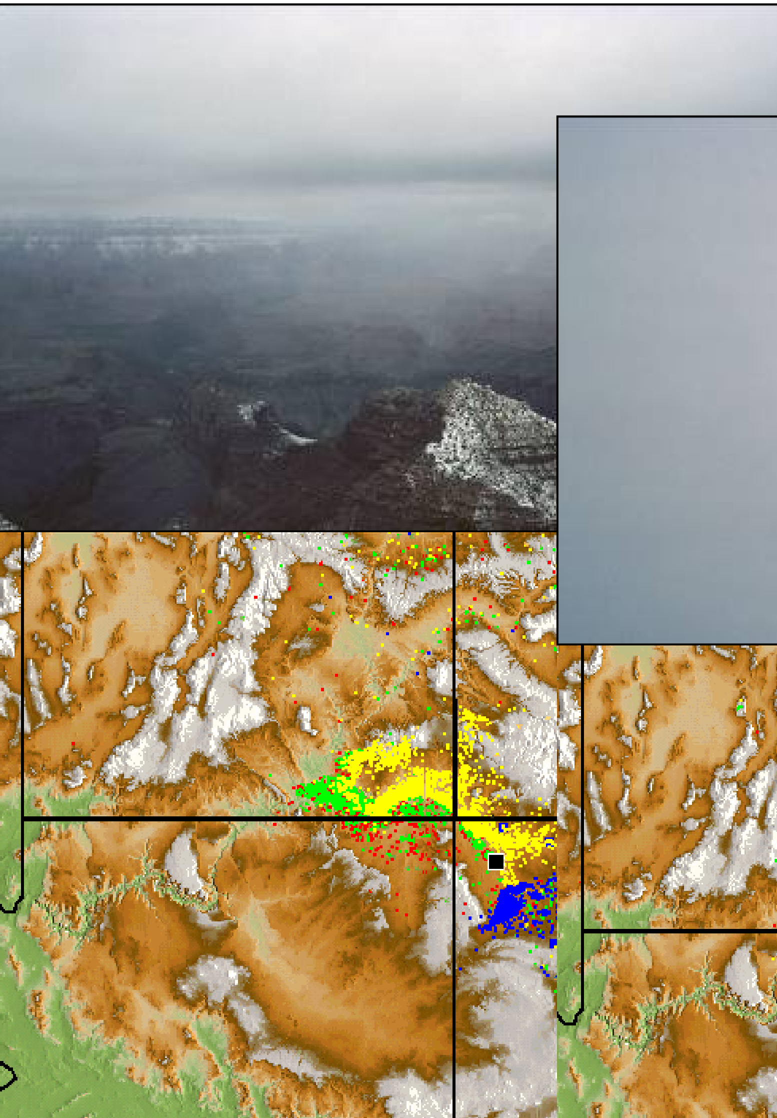




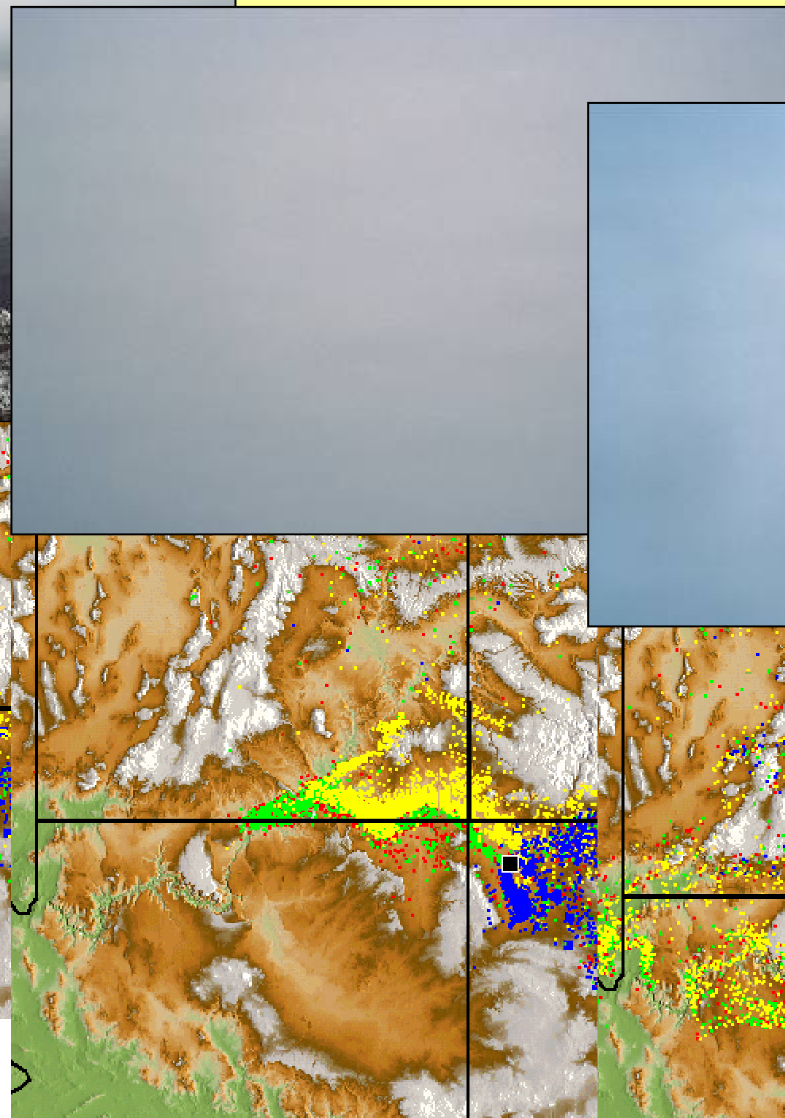
A clear day in the Grand Canyon. Airmass stagnation over the Four Corner region allows for emissions from power plants to accumulate

1/14/01 2:45

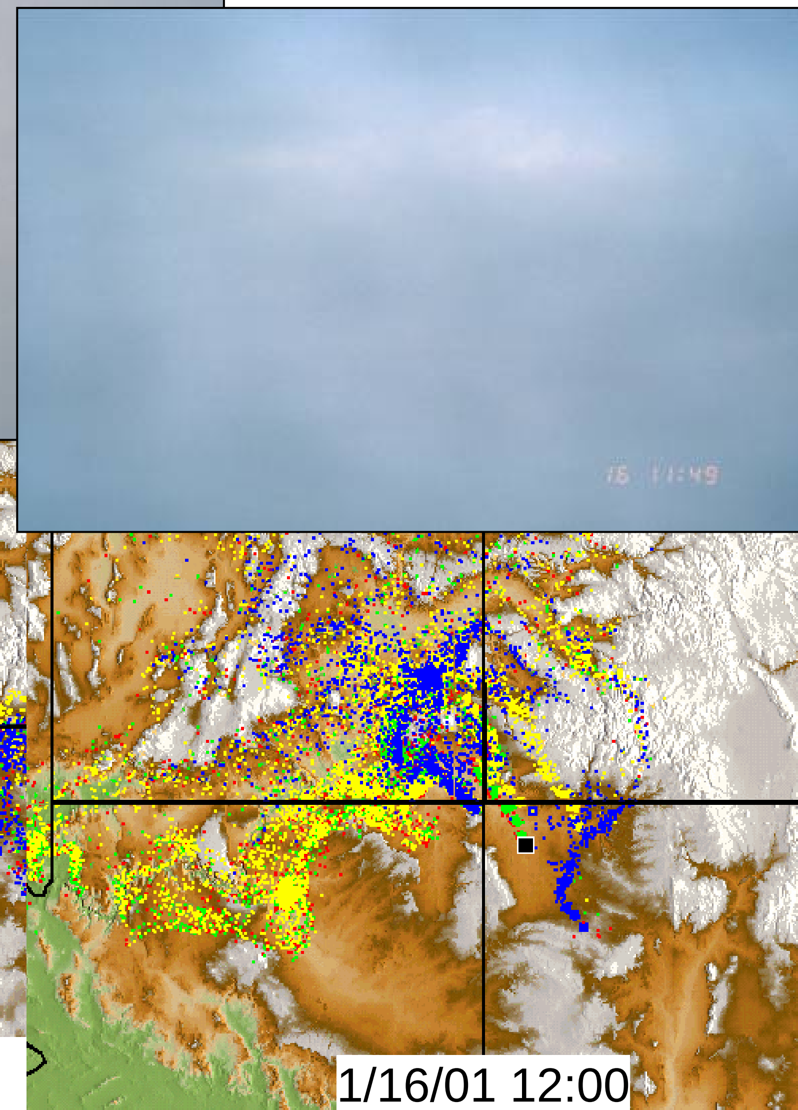
The plumes move into the Colorado River drainage along with stormy weather conditions.



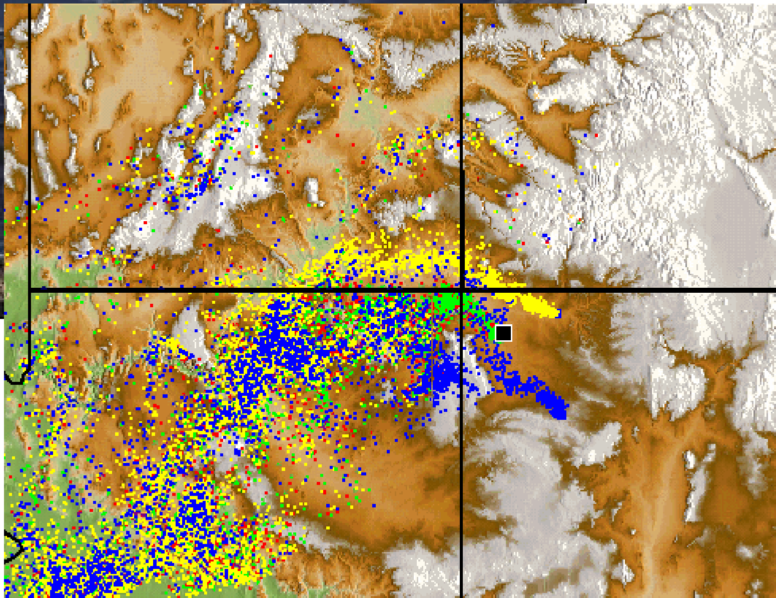
1/15/01 8:45



1/15/01 12:00

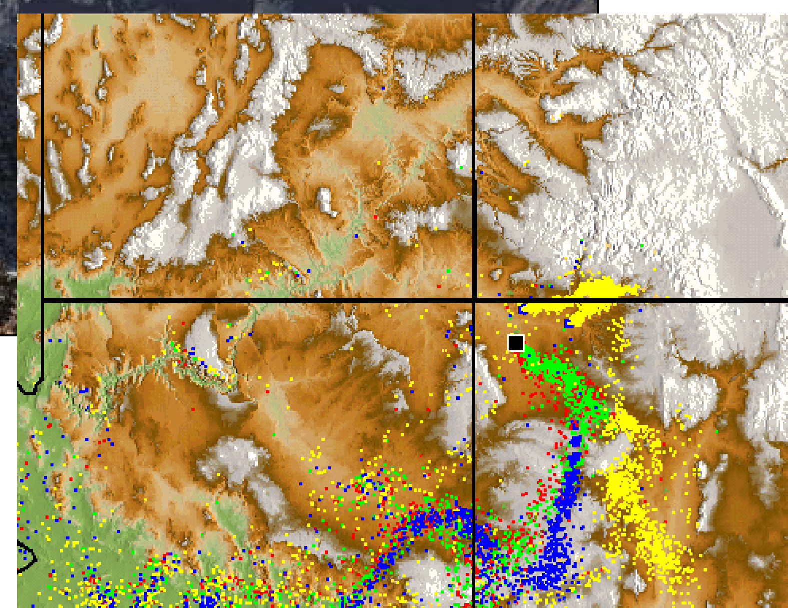


1/16/01 12:00



The clouds evaporate while the power plant plumes remain over the G.C. resulting in haze in the Grand Canyon.

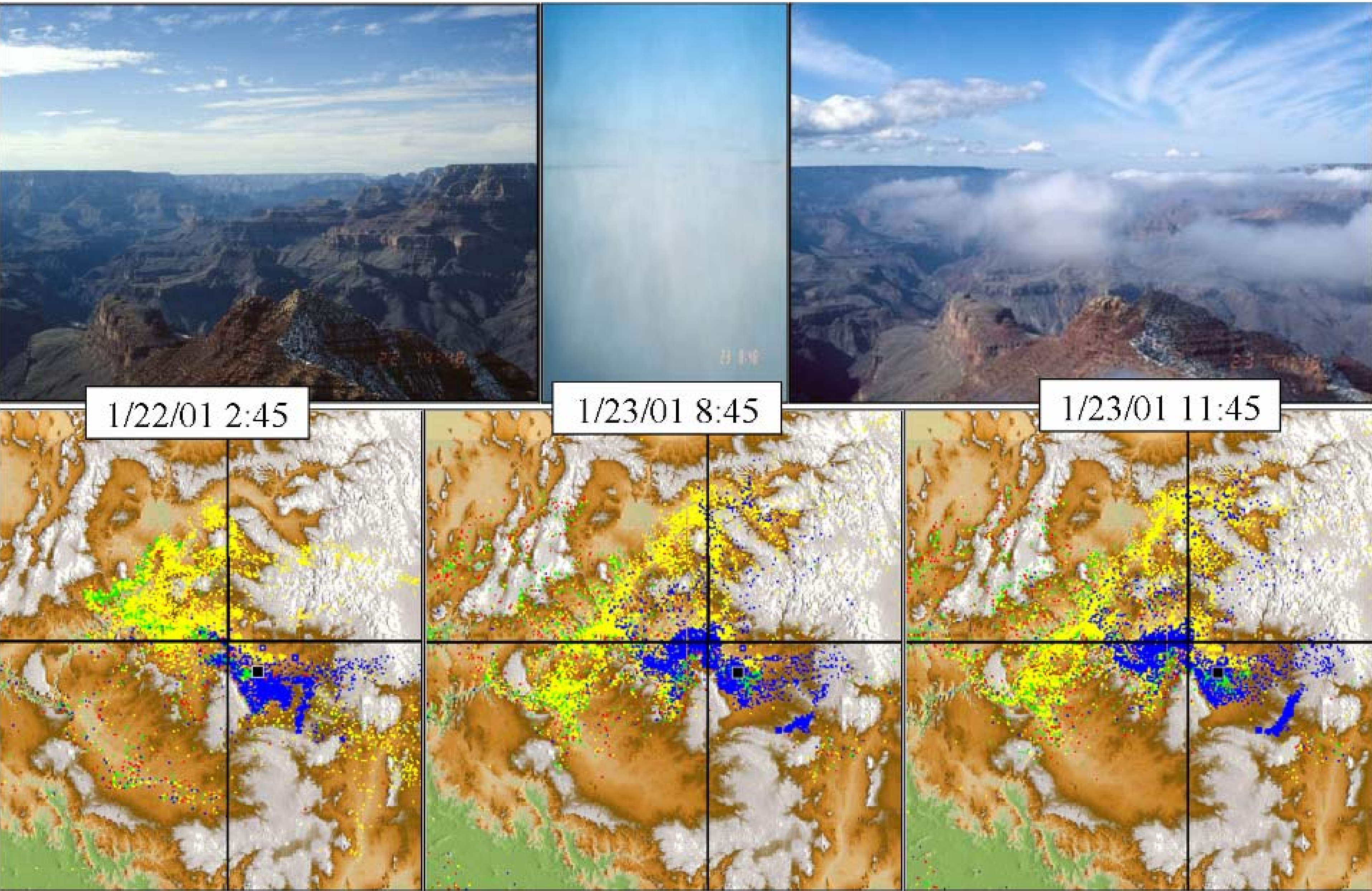
1/17/01 2:45



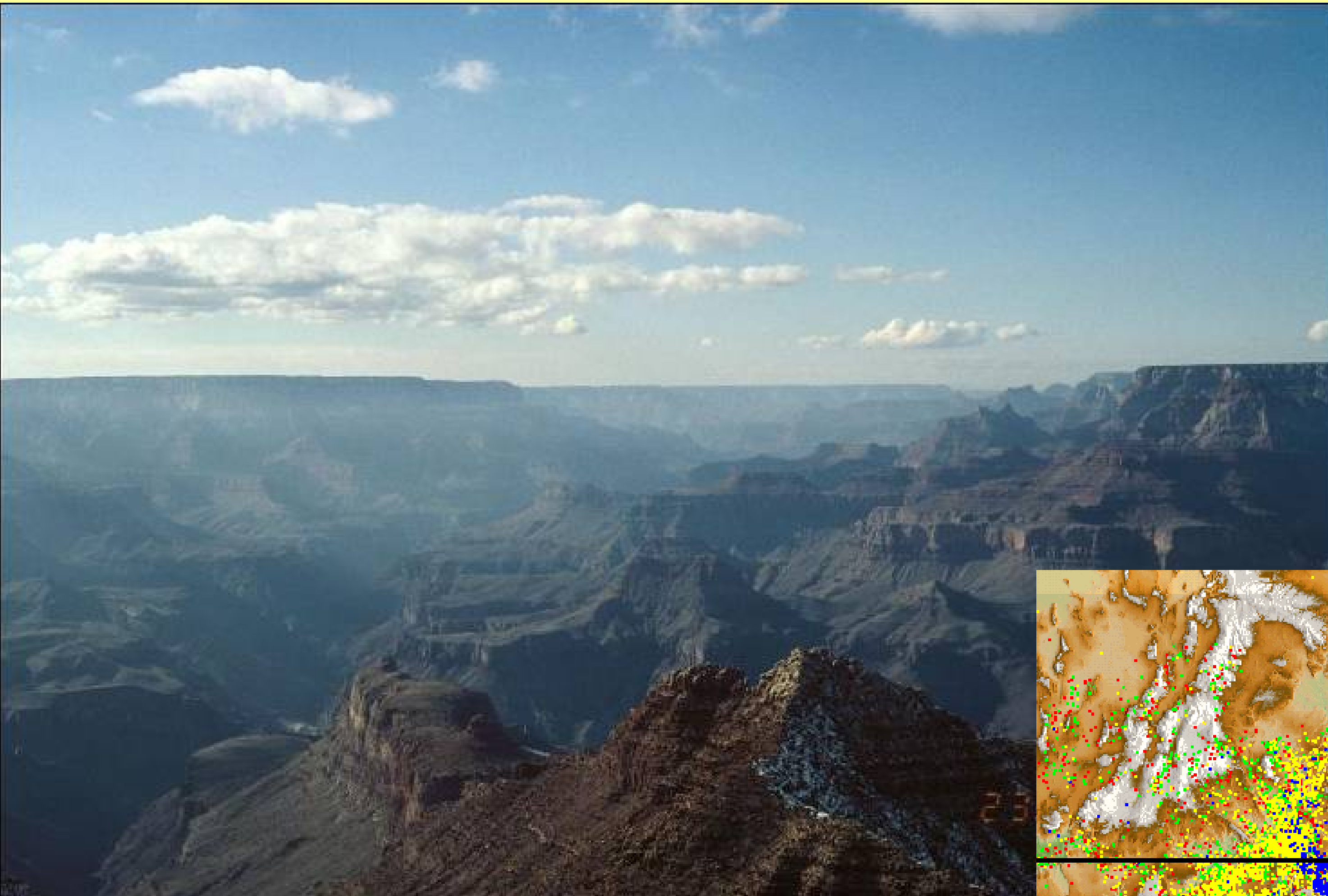
Next day the haze is reduced.

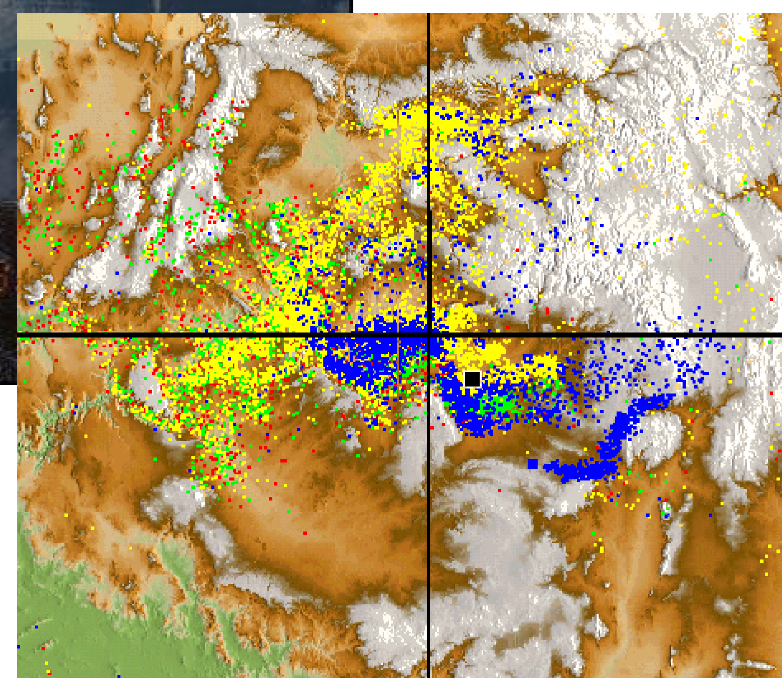
1/18/01 2:45

Grand Canyon Episode on January 23



Grand Canyon Haze - January 23 3 PM



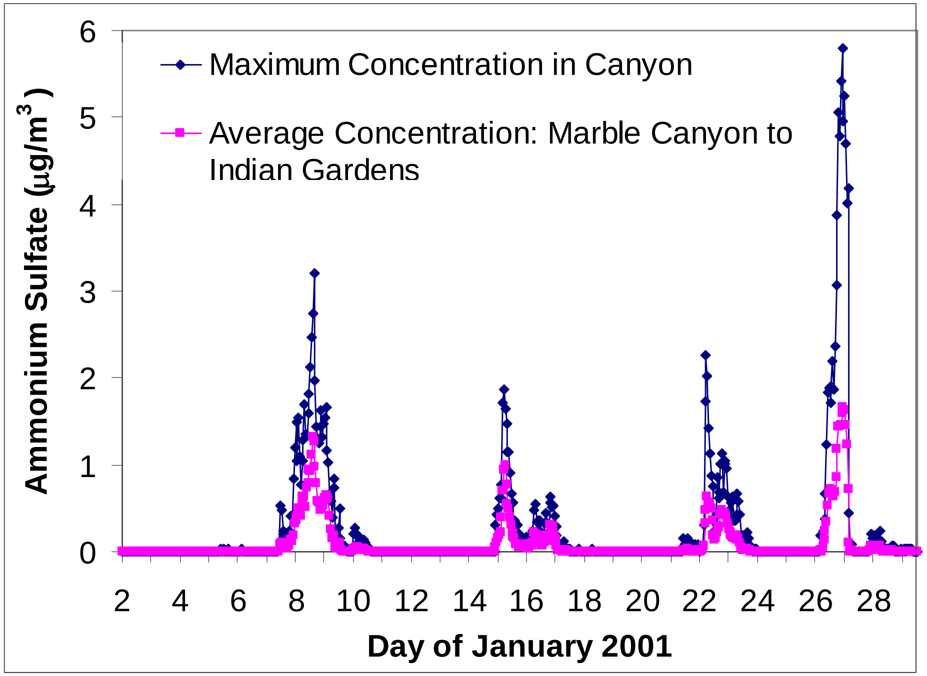


Add Simple Chemistry to CMC Simulation

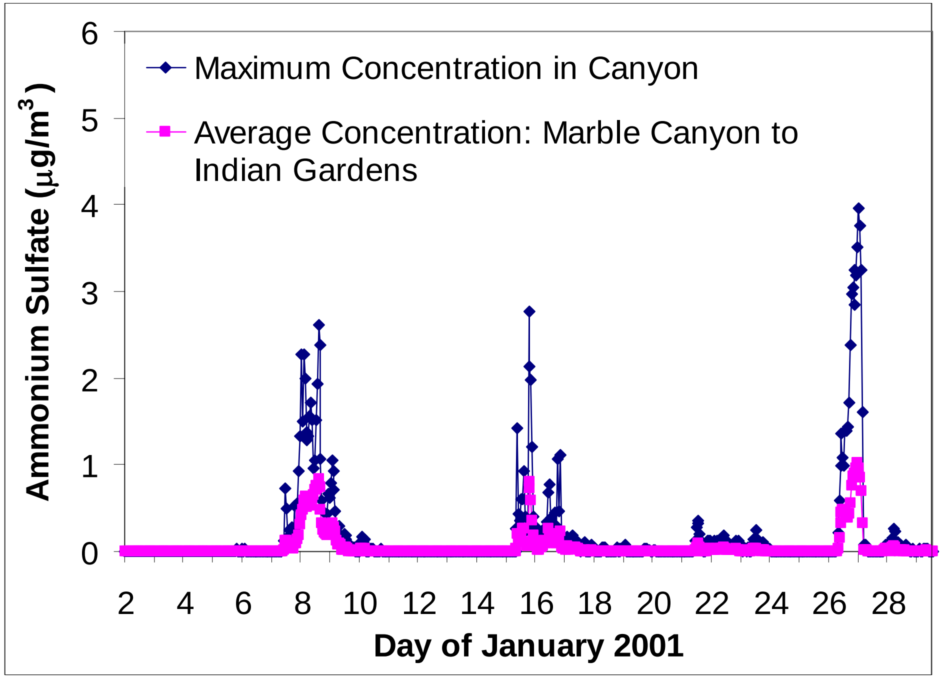
- Weight each particle based upon emissions and apply first order sulfur chemistry to each particle
- 5%/hr SO_2 – SO_4 Transformation rate
  - Assuming in cloud oxidation
  - In all four episodes the plumes entered the canyon imbedded in clouds
- Used typical SO_2 and SO_4 removal rates

Sithe Amm Sulfate Impact on Grand Canyon

Plume Release Hgt – in afternoon mixed layer (430 m)



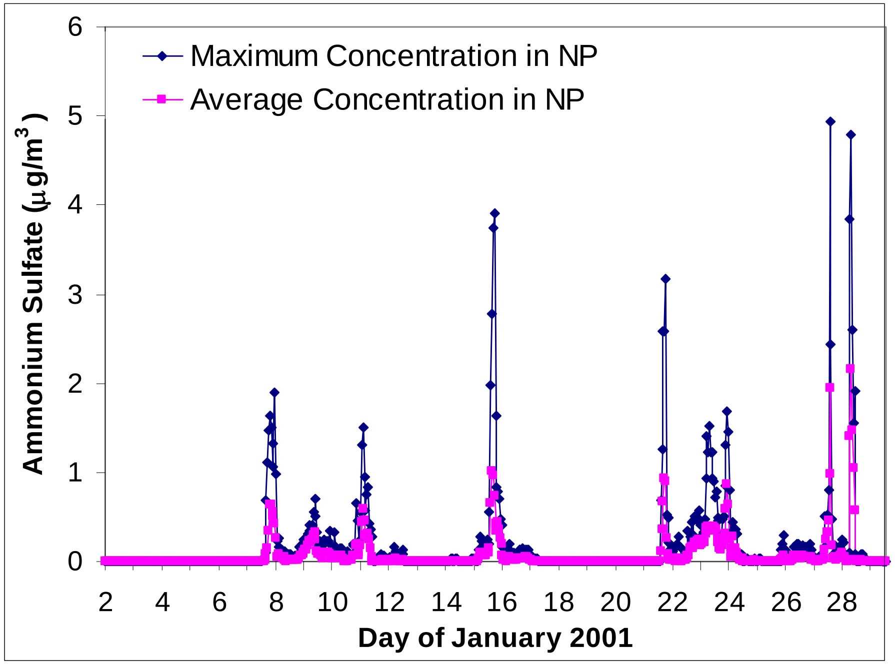
Plume Release Hgt – Variable effective stack height (≥430 m)



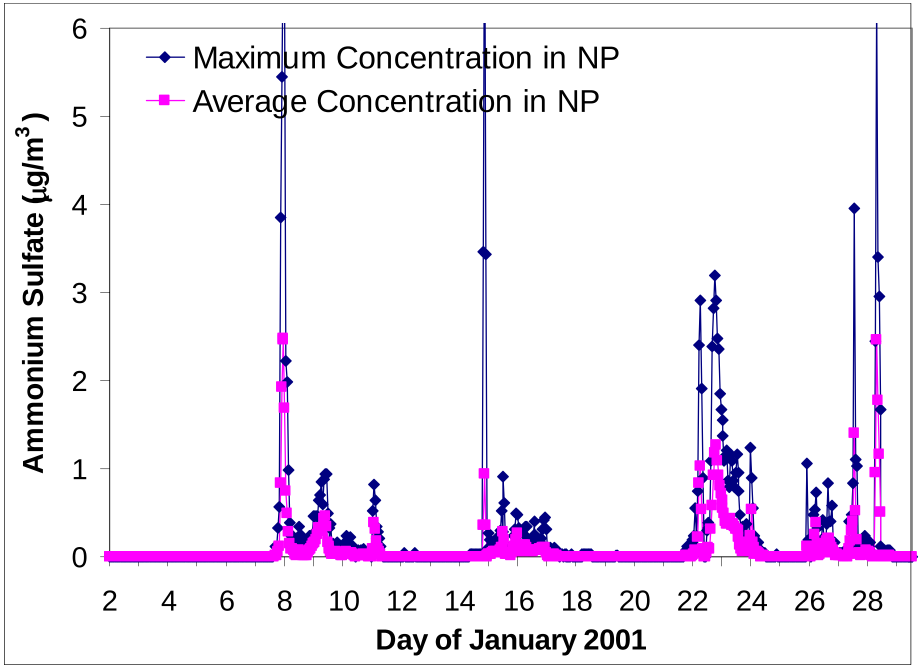
- Sithe had some impact on 12 out of 29 modeled days
- Sithe's average in-canyon contributions vary between 0.5 and 1.7 micro-g/m^3 during each episode
- When the higher variable effective stack heights are used, the maximum average in canyon concentrations decrease to 1 micro-g/m3

Sithe Amm Sulfate Impact on Canyonlands, UT

Plume Release Hgt – in afternoon mixed layer



Plume Release Hgt – Variable effective stack height



- The largest impact averaged over Canyonlands varies from 0.5 to 2.5 micro-g/m^3.
- Concentrations in Canyonlands increases when the higher variable effective stack height is used, particularly for the epidose on January 23rd

Impact of Sithe's SO_2 emissions on Mesa Verde NP, CO

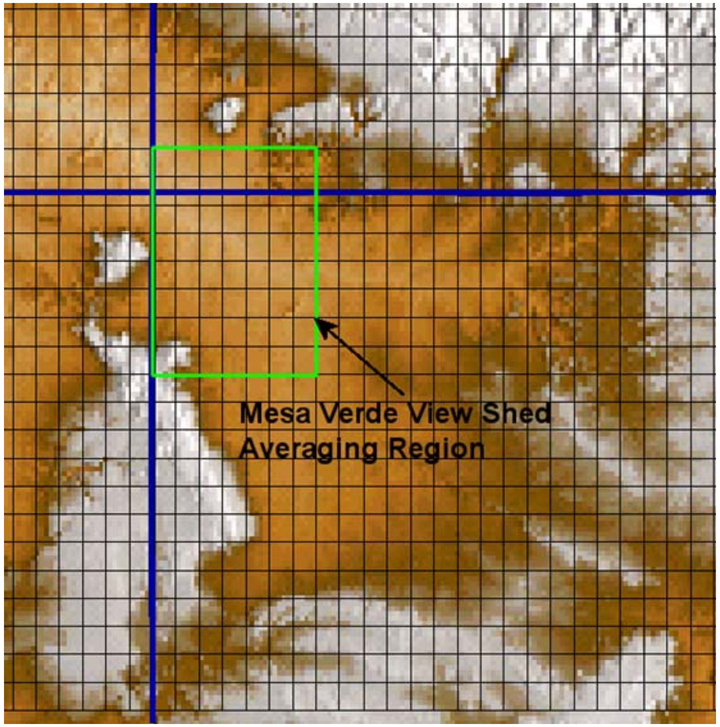
View of Shiprock and Beautiful Mtn, NM from Mesa Verde

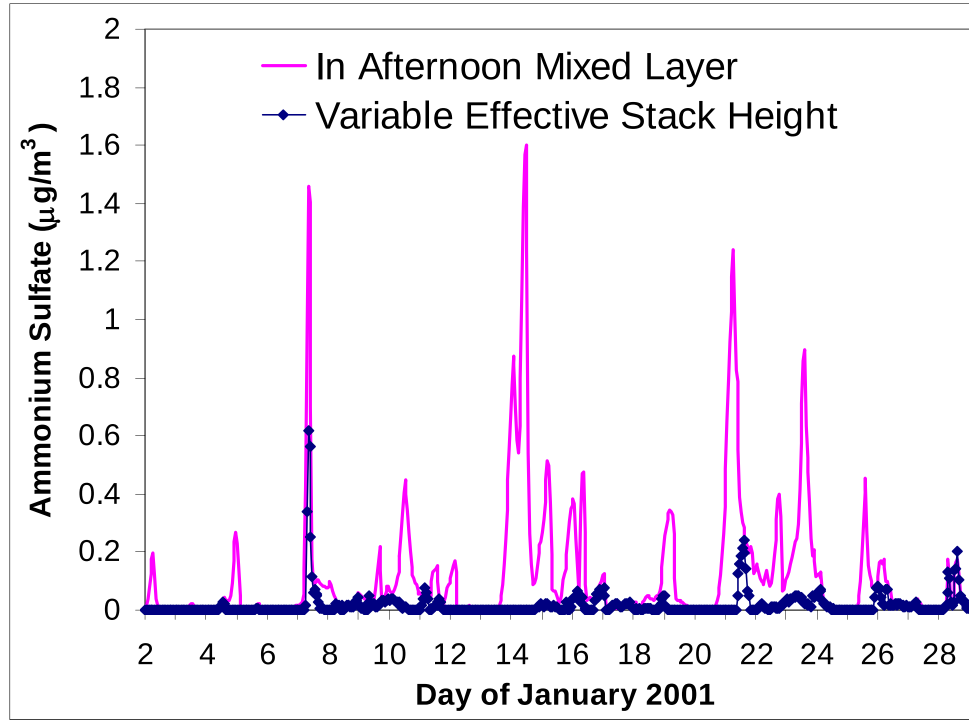
Haze Free Day

December Layered Haze

Wintertime layered hazes frequently occur in the Four Corner basin obscuring views from Mesa Verde and elsewhere.

Impact of Sithe's SO_2 emissions on Mesa Verde NP, CO





- A plume released within the afternoon mixed layer can contribute up to 1.6 μg/m^3 ammonium sulfate to a layered haze
- The elevated plume often contributes little to surface concentrations in the Mesa Verde view shed
- The elevated plume can remain as a coherent plume which could be visible at plume blight

Maximum Sithe Contributions to Class I Areas

Maximum hourly Simulated concentration of ammonium sulfate averaged over the National Park (5%/hr conversion)

	In Mixed Layer	**Variable Effective Stack Hgt**
Grand Canyon NP, AZ	1.7	1.0
Canyonlands NP, UT	2.2	2.5
Arches NP, UT	1.8	1.1
Capitol Reef NP, UT	0.86	0.93
*Mesa Verde NP, CO	1.6	0.62

*Concentration average from Mesa Verde to Chuska Mtn., the Mesa Verde view shed

A 1% transformation rate instead of 5% would decrease the concentrations by about a factor of 3.

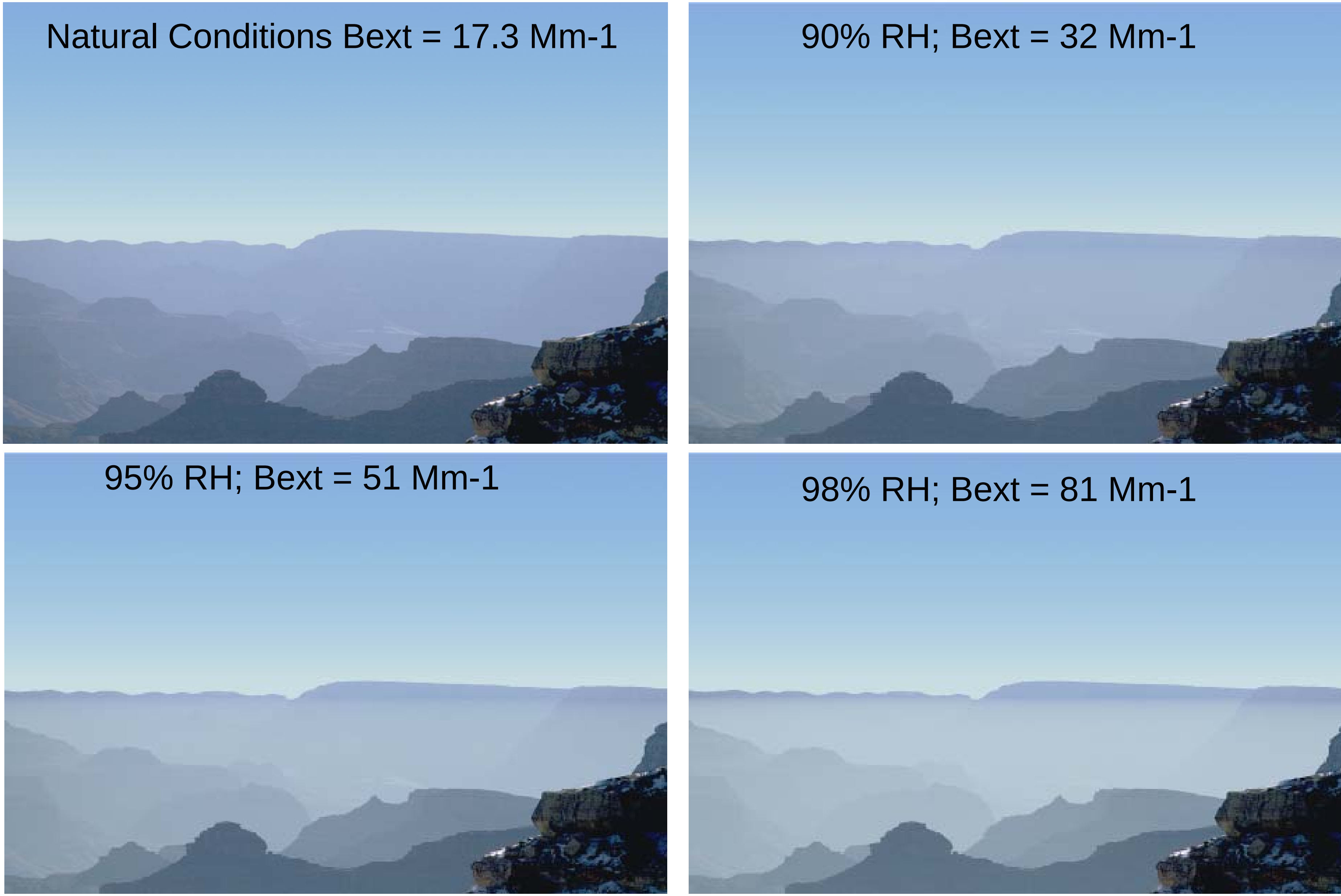
Can these concentrations be seen?

Contribution of the Maximum Amm Sulfate Concentration to Light Extinction (Haze)

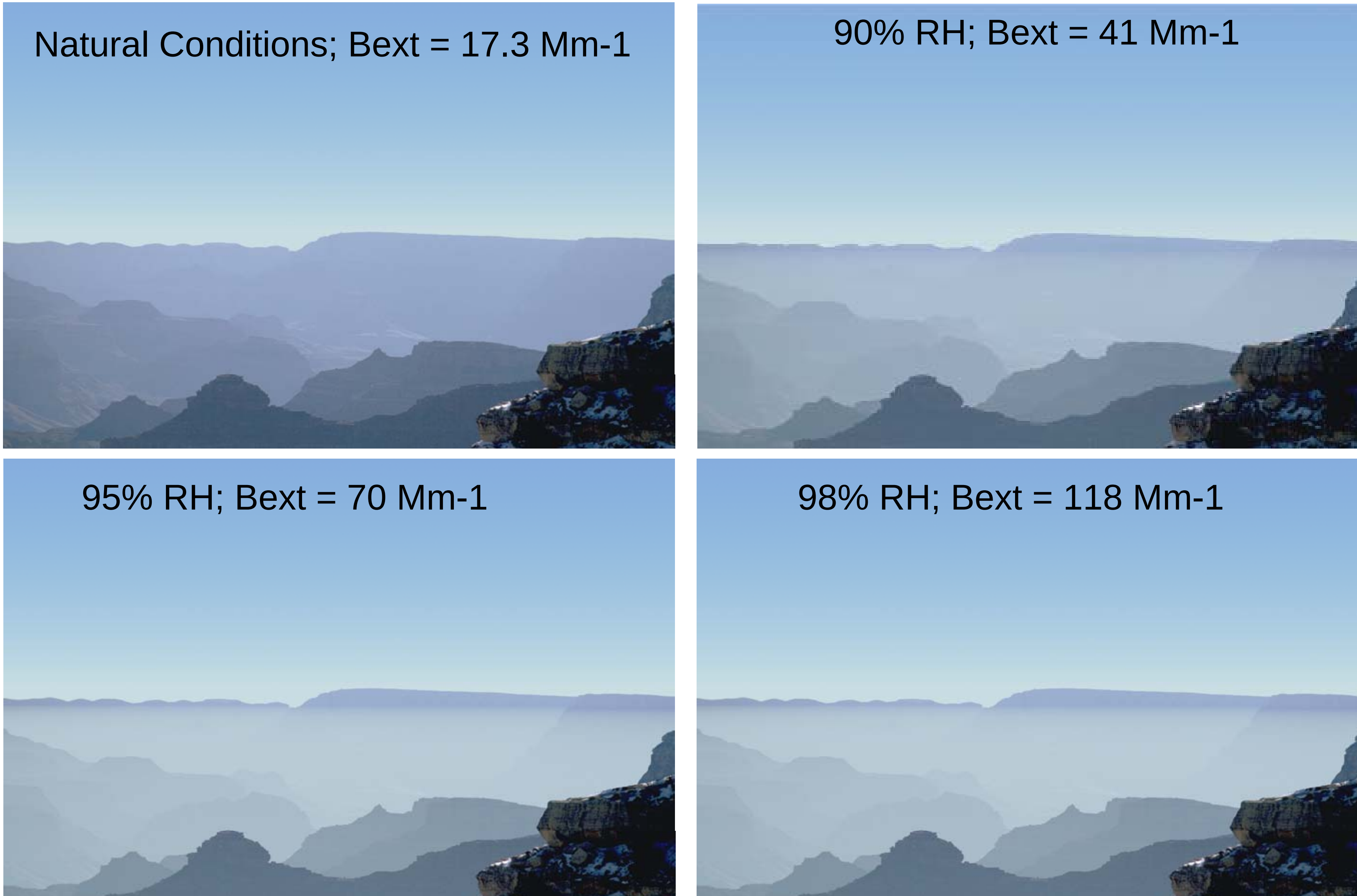
	RH (%)	f(RH)	Natural Background	In Mixed Layer	Variable Effective Stack Hgt
Grand Canyon	90	4.7	17.3	24 (1.4)	14 (0.8)
	95	9.8	20.4	49 (2.4)	30 (1.5)
	98	18.1	25.4	91 (3.6)	56 (2.2)
Canyonlands	90	4.7	17.3	30 (1.8)	35 (2.0)
	95	9.8	20.4	64 (3.1)	73 (3.6)
	98	18.1	25.4	117 (4.6)	134 (5.3)
Arches	90	4.7	17.3	25 (1.5)	16 (0.9)
	95	9.8	20.4	53 (2.6)	33 (1.6)
	98	18.1	25.4	97 (3.8)	61 (2.4)
Capitol Reef	90	4.7	17.3	12 (0.7)	13 (0.8)
	95	9.8	20.4	25 (1.2)	27 (1.3)
	98	18.1	25.4	47 (1.8)	51 (2.0)
Mesa Verde – View Shed	90	4.7	17.3	23 (1.3)	9 (0.5)
	95	9.8	20.4	47 (2.3)	18 (0.9)
	98	18.1	25.4	87 (3.4)	34 (1.3)

Values in parentheses are fraction above natural background. Note, a fractional increase of 0.1 is a one deciview change and could be perceptible.

Simulation of Grand Canyon Layered Haze due to 1 μg/m3 of Amm. Sulfate from the Sithe PP



Simulation of Grand Canyon Layered Haze due to 1.7 μg/m3 of Amm. Sulfate from the Sithe PP



Simulation of a Uniform Haze in Grand Canyon due to 1.7 μg/m3 of Amm. Sulfate from the Sithe PP

Natural Conditions; Bext = 17.3 Mm^{-1}

90% RH; Bext = 41 Mm^{-1}

95% RH; Bext = 70 Mm^{-1}

98% RH; Bext = 118 Mm^{-1}

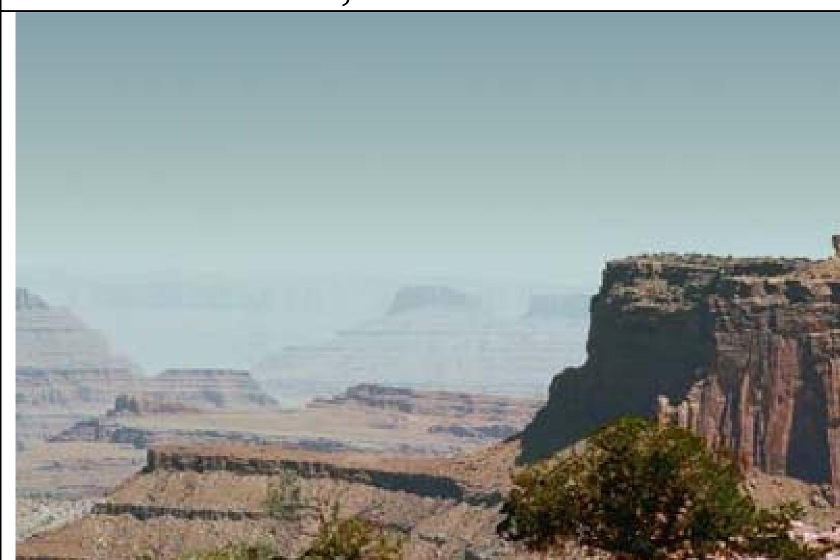
Simulation of a Uniform Haze in Canyonlands, UT due to 2.2 μg/m3 of Amm. Sulfate from the Sithe PP

Natural Conditions; Bext = 17.3 Mm^{-1}

90% RH; Bext = 48 Mm^{-1}

95% RH; Bext = 84 Mm^{-1}

98% RH; Bext = 143 Mm^{-1}

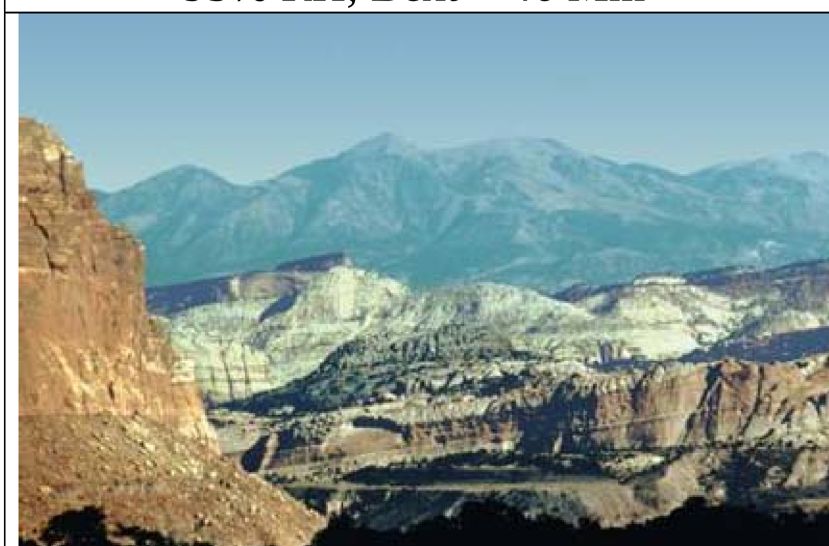


Simulation of a Uniform Haze in Capitol Reef, UT due to 0.86 μg/m3 of Amm. Sulfate from the Sithe PP

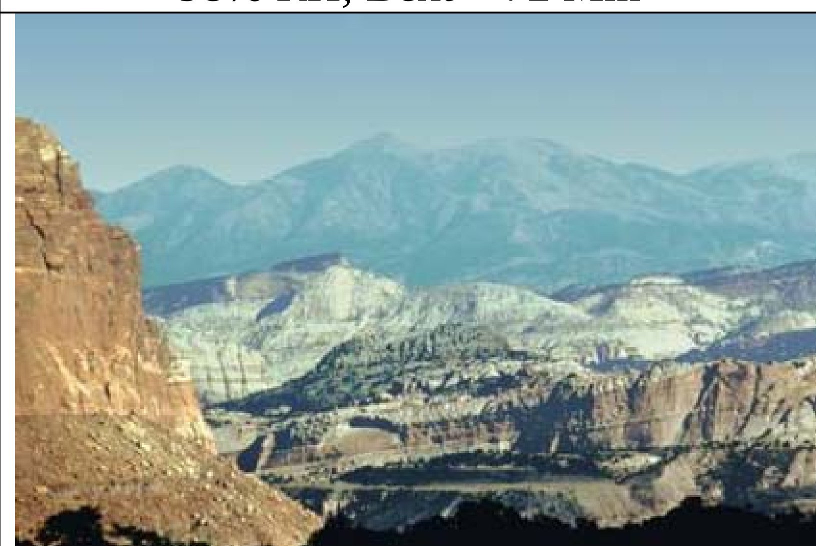
Natural Conditions; Bext = 17.3 Mm^{-1}

90% RH; Bext = 29 Mm^{-1}

95% RH; Bext = 46 Mm^{-1}



98% RH; Bext = 72 Mm^{-1}



END

Studies of Air Quality on Colorado Plateau

- Winter Haze Intensive Tracer Experiment (WHITEX) January and February 1987
  - Evaluate the feasibility of attributing single point source emissions to visibility impairment in Grand Canyon NP
- Measurement of Haze and Visual Effects (MOHAVE). Jan-Feb, Jul-Aug 1992
  - Estimate the contributions of the Mohave power plant (MPP) and other large pollution emission sources to haze at the Grand Canyon and other national parks.

Principle Findings

- Large power plants, i.e. Mohave power plant, located west of the GCNP, and the Navajo generating station, located east of the GCNP, could significantly contribute to haze in GCNP
- Power plants located east of the GCNP are most likely to have significant impacts in the winter months
- Due to the complex terrain and important micrometeorological processes, modeling the impact of power plants on the Grand Canyon was particularly challenging and no model was able to properly reproduce all of the relevant processes of a haze episode.

Photographic documentation of the development of a haze episode in the Grand Canyon during WHITEX