Gorge Science Summary Overview

Prepared by Marc Pitchford & Mark Green
for the Columbia River Gorge Haze Project
Science Day - September 25, 2007

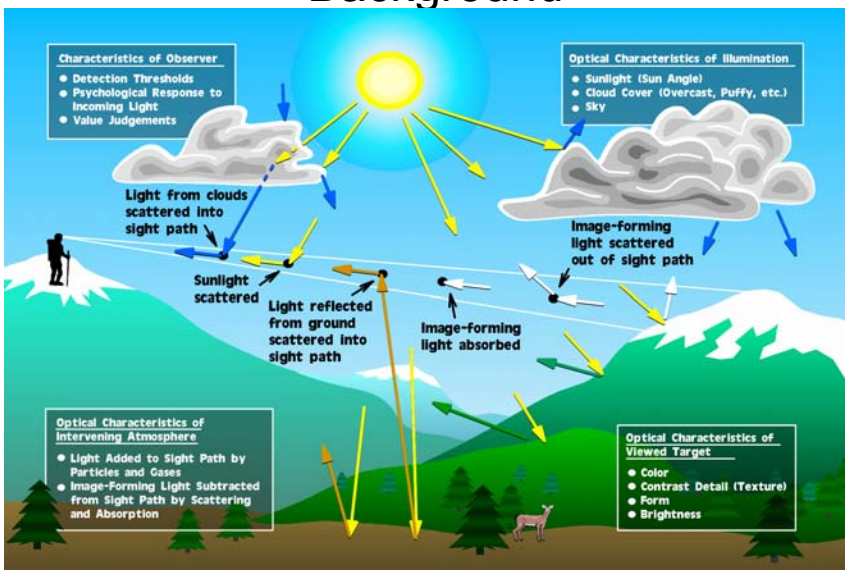
Presentation Preview

- Haze Science Fundamentals
  - What's haze? How is it related to pollution?
- Conceptual Model of Gorge Haze
  - Briefly, what causes Gorge haze?
- Six Technical Questions & Responses
  - In more detail, what causes Gorge haze and how much could it change?
- Conclusions and Observations
  - What do we think this means?

Haze & Light Extinction

- Visibility impairment is caused by particles and gases in the atmosphere that scatter and absorb light, referred to as **light extinction**
  - Light scattering by clean air limits visibility and is dependent on atmospheric density (higher at sea level)
  - Gaseous light absorption from nitrogen dioxide is typically ignored
  - **Particle light extinction** (scattering and absorption) is the **principal source of impairment** and referred to here as haze
  - Light extinction is easily converted to visual range and perceived haziness in deciview units
- The fraction of the light that is scattered and absorbed per unit of distance is the light extinction
  - its measured in units of 1/distance, usually 1/1million meters (**Mm^{-1}, pronounced inverse megameters**)

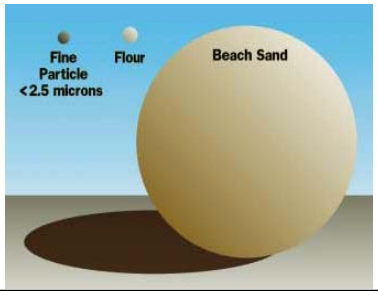
Background

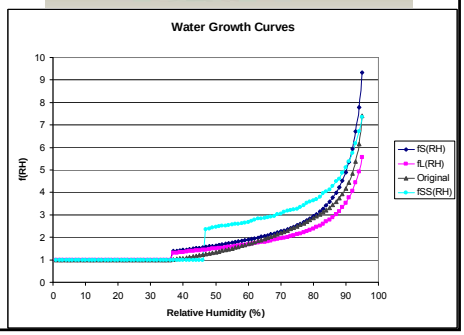


- Air quality related visibility impacts are caused by scattering and absorption by particles and gases

Light Extinction & Particulate Matter (PM)

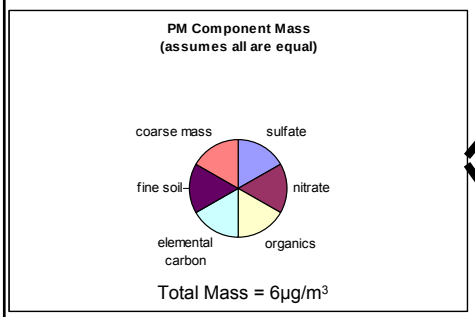
- **PM light extinction efficiency** depends on particle size and composition
  - small or fine particles ($PM_{2.5}$) scatters more light than the same concentration of large or coarse particles ($PM_{10-2.5}$)
  - Black carbon (soot or elemental carbon) and some soil mineral are the only PM that absorb light
  - Composition of some particles (e.g. sulfate and nitrate) cause them to absorb water when relative humidity is high which increases their extinction efficiency

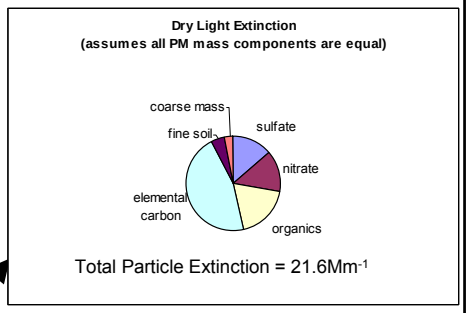


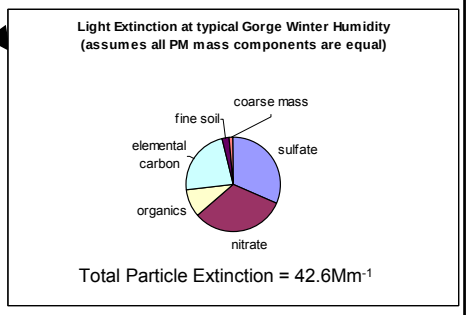


Some PM Components Creates More Haze than Others

If all PM components had the same concentration (shown below) their contributions to light extinction on a very dry day would be unequal (shown in the upper right figure)



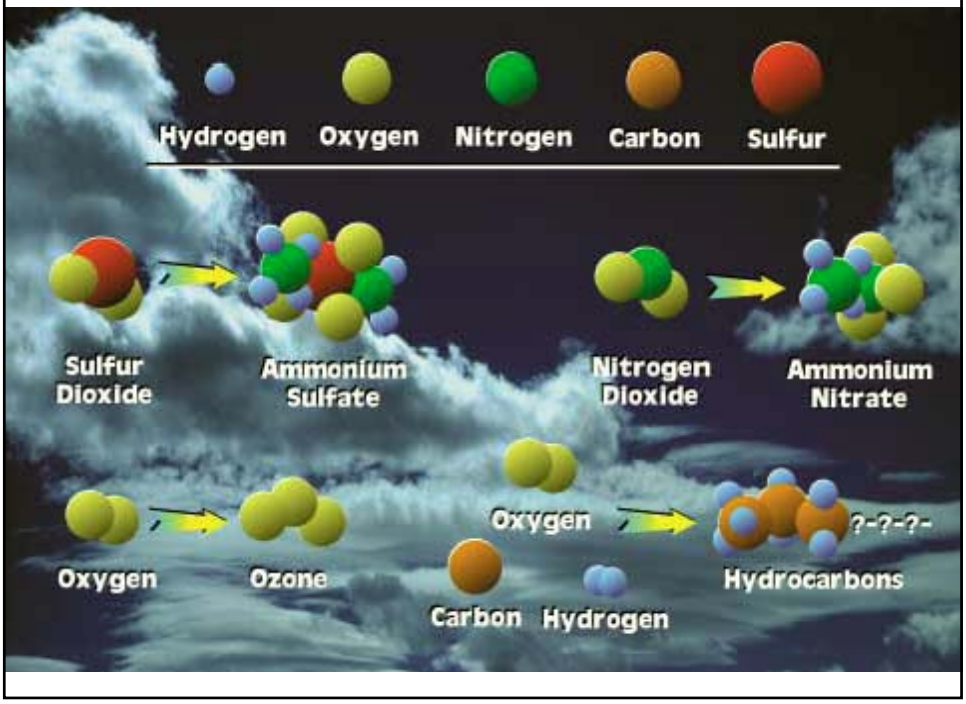




If all PM components had the same concentration (shown above) their contributions to light extinction on a typical winter Gorge day (RH~92%) would be unequal (shown in the lower right figure) and much greater overall than on a dry day

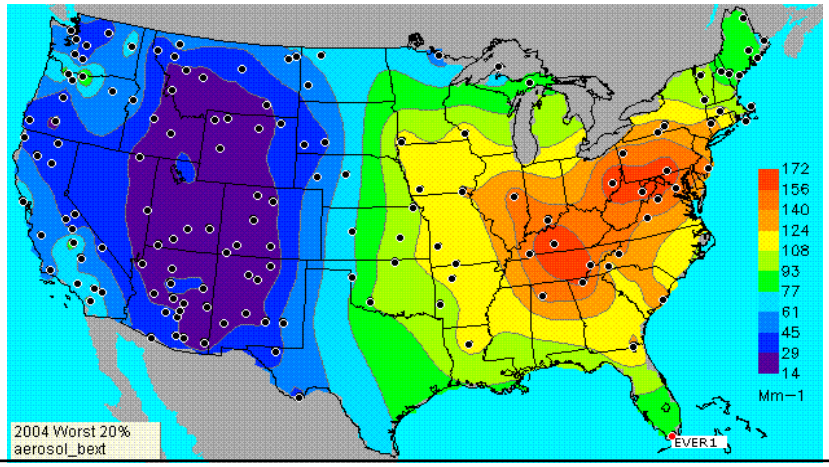
Pollution Emissions and PM

- **Primary PM** are directly emitted into the atmosphere as particles
  - Relationship between emission and ambient concentrations depends on atmospheric factors affecting dilution and deposition.
  - Includes windblown and mechanically suspended dust (coarse mass & fine soil) and organic and elemental carbon from combustion
- **Secondary PM** are formed from precursor gases emitted into the atmosphere
  - Rate of conversion to PM depends on atmospheric conditions (sunlight, temperature, humidity, presence of other gases, etc.)
  - Chemical conversion in fog droplets is much more rapid and complete than in fog free air
  - Secondary PM includes sulfate and nitrate and much of the organic PM from sulfur dioxide, nitrogen oxide, ammonia and organic precursor gases emitted by a broad variety of sources
- **Air quality simulation models** link pollutant emissions to ambient PM concentrations
  - Used to assess how much of the PM & haze is due to the various emission sources
  - Used to determine how PM & haze levels would change if emissions where different

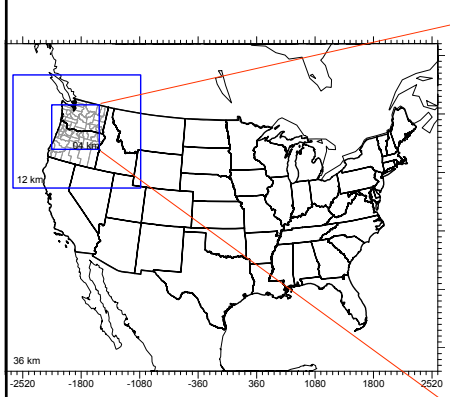


Contour Map of the Average of the 20% Worst Haze Days Particle Light Extinction for Remote-Area Monitoring Sites - 2004

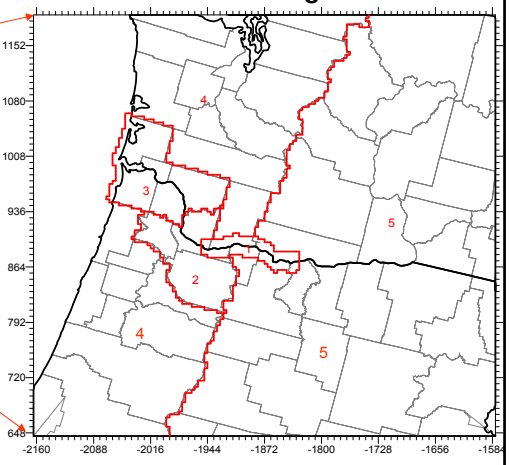
- Gorge haze levels are not as great as in the Eastern U.S., but are among the worst in the West
  - Wishram (east Gorge) and Mt. Zion (west Gorge) have the highest and third highest haze measured at remote area monitoring sites in the Western U.S.
  - Caused largely by winter stagnations that trap pollutants and fog that make the Columbia River Basin particularly productive in the generation of secondary PM from gaseous precursors



Gorge Study Model Nested Domains



Gorge Study 4km Grid Model Domain and Source Regions



Breakdown of the 4-km modeling grid into 5 source regions for use in the CAMx PSAT application. Regions are referred to as (1) in-Gorge, (2) Portland/Vancouver metropolitan area, (3) northwest of Gorge, (4) west of Gorge, and (5) east of Gorge. A sixth region was defined for all areas outside the 4-km grid.

Conceptual Model of Gorge Haze in the Summer*

- Wind is from the west with relatively dry conditions
- Large contributions from natural sources (~40% to ~60% from wildfire plus biogenic secondary organic PM)
- Western Gorge Haze
  - Portland ~20%
  - Beyond the 4-km model domain ~22%
  - Northwest of Gorge are responsible ~12%
  - In-Gorge ~6%
  - Secondary organic ~33%
- Eastern Gorge Haze
  - East of Gorge ~22%
  - Beyond the 4-km model domain ~23%
  - In-Gorge ~9%
  - Secondary organic ~32%

* Quantitative information based on air quality modeling of the August, 2004 episode.

Conceptual Model of Gorge Haze in the Winter*

- Wetter & colder means no wildfires & reduced biogenic emissions
- Natural contributions are relatively small, ~5% to ~12%
- Stagnation and fog responsible for rapid conversion of precursor gases emitted by numerous sources in the region into sulfate and nitrate PM
- Worst Gorge haze is left when fog evaporates
- Western Gorge Haze
  - Portland ~28%
  - Outside of the domain ~19%
  - Within the Gorge and east of the Gorge regions ~13% each
  - ~75% sulfate and nitrate PM
  - ~9% organic and elemental carbon from residential heating and vehicular sources
- Eastern Gorge Haze
  - East of the Gorge ~57% with (half from electric utility emissions & most of the rest from vehicular sources)
  - Outside of the modeling domain ~23%
  - Within the Gorge were responsible ~10%

* Quantitative information based on air quality modeling of the November, 2004 episode.

Conceptual Model of Gorge Haze

- Modeling of emission projections indicate that Gorge haze is likely to be reduced by 2018
  - Perhaps imperceptibly for summer episodes
  - Small but perceptibly for winter episodes
- Modeling of the two episodes indicates that regional (within Washington & Oregon) controls of man-made sources cannot eliminate Gorge haze
  - During the August episode as much as ~60% to ~80% of the haze is from natural and outside of the region emissions
  - During the November episode only ~30% of the haze is from natural and outside of the region emissions

Computer Simulations of Hazes Superimposed On a Gorge Photo to Show How Much of the August Haze is Beyond Regional Control

August 2004 episode at Mt. Zion (particle light extinction = 36Mm^{-1})

August 2004 episode with **only natural and distant source** contributions to haze (particle light extinction = 22Mm^{-1})

Computer Simulations of Hazes Superimposed On a Gorge Photo to Show How Much of the November Haze is Beyond Regional Control

November 2004 episode at Wishram (particle light extinction = 190Mm^{-1})

November 2004 episode at Wishram with **only natural and distant source** contributions to haze (particle light extinction = 54Mm^{-1})