MFE 659 Lecture 5a Air Pollution

- The boundary layer
- Conditions that promote air pollution episodes
- Anthropogenic Pollution
  - Brief History
  - Acid Rain
  - Ozone Hole

Burning of sugar cane fields on Oahu in 1993

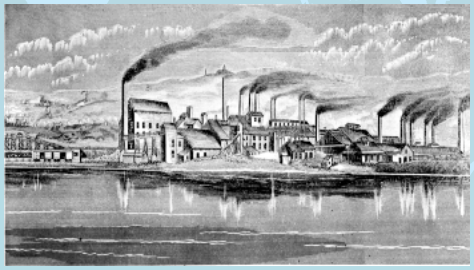
Air Pollution

Air Pollution – Elevated levels of aerosols and harmful gases

Historic Pollution Episodes

Many of the worst air pollution episodes occurred during the last two centuries in London, England.

- key ingredients - calm winds, fog, smoke from coal burning (thus the term smog)
- 1873 - 700 deaths
- 1911- 1150 deaths
- 1952 - over 4000 deaths
- this last event prompted the British parliament to pass a Clean Air Act in 1956



US Pollution Episodes

- In the U.S., air quality degraded quickly shortly after the industrial revolution
- Problem was coal burning in the central and midwestern U.S.
- 1948 - Donora, PA in the Monongahela River Valley five-day episode - 1000's became ill, 20 were killed
- 1960s - NYC experience several dangerous episodes
- 1960s-70s - Los Angeles - increase in industry and automobile usage led to many pollution episodes
- The above events led to passing the Clean Air Act of 1970 (updated in 1977 and again in 1990) empowered the federal government to set emission standards that each state would have to meet.

Hazardous Pollutants

A particularly nasty bunch of pollutants

- Carbon Monoxide (CO) enters the bloodstream and causes cardiovascular damage
- Ozone and Nitrogen Oxides (NO_2 and NO) damage the lungs, leading to asthma and other respiratory illnesses (especially in children)
- Particulate matter (PM_{10} and $PM_{2.5}$), especially from diesel trucks, is carcinogenic
- Sulfur Dioxide (SO_2) and NO_2 cause acid rain
- Lead (Pb) poisoning destroys the body's organs

Clean Boundary Layer

The atmospheric boundary layer is the lowest layer of the troposphere where friction is important. Most boundary layers are capped by a stable layer above.

We live in and breathe the air of the boundary layer.

Clean Boundary Layer

It is more than a blessing to have clean air. It is essential for good health.

We live in and breathe the air of the boundary layer.

Pollution in the Boundary Layer

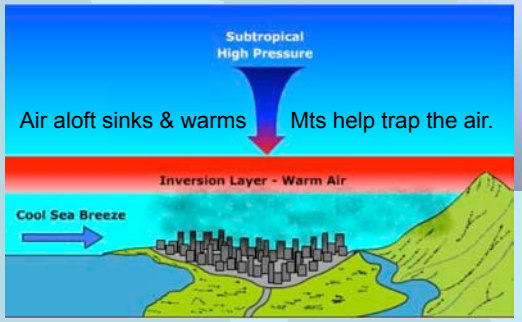
Most pollution enters the atmosphere near the surface.

Conditions that Promote Pollution Episodes

Atmospheric conditions that limit horizontal and vertical mixing of the air result in high pollution concentrations.

These conditions are found within areas of high surface pressure, especially in winter, when radiational cooling causes cold, stable air to collect near the surface.

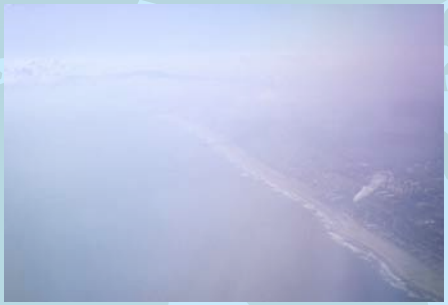
Pollution Episodes



Los Angeles from the air.

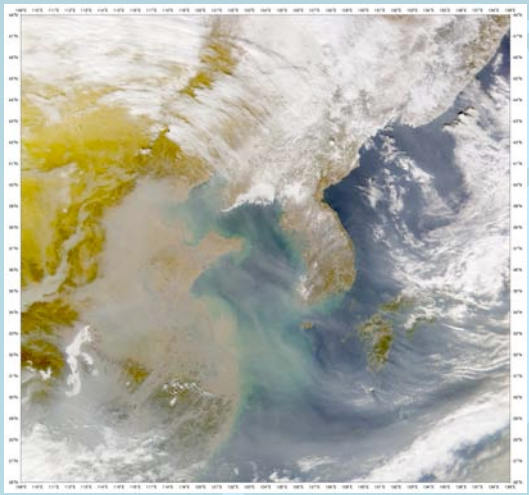
Pollution episodes occur in areas of high surface pressure resulting in stable air (temperature inversions) and light winds.

Polluted Boundary Layer

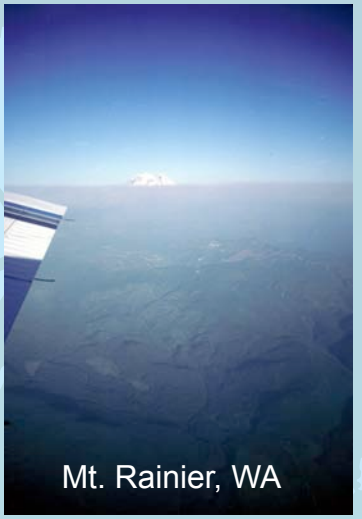


LA and Denver “brown clouds” primarily caused by automobile exhaust plus sunlight.

Polluted Boundary Layer

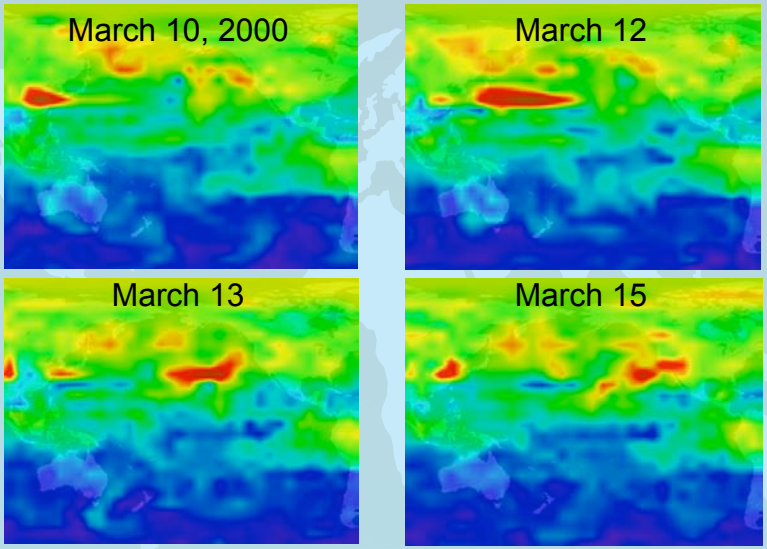


China from space.



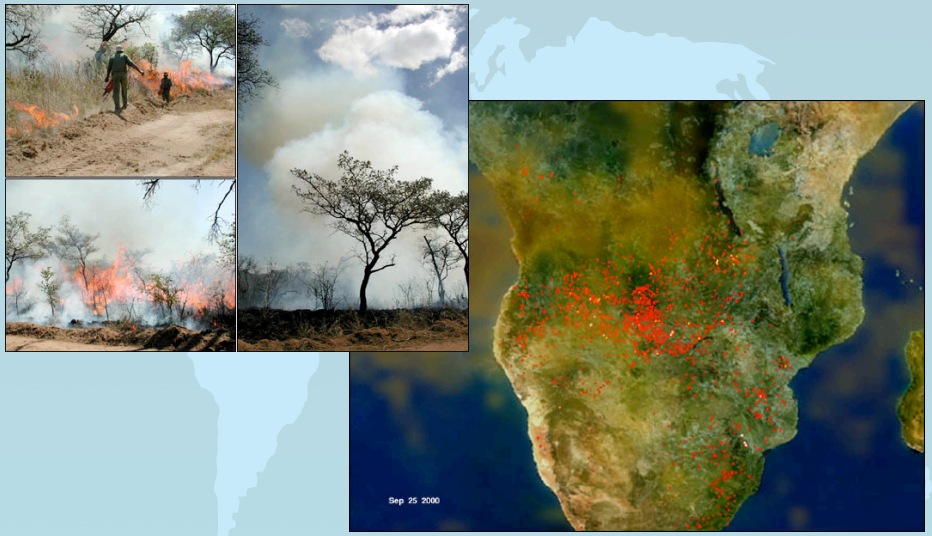
Pollution in the atmosphere can travel great distances.

CO concentration from Satellite



Carbon Monoxide (CO) at 15,000 ft traced from China to USA.
CO in the lungs prevents the uptake of oxygen!

Anthropogenic Sources of Air Pollution

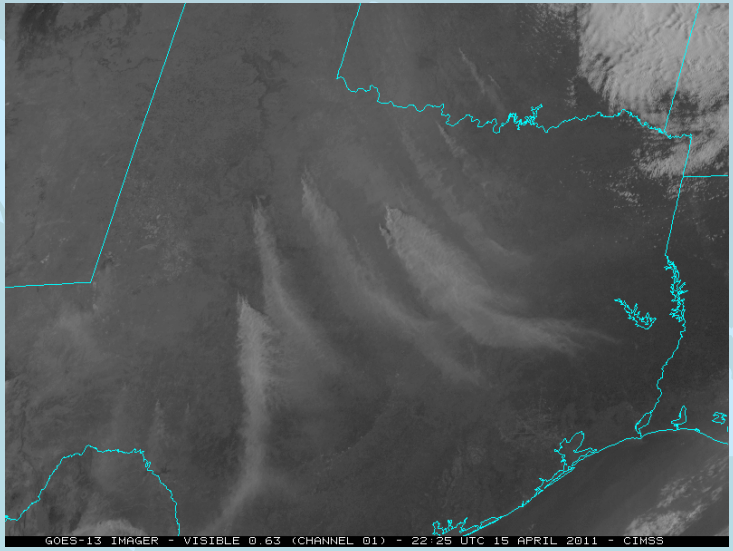


Intentionally set fires are a large source of pollution and CO_2

Fires are Promoted by Droughts

Texas wildfires fanned by high winds in April 2011.

Texas Wildfires Fanned by High Winds



Most pollution enters the atmosphere near the surface.

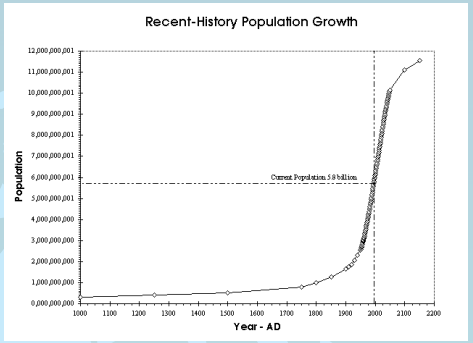
Anthropogenic Sources of Air Pollution

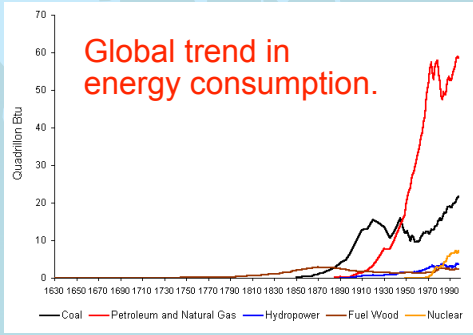
Big Meadow controlled burn --> Wild fire

Yosemite NP, August 2009

Air Pollution

Man-made pollution – related to population and industrialization.





The Horse Problem

- Prior to the car, the horse was the dominant mode of transportation.
- Horse waste was a serious problem.
- In NYC 2.5 million tuns of solid waste and 60,000 gallons of liquid waste had to be cleaned from the streets daily at the turn of the last century.
- 15,000 dead horses had to be removed from the city annually
- Odorous germ-laden street dust from dried waste caused disease.
- The car was considered the antiseptic solution,quieter, more comfortable, and cleaner.

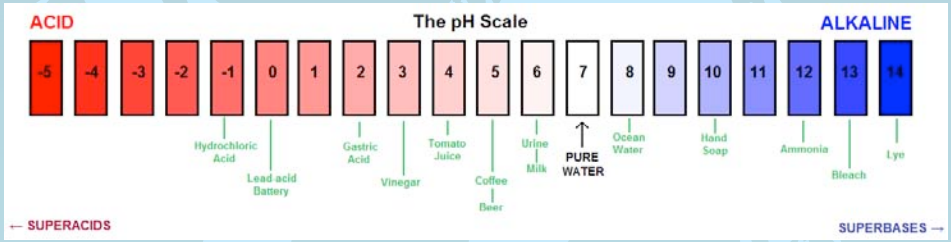
Acid Rain

Acid rain is caused by sulfur dioxide (SO_2) and nitrogen oxides (NO_x) being released into the atmosphere and producing sulfuric acid and nitric acid.

Sources of SO_2 and NO_x include factories, power plants, automobiles, trucks.

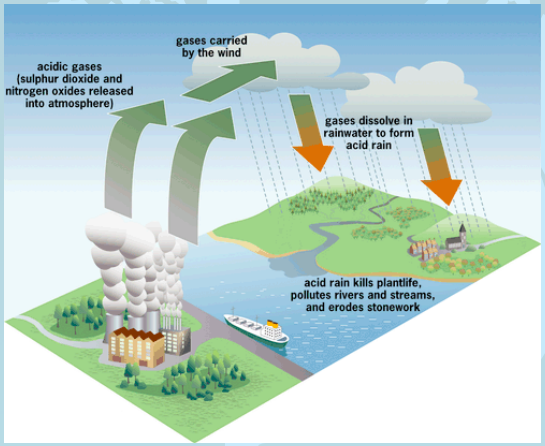
Acid Rain

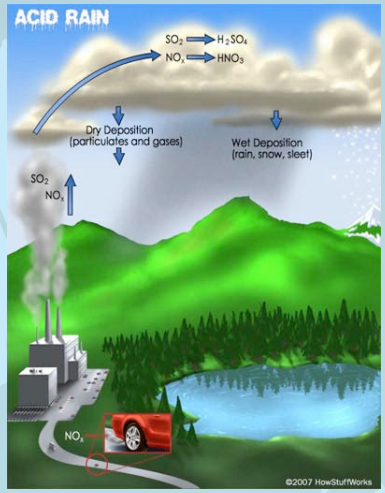
The pH scale measures how acidic or basic a substance is.



Acidic and basic are two extremes that describe chemicals, just like hot and cold are two extremes that describe temperature. Mixing acids and bases can cancel out their extreme effects, much like mixing hot and cold water can even out the water temperature. A substance that is neither acidic nor basic is neutral (e.g., pure water with a pH of 7).

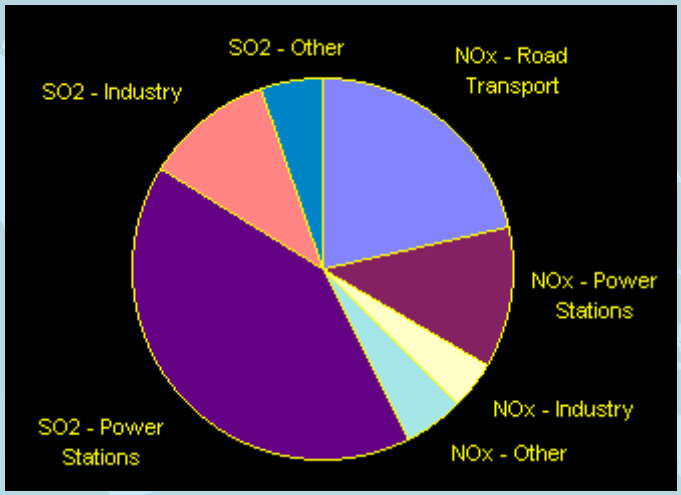
Acid Rain





Sources of SO_2 and NO_x include factories, power plants, automobiles, trucks and even pine forests.

Acid Rain



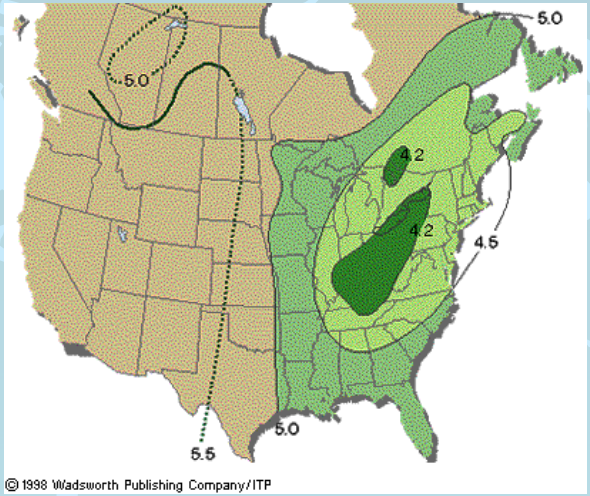
Sources of SO_2 and NO_x include factories, power plants, automobiles and trucks.

Acid Rain

Impacts of Acid Rain

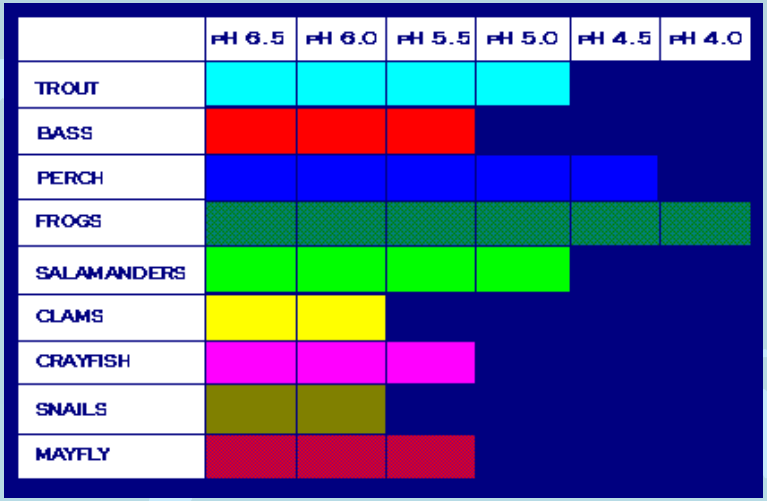
- Lakes and Streams
- Forests
- Human health: asthma, bronchitis, heart failure…
- Materials: Car coatings, roofing,…

pH of US Rain



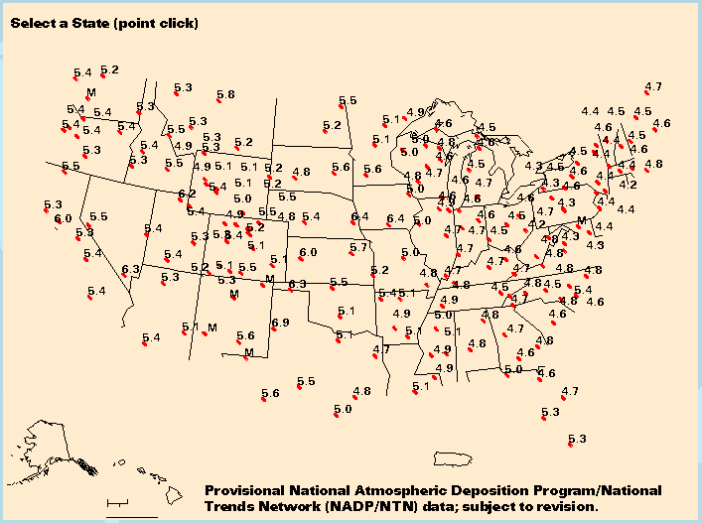
Acid rain leeches heavy metals into lakes and streams.

Acid Rain



Animals are very sensitive to pH. Acid rain also leeches heavy metals, like mercury, into lakes, streams, and drinking water.

Acid Rain



Acid rain leeches heavy metals into lakes and streams.

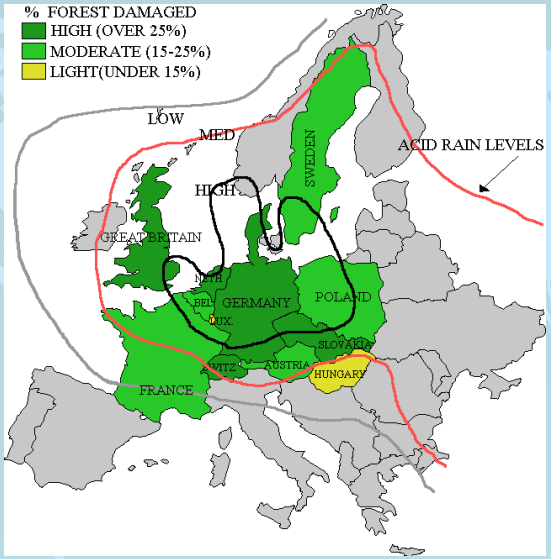
Acid Rain

Needles collect cloud water, which is extra acid.

Acid Rain

Spruce Forest in North Carolina impacted by Acid Rain

Acid Rain



Spruce Forest in Europe impacted by Acid Rain

Acid Rain

Buildings: Marble and Limestone are dissolved by acid rain.

National Ambient Air Quality Standards

The Clean Air Act requires Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards for six common air pollutants.

- Ozone
- Particulate Matter
- Carbon Monoxide
- Nitrogen Oxides
- Sulfur Dioxide
- Lead

Mexico City

National Ambient Air Quality Standards

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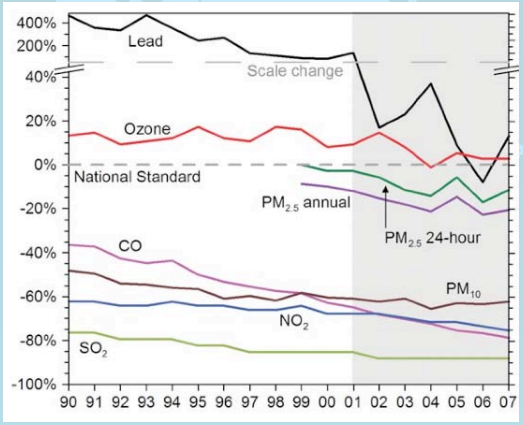
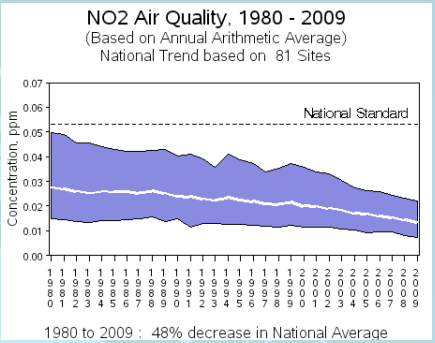
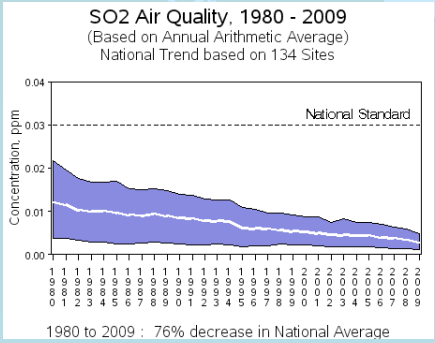
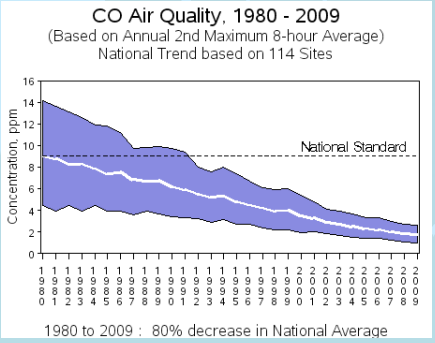


Pollution Trends 1980-2009







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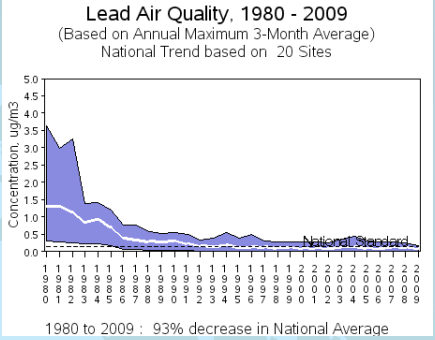
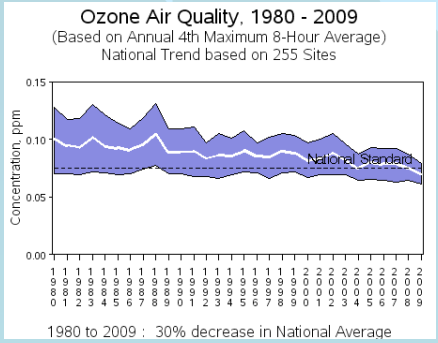
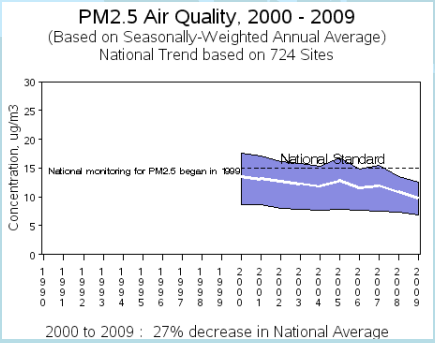
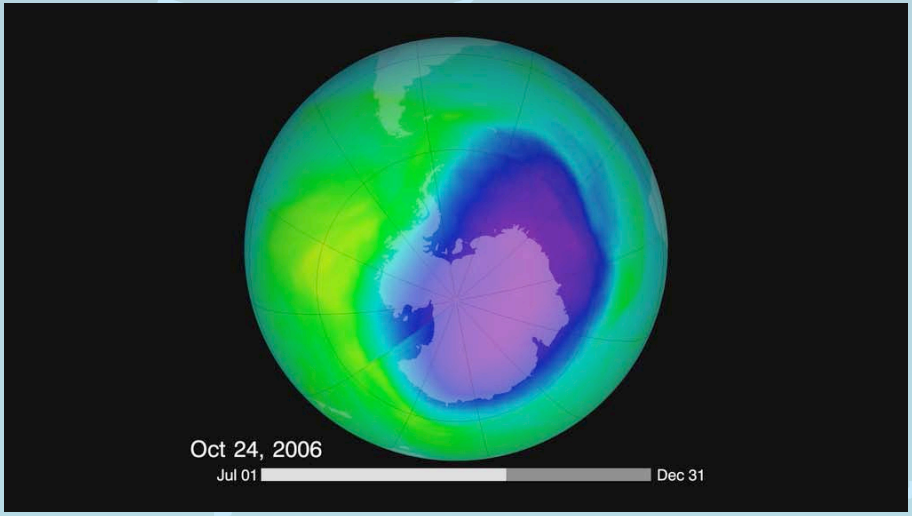




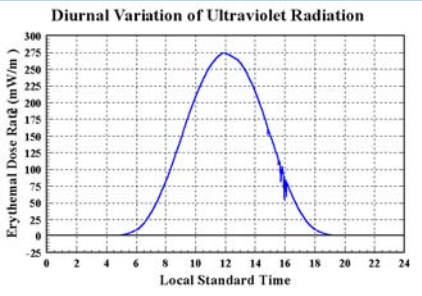


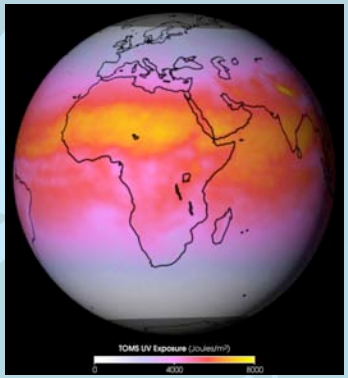
Global Ozone Depletion



The ozone hole reached its maximum extent in 2006.

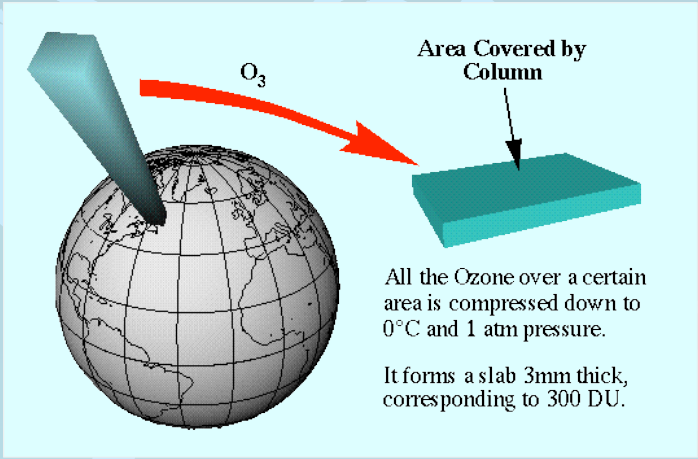
Hazards of Ozone Loss





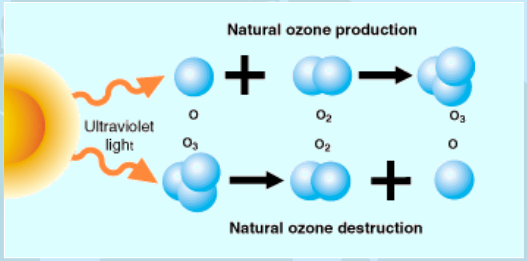
- Consequences of ozone loss
  - radiation reaching the ground
  - increase in skin cancer cases
  - increase in eye cataracts and sun burns
  - suppression of the human immune system
  - adverse impact on crops and animals due to increased UV
  - reduction in the growth of ocean phytoplankton
  - cooling of the stratosphere that could alter stratospheric wind patterns, possibly affecting the production (and destruction) of ozone.

Ozone Measurement

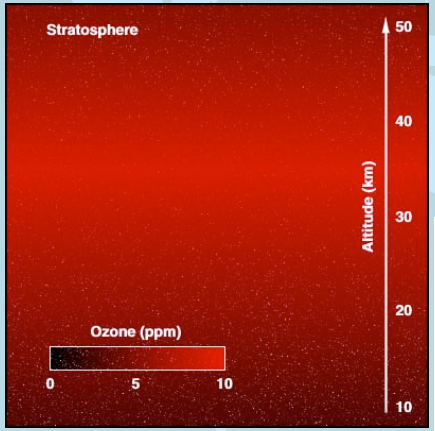


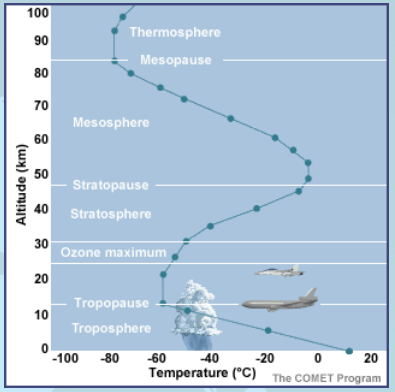
Atmospheric ozone is measured by satellite instrument in Dobson Units.

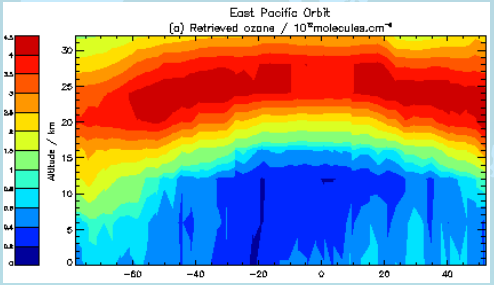
Natural Ozone Cycle



Ozone Distribution

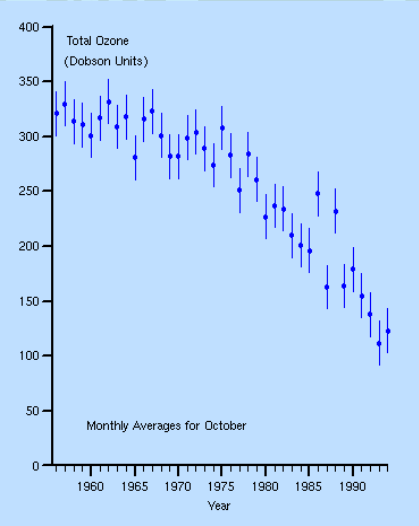


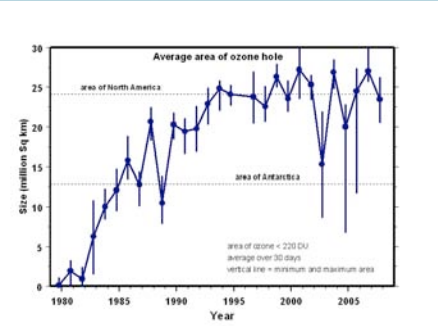




Ozone concentration is a maximum in the lower stratosphere

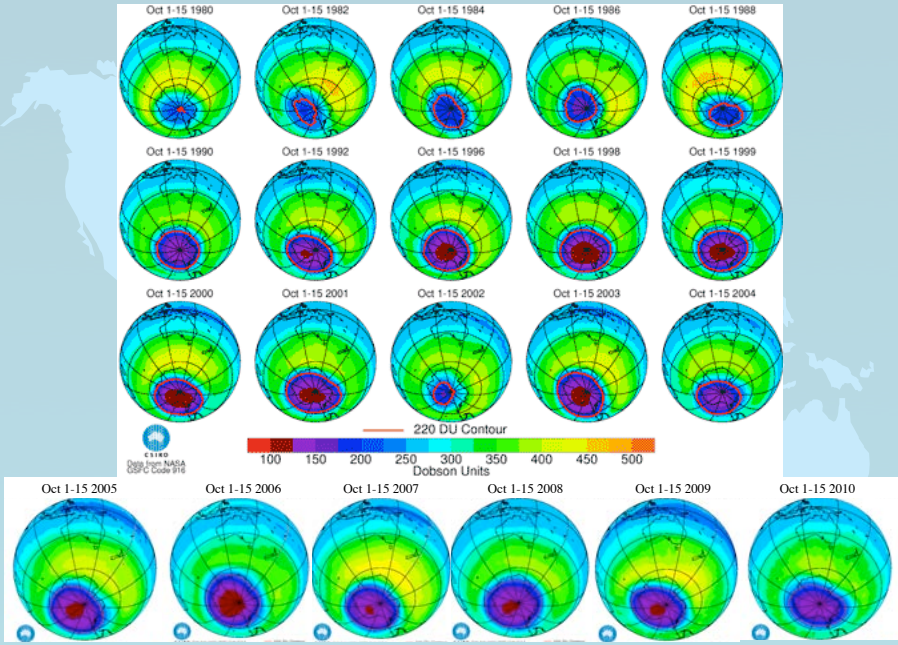
Ozone Hole





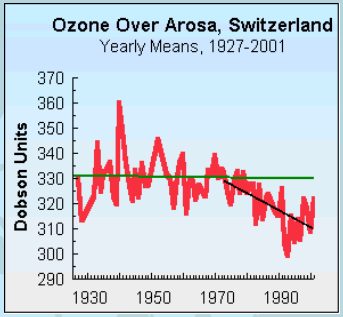
The decrease in ozone over the South Pole was first observed in the 1970's. It is linked to an increase in man made chemicals entering the atmosphere.

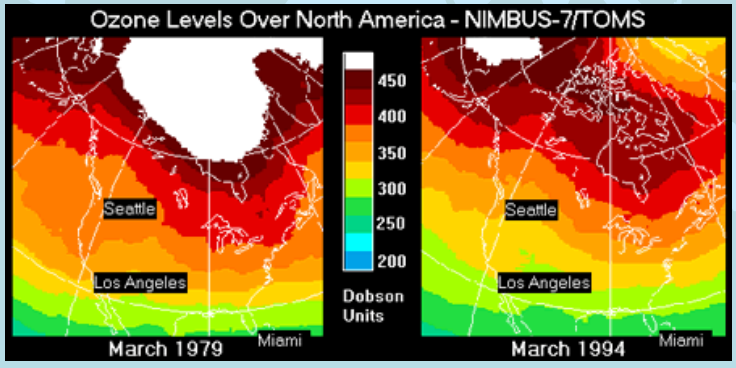
Ozone Hole



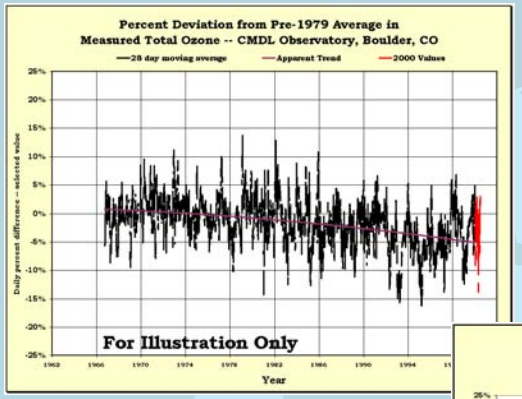
Ozone Hole

The decrease in ozone also observed at lower latitudes.

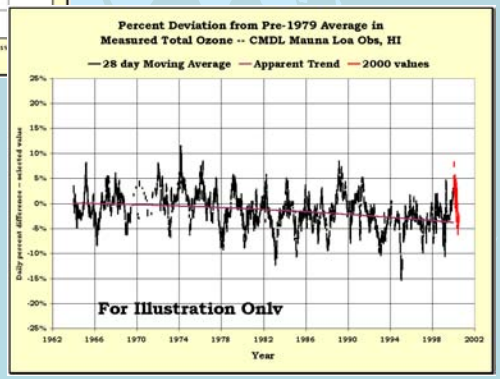




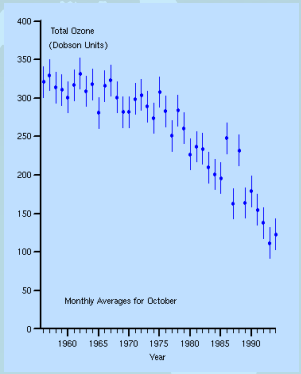
Ozone Depletion

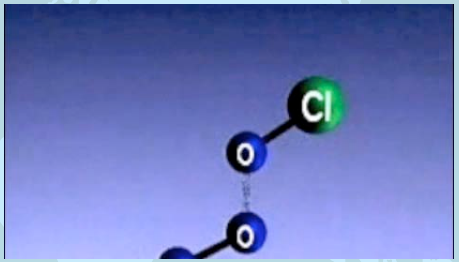


Decrease in ozone observed in Colorado and Hawaii.



Causes for Stratospheric Ozone Depletion





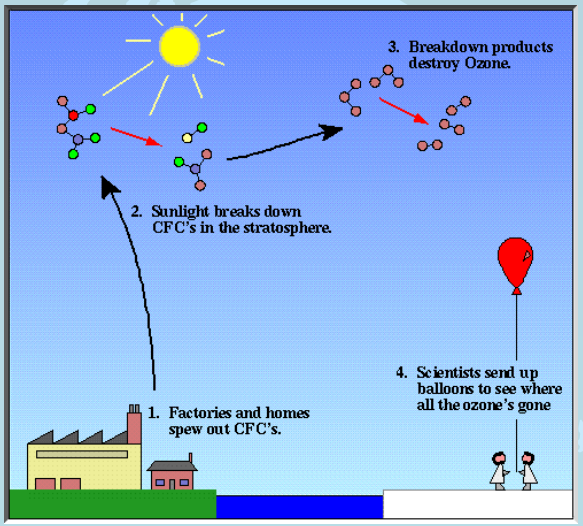
Chlorine and Bromine atoms result in global ozone depletion. CFCs release chlorine and halons release bromine. The most rapid breakdown of ozone occurs on the surface of polar stratospheric clouds.

Causes for Stratospheric Ozone Depletion

CFCs release chlorine atoms, and halons release bromine atoms

Chlorine and Bromine atoms result in ozone depletion.

Most rapid breakdown of ozone occurs on the surface of polar stratospheric clouds.



Causes for Stratospheric Ozone Depletion

Chlorine and Bromine compounds result in ozone depletion.

Most rapid breakdown of ozone occurs on the surface of polar stratospheric clouds.

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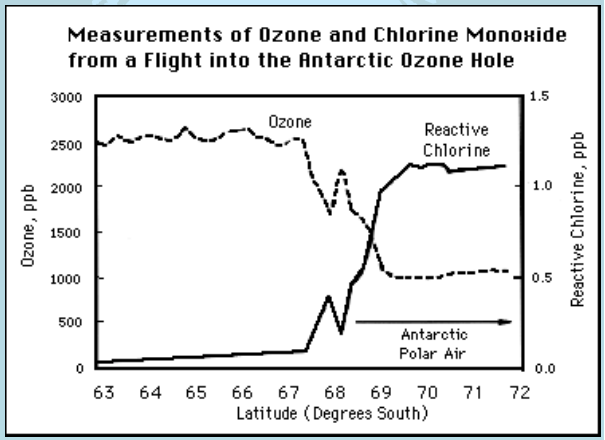
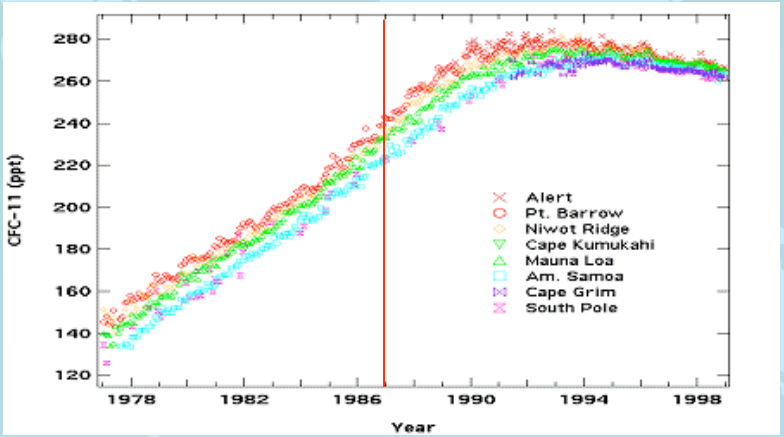


Formation of the Ozone Hole

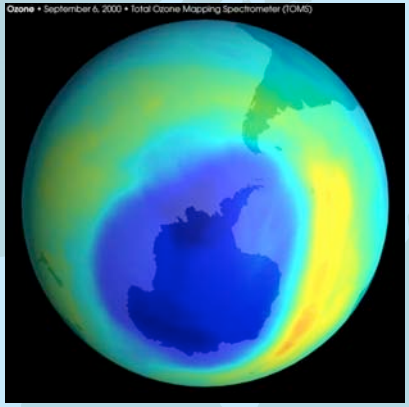
- The polar winter leads to the formation of the polar vortex which isolates the air within it.
- Cold temperatures form inside the vortex; cold enough for the formation of Polar Stratospheric Clouds. As the vortex air is isolated, the cold temperatures and the clouds persist.
- Once the Polar Stratospheric Clouds form, chemical reactions take place and convert the inactive chlorine and bromine to more active forms of chlorine and bromine.
- No ozone loss occurs until sunlight returns to the air inside the polar vortex and allows the production of active chlorine and initiates the catalytic ozone destruction cycles. Ozone loss is rapid.

Ozone Policy

The Montreal Protocol of 1987 banned CFC's and Halons. Latest projection shows ozone hole recovery by 2068.



Questions?



Observation Homework due Friday