# Introduction to Air Pollution

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# Outline

- Criteria Air Pollutants
- Greenhouse Gases
- Other Pollutants
- Units for Quantifying Air Pollutant Concentrations
- Impacts of Air Pollution
  - Acid Rain
  - Global Warming
  - Ozone Depletion

# Air Pollutants

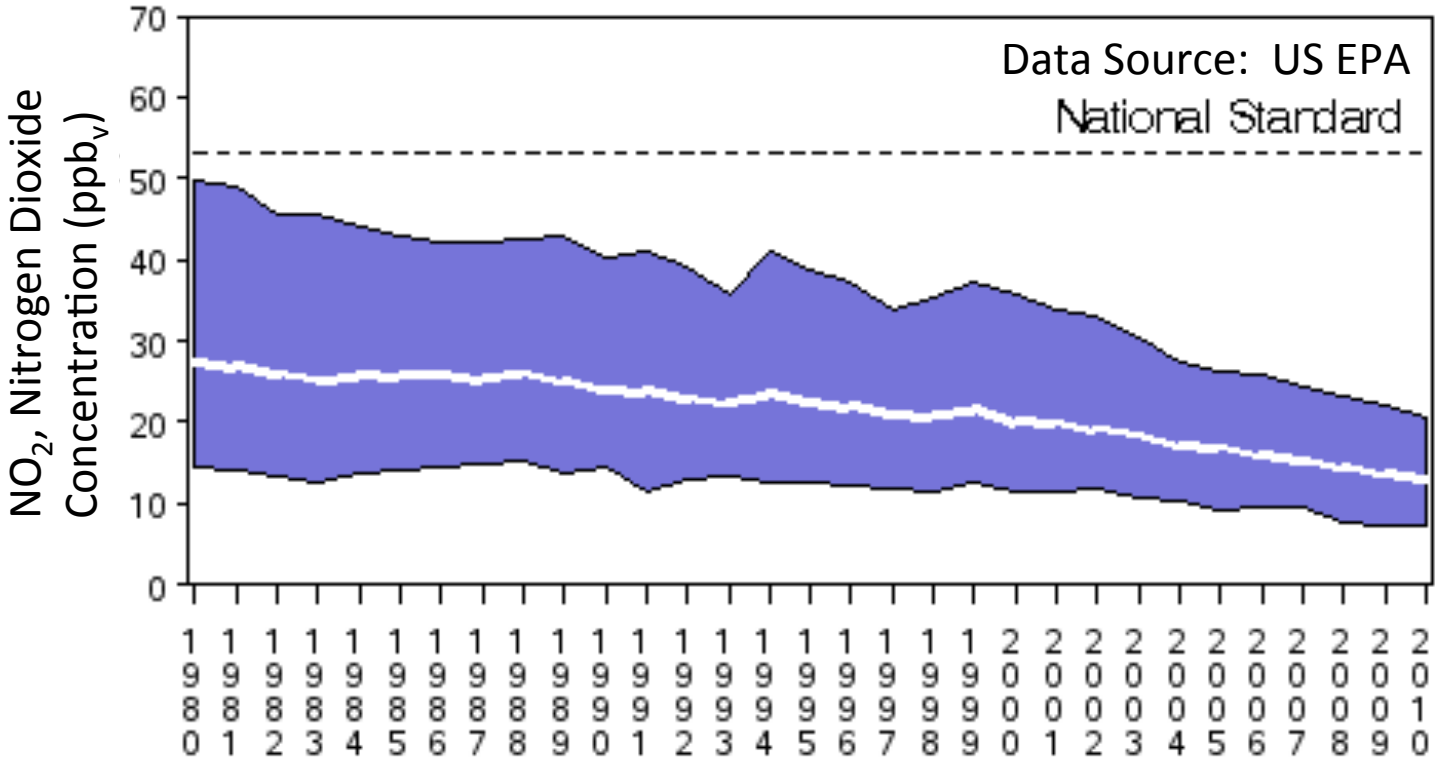
- **Criteria Air Pollutants**: Six common pollutants observed throughout the US and regulated by EPA

- **Greenhouse Gases:** Those gases that result in absorption of infrared radiation and release of heat with subsequent warming of the atmosphere

- **Other Pollutants:** Dependent on the industry that is producing the contaminants or property of pollutant (e.g., hazardous, toxic, and bioaccumulating pollutants)

# Criteria Air Pollutants

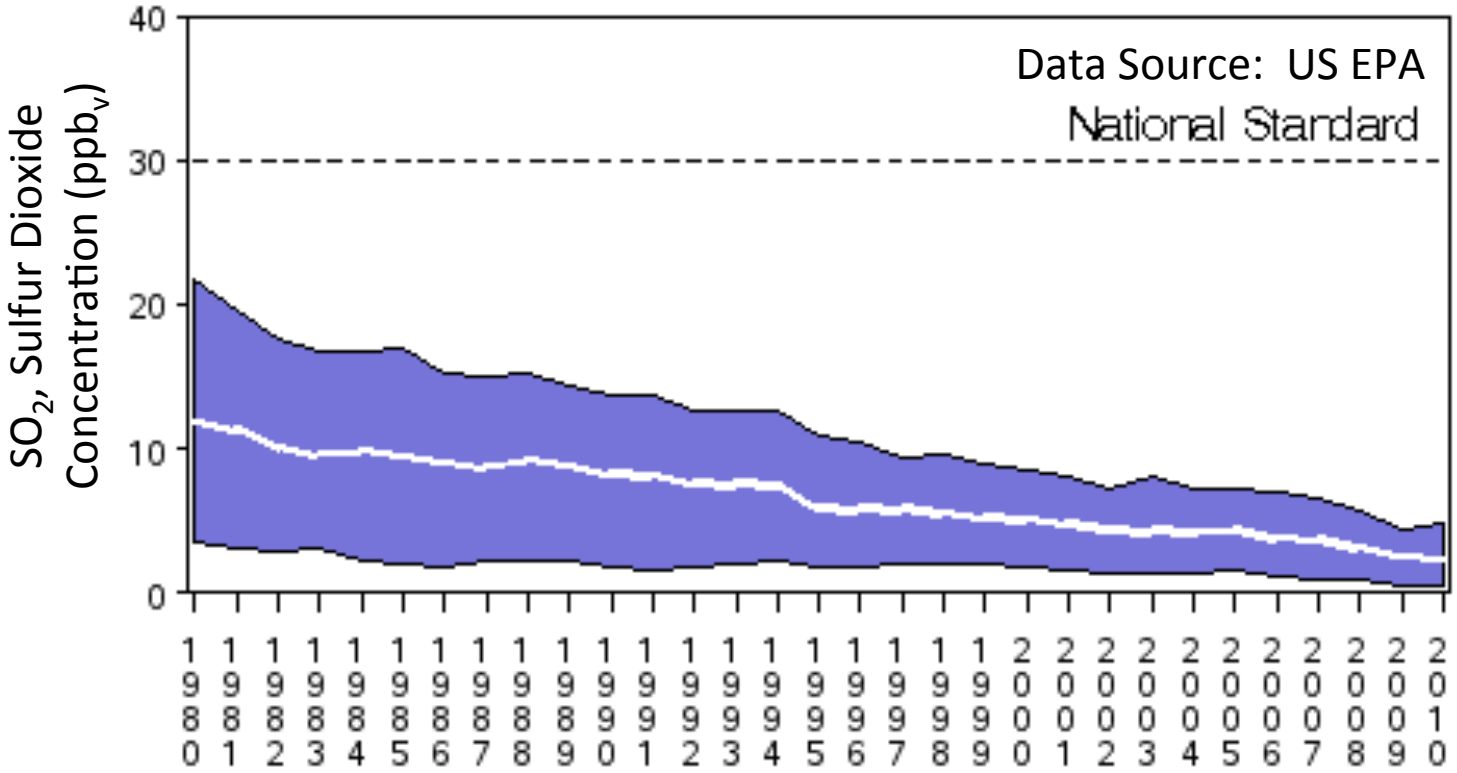
- **$NO_2$, Nitrogen Dioxide:** Nitrogen oxide is emitted to the atmosphere from combustion sources and then is oxidized to nitrogen dioxide.




**Acid Rain, Respiratory Health Problems, Ozone Precursor, Particle Precursor, Visibility Reduction**

# Criteria Air Pollutants

- **$SO_2$, Sulfur Dioxide**: A colorless gas produced during combustion of sulfur containing fuels and emitted naturally as reduced sulfur compounds (hydrogen sulfide) that form sulfur dioxide.

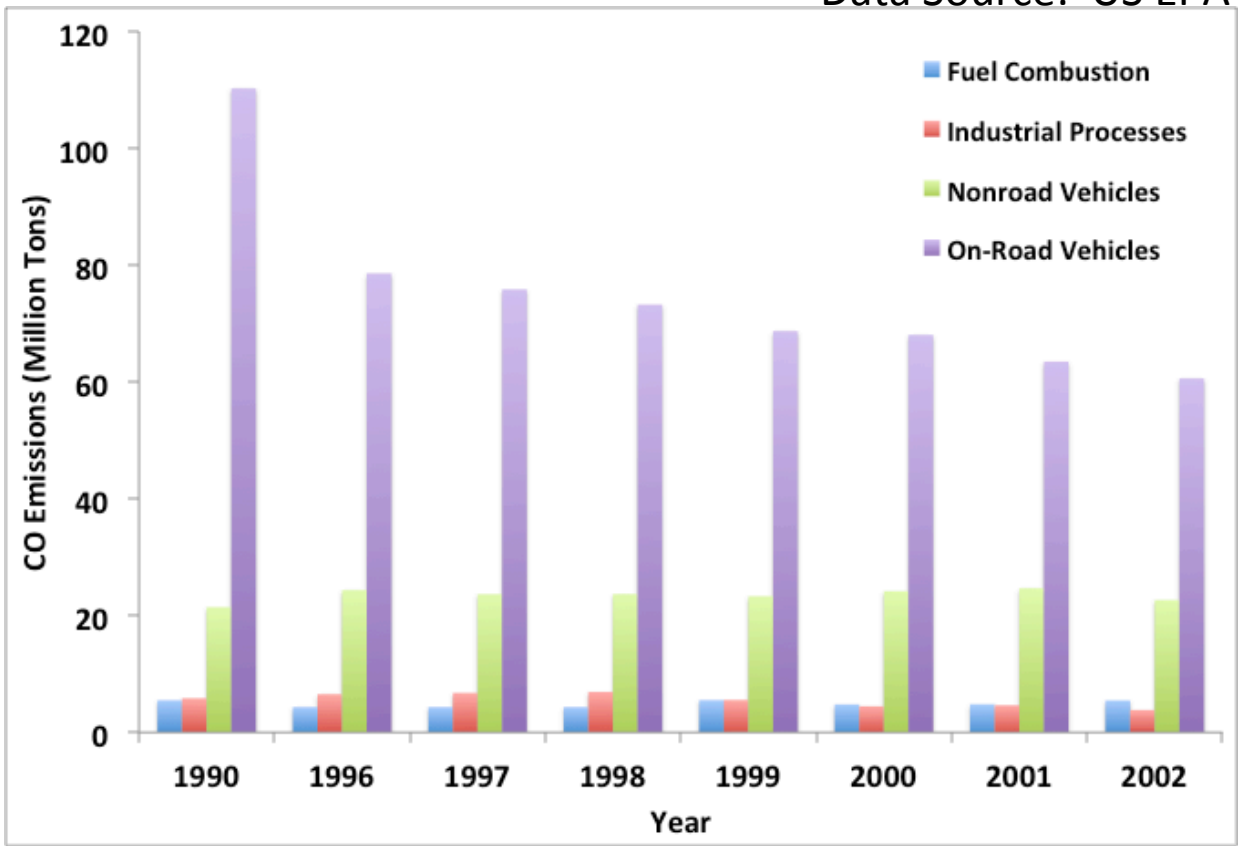



**Acid Rain, Respiratory Health Problems, Particle Precursor, Visibility Reduction**

# Criteria Air Pollutants

- **CO, Carbon Monoxide**: A colorless, odorless, toxic gas given off during incomplete combustion, primarily from motor vehicles.

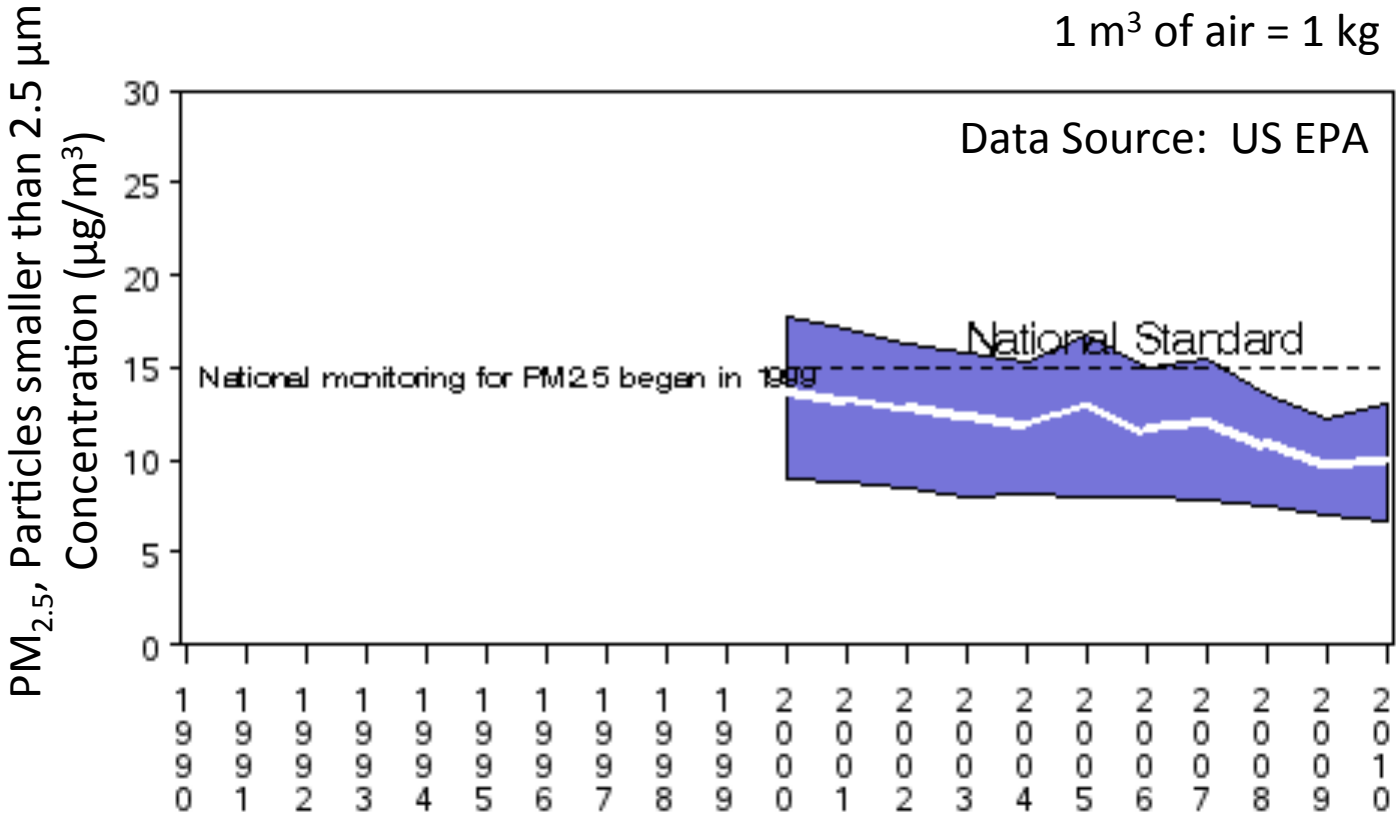
Data Source: US EPA




**Health Impacts (CO displaces $O_2$ in the blood)**

# Criteria Air Pollutants

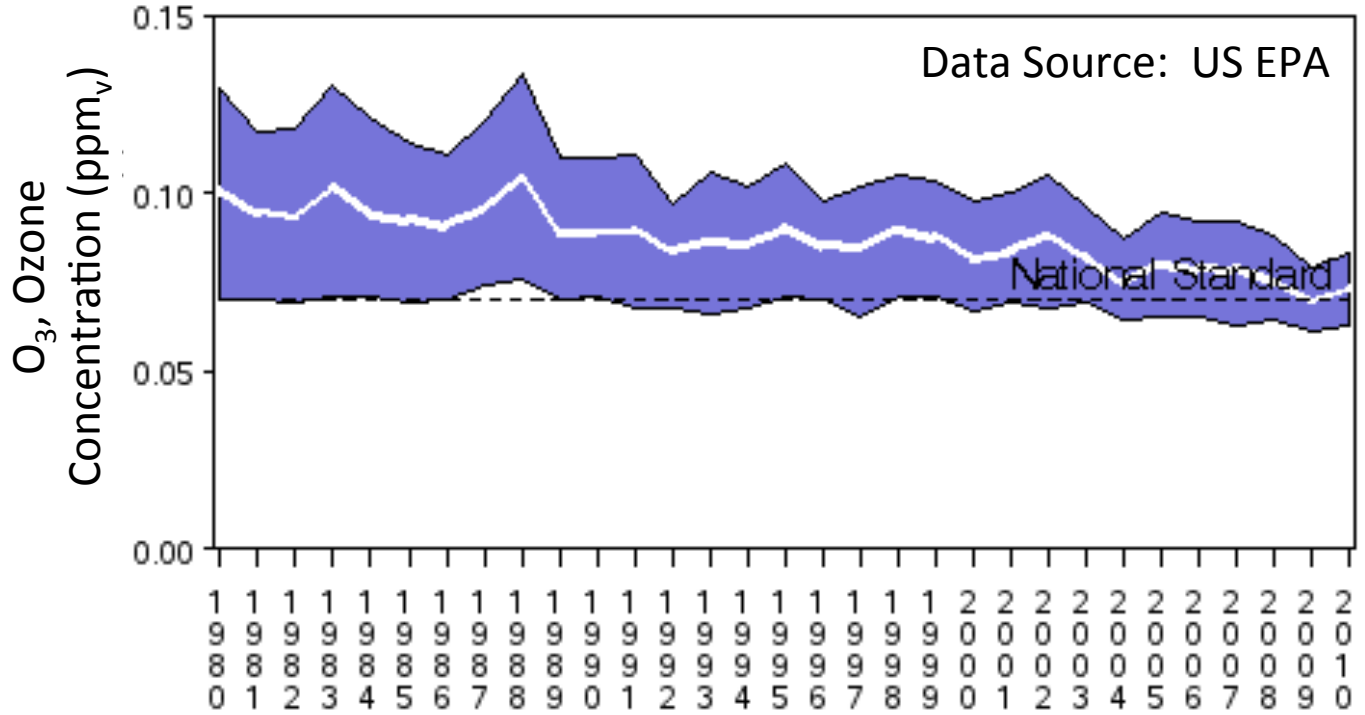
- **$PM_{10}$ and $PM_{2.5}$**, Particulate Matter: Solid or liquid particles, including fumes, smoke, dusts, and acidic droplets.




**Respiratory Health Problems, Visibility Reduction, Can Damage Statues / Stone Structures**

# Criteria Air Pollutants

- **$O_3$, Ozone:** A secondary air pollutant.
  - Tropospheric ozone or ground-level ozone causes health impact and damages crops
  - Stratospheric ozone is our shield from the sun's damaging UV rays

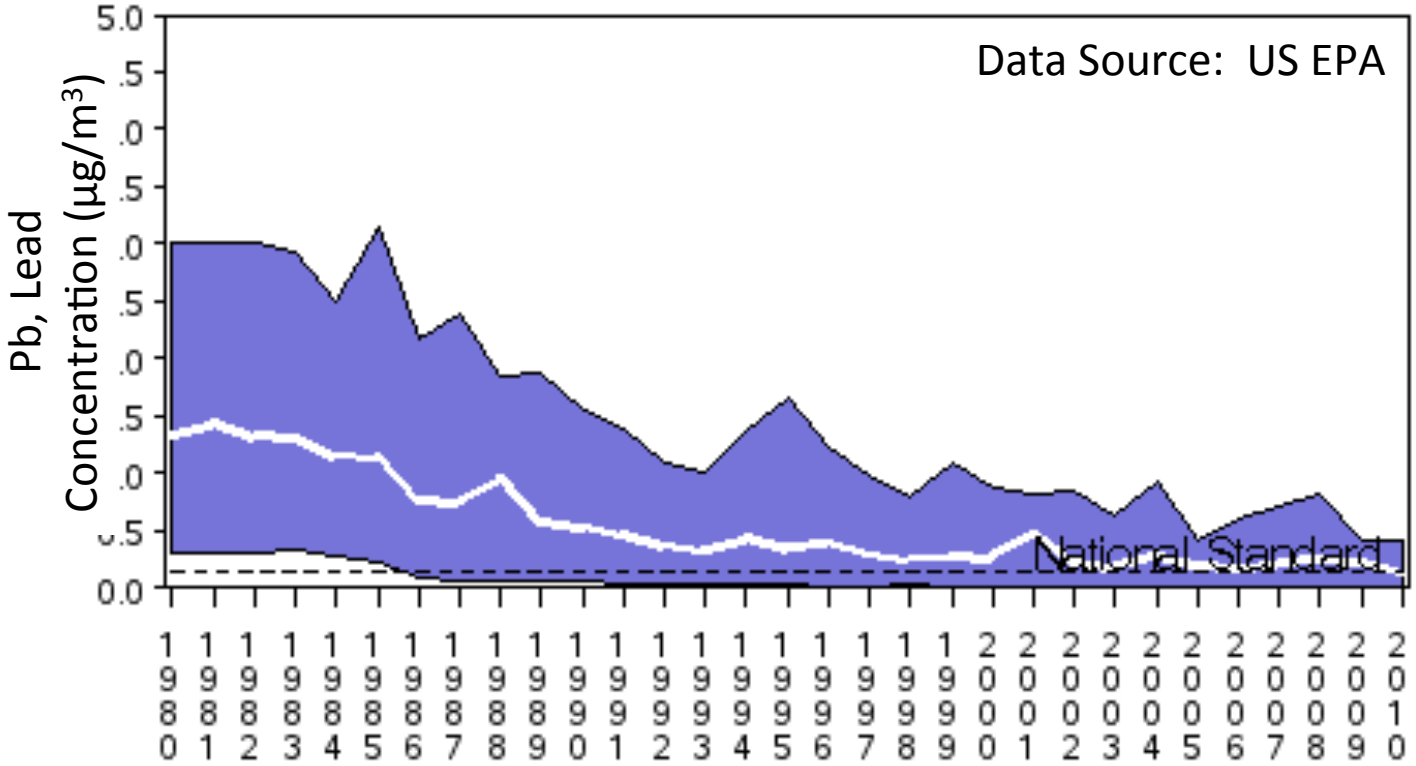



**Respiratory Health Problems, Visibility Reduction**

# Crop Damage by Ozone

# Criteria Air Pollutants

- **Pb, Lead:** Natural or anthropogenic origin, emitted from lead containing gasoline, ingredient of some paints or construction materials.




**Neurological Damage and Cardiovascular Problems (especially in children)**

# Greenhouse Gases

To evaluate a greenhouse gas, must know **amount released**, **lifetime**, and **warming potential**

| Gas | Abbreviation | 2010 Emissions (Millions of Metric Tons, $CO_2$ Equivalent) | Lifetime (Years) | Global Warming Potential |
|---|---|---|---|---|
| Carbon Dioxide | $CO_2$ | 5,700 | 50 – 200 | 1 |
| Methane | $CH_4$ | 675 | 12 | 21 |
| Nitrous Oxide | $N_2O$ | 305 | 120 | 310 |
| Hydrofluorocarbons | HFCs | 140 | 1 – 270 | 140 – 11,700 |
| Perfluorocarbons | PFCs | | 800 – 50,000 | 6,500 – 9,200 |
| Sulfur Hexafluoride | $SF_6$ | | 3,200 | 23,900 |

Data Source: US EPA

# Other Relevant Air Pollutants

- **Volatile Organic Compounds**
- **Mercury**
- **Other Toxic Metals (e.g., Cadmium, Nickel)**
- **Odors**
- **Ammonia**
- **Radioactive Pollutants (e.g., Radon)**
- **Polychlorinated Dibenzo-p-Dioxins and –Furans (PCDD/F)**

# Parts per Million, Billion, Trillion (Gas Phase Contaminants)

$$ppm_v = \frac{\text{moles of X}}{\text{moles of air}} * 1{,}000{,}000$$ → 30 seconds in a year

$$ppb_v = \frac{\text{moles of X}}{\text{moles of air}} * 1{,}000{,}000{,}000$$ → 3 seconds in 100 years

$$ppt_v = \frac{\text{moles of X}}{\text{moles of air}} * 1{,}000{,}000{,}000{,}000$$ → 3 seconds in 100,000 years

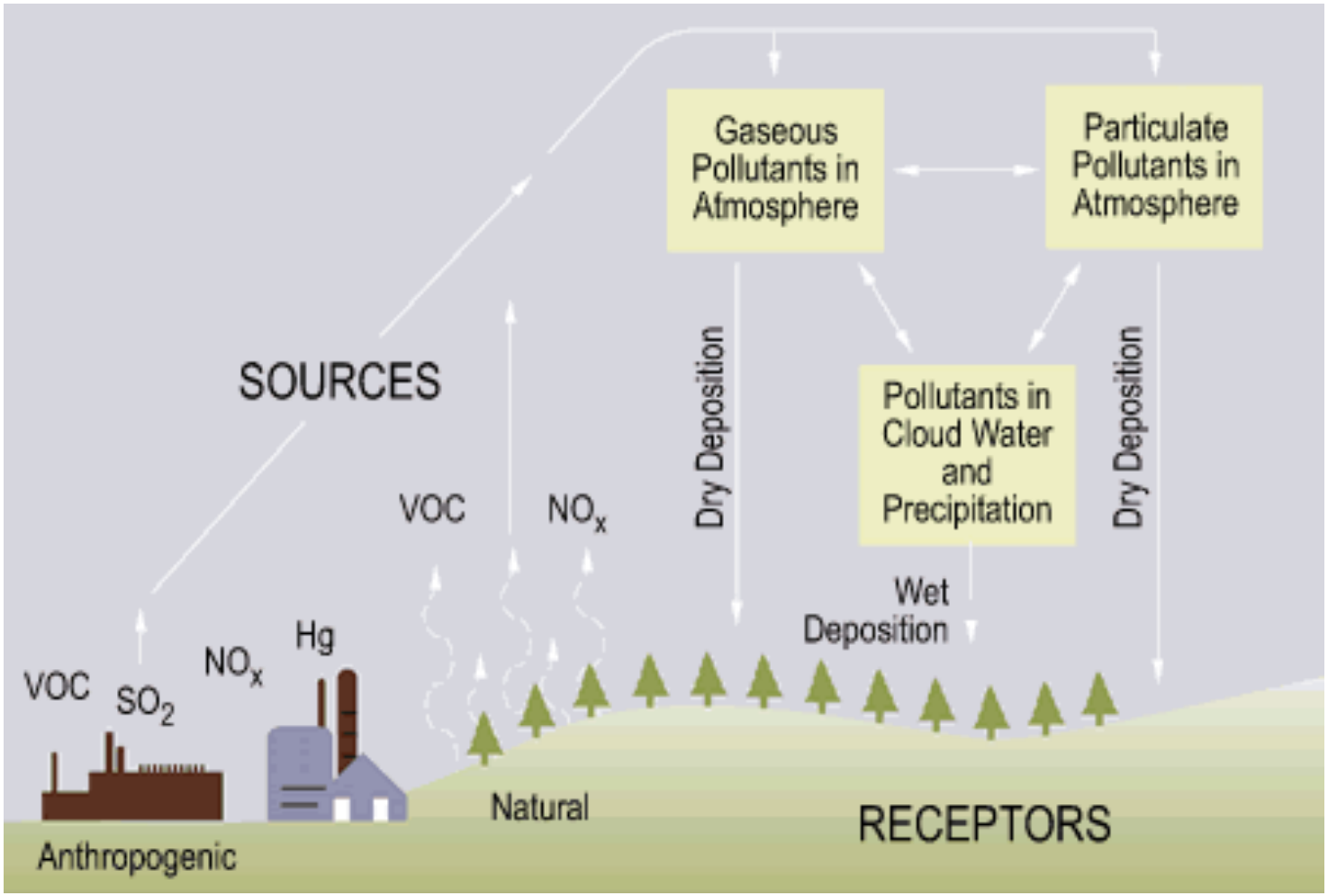
# Mass per Unit Volume ($\mu g/m^3$) (Particulate Contaminants)

Density of Air = 1,200 $g/m^3$

Density of Water = 1,000,000 $g/m^3$

Mass Concentration of Particles in the Air = 12 $\mu g/m^3$

# Emissions, Transformations, and Transport of Acid Rain Precursors Resulting in **Acid Rain**




http://www.epa.gov/acidrain/what/index.html

# Acid Rain

**Major $SO_2$ and NO Sources = Coal Combustion to Produce Electricity**

- $NO + O_3 \rightarrow NO_2 + O_2 + OH \rightarrow HNO_3 + O_2$ (30%)
  - $SO_2 + OH \rightarrow SO_3 + H_2O \rightarrow H_2SO_4$ (70%)

**Wet Deposition: Acid falls to the ground in rain, snow, or fog**

**Dry Deposition: Acid molecules stick to surfaces (buildings) and particles that fall to the ground as settling dust or smoke**

# Acid Rain

Trees killed by acid rain

Image from Wikipedia

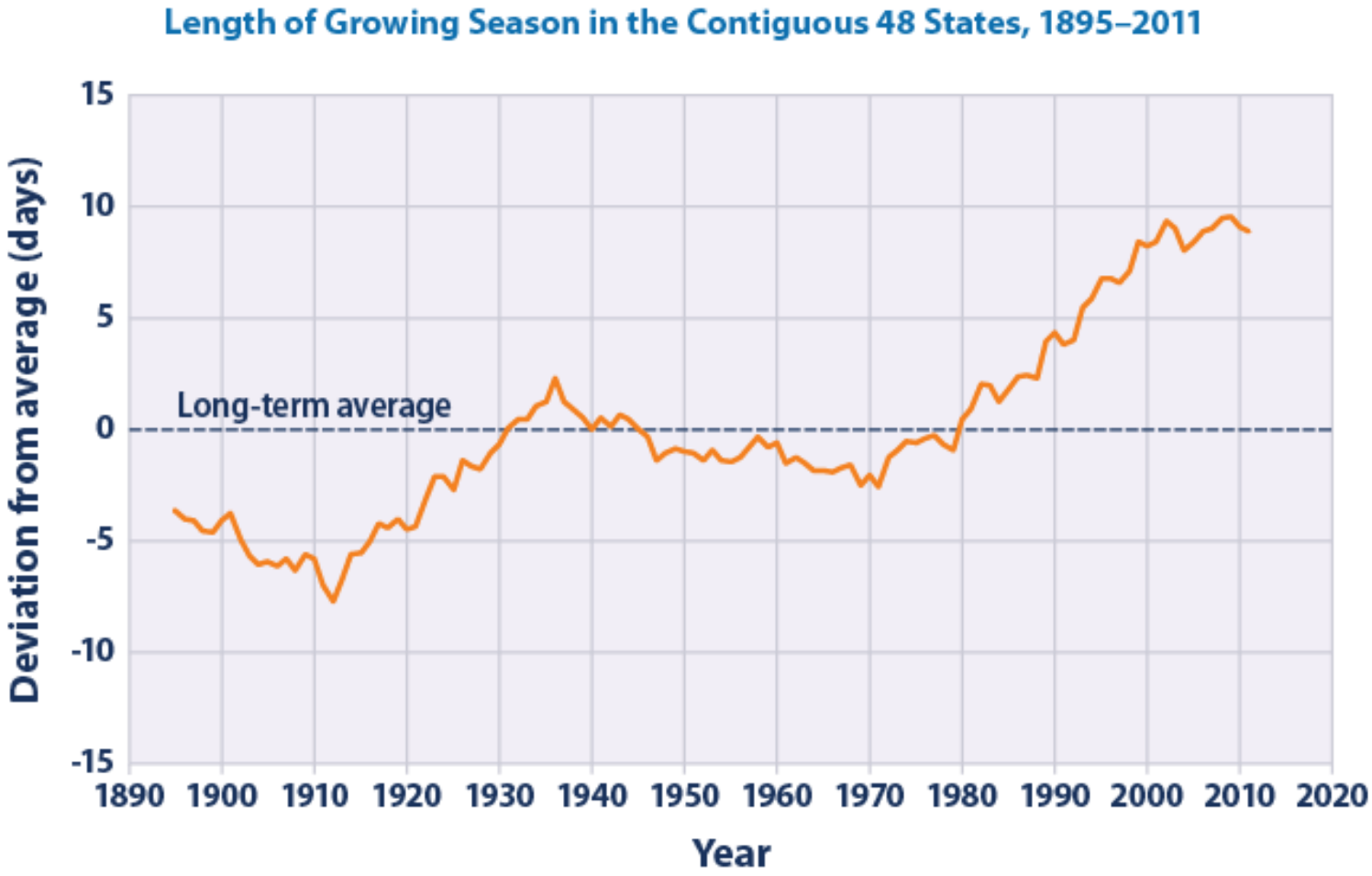
Stone statues that have dissolved due to acid rain

http://gardenofeaden.blogspot.com/2012/07/causes-of-acid-rain.html

# Global Warming and Climate Change


Koshland Science Museum of the National Academy of Sciences

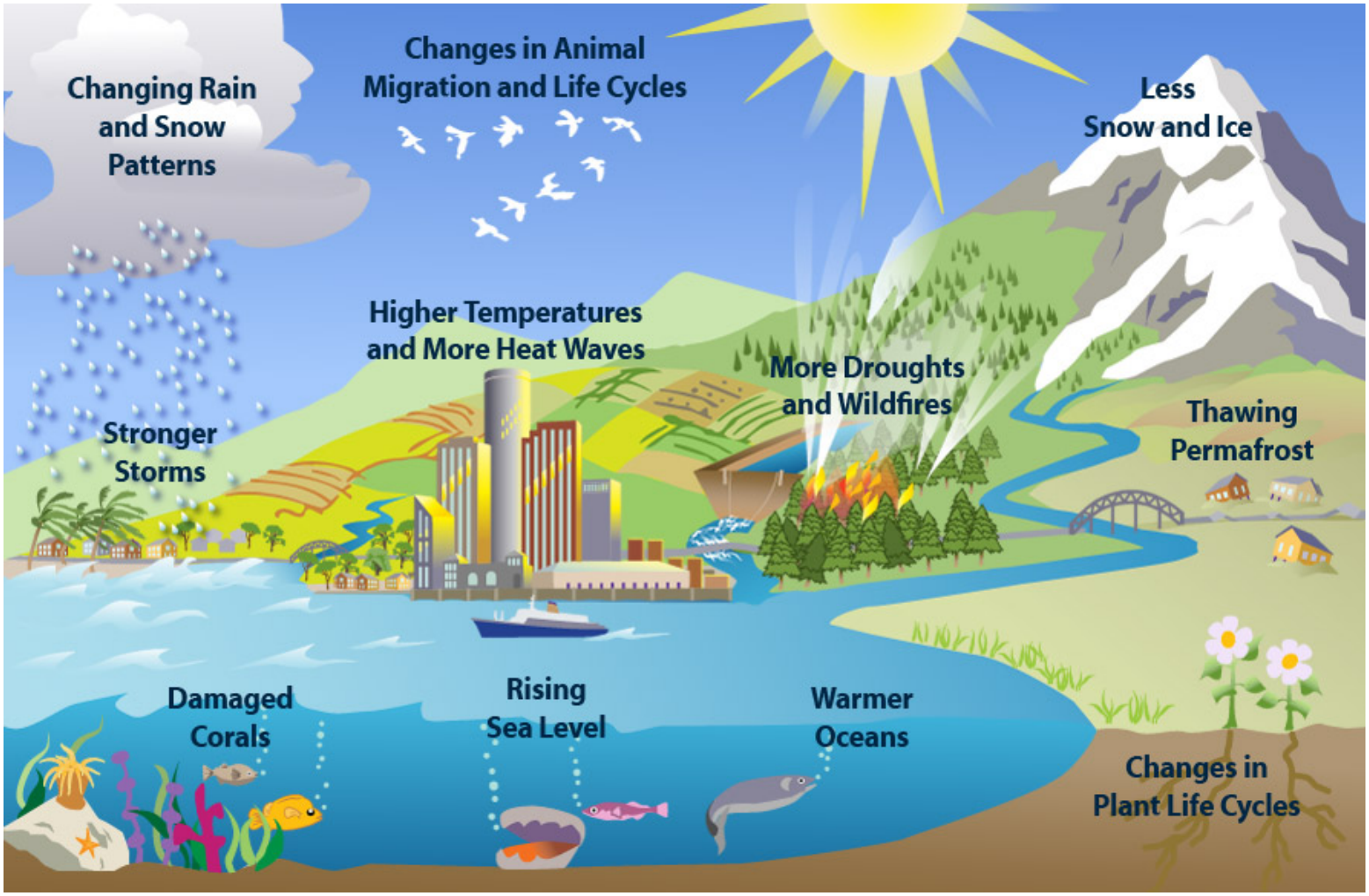
# Global Warming and Climate Change




Data source: Kunkel, K.E. 2012 update to data originally published in: Kunkel, K.E., D.R. Easterling, K. Hubbard, and K. Redmond. 2004. Temporal variations in frost-free season in the United States: 1895–2000. Geophys. Res. Lett. 31:L03201.

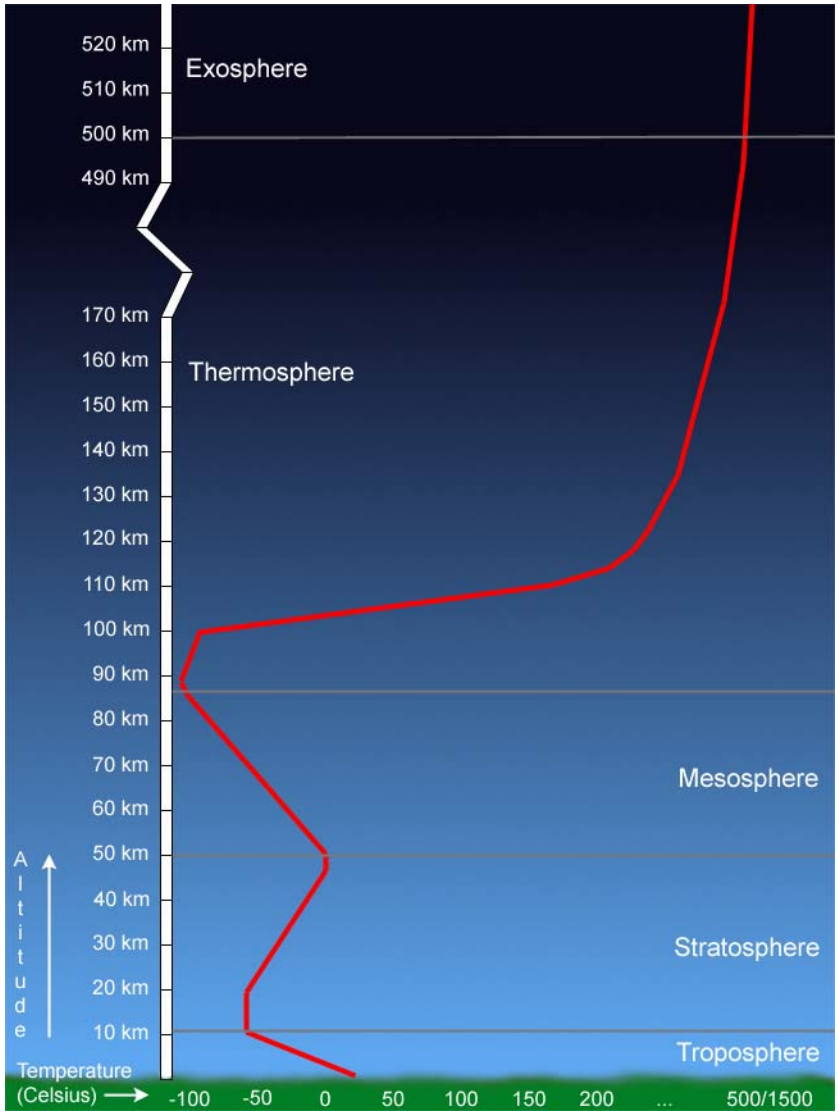
For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climatechange/indicators.

# Global Warming and Climate Change




http://www.epa.gov/climatestudents/scientists/clues.html

# Stratospheric Ozone Depletion




**Ozone in the Stratosphere = GOOD**

- Blocks UVB Radiation
- Prevents Skin Cancers
- Prevents Damage to Eyes

**Ozone in the Troposphere = BAD**

- Air Pollutant
- Impacts Respiratory System


http://www.nasa.gov/centers/langley/news/factsheets/DIAL_prt.htm

# Ozone Depletion

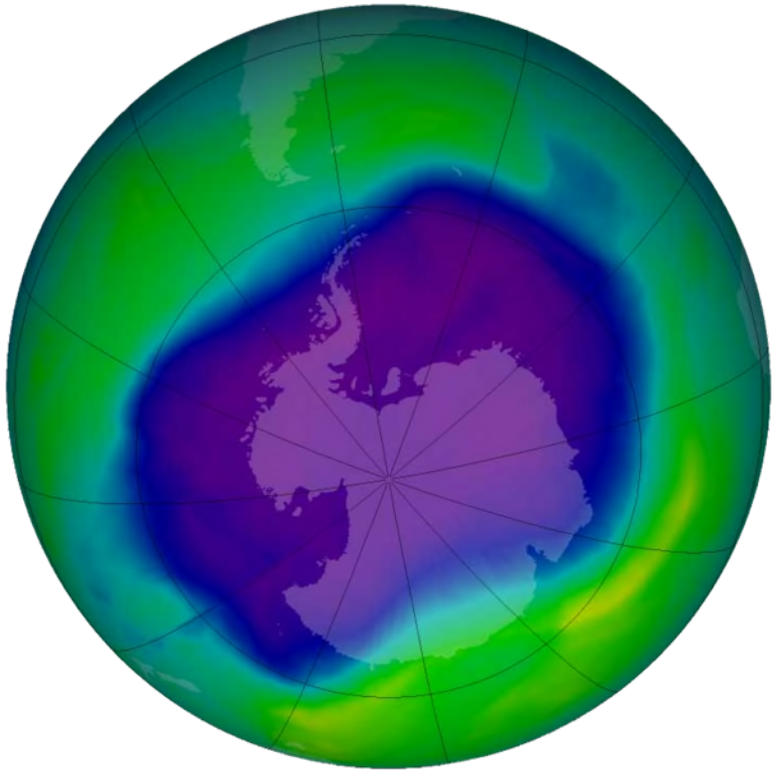
**Release of chlorinated compounds contributes to stratospheric ozone destruction.**

**Ozone is destroyed by gas phase reactions with polar stratospheric clouds**

- Chlorofluorocarbons (CFCs)
- Freon (and other coolants)

$$Cl + O_3 \rightarrow ClO + O_2$$

$$ClO + O_3 \rightarrow Cl + 2\,O_2$$





http://www.nasa.gov/vision/earth/lookingatearth/ozone_record.html

# Consequences of Stratospheric Ozone Depletion

- Increased UV radiation to troposphere
- Biological effects
  - Basal and squamous cell carcinomas
  - Malignant melanoma
  - Cortical cataracts
  - Increased tropospheric ozone
  - Increased production of vitamin D
  - Effects on animals
  - Effects on crops

http://en.wikipedia.org/wiki/Ozone_depletion

# Next Lecture… (Friday)

- Important Air Pollution Regulations
- Quantifying Air Pollutants in the Atmosphere
- Air Pollution Prevention/Control
- Introduction about Field Trip