Energy and the Environment

PHYS 4400, Principles and Varieties of Solar Energy

Instructor: Randy J. Ellingson
The University of Toledo

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Some near-term topics

Energy conversion
Need for energy conversion
Value of energy efficiency
Environmental impacts and challenges
Fossil energy
Greenhouse effect
Global climate change
Weather vs. climate

Understanding energy

When we talk about energy, our language refers to *energy generation* and *energy consumption*. Physically, these phrases refer to *energy recovery (or development)* and *energy conversion*.

Examples:

- We establish systems for bringing fuels (such as coal, natural gas, and wood) to power plants where the energy is converted to electricity;
- Mining, drilling, hydraulic fracturing, pumping, biomass harvesting -- these are all methods we use to recover (or gather) fuels (primary energy sources) – petroleum, natural gas, nuclear fuel, wood and plant matter;
- These fuels are then subjected to various processes which convert their stored energy content (chemical energy, or mass energy) to (most commonly) thermal energy to generate steam which drives turbines which generate electricity.

Environmental impacts and challenges

- Energy conversion processes and technologies always impact the environment, but in widely varying ways.
- Environment consist of air, water, soil, flora and fauna.
- Energy conversion processes include photosynthesis, photovoltaic energy conversion, combustion, hydrodynamic power, nuclear fission.
- Water quality: the combustion of coal emits substantial quantities of pollutants into the air, which ultimately enter the water supply (lakes, oceans) through rainfall. Nuclear and coal plants use copious amounts of water – in some cases the water is expelled at an elevated temperature, and in other cases the water is depleted through evaporation.

http://www.ucsusa.org/clean_energy/our-energy-choices/energy-and-water-use/water-energy-electricity-coal.html?print=t

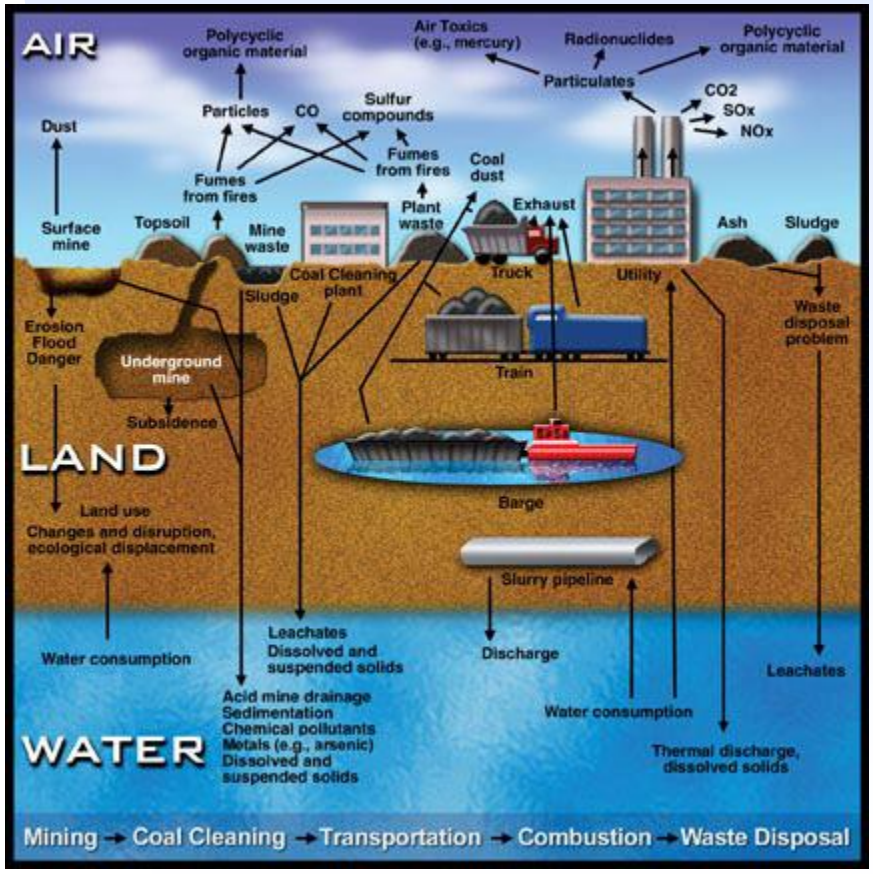
"For every three units of energy produced by the reactor core of a U.S. nuclear power plants, two units are discharged to the environment as waste heat. Nuclear plants are built on the shores of lakes, rivers, and oceans because these bodies provide the large quantities of cooling water needed to handle the waste heat discharge."

http://www.ucsusa.org/nuclear_power/nuclear_power_technology/got-water-nuclear-power.html

Environmental impacts and challenges (cont.)

Environmental impacts of coal.

NIMBY?



Health Effects of Selected Power Plant Pollutants[a,b]

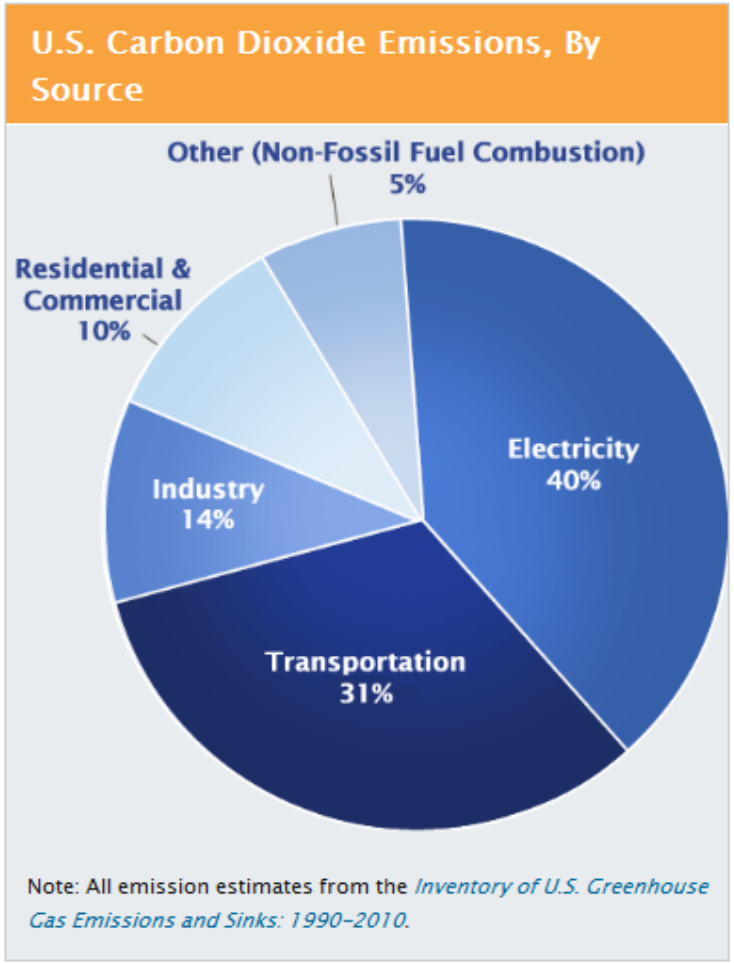
Substance	Human Toxicity: Acute	Human Toxicity: Chronic	Comments
Sulfur dioxide	Lung irritant, triggers asthma, low birth weight in infants.	Reduces lung function, associated with premature death.	Also contributes to acid rain and poor visibility.
Nitrogen oxides	Changes lung function, increases respiratory illness in children.	Increases susceptibility to respiratory illnesses and causes permanent alteration of lung.	Forms ozone smog and acid rain. Ozone is associated with asthma, reduced lung function, adverse birth outcomes and allergen sensitization.
Particulate Matter	Asthma attacks, heart rate variability, heart attacks.	Cardiovascular disease, pneumonia, chronic obstructive pulmonary disease, premature death.	Fine particle pollution from power plants is estimated to cut short the lives of 30,000 Americans each year.
Hydrogen chloride	Inhalation causes coughing, hoarseness, chest pain, and inflammation of respiratory tract.	Chronic occupational exposure is associated with gastritis, chronic bronchitis, dermatritis, photo sensitization in workers.	
Hydrogen Fluoride	Inhalation causes severe respiratory damage, severe irritation and pulmonary edema.		Very high exposures through drinking water or air can cause skeletal fluorosis.
Arsenic	Ingestion and inhalation: affects the gastrointestinal system and central nervous system.	Known human carcinogen with high potency. Inhalation causes lung cancer; ingestion causes lung, skin, bladder and liver cancer. The kidney is affected following chronic inhalation and oral exposure.	
Cadmium	Inhalation exposure causes bronchial and pulmonary irritation. A single acute exposure to high levels of cadmium can result in long-lasting impairment of lung function.	Probable human carcinogen of medium potency. The kidney is the major target organ in humans following chronic inhalation and oral exposure.	Other effects noted from chronic inhalation exposure are bronchiolitis and emphysema.
Chromium	High exposure to chromium VI may result in renal toxicity, gastrointestinal hemorrhage and internal hemorrhage.	Known human carcinogen of high potency.	Chronic effects from industrial exposures are inflammation of the respiratory tract, effects on the kidneys, liver, and gastrointestinal tract.
Mercury	Inhalation exposure to elemental mercury results in central nervous system effects and effects on gastrointestinal tract and respiratory system.	Methyl mercury ingestion causes developmental effects. Infants born to women who ingested methylmercury may perform poorly on neurobehavorial tests.	The major effect from chronic exposure to inorganic mercury is kidney damage.

http://www.catf.us/resources/publications/files/Cradle_to_Grave.pdf

Environmental impacts and challenges (cont.)

The main human activity that emits CO_2 is the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation, although certain industrial processes and land-use changes also emit CO_2. The main sources of CO_2 emissions in the United States are described below.

- **Electricity.** Electricity is a significant source of energy in the United States and is used to power homes, business, and industry. The combustion of fossil fuels to generate electricity is the largest single source of CO_2 emissions in the nation, accounting for about 40% of total U.S. CO_2 emissions and 33% of total U.S. greenhouse gas emissions in 2009. The type of fossil fuel used to generate electricity will emit different amounts of CO_2. To produce a given amount of electricity, burning coal will produce more CO_2 than oil or natural gas.
- **Transportation.** The combustion of fossil fuels. such as gasoline and diesel to transport people and goods is the second largest source of CO_2 emissions, accounting for about 31% of total U.S. CO_2 emissions and 26% of total U.S. greenhouse gas emissions in 2010. This category includes transportation sources such as highway vehicles, air travel, marine transportation, and rail.
- **Industry.** Many industrial processes emit CO_2 through fossil fuel combustion. Several processes also produce CO_2 emissions through chemical reactions that do not involve combustion, for example, the production and consumption of mineral products such as cement, the production of metals such as iron and steel, and the production of chemicals. Various industrial processes accounted for about 14% of total U.S. CO_2 emissions and 20% of total U.S. greenhouse gas emissions in 2010. Note that many industrial processes also use electricity and therefore indirectly cause the emissions from the electricity production.

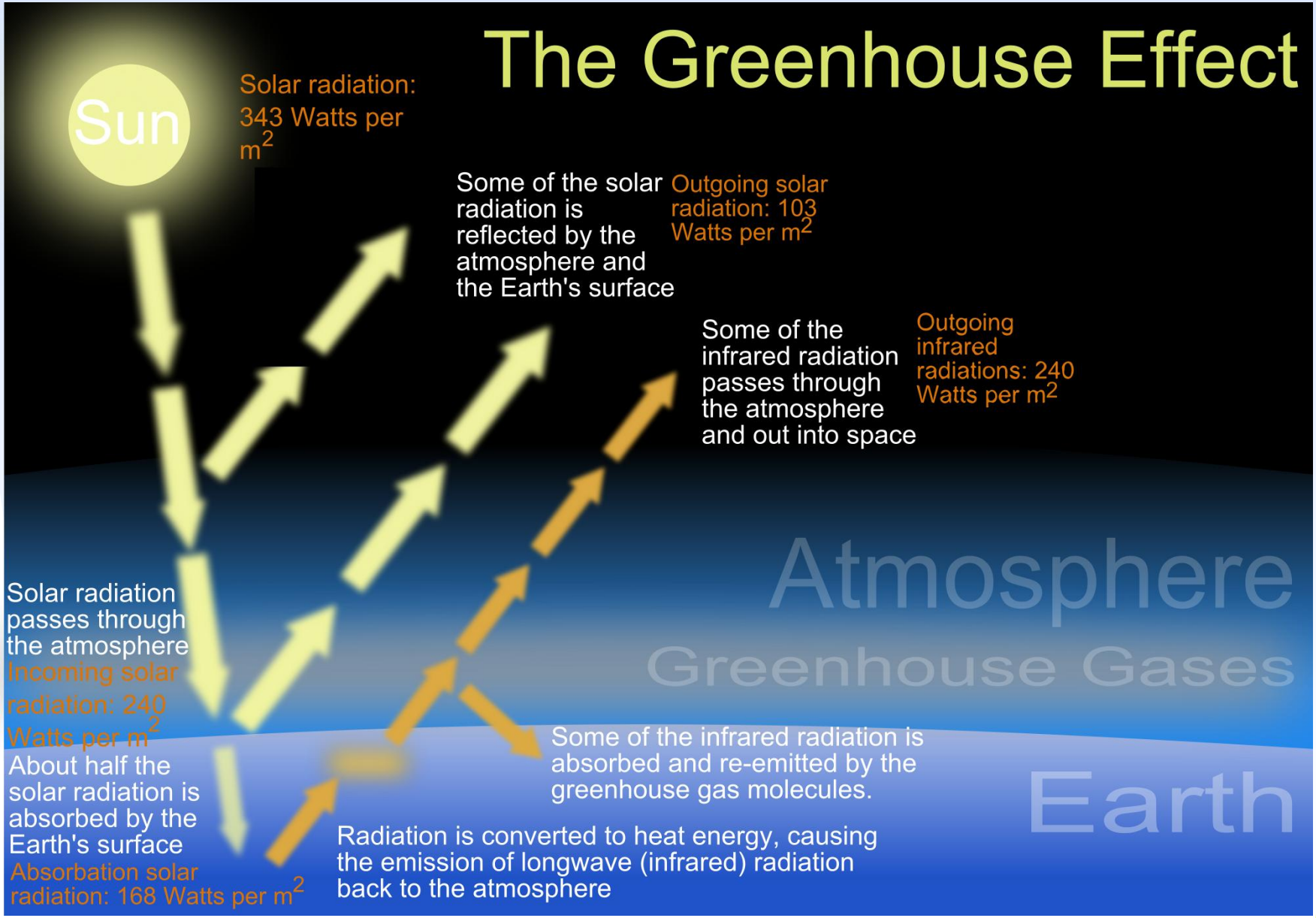


http://www.epa.gov/climatechange/ghgemissions/gases/co2.html

Environmental impacts and challenges (cont.)

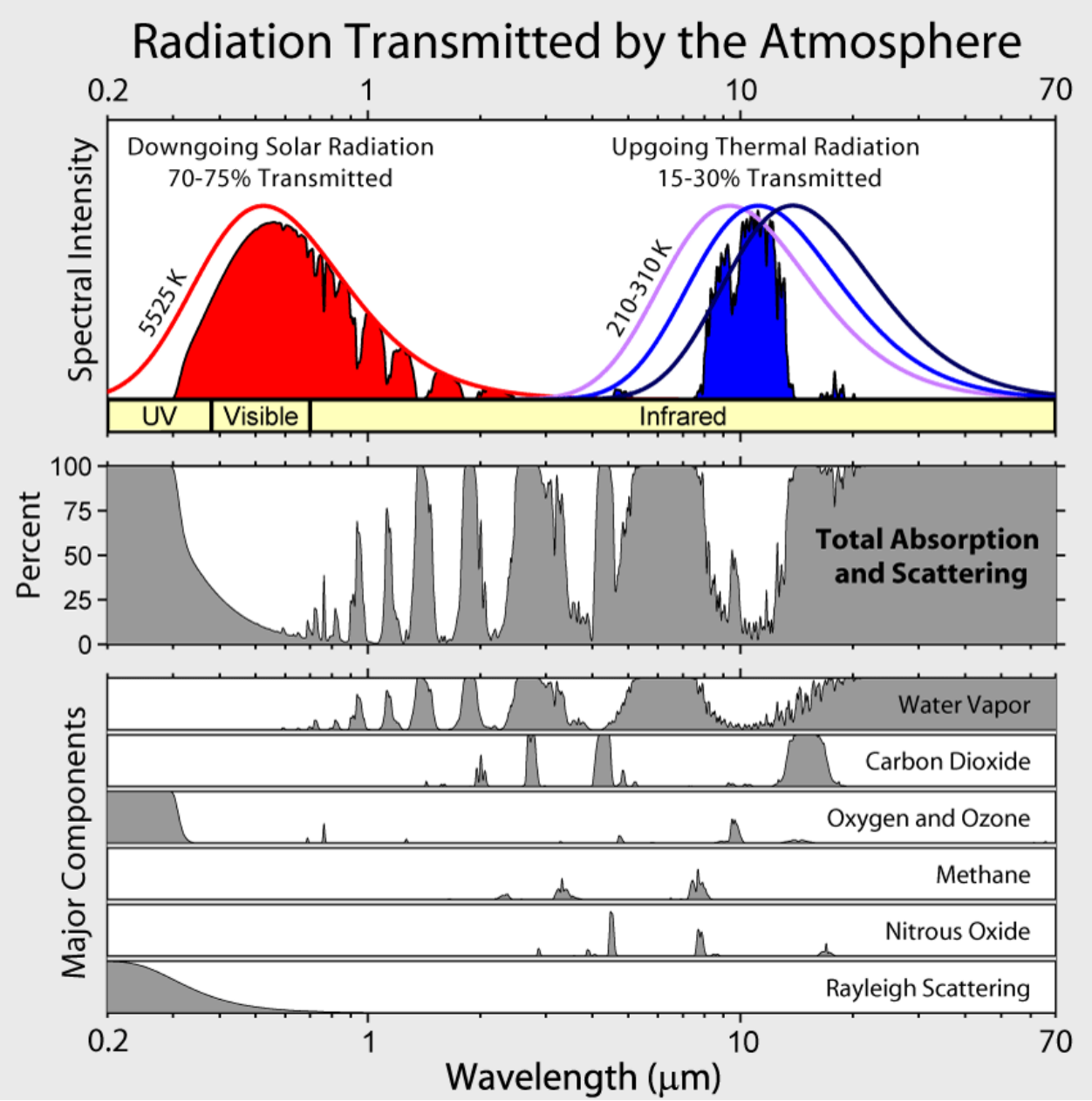
Air quality

From http://www.epa.gov/hg/about.htm: "Health effects of mercury. Mercury exposure at high levels can harm the brain, heart, kidneys, lungs, and immune system of people of all ages. Research shows that most people's fish consumption does not cause a health concern. However, it has been demonstrated that high levels of methylmercury in the bloodstream of unborn babies and young children may harm the developing nervous system, making the child less able to think and learn."



http://www.elmhurst.edu/~chm/vchembook/globalwarmA5.html

http://en.wikipedia.org/wiki/File:The_green_house_effect.svg


Radiation Transmitted by the Atmosphere
0.2
1
10
70
Spectral Intensity
Downgoing Solar Radiation
70-75% Transmitted
Upgoing Thermal Radiation
15-30% Transmitted
5525 K
210-310 K
UV
Visible
Infrared
Percent
100
75
50
25
0
Total Absorption and Scattering
Major Components
Water Vapor
Carbon Dioxide
Oxygen and Ozone
Methane
Nitrous Oxide
Rayleigh Scattering
0.2
1
10
70
Wavelength (μm)

Greenhouse effect (continued)

- Climate change has been linked principally to the generation and emission of so-called greenhouse gases.
- The most substantial greenhouse gas, due to its prevalence and direct quantitative accounting through our use of fossil fuels, is CO_2.

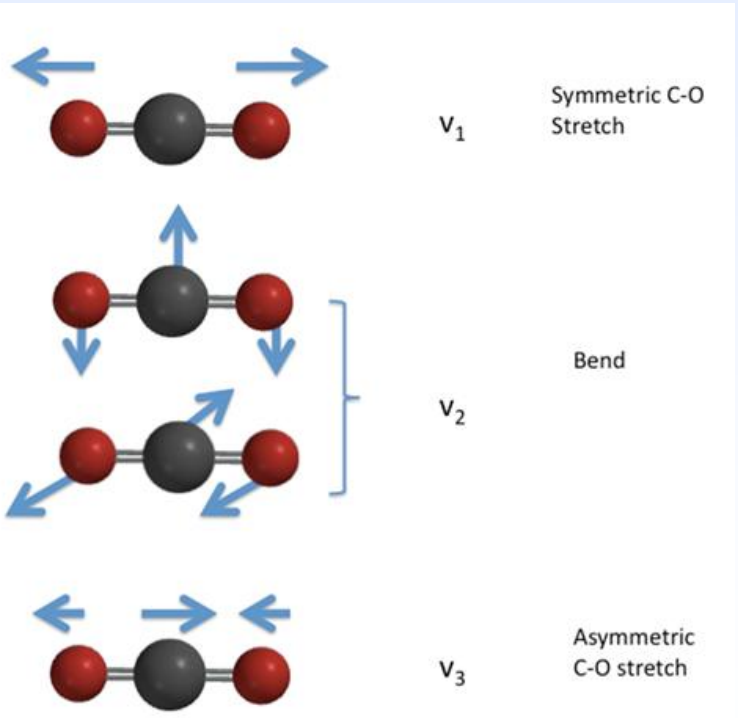


Fig. 1 Vibrational modes of CO_2

Symmetric mode, bending mode, and asymmetric mode. Corresponding "energies" are 667 cm^{-1} for the bending mode, and 2349 cm^{-1} for the asymmetric mode.

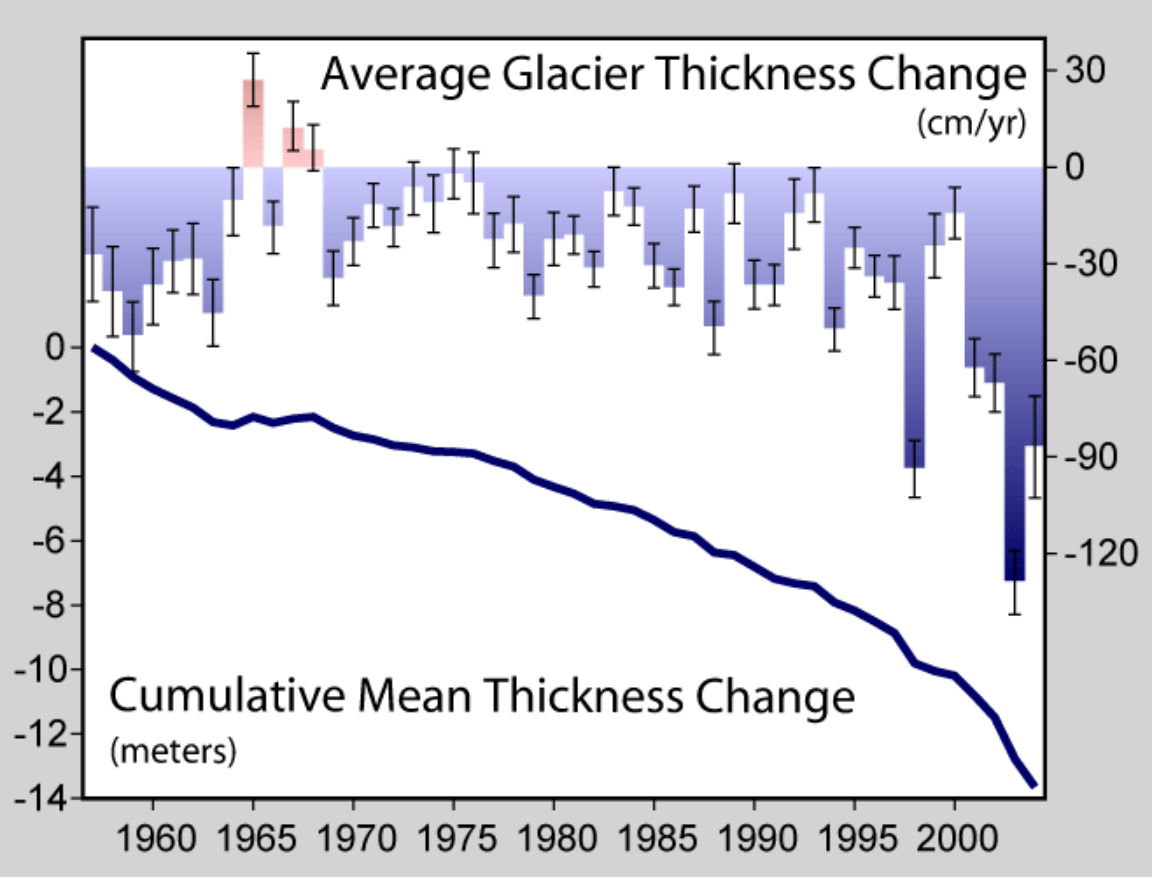
Energies expressed in units of cm^{-1} (called **wavenumber** units) are based on the fact that the energy of a photon depends on the wavelength (since h and c are constants). Larger values of wavenumbers corresponds to higher energy, with 10,000 cm^{-1} → 1 μm.

An energy of 2349 cm^{-1} can be converted to show the wavelength (e.g. in μm) by (1/2349) cm = 4.26 x 10^{-4} cm = 4.26 x 10^{-6} m = 4.26 μm.

http://chemwiki.ucdavis.edu/@api/deki/files/13250/=Slide1.png

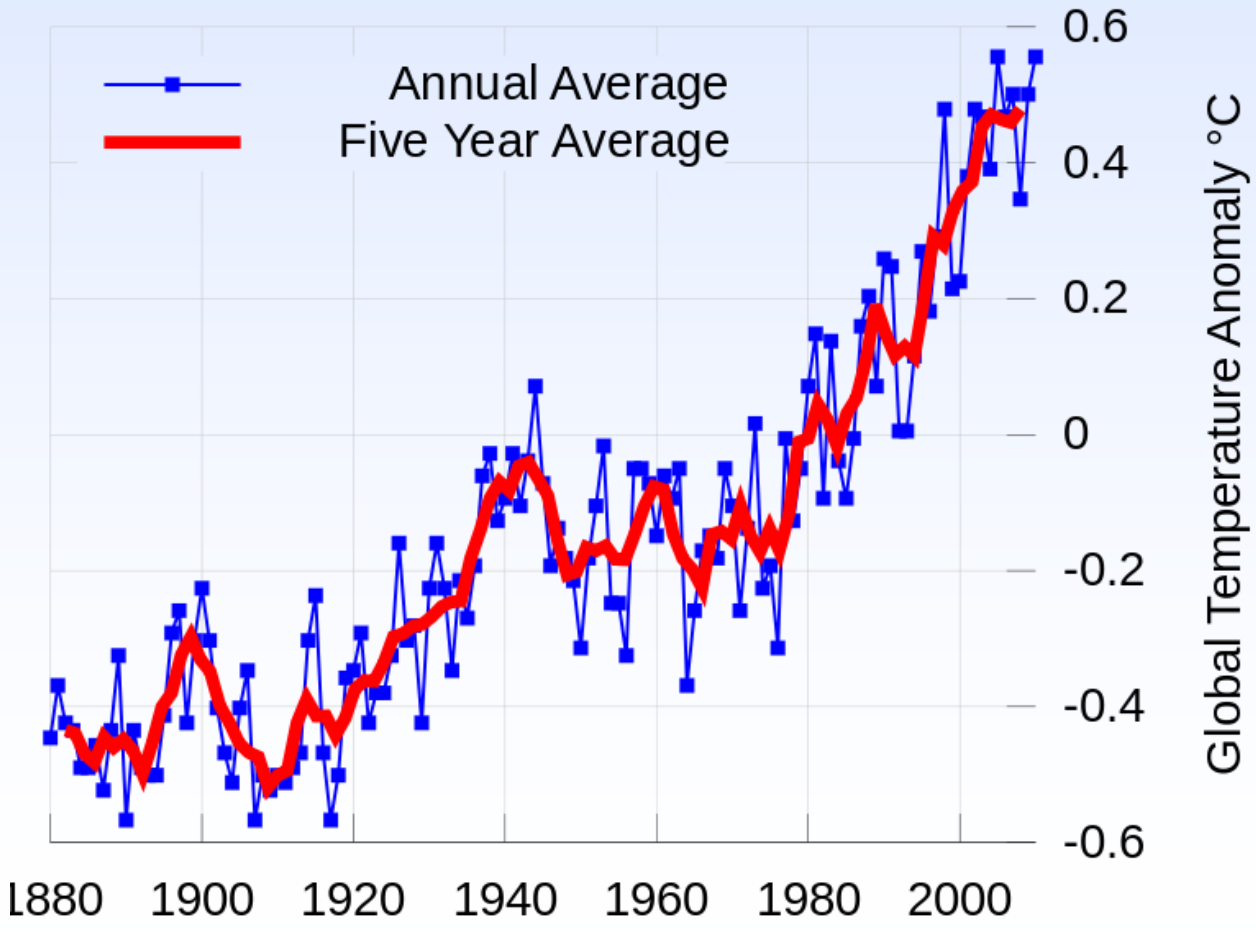
Global climate change

The most general definition of climate change is a change in the statistical properties of the climate system when considered over long periods of time, regardless of cause. - http://en.wikipedia.org/wiki/Climate_change



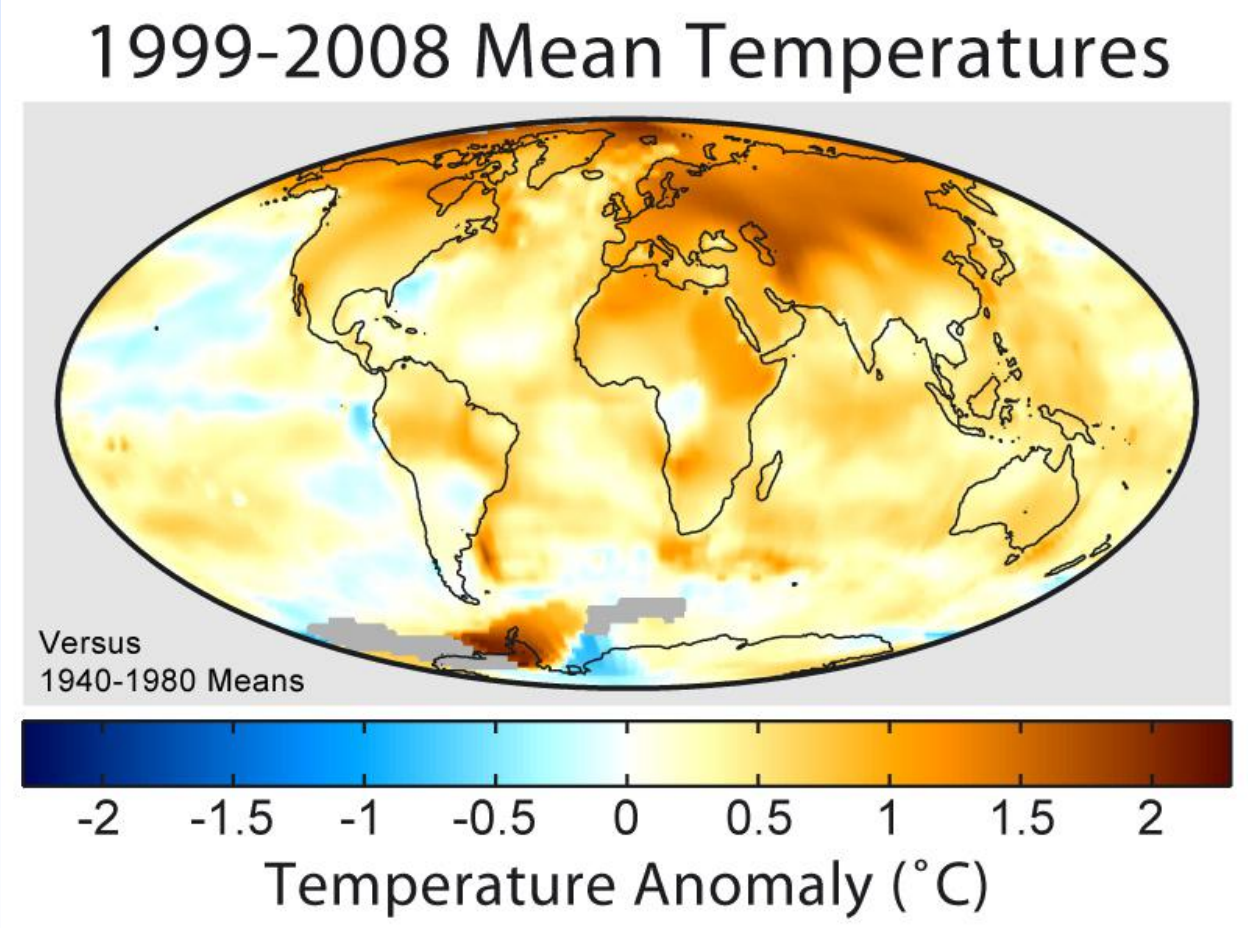
Global warming

Earth's weather system has been observed to be warming over the past > 100 years. The weather system includes the atmosphere and the oceans.



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

Global warming (cont.)



10-year average (2000–2009) global mean temperature anomaly relative to the 1940–1980 mean.

http://en.wikipedia.org/wiki/File:Global_Warming_Map.jpg

Weather vs. climate

Weather refers to the atmospheric conditions over a short period of time (e.g., "the weather forecast"), such as week or a little longer. The climate of a region refers to the average weather over a period of many years or even decades.

Weather conditions vary quite widely around climate averages.

Over long periods of time, we have observed changes in the climate for many regions on earth, leading to glaciers receding, reduced average snowfalls, and (typically) increased average temperatures.