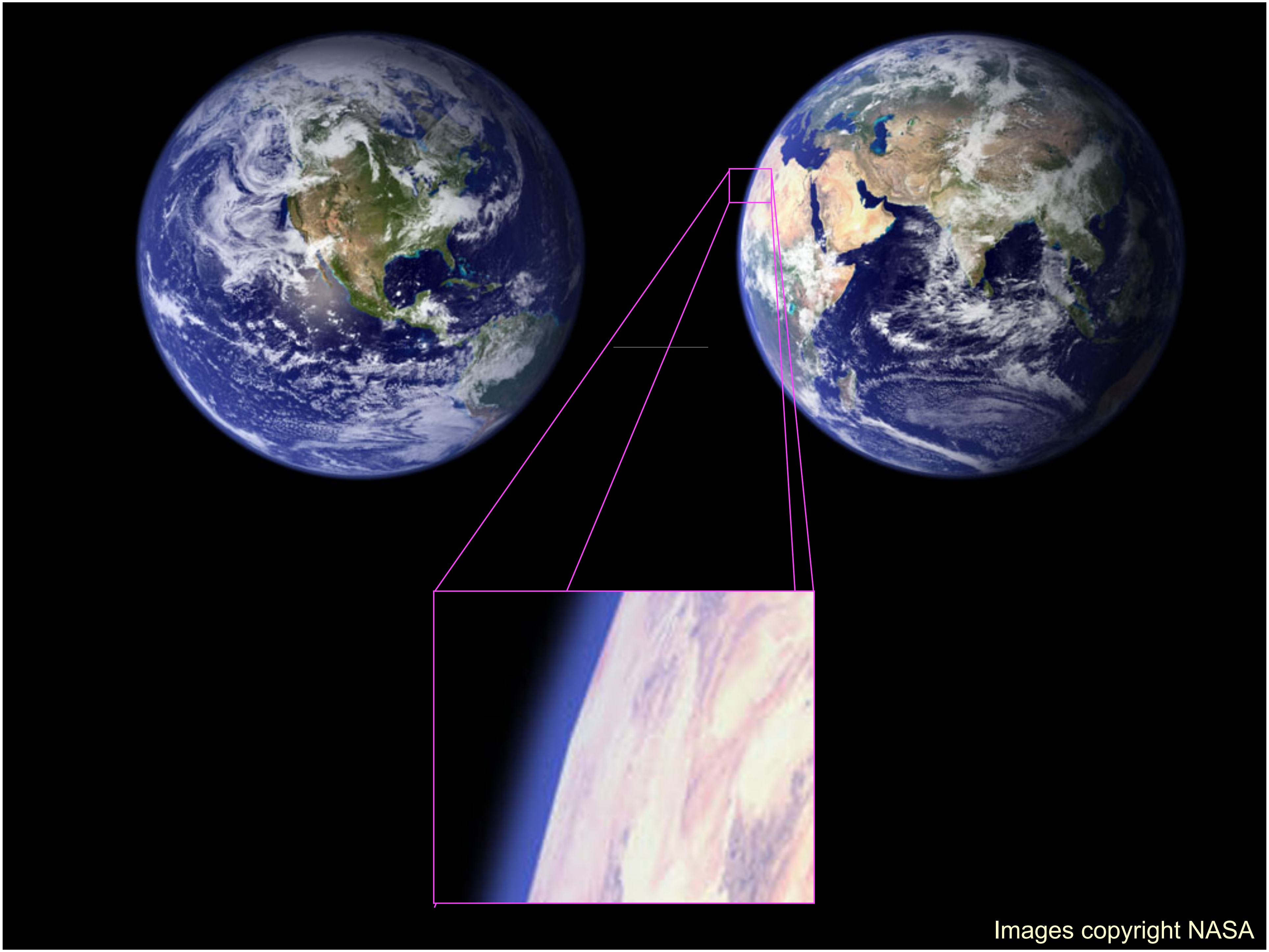

The Atmosphere
Structure and composition
Solar radiation budget
Greenhouse warming

The Atmosphere

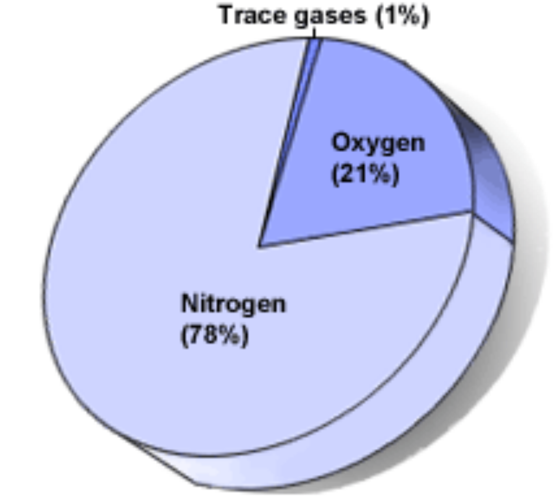
The thin envelope of air that surrounds our planet is a mixture of gases, each with its own physical properties.

http://www.ucar.edu/learn/1_1_1.htm


Images copyright NASA

Caused by interaction of high energy particles from Sun with outer atmosphere.

http://www.doc.mmu.ac.uk/aric/eae/english.html



Proportional volume of gases composing dry air. Nitrogen and oxygen obviously dominate.

The COMET Program

Composition of Dry Air

The atmosphere contains primarily N_2 and O_2

(78%+21%=99% of total)

The most abundant “trace gases” is the noble gas argon (Ar). Of the other gases, two of the most important are:

- CO_2 (carbon dioxide) – the main “greenhouse gas” responsible for keeping the surface of the Earth warm, also essential for photosynthesis and thus vital for life

- O_3 (ozone) – found primarily in the upper atmosphere, absorbs wavelengths of UV radiation that would be dangerous to surface life. When found at low altitude, it is a major pollutant.

http://www.ucar.edu/learn/1_1_1.htm

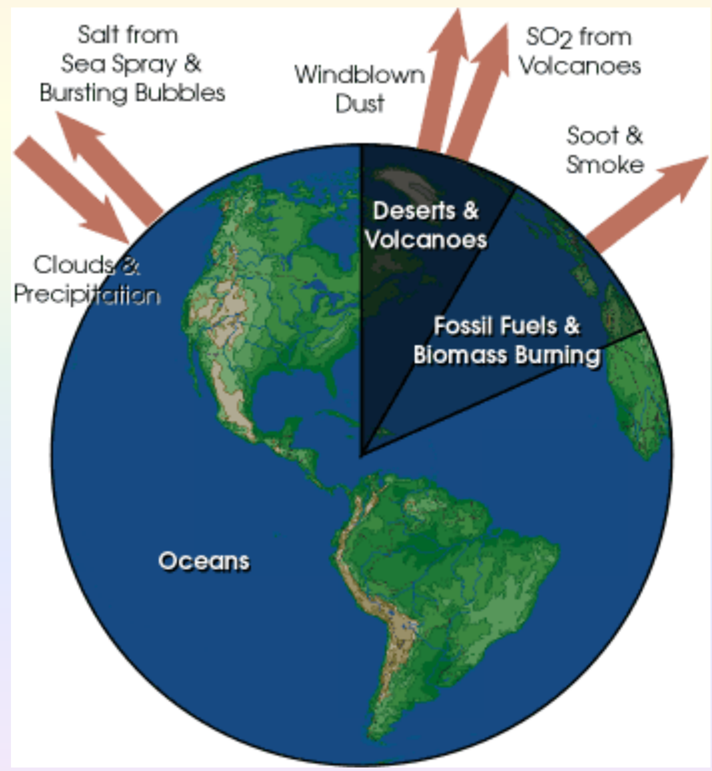
Other Components of the Atmosphere

Water Vapor

Concentrations vary from trace amounts to about 4% in very humid environments (e.g., over the oceans)

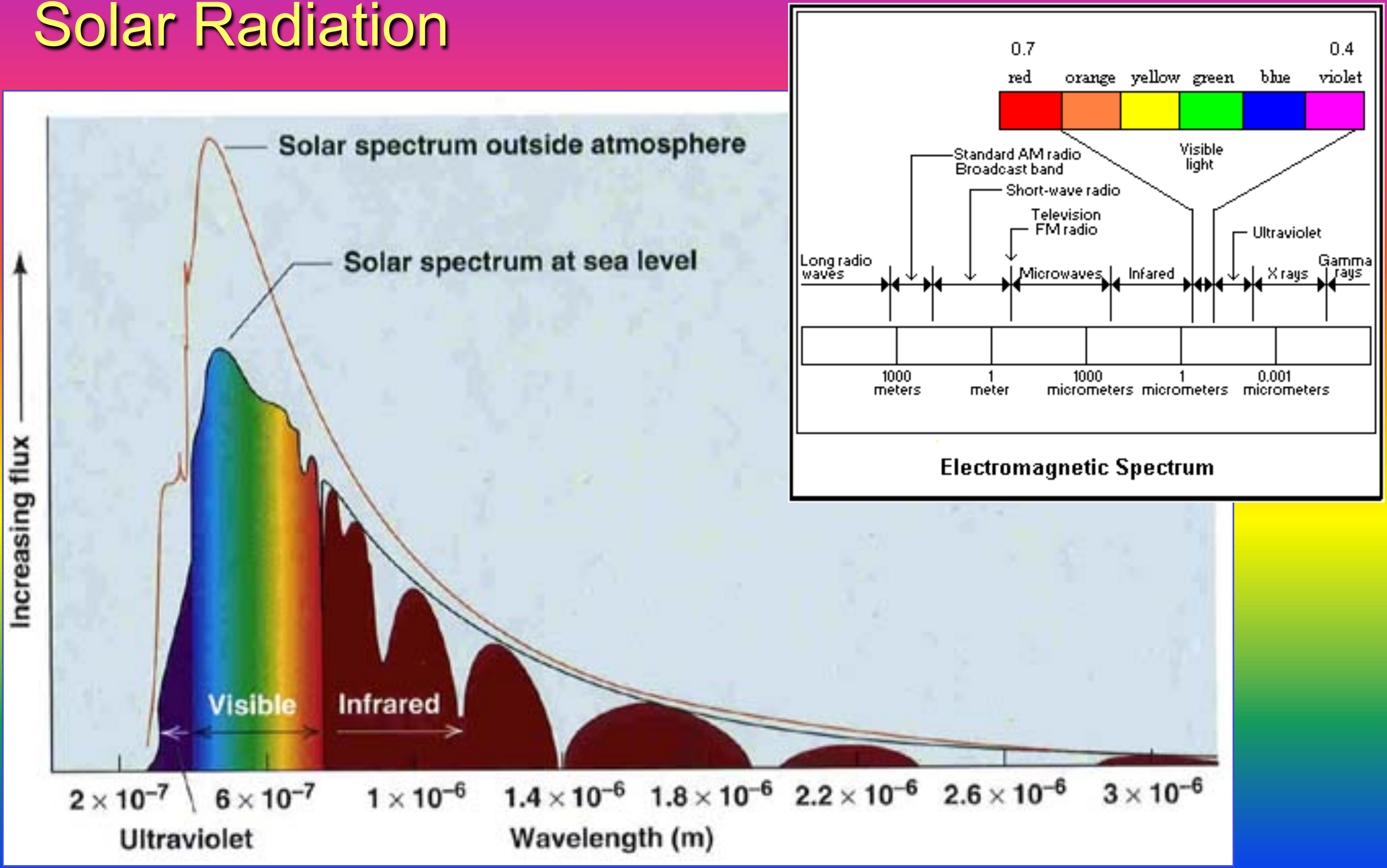
Aerosols

Tiny particles suspended in the air. Tend to cool Earth by reflecting sunlight back to space. Also very important in precipitation.



http://earthobservatory.nasa.gov/

Solar Radiation

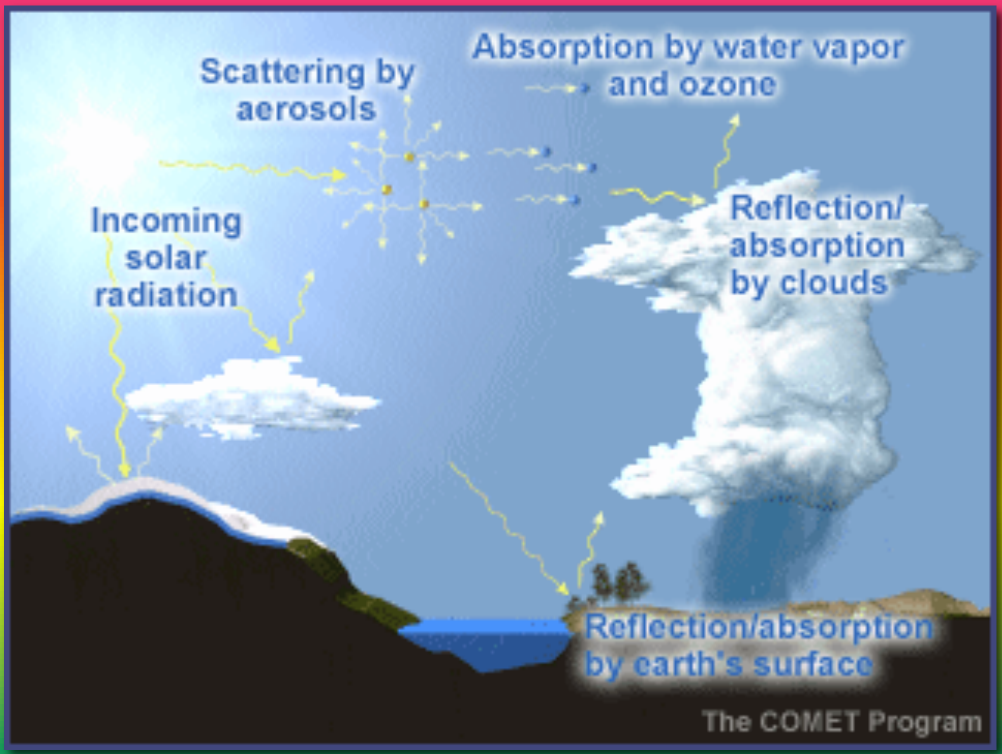


Almost all energy in the atmosphere ultimately comes from solar radiation.

http://physics.uwstout.edu/wx/Notes/ch2notes.htm

http://paos.colorado.edu/~toohey/study.html

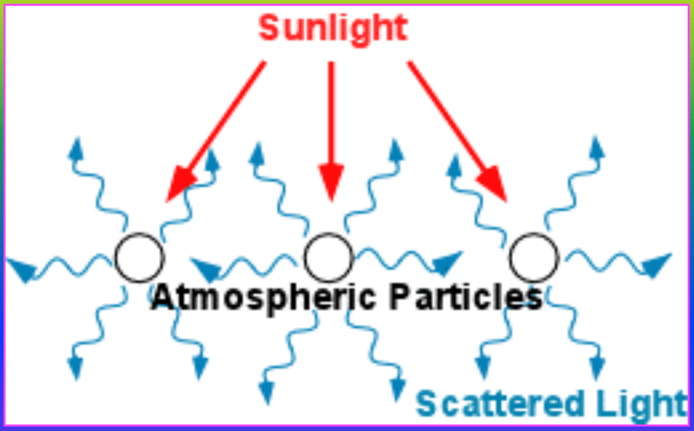
Solar Radiation



The "solar budget" sums up the fate of various portions of the incoming solar radiation

Solar radiation can be: *reflected*, *scattered*, and/or *absorbed* by the atmosphere and/or surface of the Earth.

http://www.ucar.edu/learn/1_1_1.htm



Radiation Scattering

Light ***refracts*** through gases and ***reflects*** off aerosols in the atmosphere.

The net result is that the light is ***scattered*** in all directions. This is why the daytime sky appears to be uniformly lit.

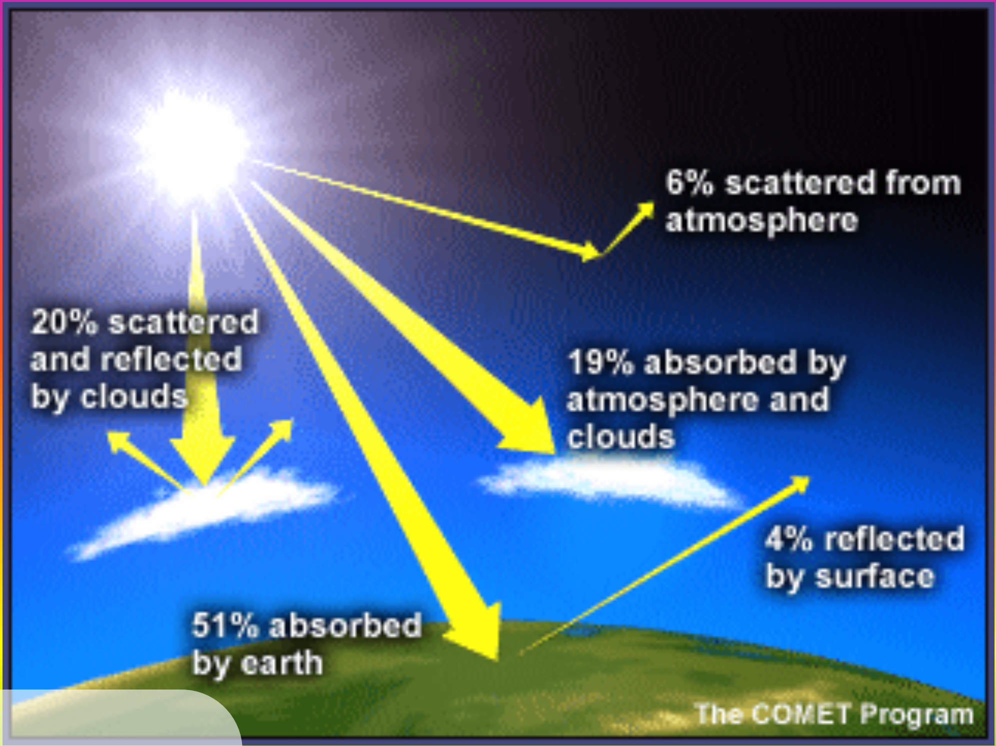
http://ww2010.atmos.uiuc.edu/(Gh)

Atmospheric Scattering

Shorter wavelengths of light (e.g., **blue**) refract more than longer wavelengths (e.g., **red**), and are therefore more easily scattered. The thicker the atmosphere through which the light passes, the less blue (and the more red) the sky will appear.

http://www.doc.mmu.ac.uk/aric/eae/english.html

Average Solar Radiation Budget



70% absorbed

- *19% by atmosphere and clouds*
- *51% by surface*

30% reflected or scattered back to space

- *20% from clouds*
- *6% from atmosphere*
- *4% from surface*

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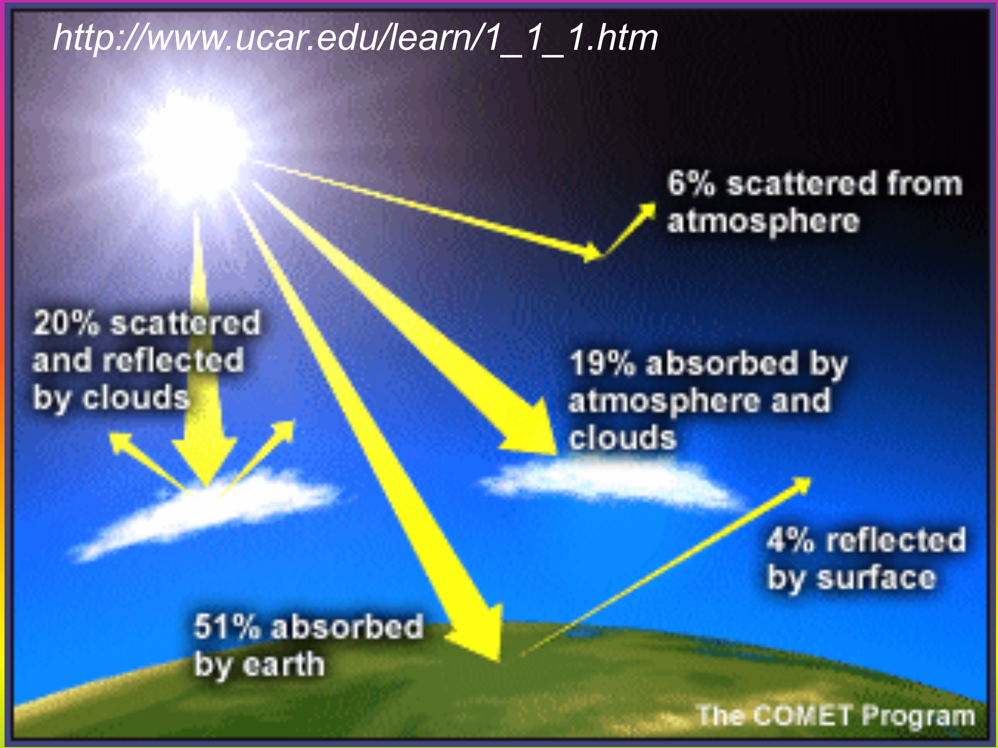

Radiation that is absorbed by the atmosphere or surface of the Earth heats those bodies.

The absorbed radiation energizes a number of natural process. Radiation absorbed by water molecules can cause a phase change (e.g., solid ice to liquid water or liquid water to water vapor).

Most of the large amount of radiation absorbed by the surface of the Earth is re-radiated to the lowest level of the atmosphere, heating it. This warm air expands, causing it to be buoyant, and thus rise into the atmosphere.

A tiny percentage of the solar budget is absorbed by photosynthetic plants, which use it to make organic fuel (sugar).

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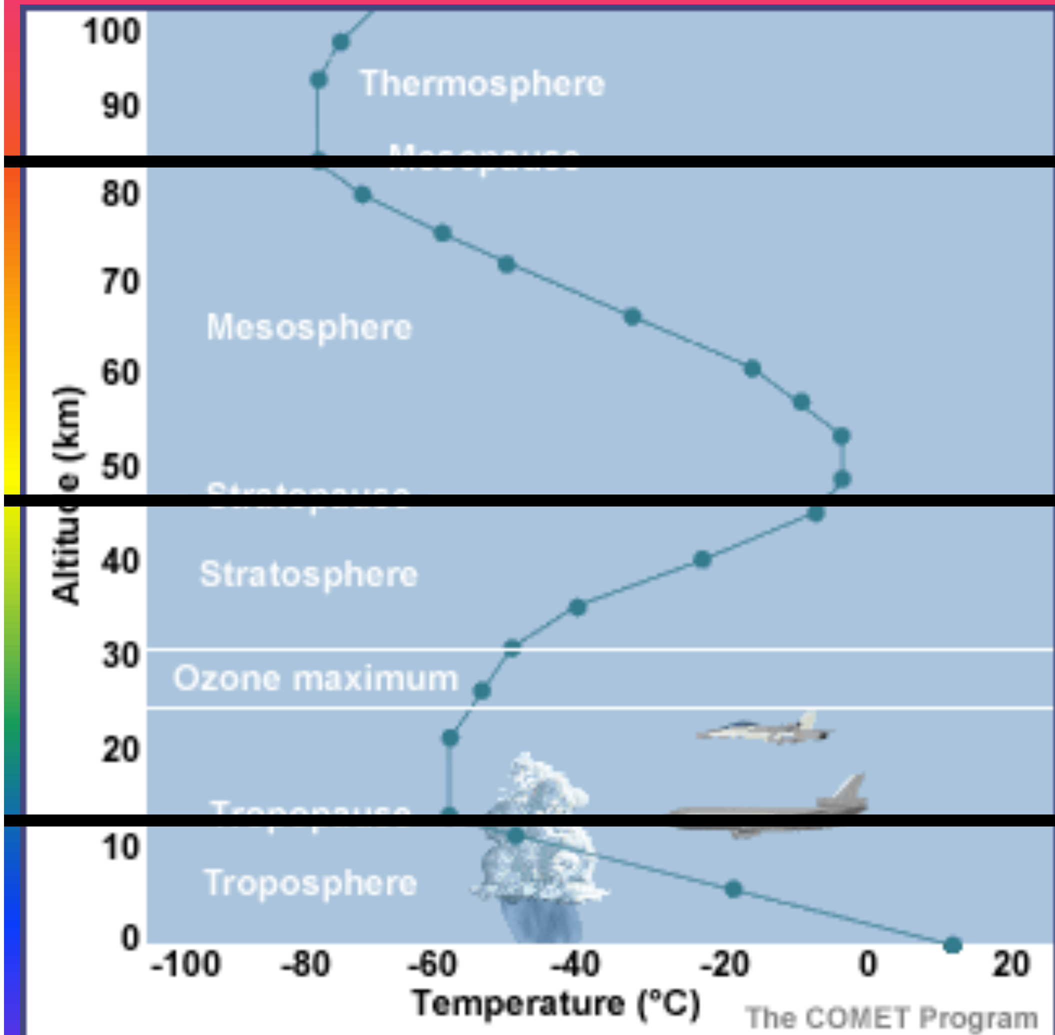
The solar budget differs from place to place on the Earth, e.g., the shiny white ice surfaces at high latitudes are much more reflective than dark green rainforests at the equator.

It also changes with climate. During ice ages, more land is covered with reflective ice, so less radiation is absorbed overall. A good volcanic eruption will put lots of aerosols in the atmosphere, increase scattering by the atmosphere.

http://www.ucar.edu/learn/1_1_1.htm

Temperature Structure of the Atmosphere



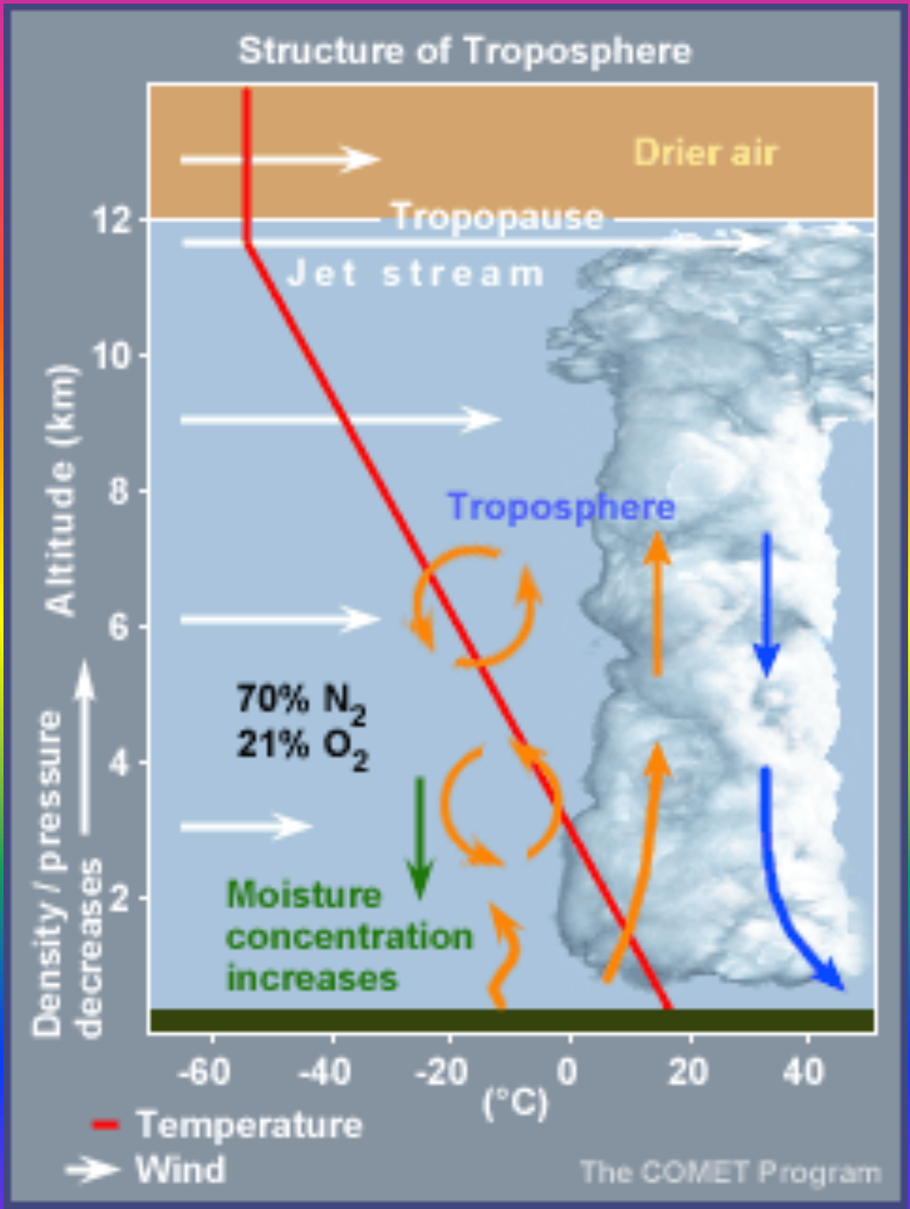
Thermosphere – temperature increases because of interaction with high energy radiation.

Mesosphere – temperature decreases with increasing altitude

Stratosphere – temperature increases due to activity in the ozone layer

Troposphere – temperature decreases with elevation above the heat source (the Earth's surface)

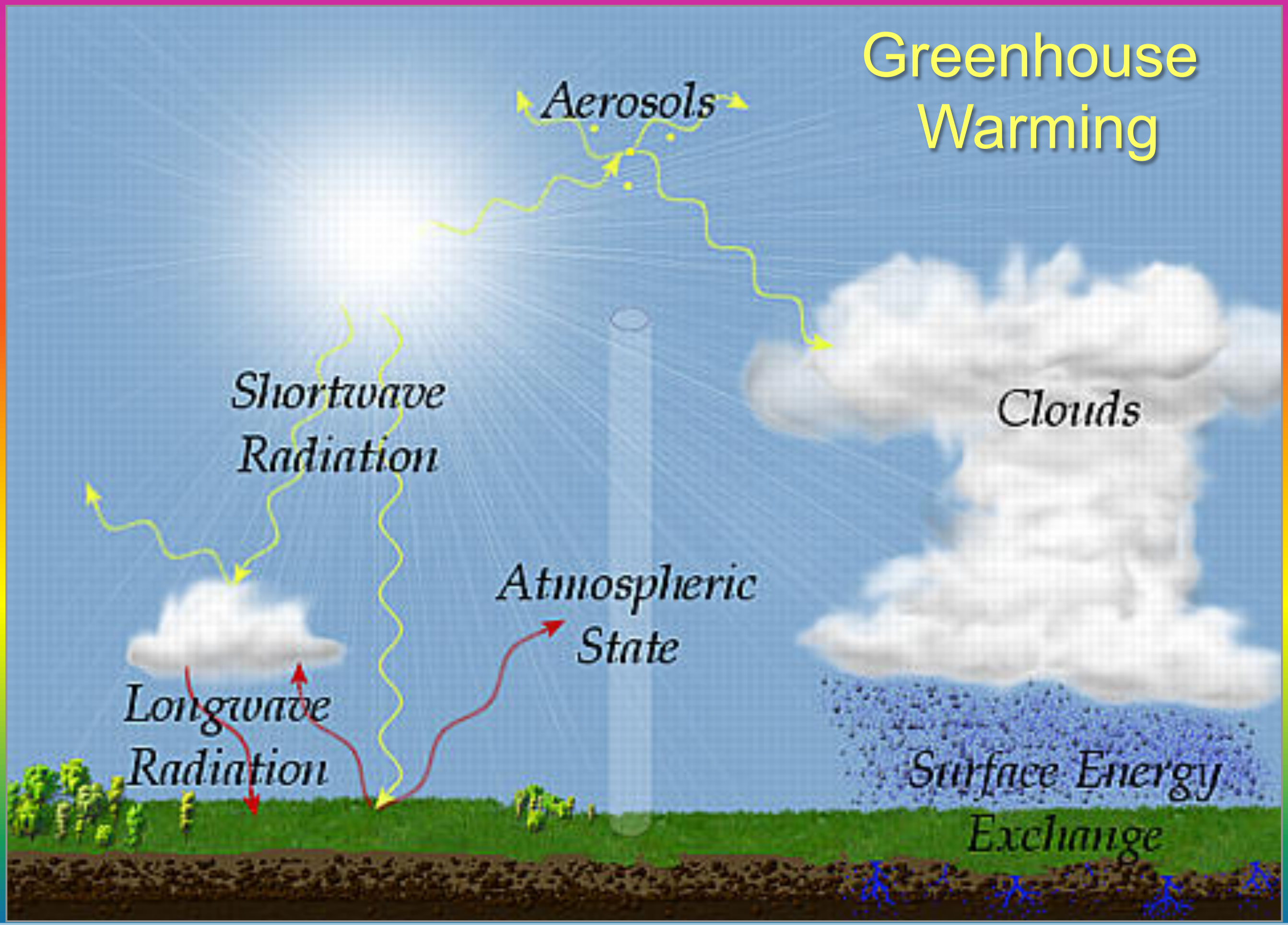
http://www.ucar.edu/learn/1_1_1.htm



Troposphere - the highly variable lowest layer of the atmosphere.

- Extends from Earth surface to approximately 12 km elevation
- Pressure ranges from 1 atm to 0.2 atm.
- Temperature averages 15°C (59°F) near surface, -57°C (-71°F) at top.
- Average temperature decrease is called the environmental lapse rate
- Wind speed increases with height up to jet stream.
- Moisture concentration decreases with height

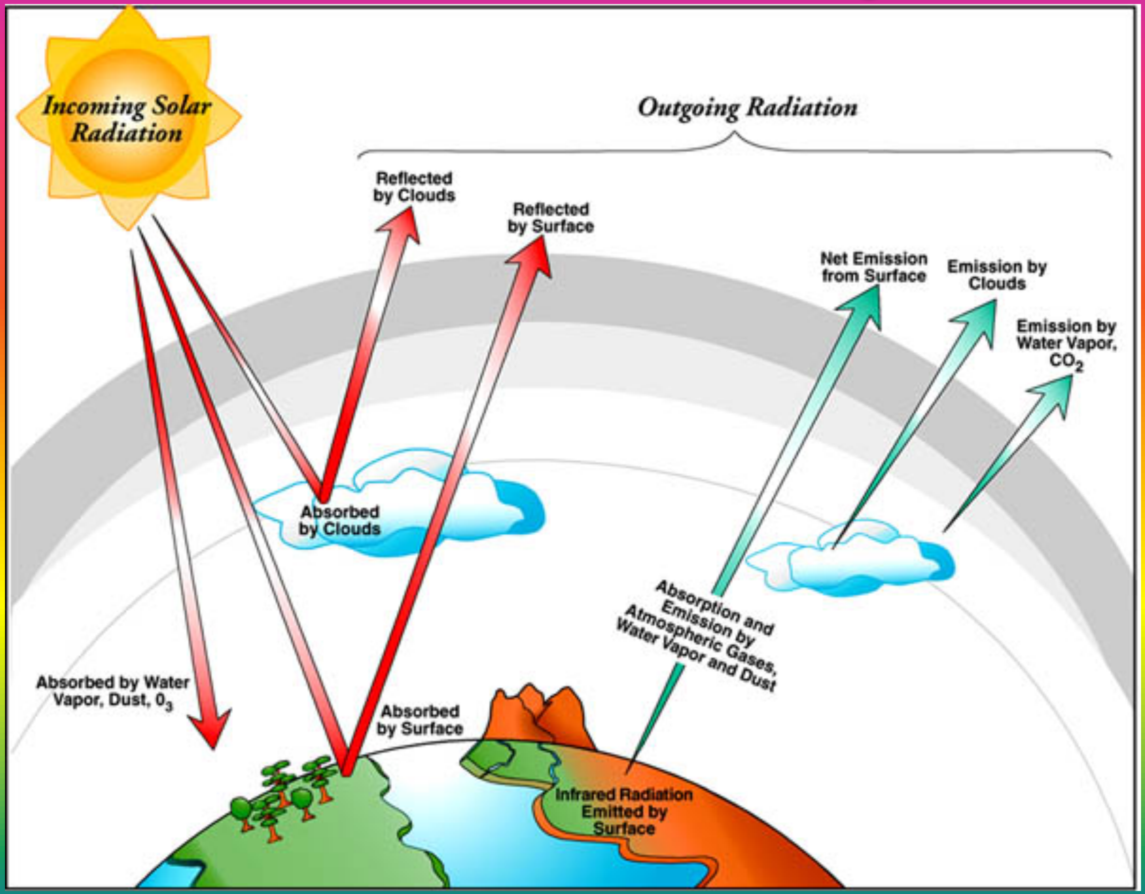
http://www.ucar.edu/learn/1_1_1.htm



As the heated atmosphere and surface cool, they release energy as radiation back into the atmosphere. However, it is *not* the same wavelength energy as the original solar radiation.

http://www.arm.gov/docs/data.html

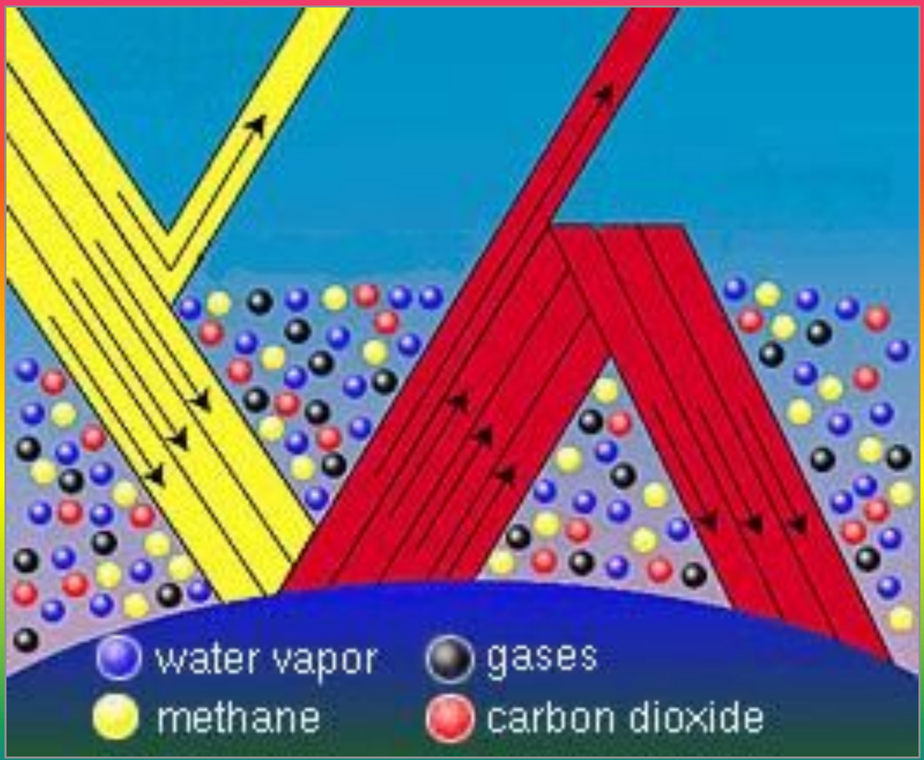
Greenhouse Warming



The Earth re-radiates energy as a “black-body” – an object that emits radiation at a wavelength dependant on its temperature. The Earth radiates in the infrared spectrum – a much longer wavelength than incoming solar radiation.

http://www.arm.gov/docs/data.html

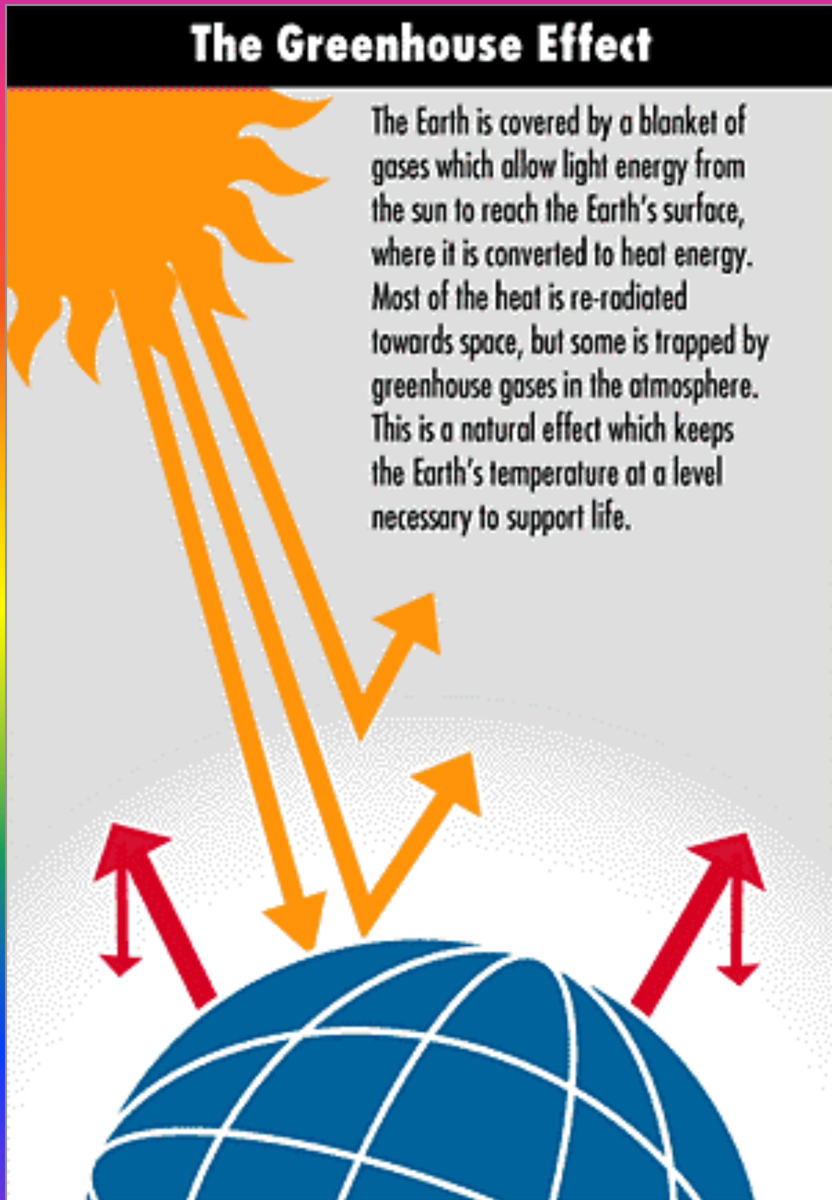
Greenhouse Warming

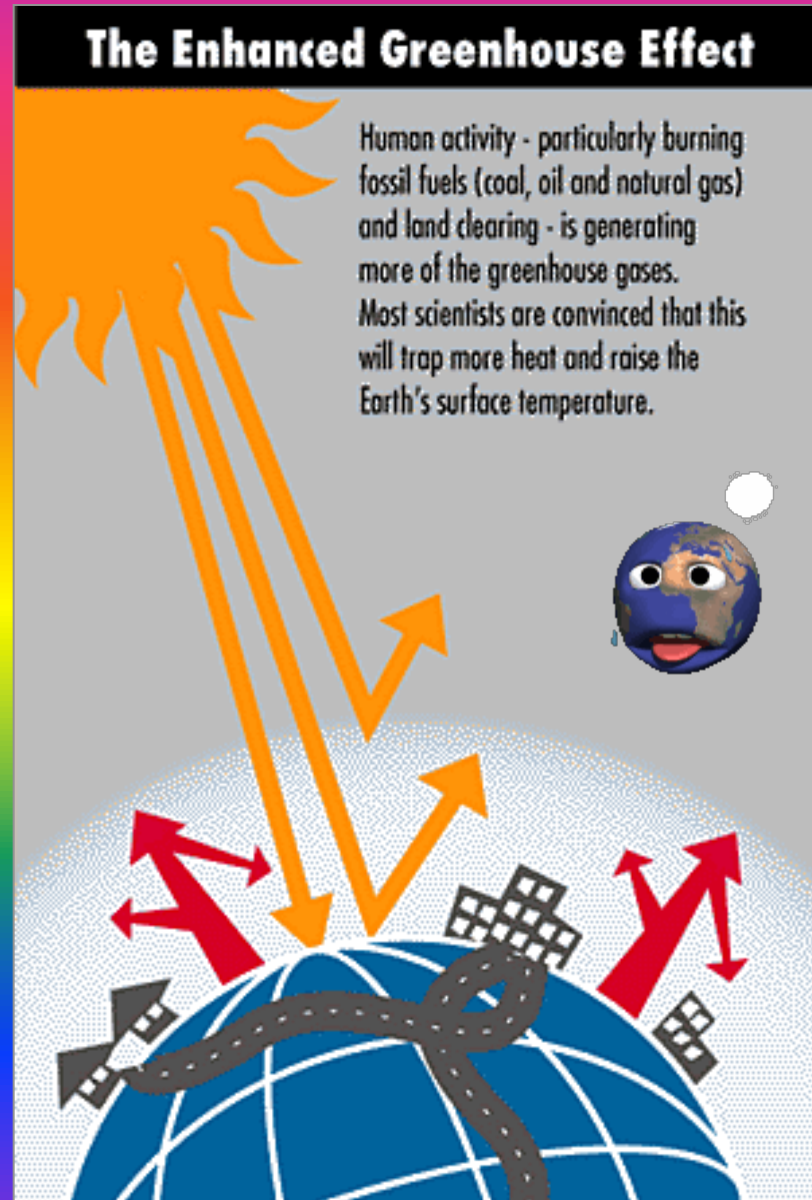


Several gases in the Earth's atmosphere (particularly water, methane, and carbon dioxide) are relatively transparent to short wavelength radiation (e.g., incoming sunlight), but will readily absorb longer wavelengths (e.g., the infrared radiation emitted from Earth).

This re-absorption and re-radiation prevents energy from escaping back to space, and thus keeps the atmosphere and surface of the Earth warmer than it would be otherwise.

http://www.cmdl.noaa.gov/info/ipcc.html

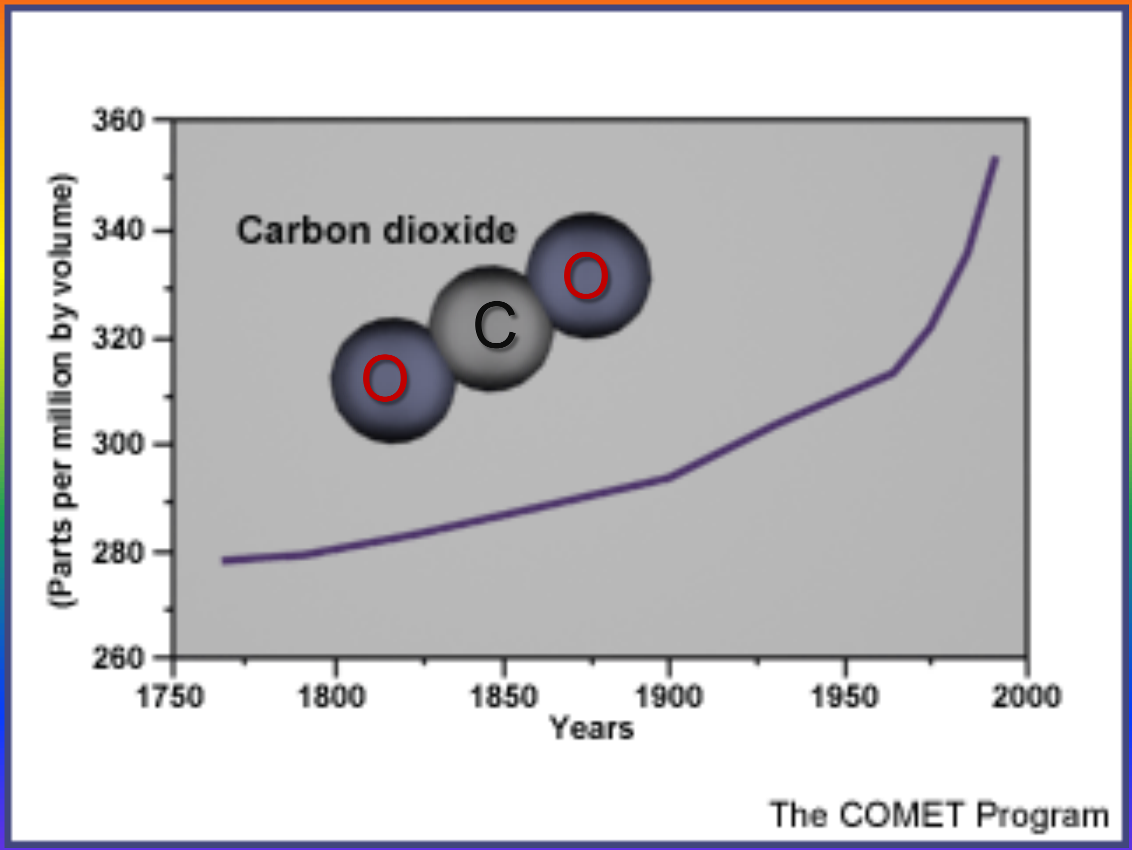




http://www.greenhouse.gov.au/

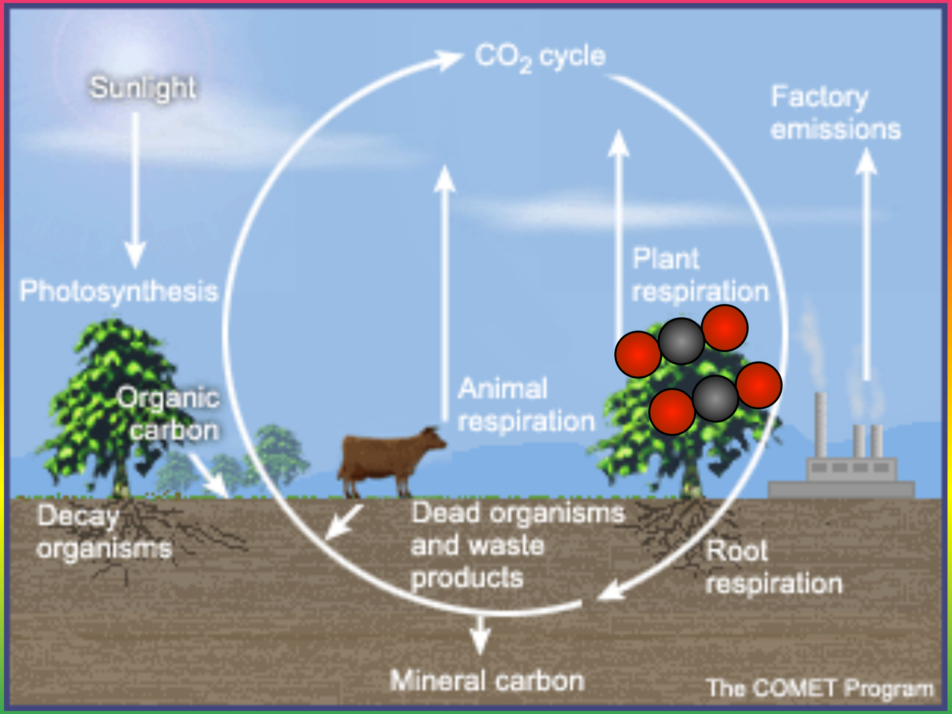
Greenhouse Warming

There are many greenhouse gasses, including the very important trace gas carbon dioxide.



http://www.ucar.edu/learn/1_1_1.htm

The Carbon Cycle

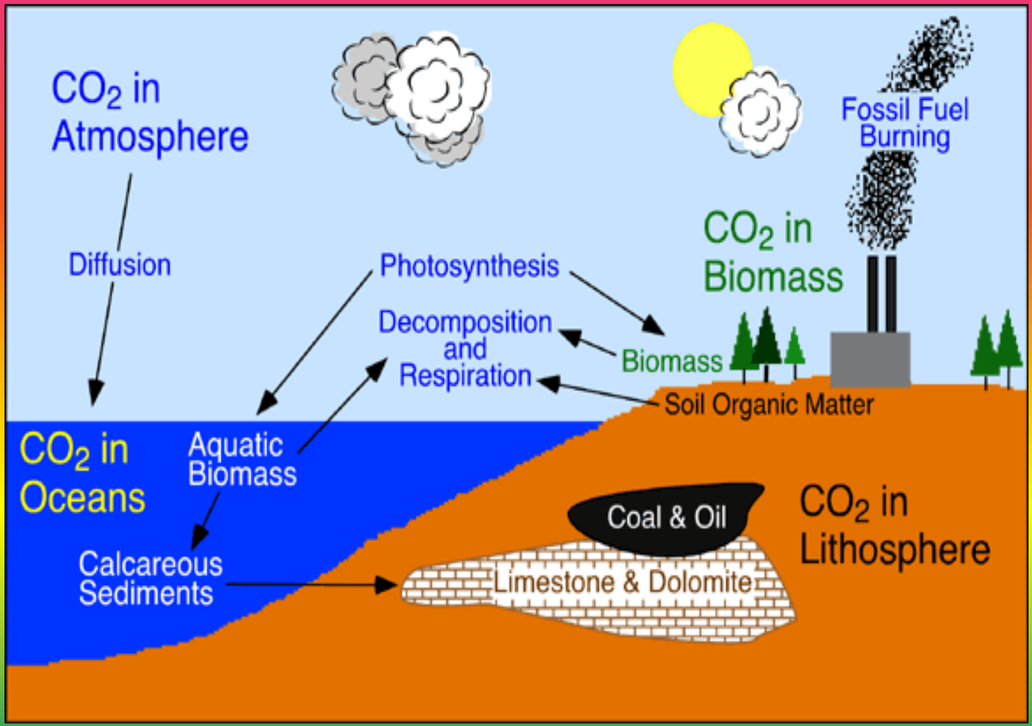


The amount of CO_2 in the atmosphere is controlled by a complex set of interacting biological and environmental processes.

Plants (and other photosynthetic organisms) remove CO_2 from the air and use it to produce biochemical energy (carbohydrates, e.g., $C_nH_{2n}O_2$). When these primary producers or their consumers use the biochemical energy, it is released back into the atmosphere as CO_2.

http://www.ucar.edu/learn/1_1_1.htm

The Carbon Cycle



Some organic matter is semi-permanently removed by being buried and converted into fossil fuels (hydrocarbons, e.g., methane - CH_4). When those fuels are burned, the CO_2 is re-released into the atmosphere.

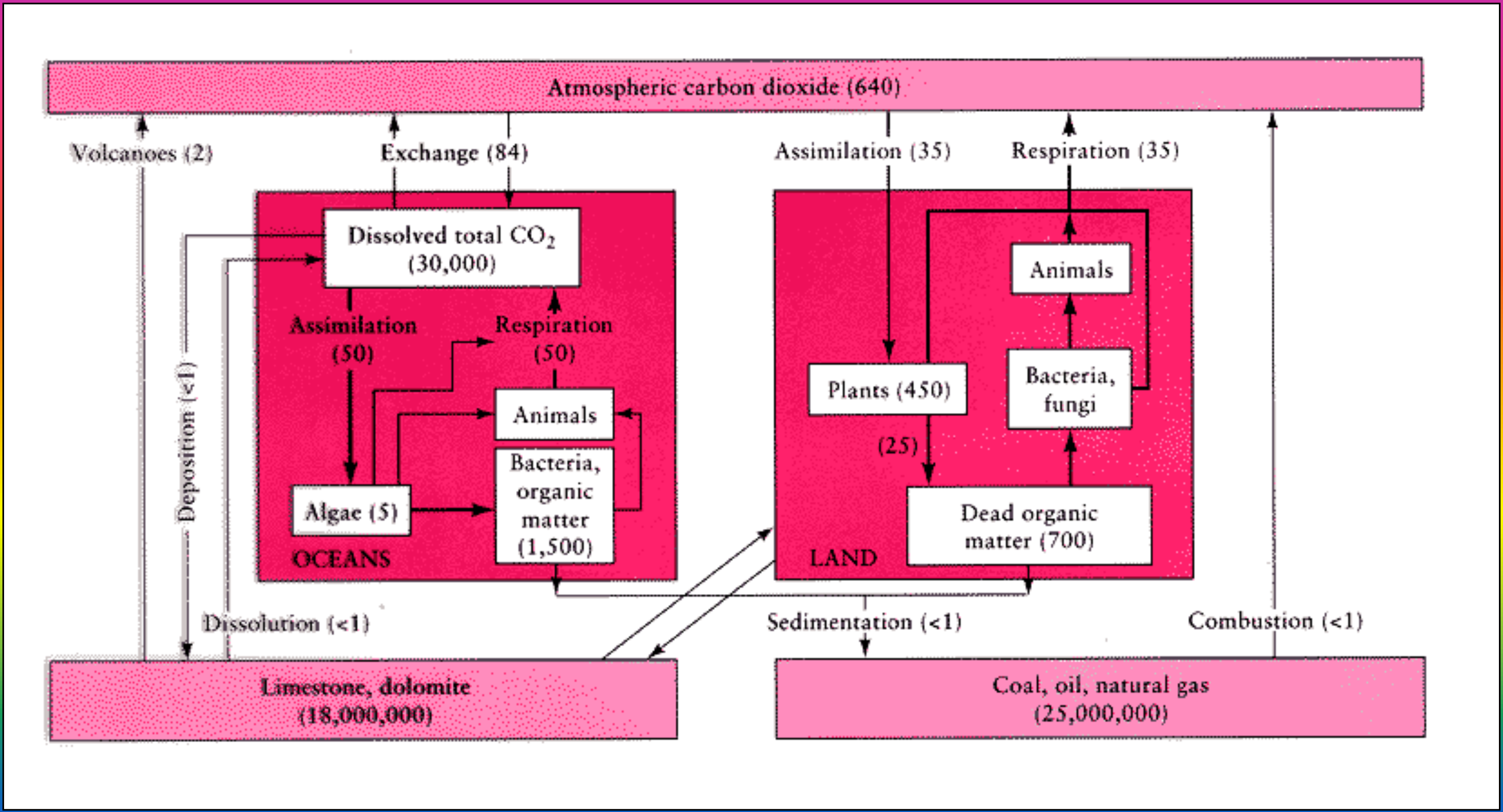
CO_2 is absorbed by processes other than photosynthesis (e.g., limestone formation $CaCO_3$). Some of these processes are very poorly understood, especially on the global scale.

http://www.geog.ouc.bc.ca/physgeog/contents/9r.html

Major Stores of Carbon on Earth

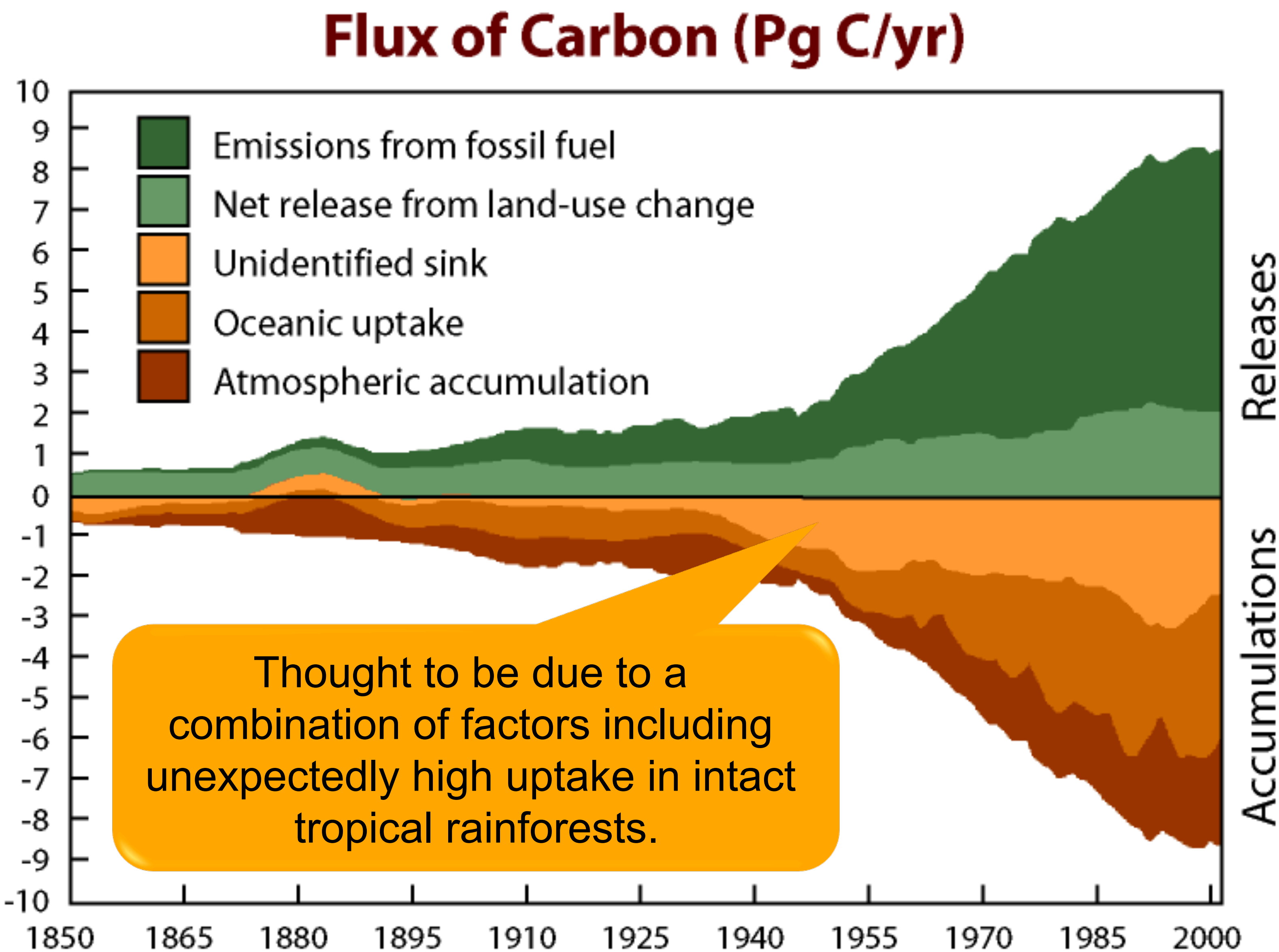
Store	Metric Tons ($x10^9$)
Sediments and Sedimentary Rocks	~100,000,000
Ocean	~39,000
Fossil Fuel Deposits	4,000
Soil Organic Matter	~1,550
Terrestrial Plants	~600
Atmosphere (1700)	578
Atmosphere (1999)	766

http://www.geog.ouc.bc.ca/physgeog/contents/9r.html



Tracking the interactions between all of the various groups of sources and sinks or CO_2 is quite complex. A linear change in one set of processes may cause an exponential change elsewhere!

http://essp.csumb.edu/esse/climate/climatefigures/Ccycle.html



http://www.blog.thesietch.org/2007/06/24/exactly-where-does-all-that-co2-go-scientists-close-in-on-missing-carbon-sink/

Non-atmospheric CO_2 does not lead to warming!

Adds to atmospheric CO_2:

Respiration + Fossil Fuel Emission + Land Use Change

Takes away atmospheric CO_2:

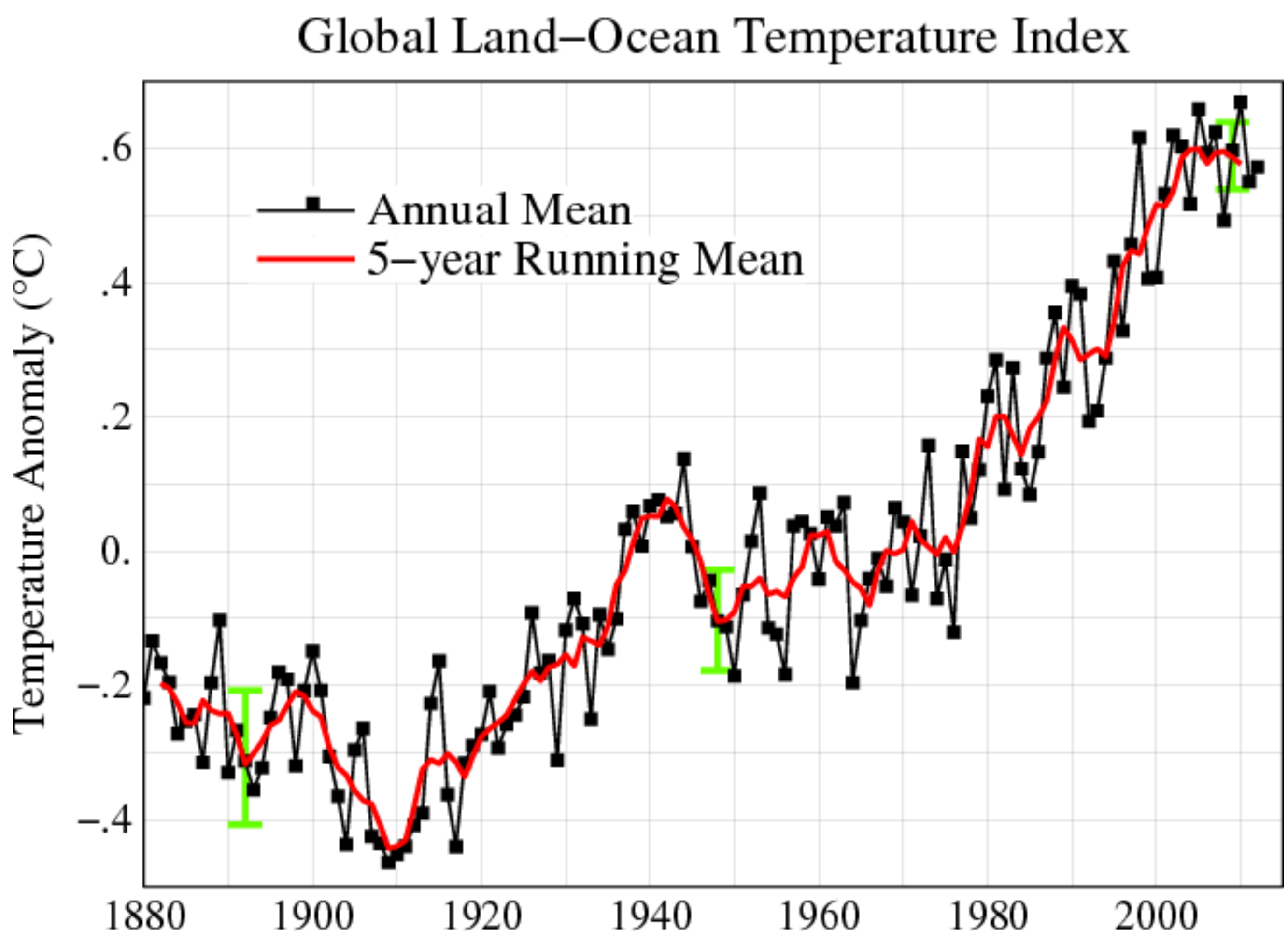
Photosynthesis + Ocean Uptake + Land Uptake + *Missing Uptake*

http://www.whrc.org/science/carbon/carbon.htm

The rate of carbon dioxide accumulation in the atmosphere has risen at a rather alarming rate when viewed against the historical trend of the past half million years.

http://climate.nasa.gov/evidence

This rise in atmospheric carbon dioxide correlates with global temperature anomalies and global climate anomalies.



http://data.giss.nasa.gov/