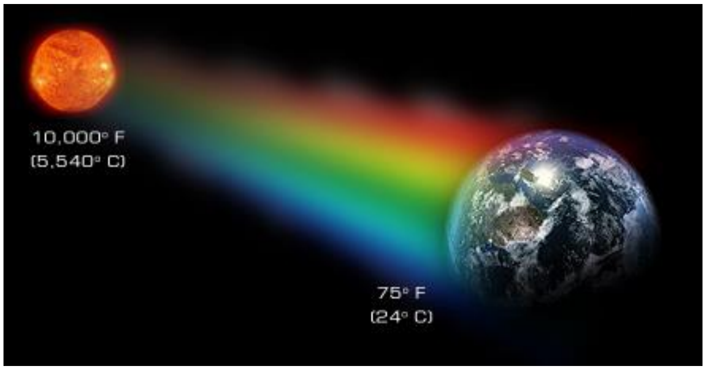
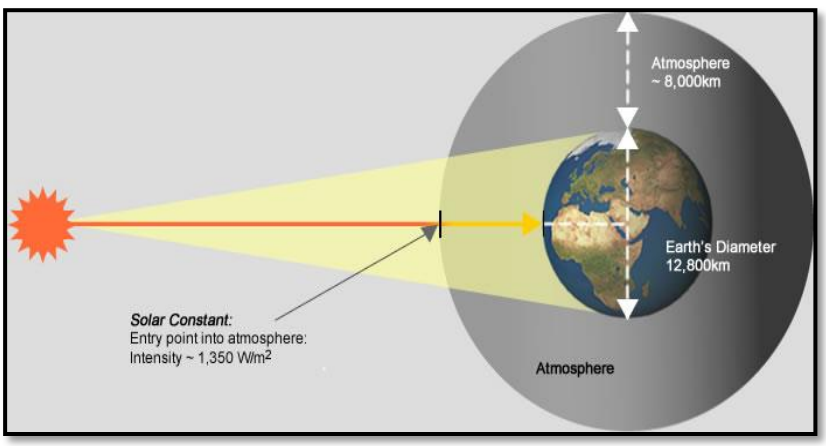
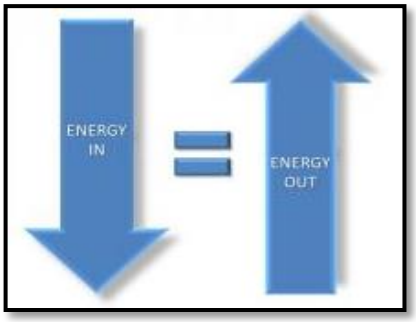
TEACHER BACKGROUND:
EARTH'S HEAT BUDGET



The Sun is the star located at the center of our planetary system. It is composed mainly of hydrogen and helium. In the Sun's interior, a thermonuclear fusion reaction converts the hydrogen into helium releasing huge amounts of energy. The energy created by this reaction is converted into ***thermal energy*** (heat). This energy raises the temperature of the Sun to levels that are about twenty times greater than that of the Earth's surface. The solar heat energy travels through space in the form of ***electromagnetic waves*** enabling the transfer of heat through a process known as ***radiation***.

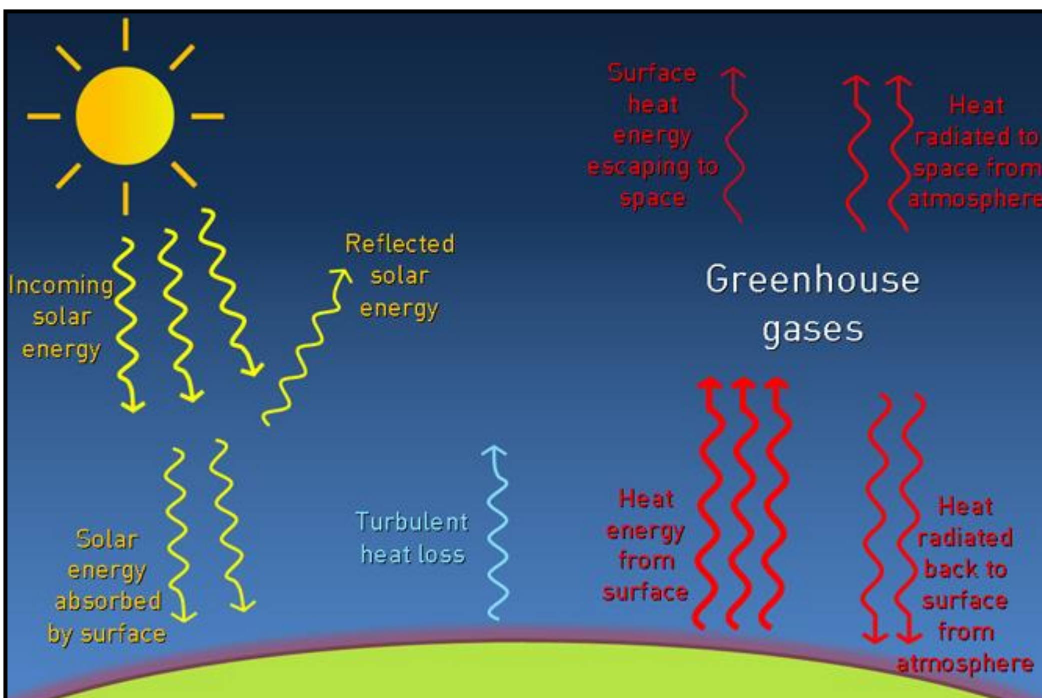


The surface of the Sun has a temperature of about 5,800 Kelvin (about 5,500 degrees Celsius, or about 10,000 degrees Fahrenheit). At that temperature, most of the energy the Sun radiates is visible and near-infrared light. At Earth's average distance from the Sun (about 150 million kilometers), the average intensity of solar energy reaching the top of the atmosphere directly facing the Sun is about 1,360 watts per square meter. This amount of power is known as the ***solar constant***. The solar constant is the maximum possible power that the Sun can deliver to a planet at Earth's average distance from the Sun. This energy balance is governed by the ***first law of thermodynamics***, also known as the ***law of***



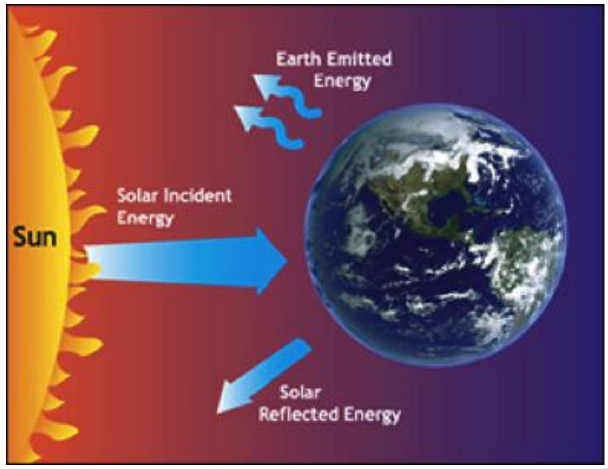
conservation of energy. This law states that energy can be transferred from one system to another in many forms, but it cannot be created or destroyed. Therefore, any energy "lost" during one process will equal the same amount of energy "gained" during another.

The energy flows and the storage in and between each of the Earth's subsystems involve many components. Each of these parts represents either ***input*** of radiation to the planet (solar heating), its ***output*** from the planet (infrared cooling), ***storage or release of heat*** within the climate system (evaporation, condensation, melting and freezing), or ***transport of heat*** from one part of the climate system to another (wind and ocean currents). Together, these processes serve as the driving forces of the climate system. The total energy available to drive all climate processes comes mainly from the distribution of solar radiation arriving and leaving the Earth.

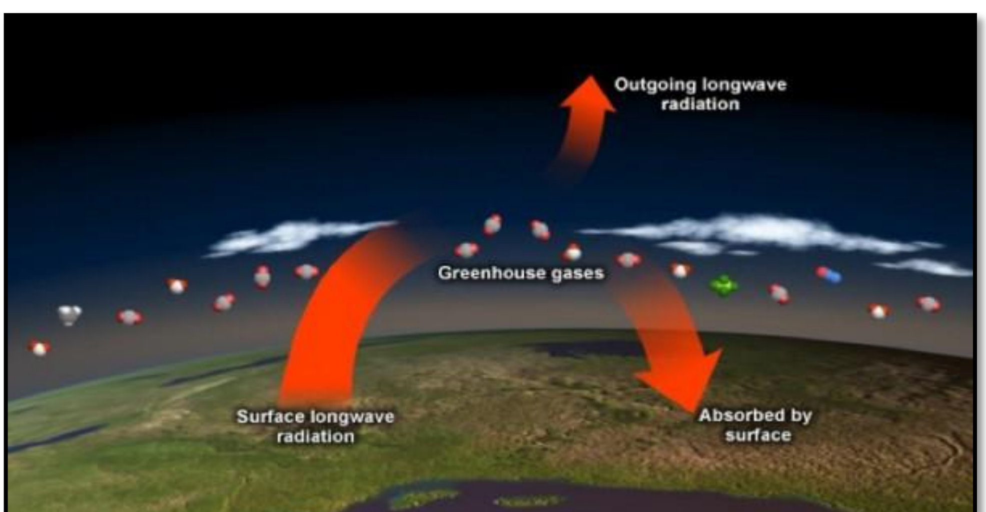


A simplified diagram of Earth's energy budget

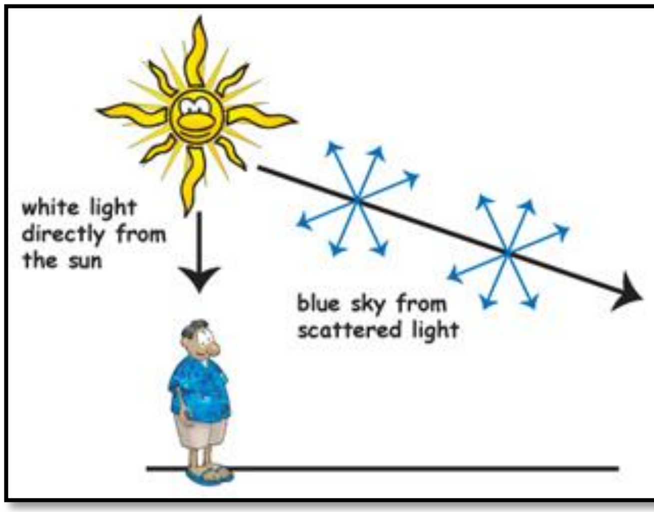
To maintain a constant global average temperature, all of the sun's radiation that enters Earth's atmosphere must eventually be sent back to space. This is achieved through Earth's ***energy balance***. Of the total solar energy entering Earth's atmosphere, about 50% is absorbed by the Earth's surface (the land and oceans), 30% is directly reflected back to space by clouds, the Earth's surface and different gases and particles in the atmosphere and 20% is absorbed by the atmosphere and clouds. The 70% of the sun's energy that is absorbed by the surface, clouds, and atmosphere causes warming. Any object or gas that has a temperature emits radiation outward which is eventually re-radiated back into space as long-wave radiation 24 hours a day.



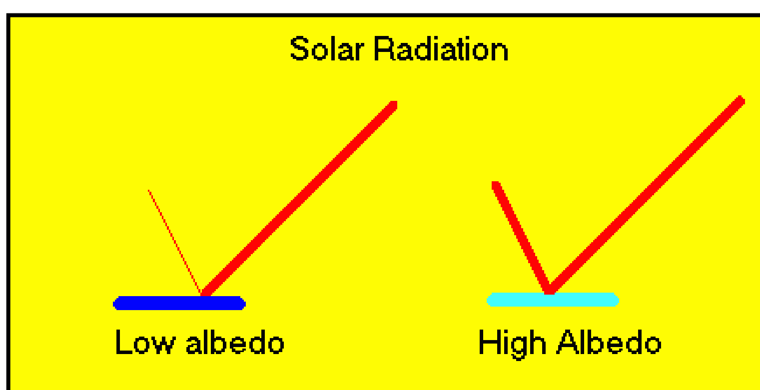
Most of the energy emitted from the earth's surface does not go directly out to space. This emitted energy is reabsorbed by clouds and by the gases in the atmosphere. Some is redistributed by ***convection***, while even more energy is released into the atmosphere through ***condensation***. The majority of the energy is absorbed by the ***greenhouse gases***, methane, nitrous oxide, ozone, carbon dioxide and water vapor. These gases constantly emit the sun's energy back into the atmosphere and keep the Earth at a habitable temperature. Eventually, most of the energy makes its way back out to space and Earth's energy balance is sustained.



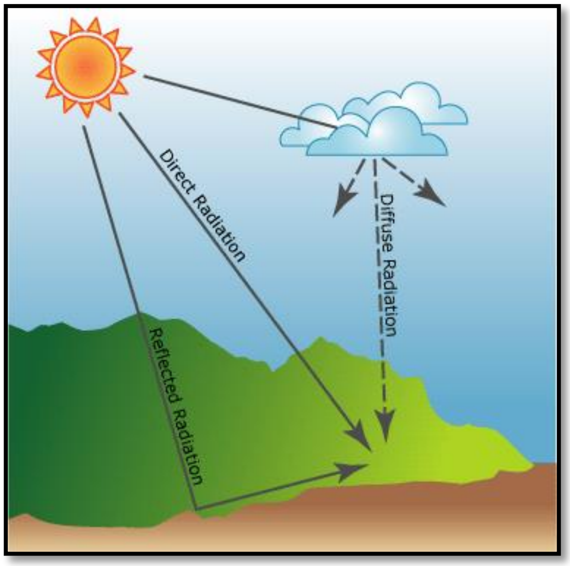
As solar energy strikes the Earth, some of it is absorbed, some of it is scattered, and some of it is transmitted directly to lower levels of the atmosphere. Absorption, scattering and transmission do not occur equally within the atmosphere. A variety of molecules, particles or surface features absorb, transmit or scatter energy with very different energy levels, depending upon the wavelengths of the transmitted energy.



Molecules tend to ***scatter*** radiation. The degree of scattering depends on the distance, the wavelength and the characteristics of the particles (size, shape, density). The molecules that compose the gases of the atmosphere are all very small relative to the wavelengths of most sunlight. For this reason, shorter wavelength radiation is scattered more effectively than longer wavelengths through a process known as ***Rayleigh scattering.*** The sky is blue during the day because the scattering of sunlight by the many tiny molecules of the Earth's atmosphere favors shorter wavelengths, such as blue light. For the much larger particles, such as soil, dust or sulfuric acid, which make up ***atmospheric aerosols,*** the scattering efficiency is much more uniformly distributed across the visible wavelengths.



Some of the scattering from clouds and dust results in ***back scattering,*** where a fraction of the incoming solar energy is scattered back, or ***reflected*** to space. ***Albedo*** is another name for reflectivity determines how much sunlight will be absorbed and warm the surface compared to another surface that reflects most of the light and does not change temperature. Something that appears white reflects most of the light that hits it and has a high albedo, while something that looks dark absorbs most of the light that hits it, indicating a low albedo.



Gases and particles in the atmosphere allow about half of the solar rays to pass through to the Earth's surface. However, not all of it passes directly through to the surface uninterrupted. Much of it - virtually all of it on a cloudy day - arrives as ***diffuse radiation***, having been scattered by atmospheric particles and molecules. About one-third of the total of the Sun's radiant energy that reaches the Earth eventually hits the surface without being scattered and about 25% reaches the surface as diffuse radiation. At the surface, about 85% of the total amount is absorbed. Over dark a surface such as the oceans, more than 90% is absorbed. In the seas or in very wet, vegetated areas this absorbed heat is used to evaporate water. Over bright surfaces, such as deserts and snowfields, 40-80 percent is reflected. Over deserts for example, as little as 1 percent of the absorbed energy is used to evaporate water: the rest simply warms the surface.

To summarize, a little less than a third of the Sun's radiation that reaches the Earth is reflected away, almost half is absorbed at the surface and the remaining 20 percent or so is absorbed by gases and particles in the atmosphere. The principle energy driving mechanism of the climate system is the absorption of solar energy by the molecules and particles of the atmosphere and the surface features of the Earth.