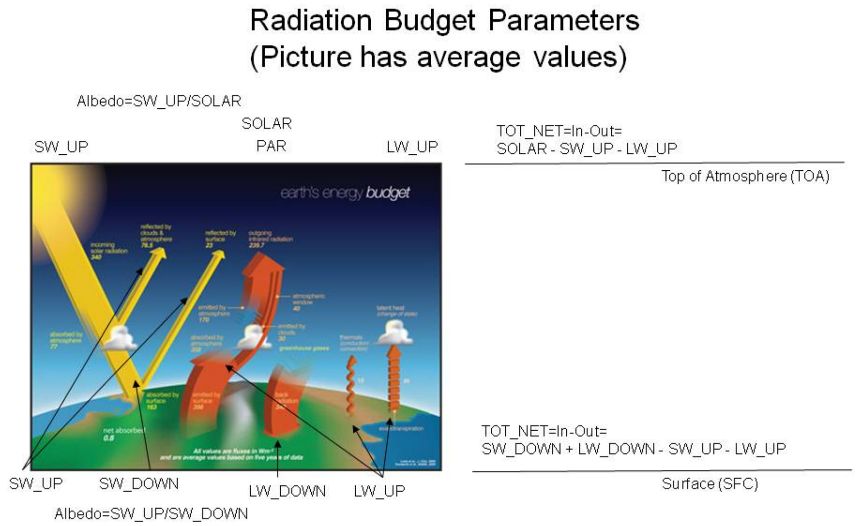
Radiation & Energy Transfer

[Click here for a print quality PDF version of the radiation parameters diagram]

The MY NASA DATA Live Access Server contains a number of parameters of the Earth's Radiation Budget. The schematic at the right shows where these parameters fit into the bigger picture of the Earth system. The information below further explains these various parameters, which are marked **in bold** in the text below.



See a NASA Fact Sheet on this topic.

View Earth's Energy Budget (graphic courtesy Loeb et al., 2009).

Location

There are two main locations where we measure the radiation budget:

- at the surface (**SFC**; using surface instrumentation or satellite techniques)
- at the top of the atmosphere (**TOA**; using satellites).

In theory one could also measure the radiation flow at any level between those two, but it's not so easy to do in practice. Also, the meaning of **TOA** depends on what you are measuring. For Earth radiation, the best value for the TOA is 20 km, which corresponds to the absorption cross-section of the Earth-atmosphere system (i.e., sunlight that is captured by the Earth and its atmosphere).

Direction

There are two important directions when dealing with the Earth's radiation budget. Energy can either be

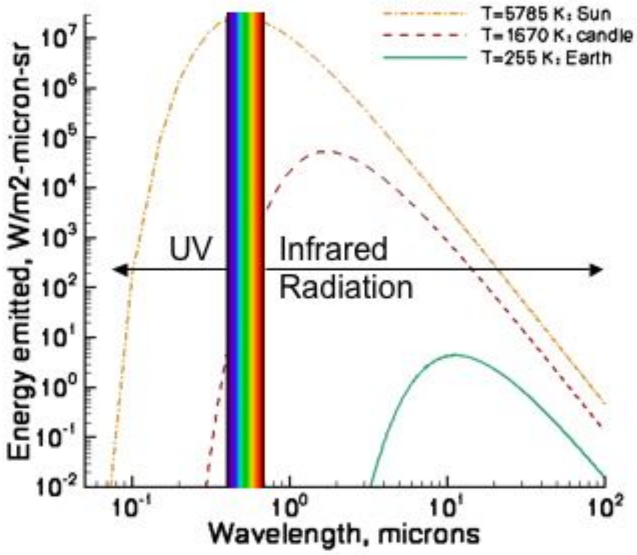
- incoming (**Down**)
- or outgoing (**Up**).

Of course energy goes sideways as well, but that has no effect on the Earth's radiation budget since it does not change the amount of energy in the Earth system.

The **NET** energy added to the Earth system is simply: **NET** = incoming – outgoing = **Down** – **Up**.

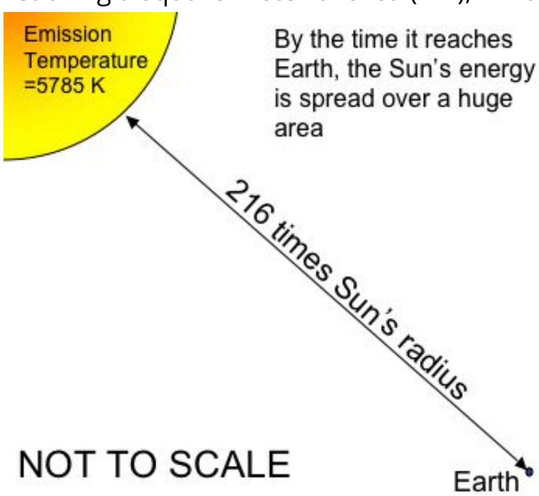
Basics

Everything emits electromagnetic radiation, according to its temperature. The graph shows examples for three objects with widely different temperatures (given in degrees Kelvin [K = C + 273.15]). Note that hotter objects emit more energy than cooler objects at every wavelength, and that the hotter objects emit most of their energy at shorter wavelengths than do cooler objects. The peak of the Sun's energy emission is in the wavelengths of visible light (denoted by the rainbow colors in the graph), although it emits other types of energy (like ultraviolet [UV] and infrared [IR]) also. In comparison, the Earth emits orders of magnitude less radiation, and that radiation peaks in the infrared.



A Bit About Units

The units for this energy emission start with the familiar unit Watts, which is used to identify the brightness of light bulbs. However, the units here are more complicated, as they identify Watts PER square meter, PER micron, PER steradian (sr). Decoding this, it means the number of Watts reaching a square meter of area (m2), which depends on the wavelength (measured in microns), and is spread over a solid angle (measured in steradians). A solid angle is an angle measured in 3D space. The Sun emits in all directions, which means its energy is spread over 4π steradians. Only a small amount of the Sun's energy emission reaches the Earth. Most of it goes off into space in other directions.

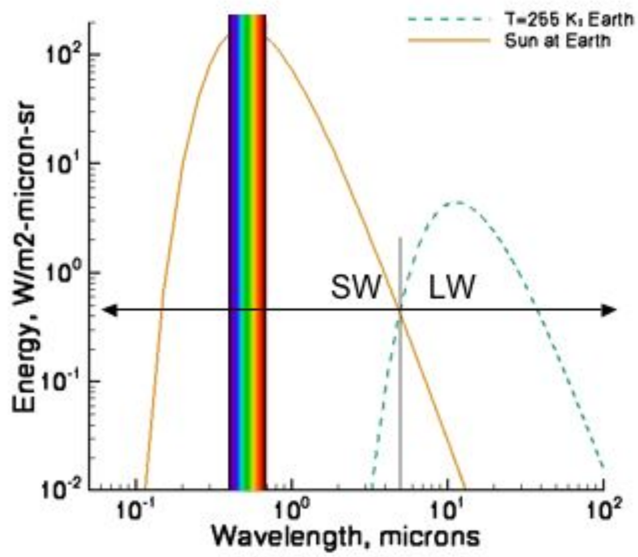


The Sun is also very far from the Earth (about 150 million km). So, by the time the Sun's emitted energy reaches the Earth, it is spread over a very large area (a sphere with a radius 216 times larger than the radius of the Sun itself), thus reducing the intensity of energy that Earth receives.

Energy at the Earth

The figure at right compares the emission from the Earth with the amount of solar energy that reaches the top of the Earth's atmosphere. (*The amount of energy from the Sun that actually reaches the Earth's surface is smaller still, and has some very definite spectral features due to absorption and scattering that occur at specific wavelengths in the atmosphere. See a picture. In particular, most of the UV radiation is absorbed in the ozone layer, protecting living things from these harmful rays.*) Notice that now, the emission from the Earth is larger than the energy received from the Sun, for wavelengths longer than about 5 microns (a micron is 1.e-6 meters, or one thousandth of a meter). The exact cross-over point depends on the Earth's emission temperature. The average surface temperature is a bit warmer than the emission temperature shown in this graph, so the cross-over point for surface emission occurs at a shorter wavelength. This slightly fuzzy cross-over point is used to define two principal wavelength ranges:

- shortwave (**SW**) radiation and
- longwave (**LW**) radiation.



Photosynthetically active radiation (**PAR**) (wavelengths between 0.4 and 0.7 microns) is a subset of the solar radiation that is important for photosynthetic activity in plants.

The combination of **SW** and **LW** radiation covers the whole spectrum and is sometimes called the total (**TOT**) radiation.

Time Interval

The components of the radiation budget change with time. It is not really practical to keep an infinitely detailed, second by second, record. We typically have information averaged over time periods such as

- hourly,
- daily,
- monthly,
- seasonal,
- annual averages or
- climatology: an average over several years.

The numbers in the radiation budget diagram at the top of the page are climatological values. Most of the parameters in the LAS are for monthly or longer time periods, with a few parameters available at a daily time scale. Given monthly information, you can create seasonal, annual or longer averages.

Sky Condition

The Earth's radiation budget is determined by the amount of energy that actually enters and leaves the Earth, under the sky conditions that actually exist. Clouds have the most influence on what the upward and downward energy actually is. In the shortwave, clouds reflect sunlight. In the longwave, clouds effectively trap infrared energy. To help study and understand how clouds affect the radiation budget, we therefore look at radiation budget parameters under two different sky conditions:

- All-sky is the term for the actual observed conditions, including clear or cloudy skies wherever they occur.
- Clear-sky parameters are obtained by taking all observations for a month, discarding any where clouds were present, and computing average conditions for cases of clear sky.

Clear-sky parameters therefore allow you to see more clearly the effects of the Sun's location, and of the Earth's surface (i.e., land vs ocean).

Parameters

Important parameters of the Earth's radiation budget include:

- Flux: can be **SW**, **LW**, or total (**TOT**=**SW**+**LW**); can be **Up** or **Down**.
- Albedo: **Albedo** is defined for **SW** radiation. It tells what fraction of the incoming (**Down**) radiation is reflected (**Up**). The albedo of the surface (**SFC**) is NOT the same as the albedo at the **TOA**, due to the effects of clouds, the atmosphere, and aerosols.
- Net radiation: This gives the amount of energy actually added to the system. It is easy to calculate:

  NET = Energy in – Energy out
- But there are multiple kinds of net radiation, both at TOA and at the surface:
-
  - **SW_NET** = **SW_Down** – **SW_Up**.
  - **LW_NET** = **LW_Down** – **LW_Up**.
  - **TOT_NET** = **SW_NET** + **LW_NET** = **SW_Down** – **SW_Up** + **LW_Down** – **LW_Up**

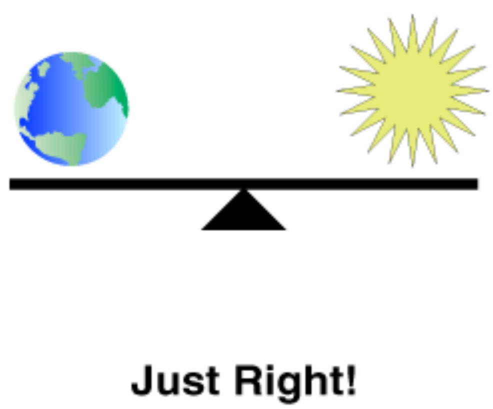
What's The Earth's Radiation Budget?

The Earth's Radiation Budget is a concept used for understanding how much energy the Earth gets from the Sun and how much energy the Earth-system radiates back to outer space.

If the Earth system (Earth surface, atmosphere, oceans and ice mass) retains more solar energy than it radiates back to space, the Earth will warm. If the Earth-system radiates more energy to space than it receives from the Sun, the Earth will cool.

Scientists think of the Radiation Budget in terms of a see-saw or balance. If the Earth retains more energy from the Sun, the Earth warms and emits more infrared energy. This brings the Earth's Radiation Budget into balance. If the Earth emits more of this energy than it absorbs, the Earth cools. As it cools, the Earth emits less energy. This change also brings the Radiation Budget back into balance.

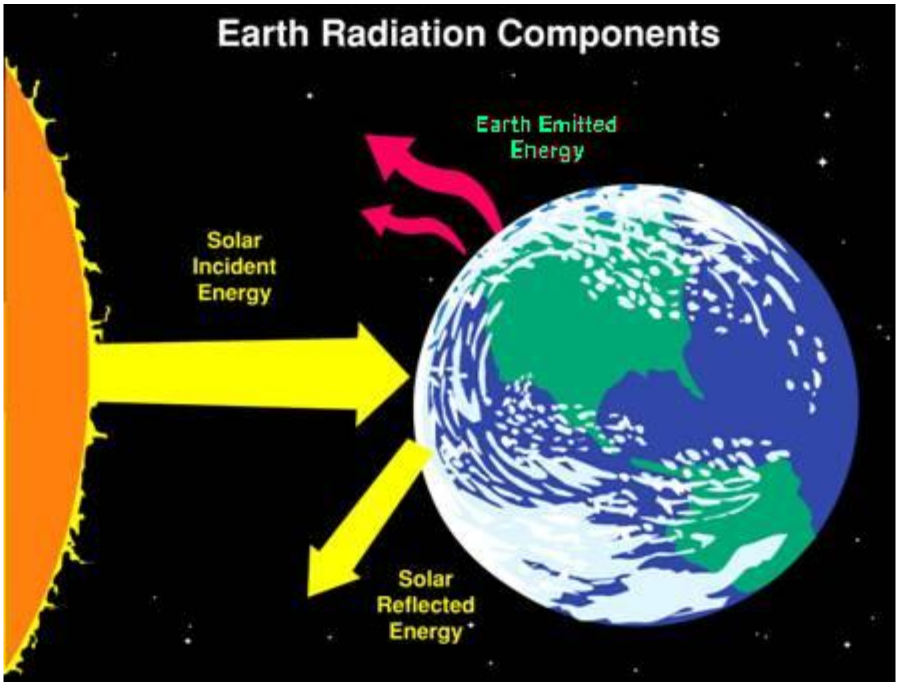
Absorbed sunlight raises the Earth's temperature. Emitted radiation or heat lowers the temperature. When absorbed sunlight and emitted heat balance each other, the Earth's temperature doesn't change – the radiation budget is in balance.



Basic Parts of the Radiation Budget

- Solar Incident Energy
- Solar Reflected Energy
- Earth Emitted Energy

Incoming solar radiation is absorbed by the Earth's surface, water vapor, gases, and aerosols in the atmosphere. This incoming solar radiation is also reflected by the Earth's surface, by clouds, and by the atmosphere. Energy that is absorbed is emitted by the Earth-atmosphere system as longwave radiation. The component diagram has additional details.


Earth Radiation Components
Earth Emitted
Energy
Solar
Incident
Energy
Solar
Reflected
Energy