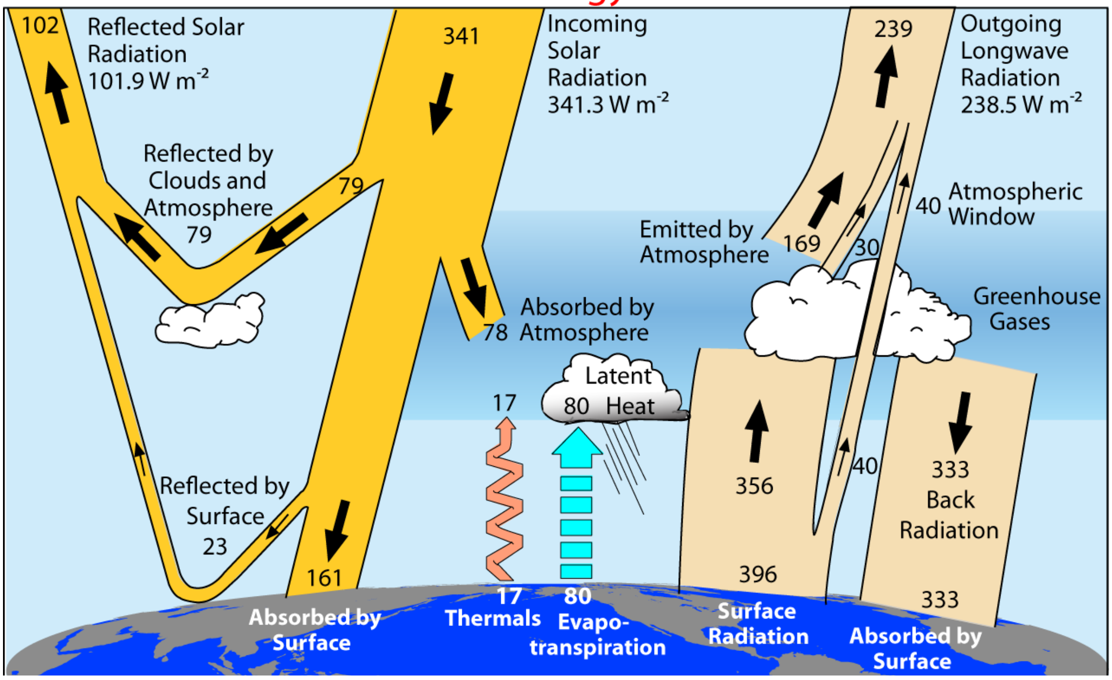
OCEA90 Activity: Heat transfer

1. The figure below is showing global energy flows (W/m^2) of radiation coming to the Earth's surface and back to space.



a) Calculate the incoming solar radiation minus the sum of outgoing radiation using the three main flows on top of the figure (make sure to use the numbers with one decimal place). Is the Earth in radiative equilibrium (i.e. net radiation absorbed = net radiation emitted)?

The image above shows the incoming solar radiation is 341.3 W m^2, and the sum of outgoing radiation is 239 W m^2. In this case, the Earth is not in radiative equilibrium because the incoming radiation has more than the outgoing radiation. which also means there is a net surplus of energy.

b) Now repeat the same exercise using the bottom of the figure. Calculate the radiation absorbed by the Earth's surface and subtract the radiation emitted by the Earth's surface. Similar to the answer you got in a)?

The image above shows the radiation absorbed by the Earth's surface is 494 W m^2 and the radiation emitted by the Earth's surface is 396 W m^2. 396 - 494 = -98 W m^2. This again shows the Earth is not in radiative equilibrium. The radiation absorbed is negative, which means more radiation is being collected but less emitted.

c) From the 396 W/m^2 radiation emitted by the Earth's surface, only 40 W/m^2 go directly back to space. Why?

I think it's only 40 because the rest of the radiation is either absorbed by the atmosphere or reflected to the earth's surfaces. The Greenhouse gases in the Earth's atmosphere absorb energy and are then re-emitted in various directions, including back toward the Earth's surface.

d) Based on the global energy flows presented above, estimate the fraction of incoming solar radiation that is reflected back to space (in other words, what is the albedo)?

The incoming solar radiation is 341.3 W m^2 and the reflected radiation is 161 W m^2. Hence, 161/341.2 = 0.472.

2. The planetary energy balance to a first approximation implies that the energy emitted by Earth is equal to the energy absorbed by Earth, or:

$$\sigma T_E^4 = \frac{S(1-a)}{4}$$

The left side uses the Stefan-Boltzmann law for describing energy flux as a function of temperature. Here we use it to describe the energy emitted by Earth as a function of T_E, the effective radiative temperature of the Earth, and σ a constant of 5.67×10^{-8} W m^{-2} K^{-4}.
The right side represents the energy absorbed by the Earth where *S* is the known solar flux of energy of 1367 W m^{-2} and *a* is the albedo (0.31).

a) In which part of the electromagnetic spectrum are the radiation emitted from the Earth's surface? And from the Sun?

Radiation emitted from the Earth's surface is in the infrared part of the electromagnetic spectrum, specifically longwave infrared. The Sun emits radiation primarily in the visible and ultraviolet parts of the spectrum.

b) Isolate and estimate T_E in the equation above. T_E is the effective radiative temperature of the Earth.

$$\sigma T_E^4 = \frac{S(1-a)}{4}$$

$$\Rightarrow T_E^4 = \frac{S(1-a)}{4\sigma} = \frac{1367(1-0.31)}{4\sigma} = \left(\frac{943.23}{4(5.67*10^{-8})}\right)^{1/4} = \mathbf{253.94732}$$

c) It turns out that the actual surface temperature of the Earth is 288K (15°C). Why is Earth much warmer than what you obtained in the previous calculation?

The reason why Earth's actual surface temperature is warmer than the previous is because the calculation may not consider factors such as the greenhouse effect.

d) In your own words, explain the greenhouse gas effect. Can you name a few greenhouse gases?

The greenhouse gas effect refers to the process by which certain gases in Earth's atmosphere, known as greenhouse gases, absorb and reemit infrared radiation. Common greenhouse gases I know are water vapor, carbon dioxide, and ozone.