

Albedo and the Temperature of the Earth

Albedo

The accompanying article describes the nature of “albedo”, which is basically a measure of reflectance. For albedo we use the value A . The average value for the Earth is about $A = 0.36$. Here we will consider how the temperature of the Earth would change if the Earth’s albedo were different.

The Earth’s surface and atmosphere derives its temperature from the fact that the Sun is shining on it. In addition, the atmosphere of the Earth contains some greenhouse gases that help to elevate the temperature at the surface level. Ignoring those greenhouse gases, the condition of radiative equilibrium (all the radiation out must balance all the radiation received) can be used to predict the temperature of the Earth from the expression:

$$T = 280 \text{ K} \times \sqrt[4]{1 - A} \times \sqrt{\frac{1 \text{ AU}}{d}},$$

where again A is the albedo (a number between 0 and 1), T is the temperature of the Earth in Kelvin, and d is the distance of the Earth from the Sun in astronomical units. By definition 1 AU is the average distance of the Earth from the Sun. This expression actually makes use of the Stefan-Boltzmann law for how blackbodies radiate, where emissivity $\epsilon = 1 - A$.

- a) • Calculate the temperature of the Earth with $A = 0.36$ for the average value of our planet.
- Convert this to Celsius and then Fahrenheit. (Recall that $T_C = T_K - 273.15$ and $T_F = 32 + (9T_C/5)$.)
 - Given that the average temperature of the Earth is about 15° C , how many degrees of additional warmth are provided by greenhouse gases?

- b) The Earth's distance from the Sun varies from about 0.96 AU to 1.04 AU. Determine corresponding change in temperature $\Delta T = T_{\max} - T_{\min}$ over the course of a year due these changes in position, in Fahrenheit. Do you think variation in Earth distance from the Sun can account for changes in seasons (summer to winter)?
- c)
- Use Table 1 in the accompanying article to calculate the temperature of the Earth, based on the equation of the previous page, if the Earth were covered entirely by forest, grassland, sand, light-colored soil, or fresh deep snow. Convert to Fahrenheit and plot on the graph below.
 - Assume in all cases that greenhouse gases would add an additional 15°C to our temperature, and sketch this curve in graph.
 - Identify those ranges of albedos for which the temperature would be tolerable for human life (in your estimation).

