

SOLAR RADIATION AND CLIMATE EXPERIMENT (SORCE)

Earth's Energy Balance

For the past quarter century, Earth scientists have been trying to get a handle on how much solar energy illuminates the Earth and what happens to the energy once it penetrates the atmosphere. To date they estimate that roughly $1,368 \text{ W/m}^2$, averaged over the globe and over several years, strikes the outermost atmosphere at the Earth. This is called the "Total Solar Irradiance," or TSI. TSI depends only on the total energy per second produced by the Sun (its absolute luminosity) and the distance from the Sun to the Earth, 93 million miles or 150 million kilometers.

Though sunlight may appear white and nondescript, it consists of electromagnetic waves that have a wide range of wavelengths. One can separate these wavelengths by simply holding up a prism to sunlight, which causes light rays of shorter wavelengths to bend at larger angles. The various purples, blues, greens, yellows, and reds that emerge from the prism represent all the wavelengths of light that are visible to the human eye, which only detects wavelengths between 400 and 700 nanometers (billionths of a meter). The visible spectrum, however, accounts for just under half of the Sun's total energy. Much of the Sun's energy is made up of ultraviolet (UV) radiation, which has shorter wavelengths (higher energy levels) than visible light and extends off the purple end of the visible spectrum. An even larger amount of this invisible energy can be found in the longer infrared wavelengths (lower energy levels) of light that extend off the opposite end of the visible spectrum.



The Sun emits light in a very wide range of wavelengths—from radio waves, through visible light, to x-rays. The most familiar example is the visible spectrum revealed in a rainbow, but all the colors of the rainbow occur in a relatively narrow band of wavelengths. In addition to visible light, infrared and ultraviolet light also play a role in the Earth's climate. (Photograph courtesy [Philip Greenspun](#))

Not all of this light is absorbed by the Earth. Roughly 30 percent of the total solar energy that strikes the Earth is reflected back into space by clouds, atmospheric aerosols, snow, ice, desert sand, rooftops, and even ocean surf. The remaining 70 percent of the TSI is absorbed by the land, ocean, and atmosphere. In addition, different layers of the Earth and atmosphere tend to absorb different wavelengths of light. Only one percent of the TSI, mostly in the form of UV radiation, is absorbed by the upper atmosphere, mainly by stratospheric ozone. Twenty to 24 percent of the TSI and a majority of the near infrared radiation is absorbed in the lower atmosphere (troposphere), mainly by water vapor, trace gases, clouds, and darker aerosols. The remaining 46 to 50 percent of predominately visible light penetrates the atmosphere and is taken in by the

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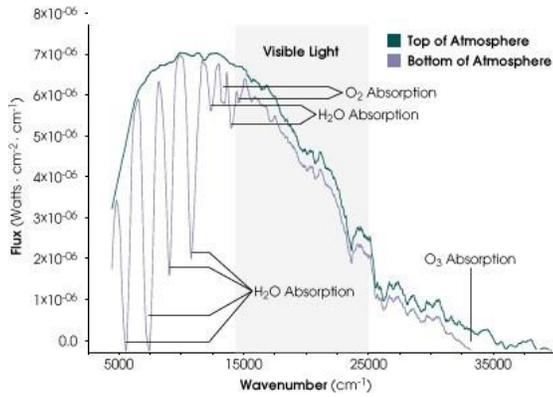
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land and the oceans.



Solar radiation is not emitted in a smooth continuum. Superheated atoms in the Sun, particularly Hydrogen and Helium, absorb radiation in distinct wavelengths. These absorption bands are visible as dips in the green line in the graph above, which represents the spectrum of sunlight that arrives at the top of the Earth's atmosphere. Additionally, gas molecules absorb radiation in the Earth's atmosphere, further reducing the radiation at the surface. The blue line represents the spectrum of radiation arriving at the surface of the Earth on a clear day in the tropics, based on an atmospheric model. (Graph by Robert Simmon, based on model data from the NASA GSFC Laboratory for Atmospheres)

The absorption of solar energy heats up our planet's surface and atmosphere and makes life on Earth possible. But the energy does not stay bound up in the Earth's environment forever. If it did, then the Earth would be as hot as the Sun. Instead, as the rocks, the air, and the sea warm, they emit thermal radiation (heat). This thermal radiation, which is largely in the form of long-wave infrared light, eventually finds its way out into space, leaving the Earth and allowing it to cool. For the Earth to remain at a stable temperature, the amount of longwave radiation streaming from the Earth must be equal to the total amount of absorbed radiation from the Sun.

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