FORUM

What Is the Atmosphere's Effect on Earth's Surface Temperature?

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It is frequently stated in textbooks and scholarly articles that the surface temperature of Earth is 33°C warmer than it would be without the atmosphere and that this difference is due to the greenhouse effect. This Forum shows that the atmosphere effect leads to warming of only 20°C. This new conclusion requires a revision to all of the relevant literature in K-12, undergraduate, and graduate education material and to science papers and reports.

The greenhouse effect on Earth's surface temperature is well understood qualitatively and is regarded as basic knowledge about Earth's climate and climate change. The 33°C warming has been used to quantify the greenhouse effect of greenhouse gases, or of greenhouse gases and clouds, in K-12 educational material (e.g., http://epa.gov/climatechange/kids/greenhouse.html), undergraduate freshman introductory textbooks on weather and climate [e.g., *Ahrens,* 2008], and graduate textbooks on climate [e.g., *Peixoto and Oort,* 1992]. Some textbooks and various other publications have less stringently attributed the warming to the greenhouse effect [e.g., *Wallace and Hobbs,* 2006; *Le Treut et al.,* 2007; *American Meteorological Society,* 2000].

The 33°C warming is obtained as the difference between the observed globally averaged surface air temperature (T_s) of 15°C and the radiative equilibrium temperature of Earth (T_e) of –18°C, and it represents the longwave radiation effect of the atmosphere (i.e., without changing the planetary albedo). T_e is computed from Earth's radiation balance with the observed planetary albedo of 0.3 [*Trenberth et al.,* 2009].

Certain trace gases in the atmosphere—such as water vapor, carbon dioxide, methane, nitrous oxide, and ozone—which absorb a much higher percentage of radiative energy in the infrared than in the solar spectrum, are popularly referred to as greenhouse gases [*Fleagle and Businger,* 1963]. The warming effect of these trace gases on Earth's surface temperature is referred to as the greenhouse effect, which can be qualitatively understood through the selective absorption of the greenhouse gases mentioned above and which is quantitatively computed as the temperature difference with, versus without, these gases in the atmosphere.

Because clouds strongly affect solar and longwave radiation, the widely used term "greenhouse effect of clouds" is confusing and should be avoided or replaced by standard and clearer phrases such as "longwave radiation effect of clouds." Similarly, because clouds play a crucial role in the radiation balance, 23% of solar energy is absorbed by Earth's atmosphere; while this number cannot be neglected, it is smaller than the atmospheric absorptance of 90% of surface longwave radiation [*Trenberth et al.,* 2009]. Therefore, the greenhouse effect of the atmosphere is not the same as the longwave radiation effect.

To consider the effects of the atmosphere on solar and longwave radiation in the T_e computation, the planetary albedo (0.3) due to the combined reflection of the atmosphere and surface should be replaced by the surface albedo (0.14) [*Trenberth et al.,* 2009], if the atmosphere was removed. Then T_e is obtained as –5°C from Earth's radiation balance. The 20°C difference between T_s (15°C) and T_e (–5°C), rather than the widely used 33°C warming, represents the "atmosphere effect" (a term borrowed from *Fleagle and Businger* [1963]) on Earth's surface temperature.

Note that the term "atmosphere effect" rather than "atmospheric radiation effect" is used, because the observed T_s is caused by the atmospheric radiation effect (primarily from greenhouse gases and clouds) and surface sensible and latent heat fluxes due to fluid motions in the atmosphere. Without these heat fluxes, the disparity between T_s and T_e would be larger. Also note that this revision does not affect the current interpretation of the term "enhanced greenhouse effect" associated with the increase of greenhouse gases in the atmosphere from human activities.

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