Teaching the Greenhouse Effect

Brian Hornbuckle and Ray Arritt
It is true that there are other factors (such as volcanic activity, variations in the earth’s orbit and axis, the solar cycle), yet a number of scientific studies indicate that most global warming in recent decades is due to the great concentration of greenhouse gases (carbon dioxide, methane, nitrogen oxides and others) released mainly as a result of human activity. Concentrated in the atmosphere, these gases do not allow the warmth of the sun’s rays reflected by the earth to be dispersed in space.” (Page 19)
“It is true that there are other factors (such as volcanic activity, variations in the earth’s orbit and axis, the solar cycle), yet a number of scientific studies indicate that most global warming in recent decades is due to the great concentration of greenhouse gases (carbon dioxide, methane, nitrogen oxides and others) released mainly as a result of human activity. Concentrated in the atmosphere, these gases do not allow the warmth of the sun’s rays reflected by the earth to be dispersed in space.” (Page 19)
There are 2 sources of radiation that warm Earth's surface.

Earth's surface absorbs shortwave radiation from the Sun. Earth surface warms.

“greenhouse effect”

Earth surface absorbs longwave radiation emitted by the atmosphere. Earth surface warms.
Earth’s energy balance (Pearson Education, Inc.)

[Diagram showing the Earth's energy balance, with various inputs and outputs labeled.]
energy balance summary

Earth surface absorbs some shortwave radiation from Sun. Earth surface warms.


Sensible and latent heat flux transport energy from Earth's surface to the atmosphere. Atmosphere warms.

Atmosphere emits longwave radiation. Earth's surface absorbs nearly all longwave radiation emitted by the atmosphere. Earth surface warms.
The **total** amount of radiation emitted is given by the **Stefan-Boltzmann law**.

All things emit radiation, all of the time! **Hot** objects radiate more than **cool** objects.

The wavelength of **peak** radiation is given by **Wien's law**.

The Sun emits **shortwave** radiation. The Earth emits **longwave** radiation.
The behavior of radiation in the atmosphere depends on its wavelength!

H₂O, CO₂ and other “greenhouse gases” absorb longwave from Earth and emit longwave to Earth.

O₃, O₂, H₂O

Petty (2006)
Take away the “greenhouse effect” and Earth's mean surface temperature would be

\[-19 \, ^\circ \text{C} = -2 \, ^\circ \text{F}!\]

Earth's surface is warmer (15 °C = 59 °F) because (due to the “greenhouse effect”) it receives energy from 2 sources: the **Sun** and the **atmosphere**.

Remember this!
“greenhouse effect” good or bad?

**Good:** essential for life!

Earth surface average temperature: 15 °C = 59 °F.
Earth surface with NO “greenhouse effect:” -19 °C = -2 °F.

**Bad:** too much of a good thing!

Additional CO₂ (and other greenhouse gases) increases “greenhouse effect” and will cause climate change.
Assignment 3: Infrared Thermometer

First ~125 students (last names A-K) check out from 206 Help Room, 3008 Agronomy Hall, must return at least by noon Wednesday 9/16.

Assignment 3 could take less than an hour, or as long as a few days, depending on your experiment. Please don't wait until the end of the week to return your IR thermometer if you finish early.

Other half of class from 9/16 until 9/23.

Final deadline for report is Wed 9/30.
“Wheel in the Sky” by Journey

Sun and atmosphere

“The radiators in the sky keep on burning. It is not at all like a gree-een-house.”
Q: How does the greenhouse effect warm Earth's surface? Is it good or bad? Justify.

A: Earth's atmosphere emits longwave radiation, which warms the surface. This is the greenhouse effect. The greenhouse effect is good / bad / good and bad because...

Of 241 students, 96% score 3/5 or better and thus were able to demonstrate why the “greenhouse effect” is both good and bad! But not many got 5/5!
Bad: Greenhouse effect.

Why: Greenhouses prevent loss of heat by suppressing convection.

glass greenhouse
transmits shortwave
absorbs virtually all longwave

polyethylene greenhouse
transmits shortwave
transmits virtually all longwave

Glass greenhouse only 0.2 to 0.6 °C warmer than polyethylene greenhouse (Dayan et al., 1986)!
Bad: Greenhouse effect.

Why: Plants don’t cause the greenhouse effect.

Libarkin et al., 2015
Bad: Traps energy from the Sun, it’s like a blanket.

Why: About longwave and not shortwave radiation, no “impervious cover,” no reflections, not insulation.

Libarkin et al., 2015
Bad: Something about ozone?
Why: ?!?!?

Libarkin et al., 2015
Bad: The atmosphere re-radiates longwave energy.

Why: The atmosphere receives energy from many sources. It radiates longwave energy simply due to the S-B law.
“It is true that there are other factors (such as volcanic activity, variations in the earth’s orbit and axis, the solar cycle), yet a number of scientific studies indicate that most global warming in recent decades is due to the great concentration of greenhouse gases (carbon dioxide, methane, nitrogen oxides and others) released mainly as a result of human activity. Concentrated in the atmosphere, these gases do not allow the warmth of the sun’s rays reflected by the earth to be dispersed in space.” (Page 19)
“It is true that there are other factors (such as volcanic activity, variations in the earth’s orbit and axis, the solar cycle), yet a number of scientific studies indicate that most global warming in recent decades is due to the great concentration of greenhouse gases (carbon dioxide, methane, nitrogen oxides and others) released mainly as a result of human activity. Concentrated in the atmosphere, these gases do not allow the warmth of the longwave radiation emitted by the earth to be dispersed in space.” (Page 19)
There are 2 sources of radiation that warm Earth’s surface!

The Sun

and the atmosphere!

Longwave radiation emitted by the atmosphere is what has been called the “greenhouse effect.”

But “atmospheric effect” or “atmospheric radiator effect” is more physically accurate and sets the stage for building more complex conceptual models in the future.

Be sure to present the positives and negatives of the greenhouse effect, this is important to appreciate!