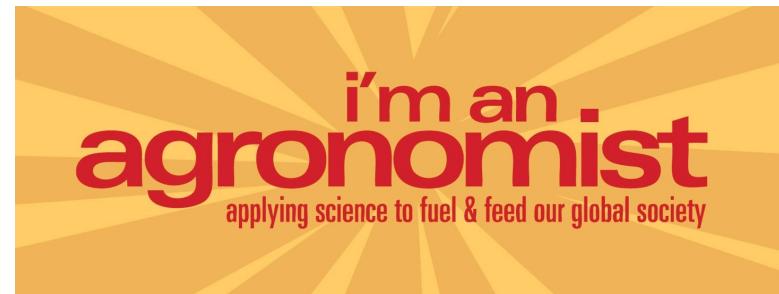
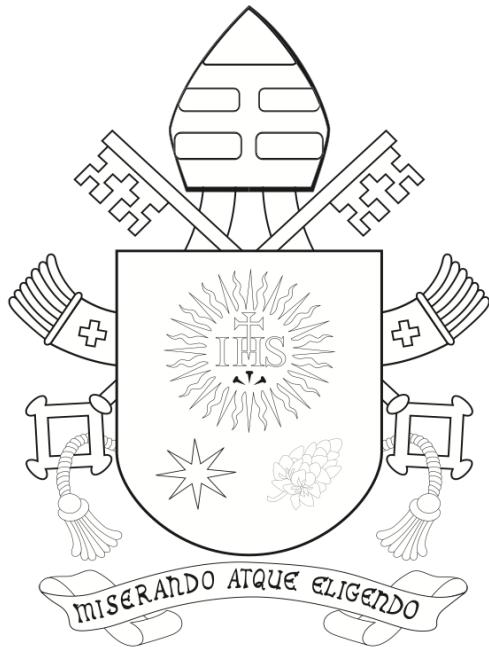


Teaching the Greenhouse Effect



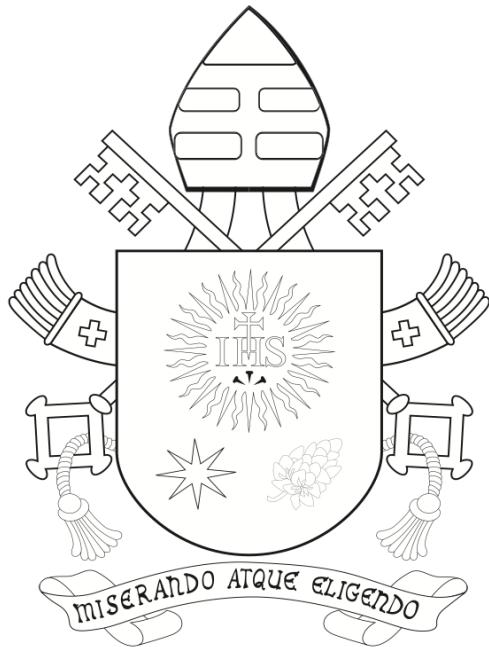
Brian Hornbuckle and Ray Arritt





ENCYCLICAL LETTER
LAUDATO SI'
OF THE HOLY FATHER
FRANCIS
ON CARE FOR OUR COMMON HOME

“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)



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There are **2** sources of radiation that warm Earth's surface.

Earth's surface absorbs
shortwave radiation from the Sun.

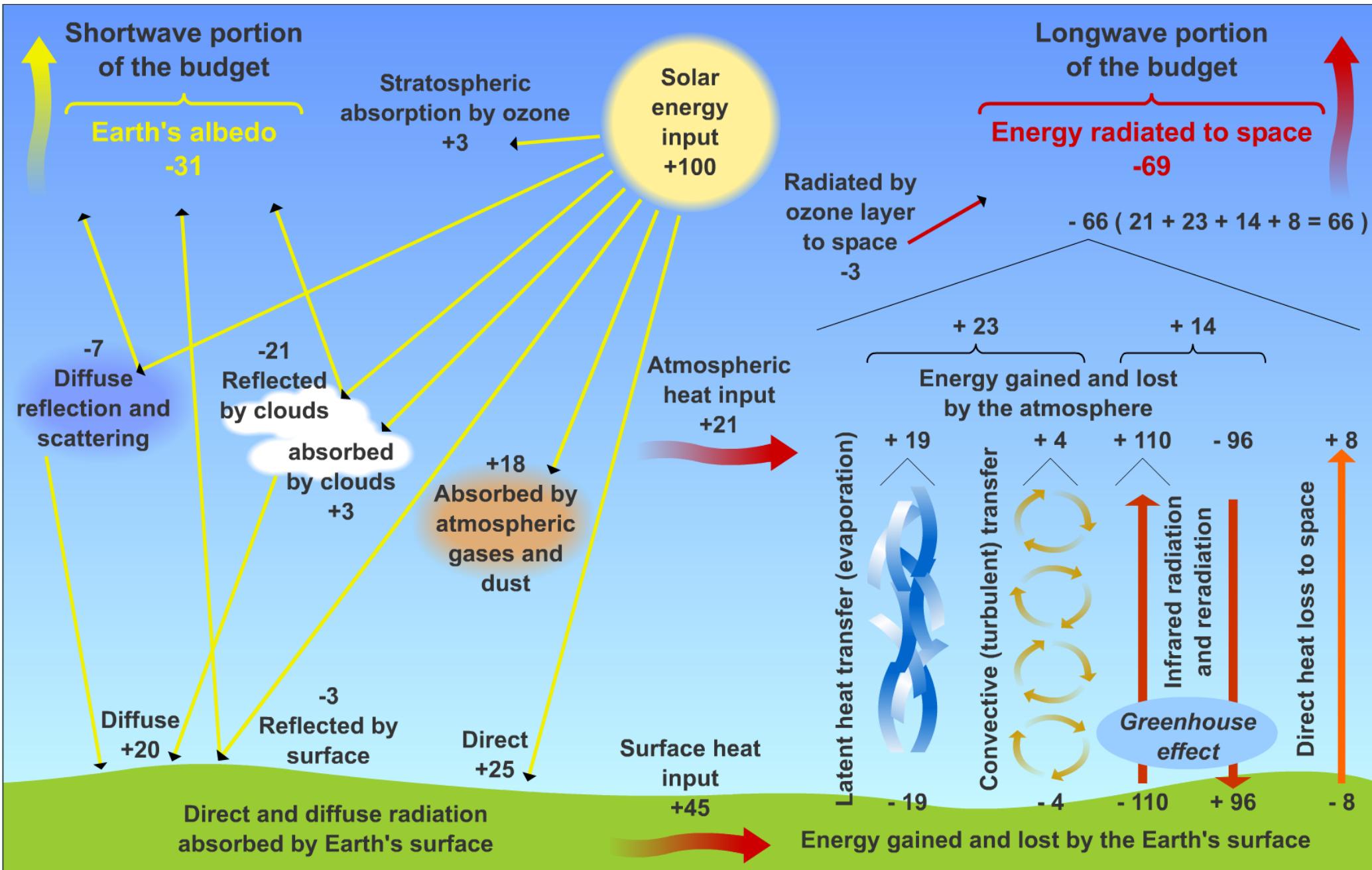
Earth surface warms.

“greenhouse effect”

Earth surface absorbs
longwave radiation emitted by the atmosphere.

Earth surface warms.

Earth's energy balance (Pearson Education, Inc.)



energy balance summary

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

Atmosphere absorbs some shortwave radiation from Sun.
Atmosphere warms.

Earth's surface emits longwave radiation.

Atmosphere absorbs nearly all longwave radiation emitted by Earth's surface. Atmosphere 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.**

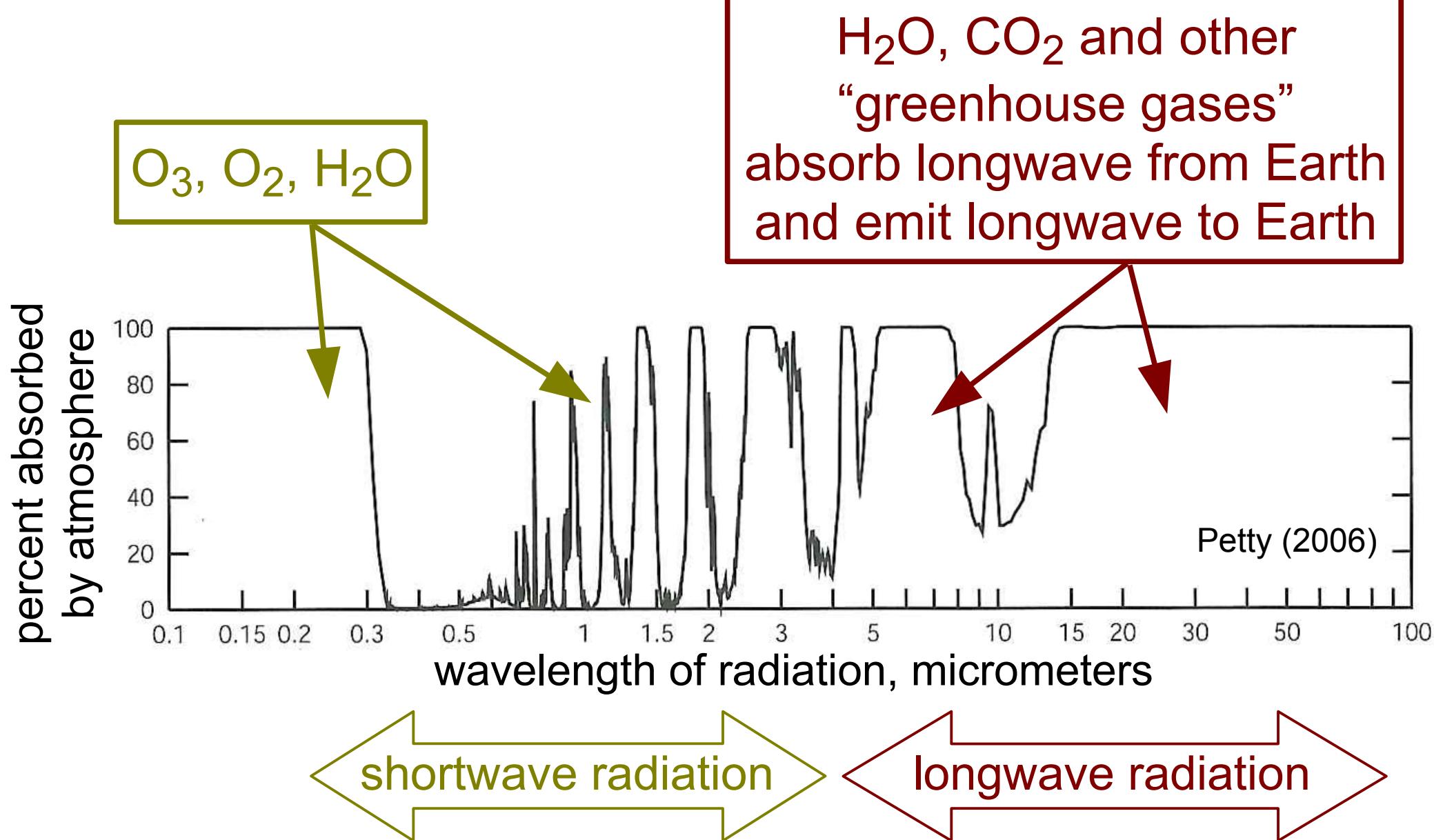
All things emit radiation, all of the time!

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!*



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 ($15^{\circ}\text{C} = 59^{\circ}\text{F}$)
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: $15^{\circ}\text{C} = 59^{\circ}\text{F}$.

Earth surface with NO “greenhouse effect:” $-19^{\circ}\text{C} = -2^{\circ}\text{F}$.

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.

JOURNEY "Wheel In The Sky"



“Wheel in the Sky”
by Journey

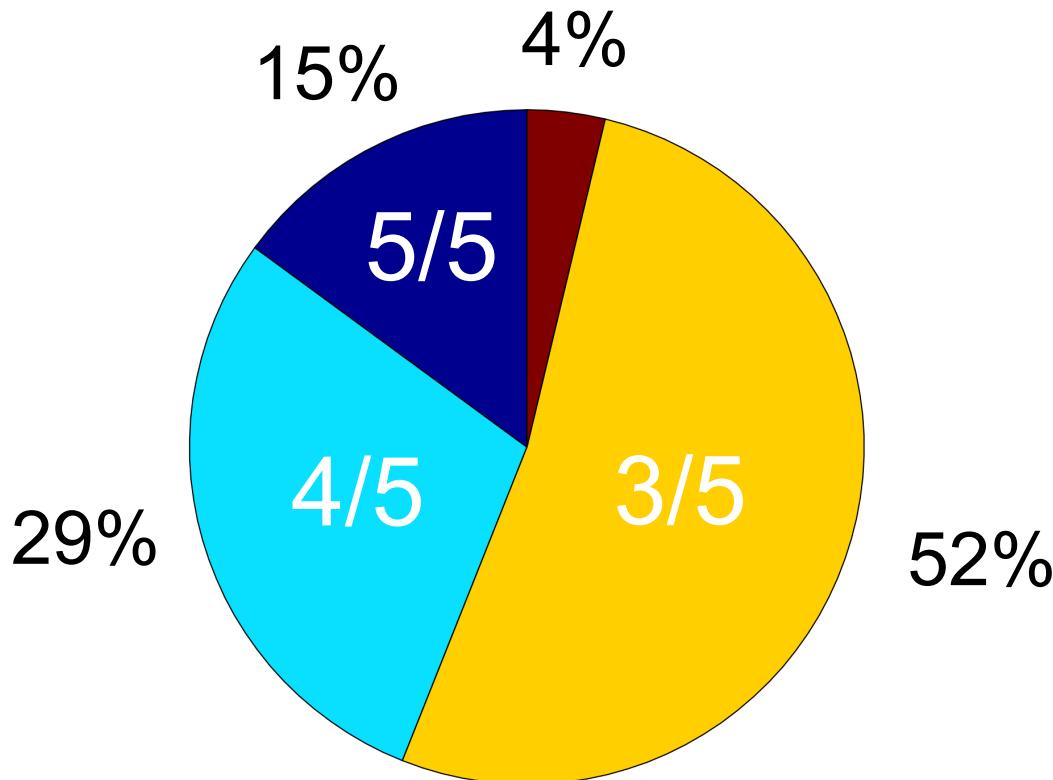
New lyrics:

“The **radiators** in the sky keep on burning.
It is not at all like a gree-een-house.”

Sun and **atmosphere**

Q: How does the greenhouse effect warm Earth's surface?
Is it good or bad? Justify.

A: Earth's atmosphere emits (1) longwave radiation (2), which warms the surface. This is the greenhouse effect.
The greenhouse effect is good / bad / good and bad (3) because... (4) (complete sentences (5))



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.

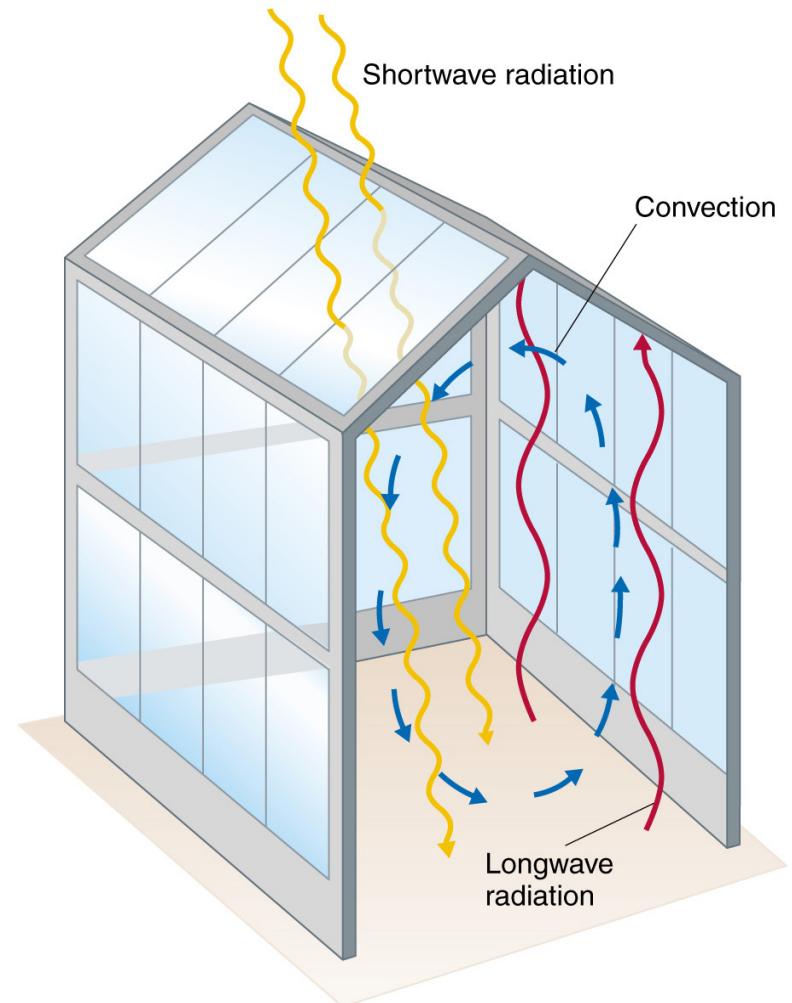
Why: Greenhouses prevent loss of heat
by suppressing convection.

glass greenhouse

transmits shortwave
absorbs virtually all longwave

Polyethylene greenhouse

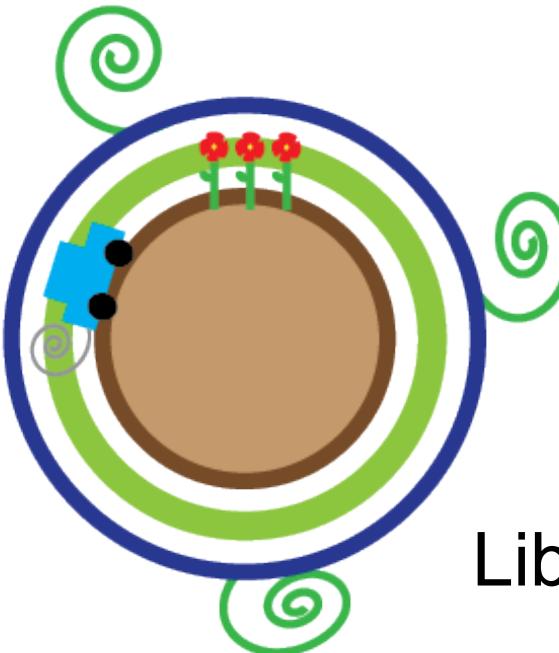
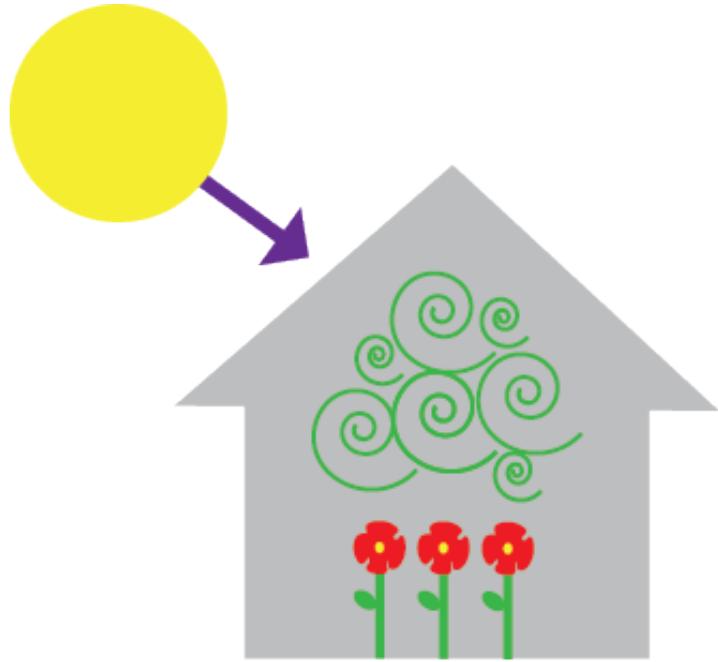
transmits shortwave
transmits virtually all longwave



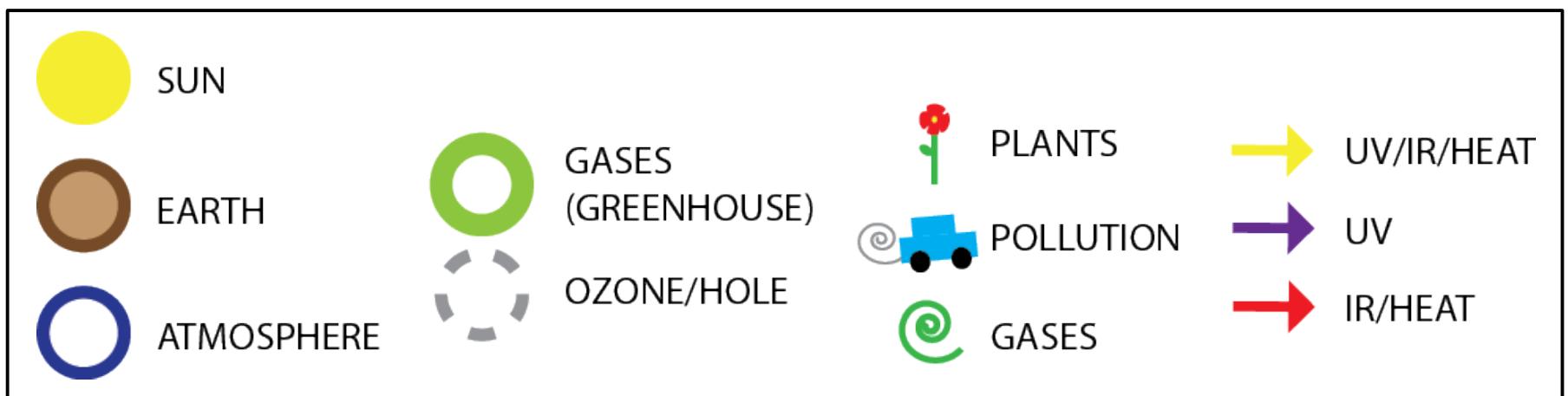
Glass greenhouse only 0.2 to 0.6 °C warmer
than polyethylene greenhouse (Dayan et al., 1986)!

Bad: Greenhouse effect.

Why: Plants don't cause the greenhouse effect.



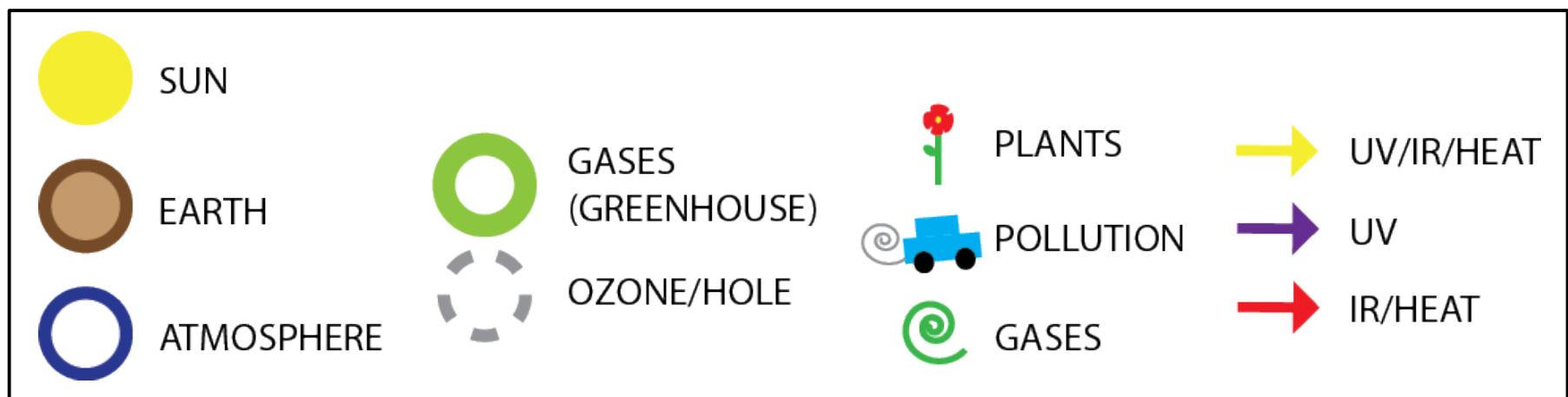
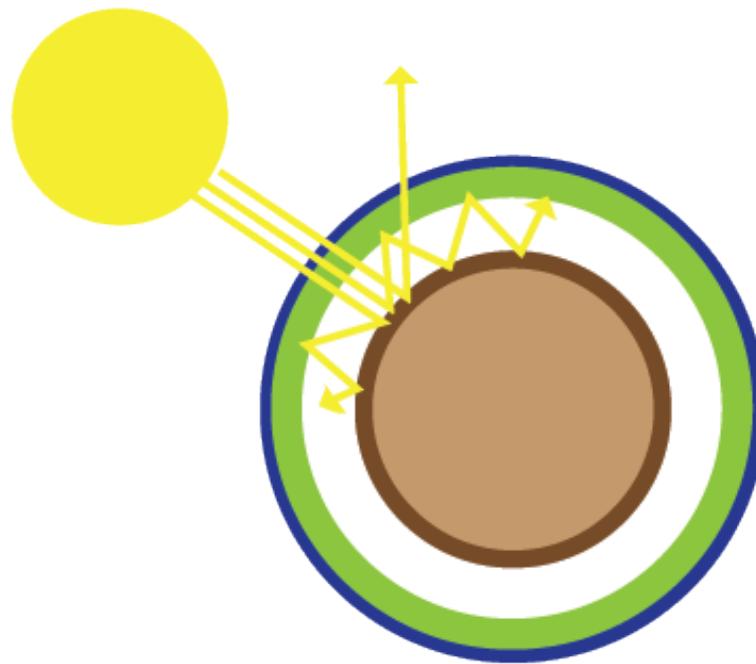
Libarkin et al., 2015



Bad: Traps energy from the Sun, it's like a blanket.

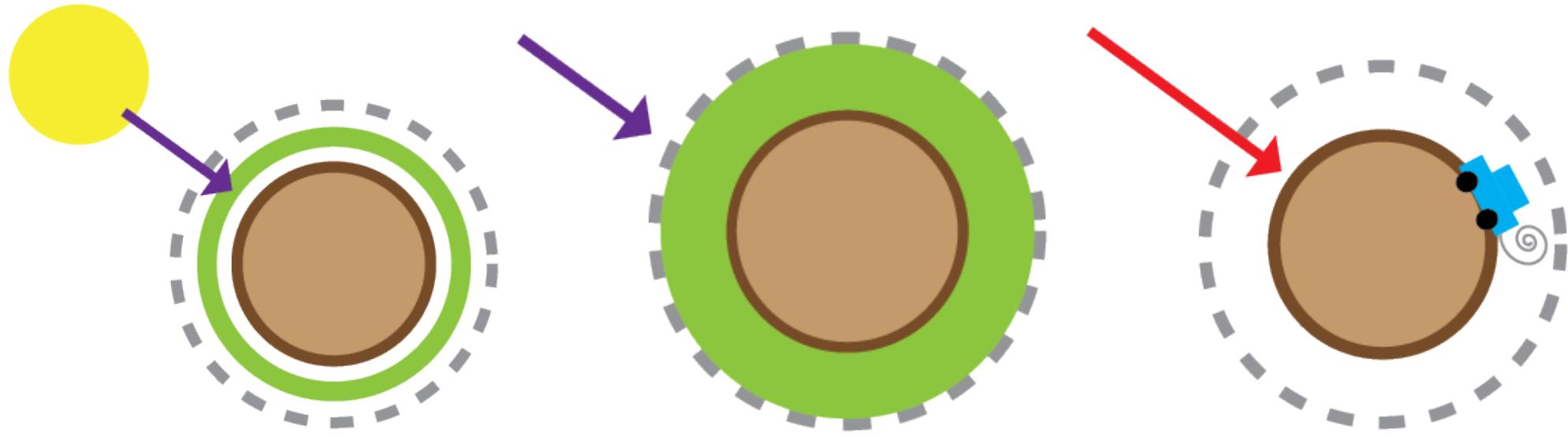
Why: About longwave and not shortwave radiation,
no “impervious cover,” no reflections, not insulation.

Libarkin et al., 2015

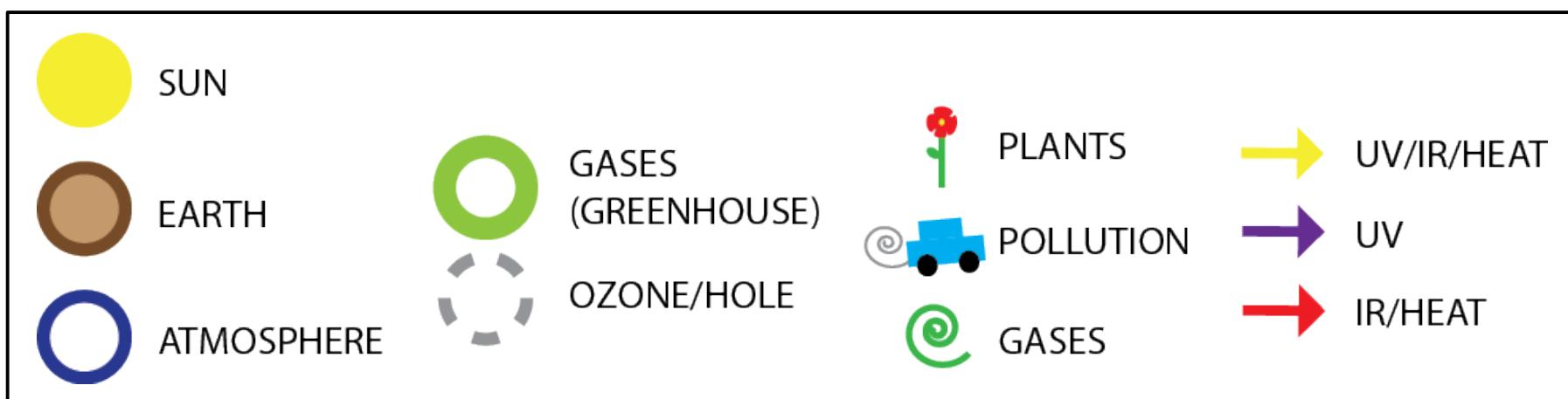


Bad: Something about the ozone hole?

Why: The hole isn't relevant (but ozone is a greenhouse gas).

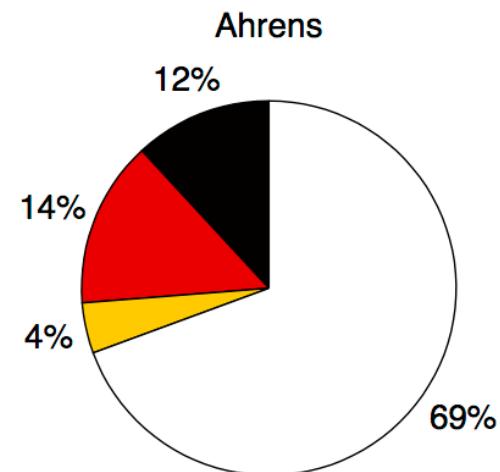
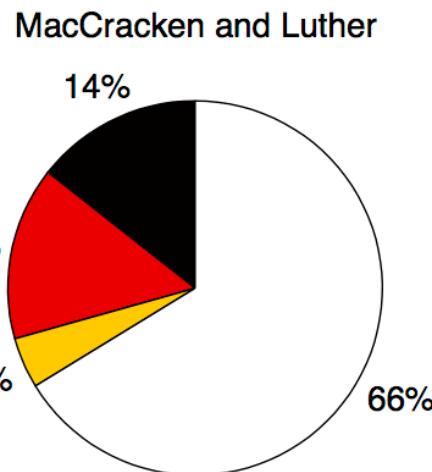
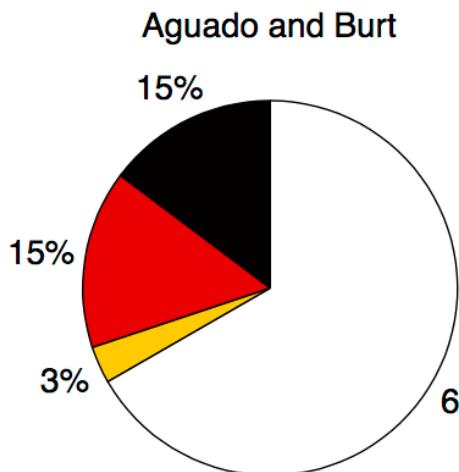
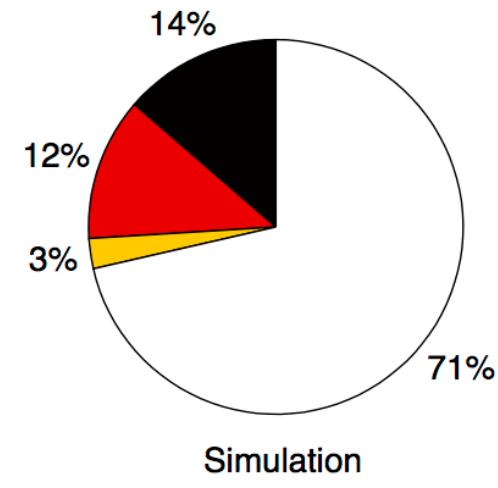
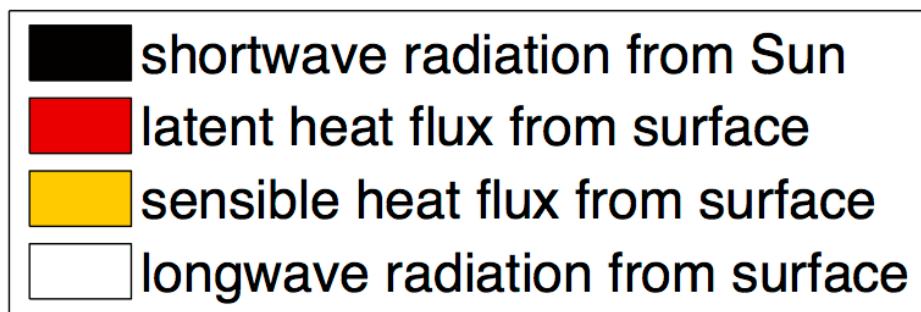


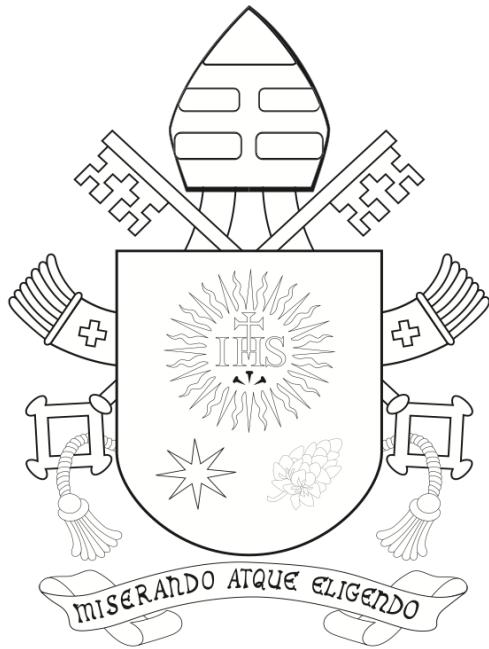
Libarkin et al., 2015



Bad: The atmosphere re-radiates longwave energy.

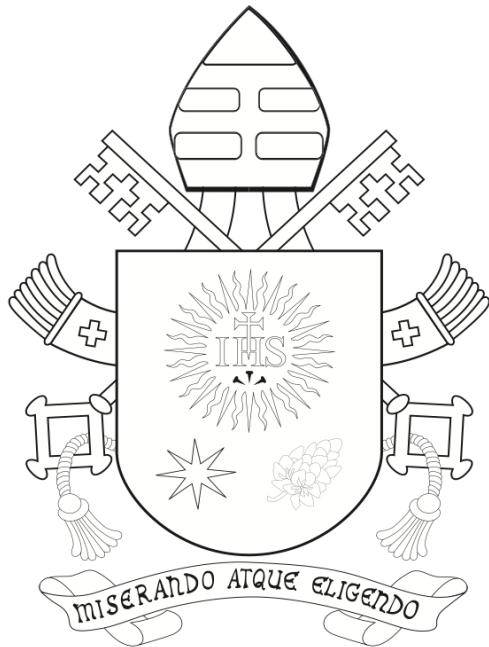
Why: The atmosphere receives energy from many sources.
It radiates longwave energy simply due to the S-B law.





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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!

