ATM S 111: Global Warming

The Greenhouse Effect

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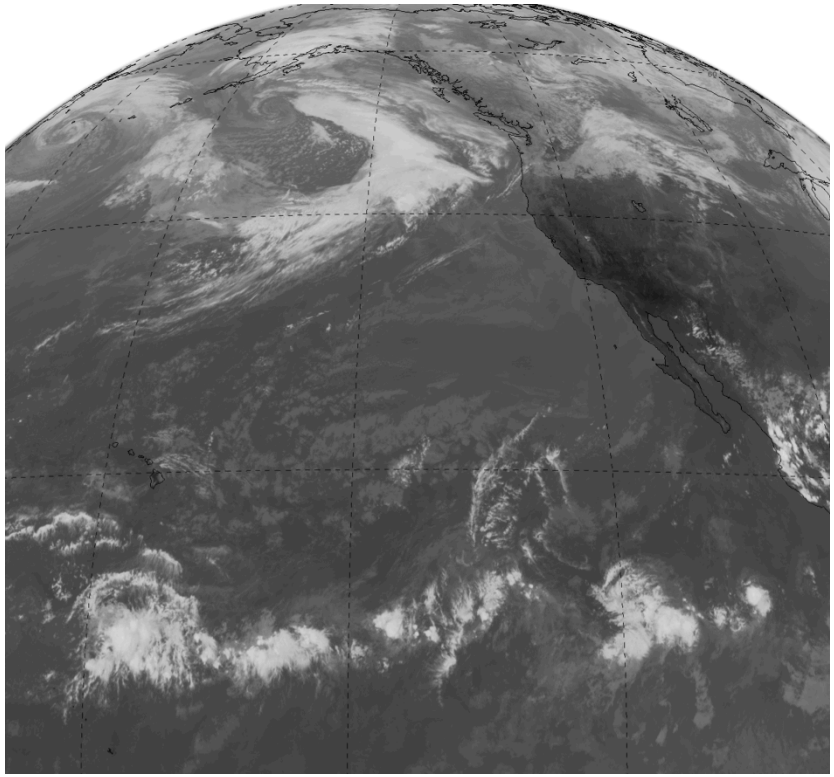
Outline of This Lecture

- How the Earth cools by radiation
- Energy balance
- How the **greenhouse effect** works

“Longwave Radiation”

- The Sun is the energy input to the climate system
- But if the Sun is constantly putting energy into the climate system, why doesn’t the Earth get hotter and hotter?

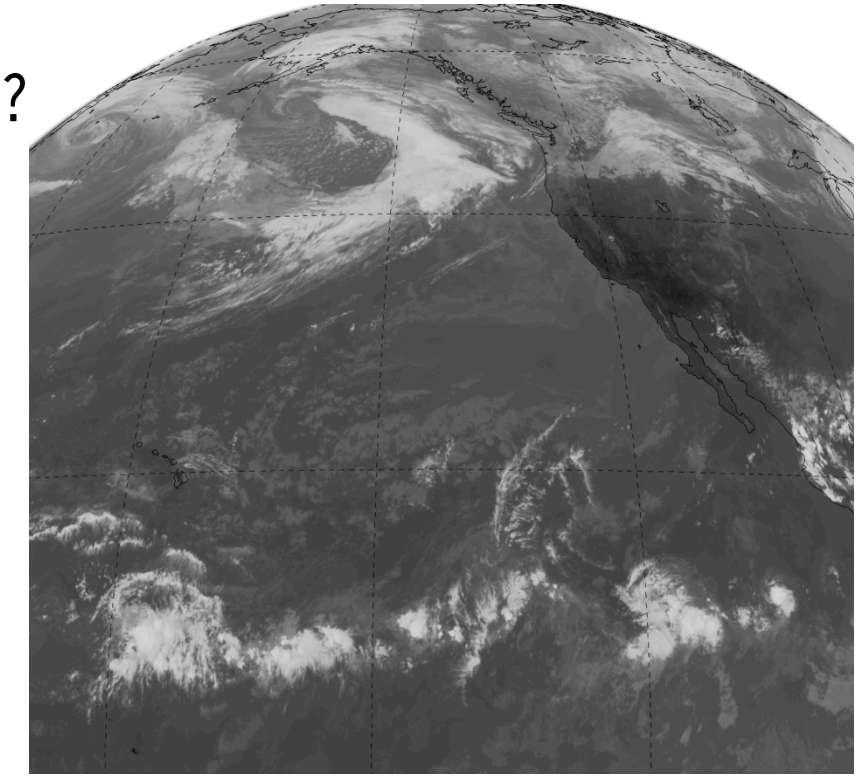
Infrared satellite image →



“Longwave Radiation”

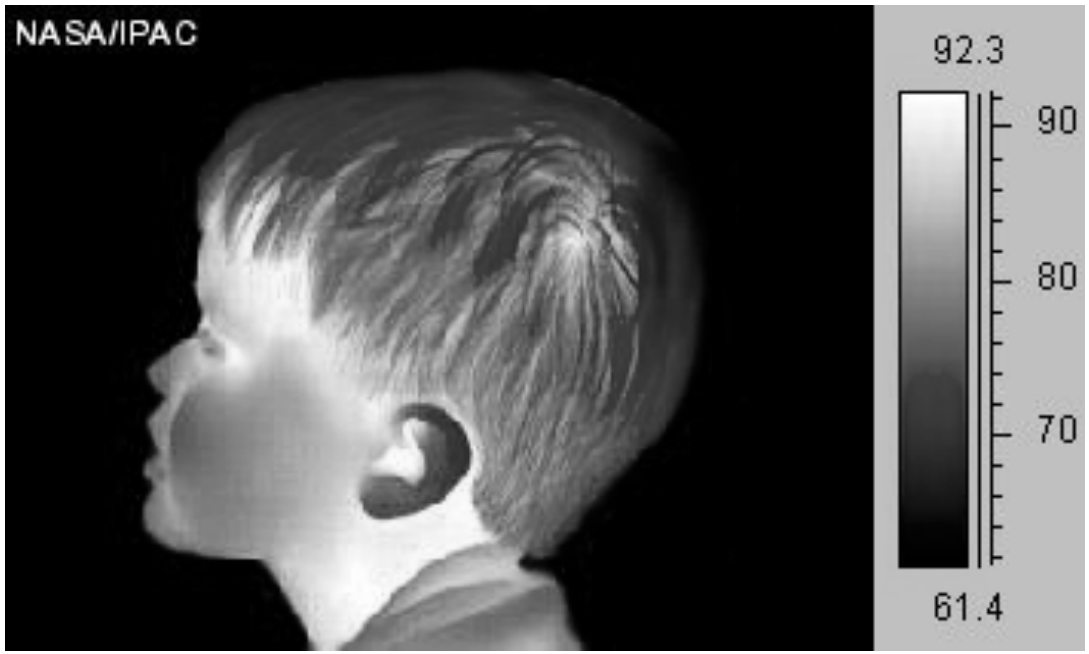
- The Sun is the energy input to the climate system
- But if the Sun is constantly putting energy into the climate system, why doesn’t the Earth get hotter and hotter?
- How does the Earth **lose energy**?
  - Turns out it’s also by **radiation**
  - But it’s not visible light like from the Sun, it’s *infrared radiation* AKA **“longwave radiation”**

Infrared satellite image →



“Longwave Radiation”

- Everything actually emits radiation
  - Depends partly on the substance but mostly on **temperature**

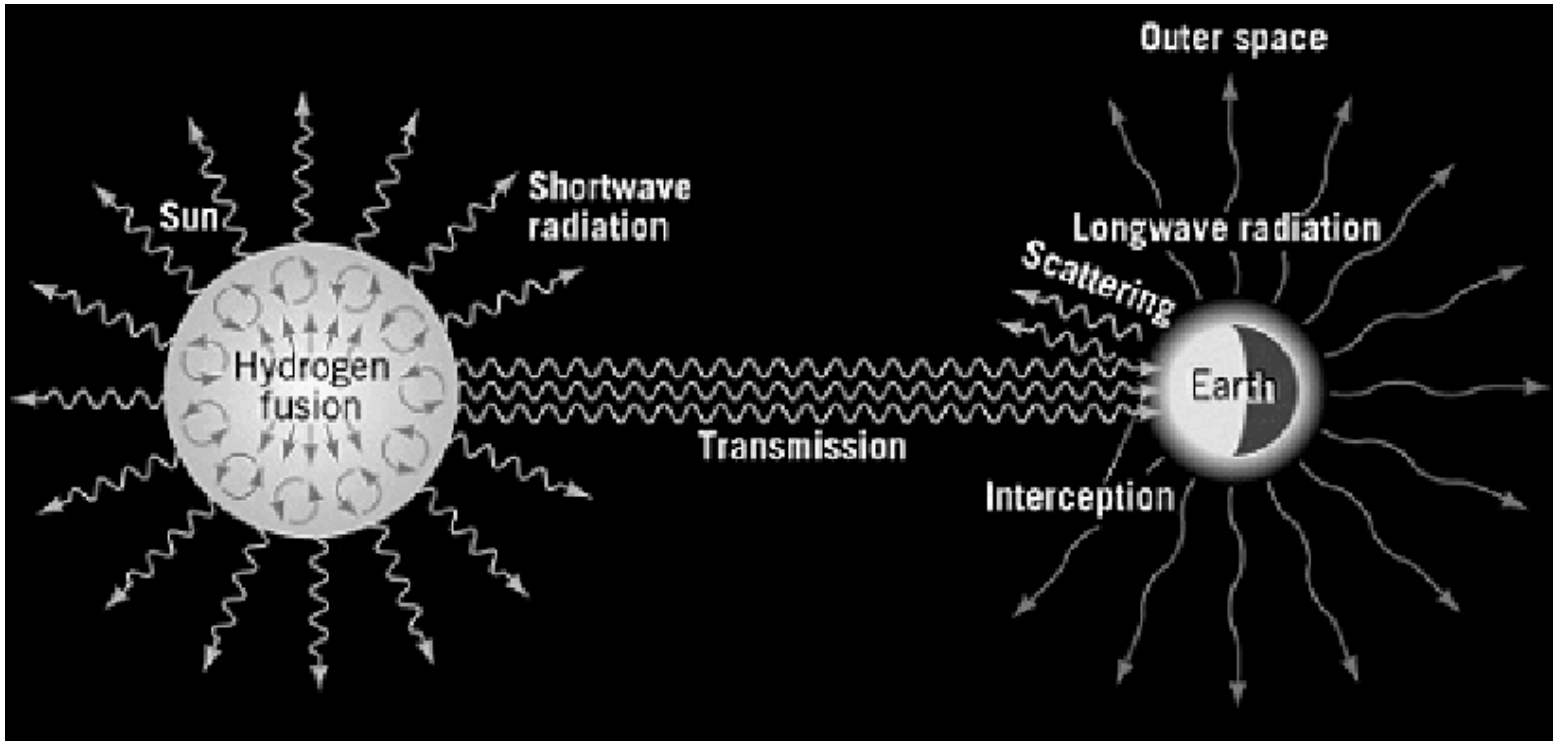


Neck = hotter
Hair = colder

Infrared thermometer

Energy Into and Out of the Earth

- Heating/cooling of Earth
  - The Earth is heated by the Sun (shortwave radiation)
  - The Earth loses energy by longwave radiation (out to space)



“Energy Balance”

- If the **energy into** a system **is greater** than the **energy out**, the temperature will **increase**
  - A temperature increase then results in an increase of energy out because **hotter things radiate more**
  - This will happen until:

$$E_{in} = E_{out}$$

Energy in Energy out

- When energy in equals energy out, we call this “energy balance”

Energy Balance on Earth

- If the **solar radiation** into Earth **is greater** than the **outgoing longwave radiation**, the temperature will **increase**
  - A temperature increase then results in an increase of the longwave radiation out (hotter things radiate more)
  - This will happen until:

$$E_{in} = E_{out}$$

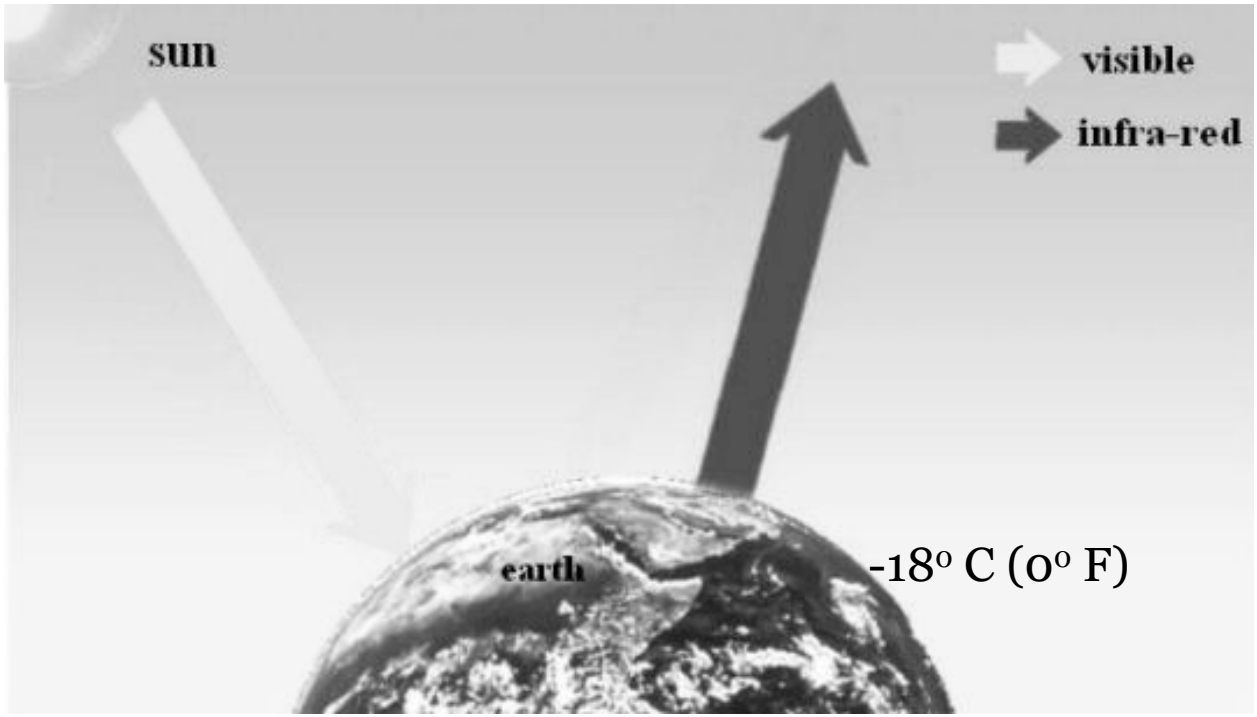
Shortwave in

Longwave out

- Global warming upsets the energy balance of the planet

Earth with No Greenhouse Effect

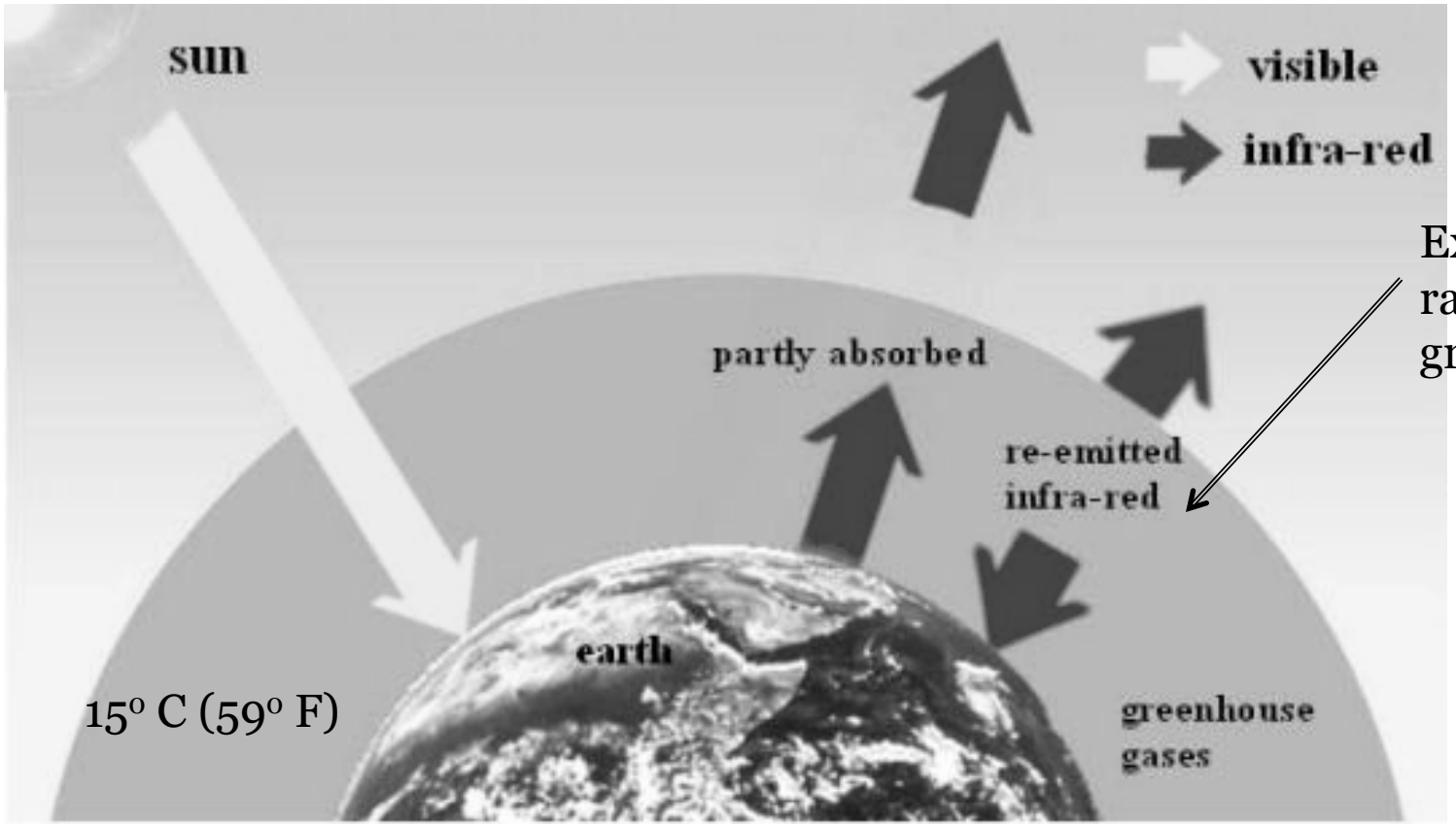
- If there was **no atmosphere**, longwave radiation from the surface would escape directly to space & Earth's temperature would be 0° F (-18° C)



- Missing piece: **the greenhouse effect**
  - All longwave radiation doesn't escape directly to space

The Greenhouse Effect

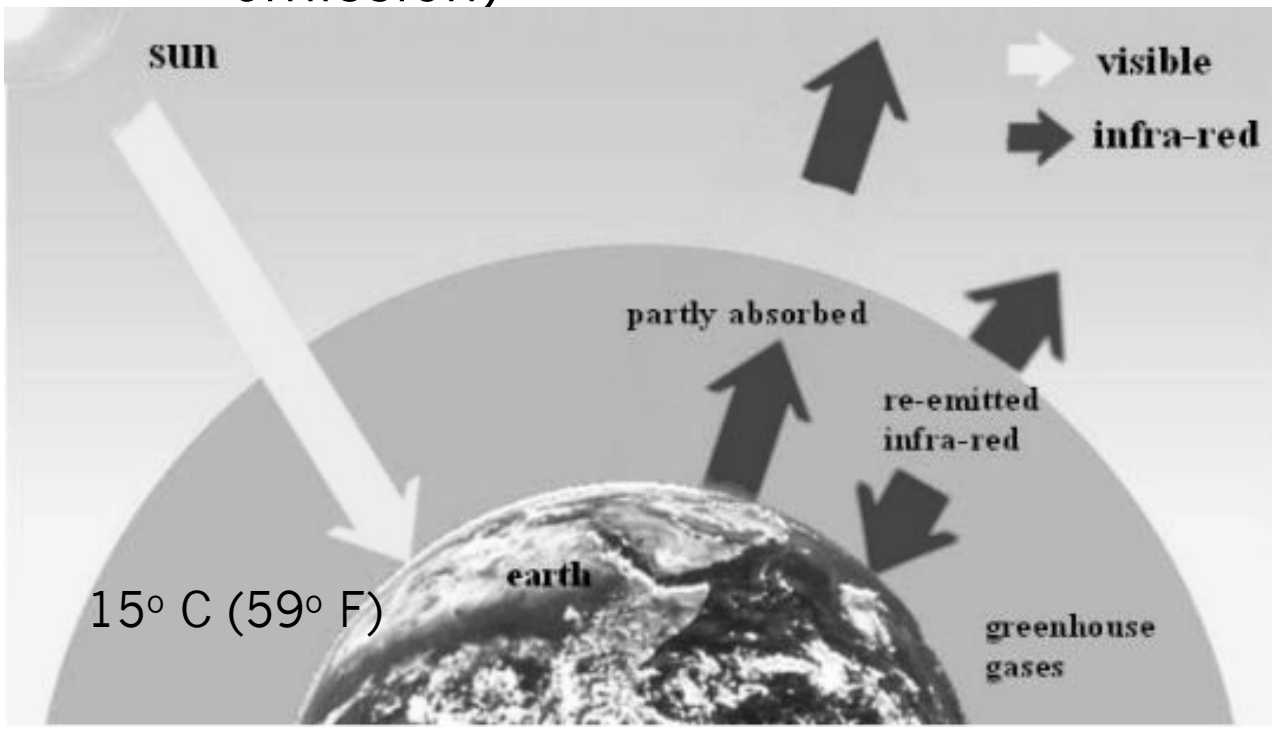
- Greenhouse gases **block longwave** radiation from escaping directly to space
  - The extra downward longwave radiation from above warms the surface



Extra downward radiation due to greenhouse gases

The Greenhouse Effect

- Greenhouse gases cause the outgoing radiation to happen at higher levels (no longer from the surface)
  - Air gets much colder as you go upward
  - So the radiation to space is much less (colder → less emission)



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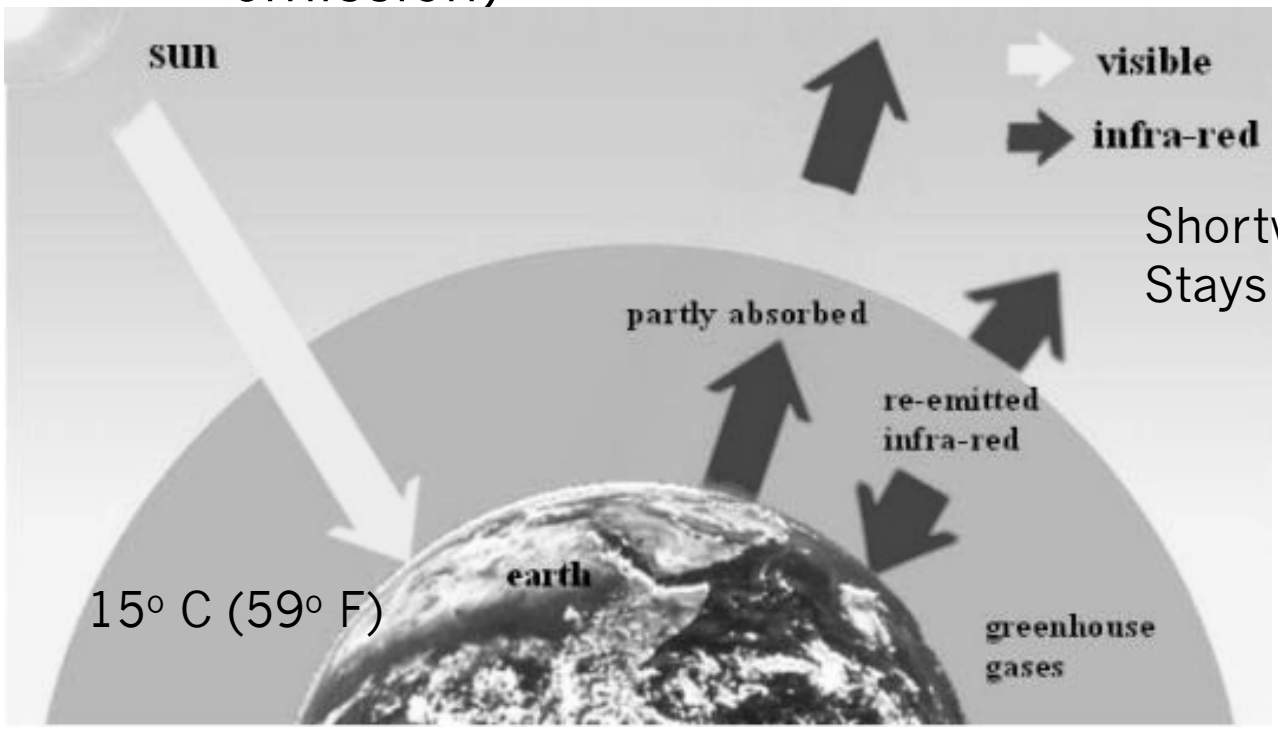


$$E_{in} = E_{out}$$

Shortwave in
Stays the same

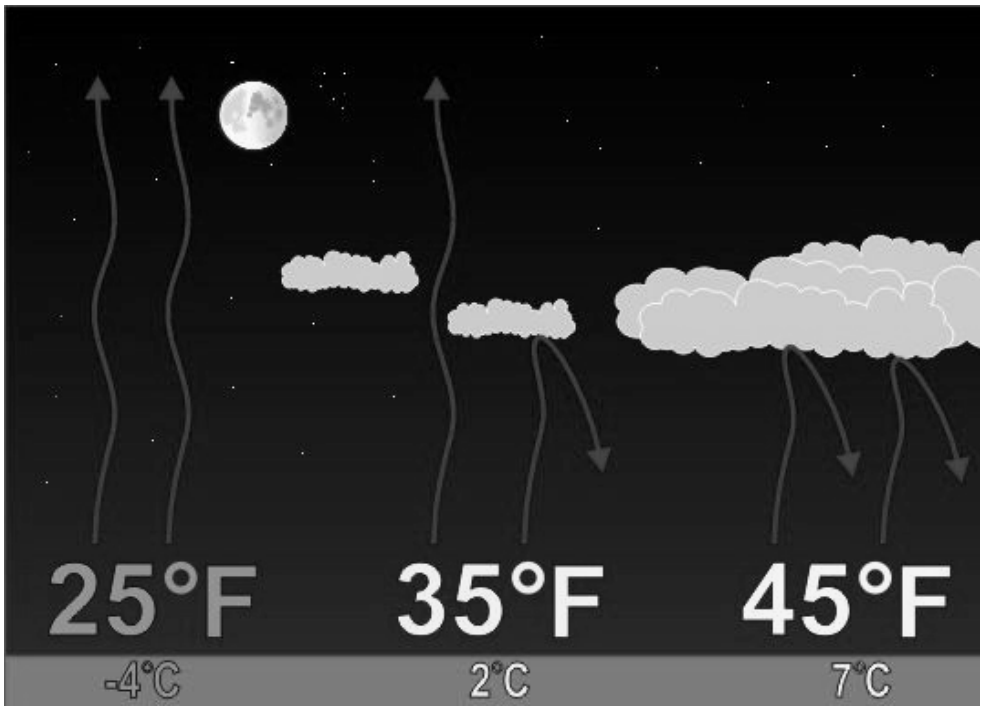
Longwave out
decreases

Earth is out of energy balance!

The Greenhouse Effect

- Greenhouse effect is intuitive if you pay attention to the weather!
  - **Cloudy nights**

  cool less quickly



  - In the **desert**, temperatures plunge at night!
    - No clouds & little water vapor in the desert: little greenhouse effect