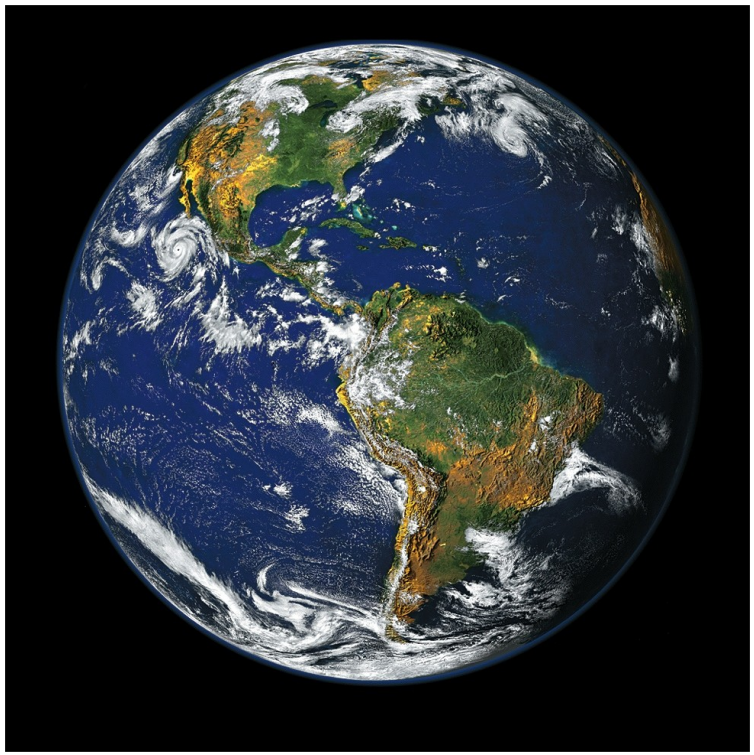

Lecture 6: Climate basics

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Department of Physics and Astronomy
Denver, CO
Jonathan F. Ormes
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It's a complex business

- Climate science is multi-disciplinary
  - Astrophysics, physics, chemistry, geology, biology, fluid dynamics, etc.
- Now add the human social and geopolitical aspects of the problem etc.
- It's an interesting complex problem keeping the mind of an old man active.

Summery

- Earth's global temperature and climate has varied widely on geologic timescales.
- CO_2 has varied widely over the history of Earth, and has been an important contributor to climate.
- CO_2 has been less than 295 ppm for the past 800,000 years. Now it is 410 ppm.
- Ice and benthic core data has been essential to these understandings.

JOEL PETT
LEXINGTON HERALD-LEADER

Cartoonists International: www.mysyn.com/cartoons

Effect of the sun

- I once had a colleague tell me that the sun has nothing to do with our climate.

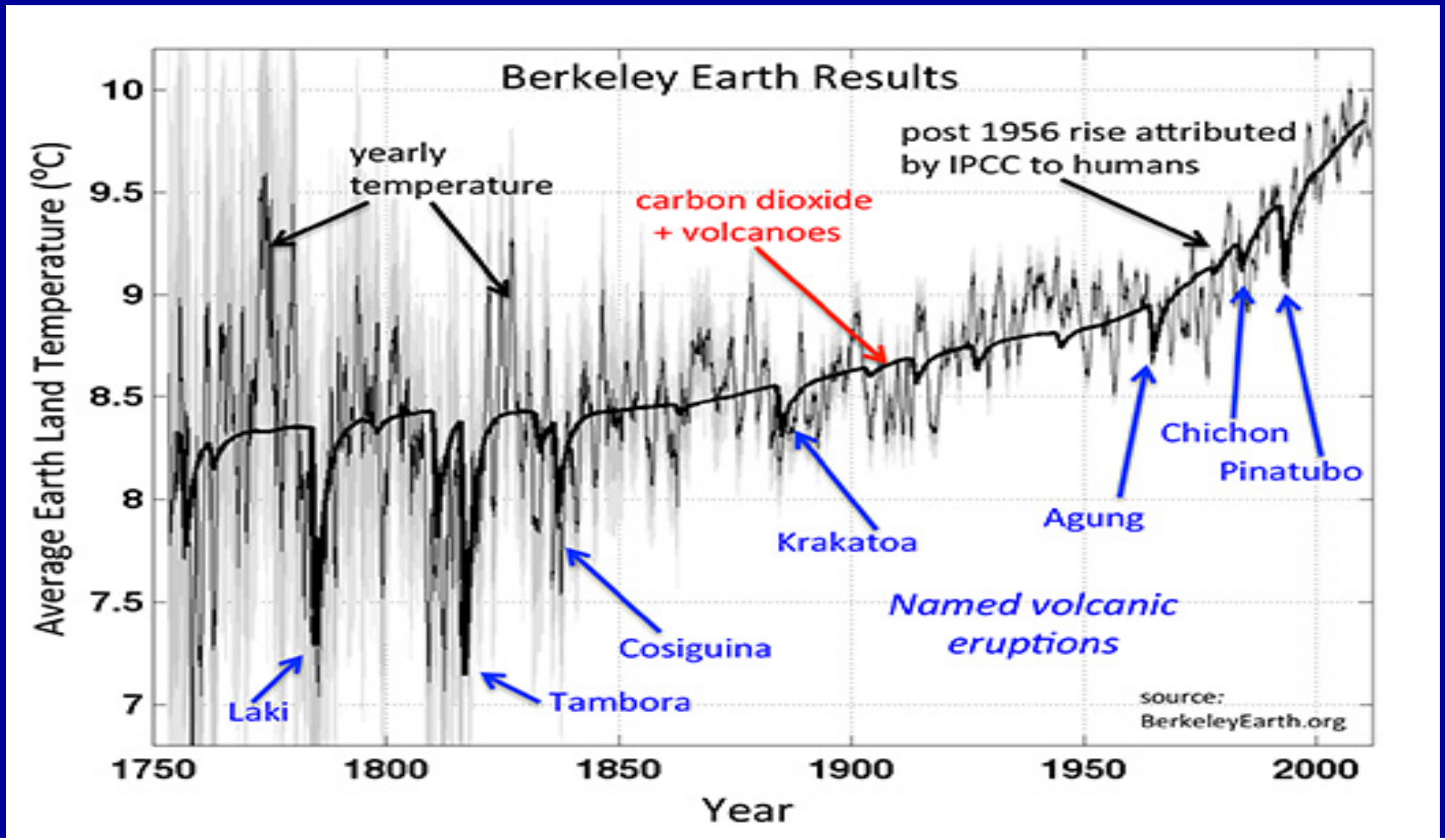
- My reply: "Oh yeah, just try turning it off and see what happens."

- Of course this person was talking about the variability of the sun, but this is an object lesson in how hard it is to be sufficiently precise in talking about such subjects.

Reanalysis by "Berkeley Earth"

T_{avg} fit by function f(Ln(CO_2) - 1.5 x mVS (Tg))

mVS = Mass of Volcanic Sulfates in Terragrams



The Greenhouse effect

140 ^{o}F = 60 ^{o}C

I had a window blown out of my car left at an airport parking lot.

Cloudless night

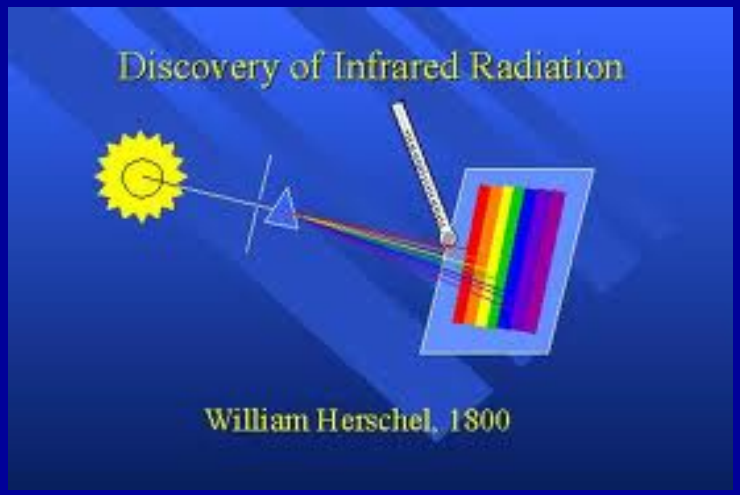
What happens? It gets cold. Cold desert night!

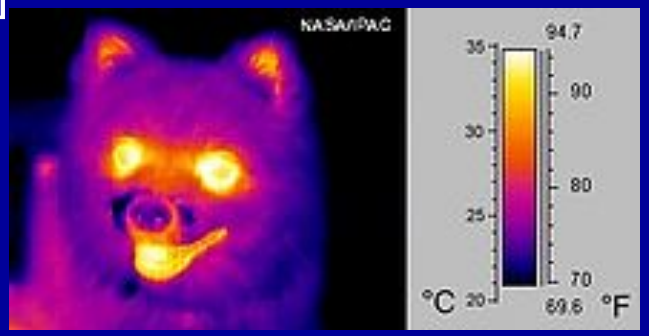
Earth cools by radiation! You all know it!

How was thermal radiation discovered?

- William Herschel
  - also discovered the first new planet since antiquity (Uranus) and studied sunspots,
- In an 1800 experiment, Herschel used a glass prism to spread sunlight into a rainbow of colors.
  - measured the temperature of each color of visible light and noted differences.
  - readings when the thermometer bulb was placed just beyond the red portion of the visible spectrum.

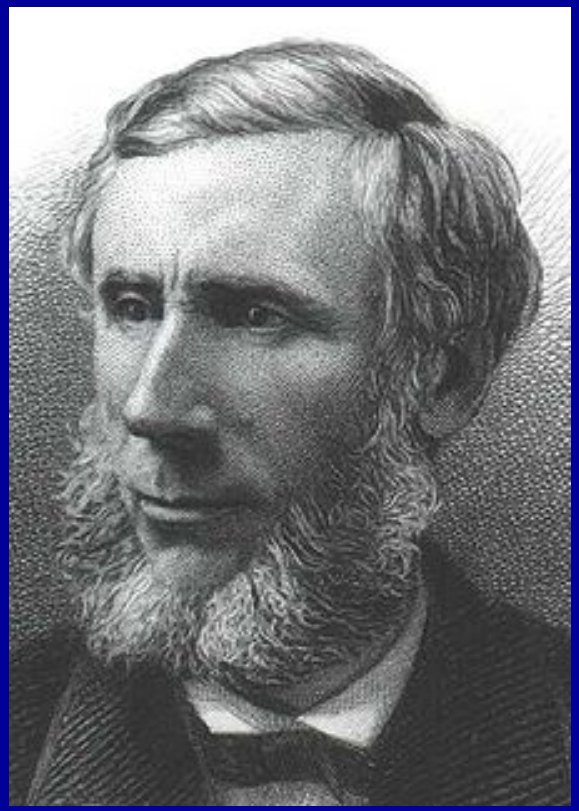
• He had discovered thermal radiation, which has come to be known as infrared. [The prefix "infra" means "below."]





Greenhouse gases keep the planet warm

Joseph Fourier computed that the Earth should be much colder than it is (1824, 1827)



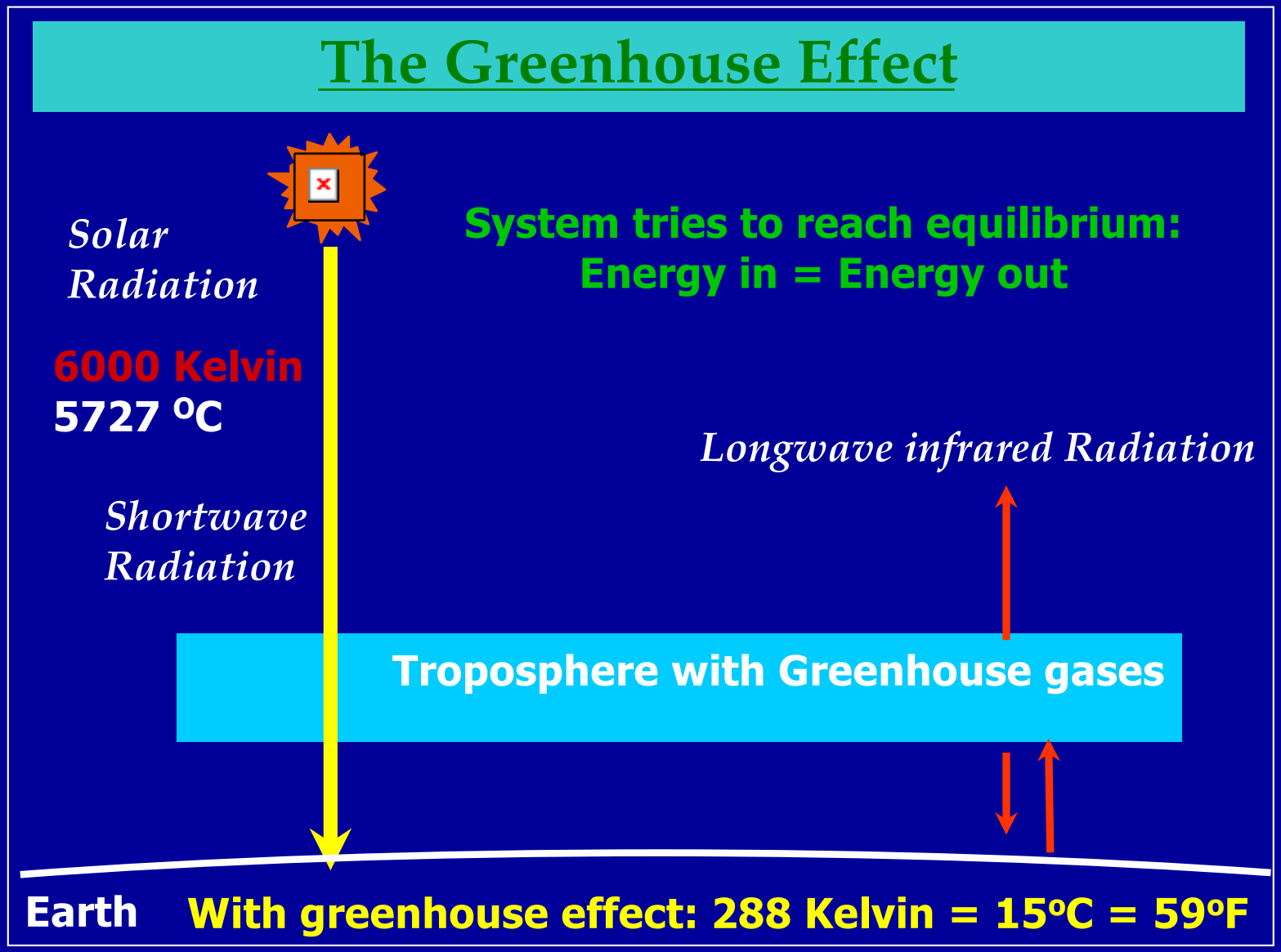
John Tyndall, January 1863

Measured the absorption and emission of heat radiation by CO_2 in air (made the measurements of the physics.)

Svante Arrhenius, 1896

Calculated in detail effect of CO_2 on Earth's temperature.

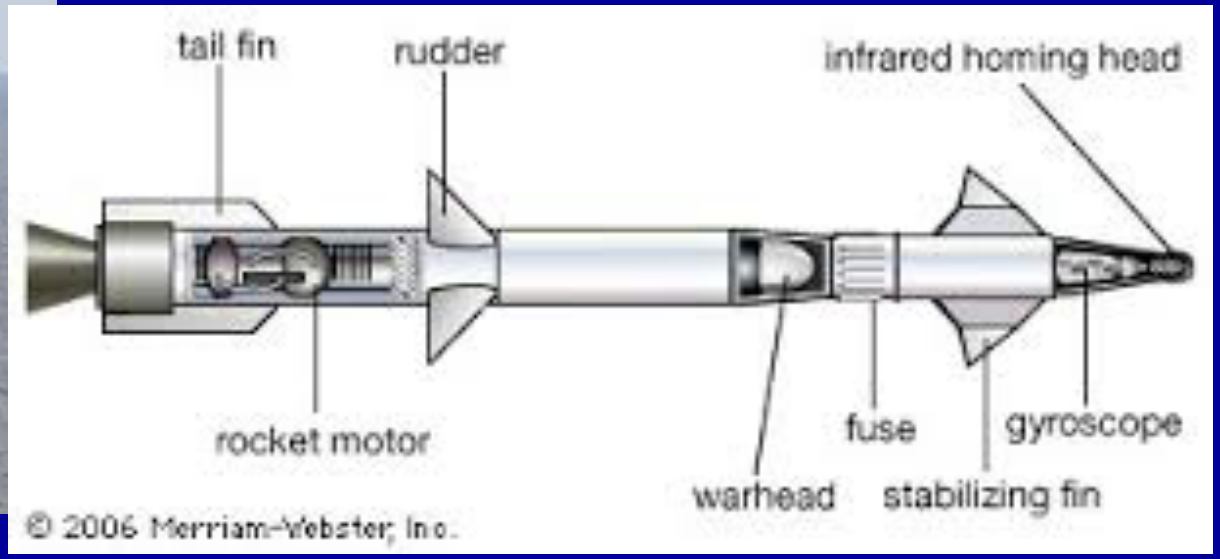
Earth is 33 °C (59°F) warmer than
it would be without the current greenhouse effect.



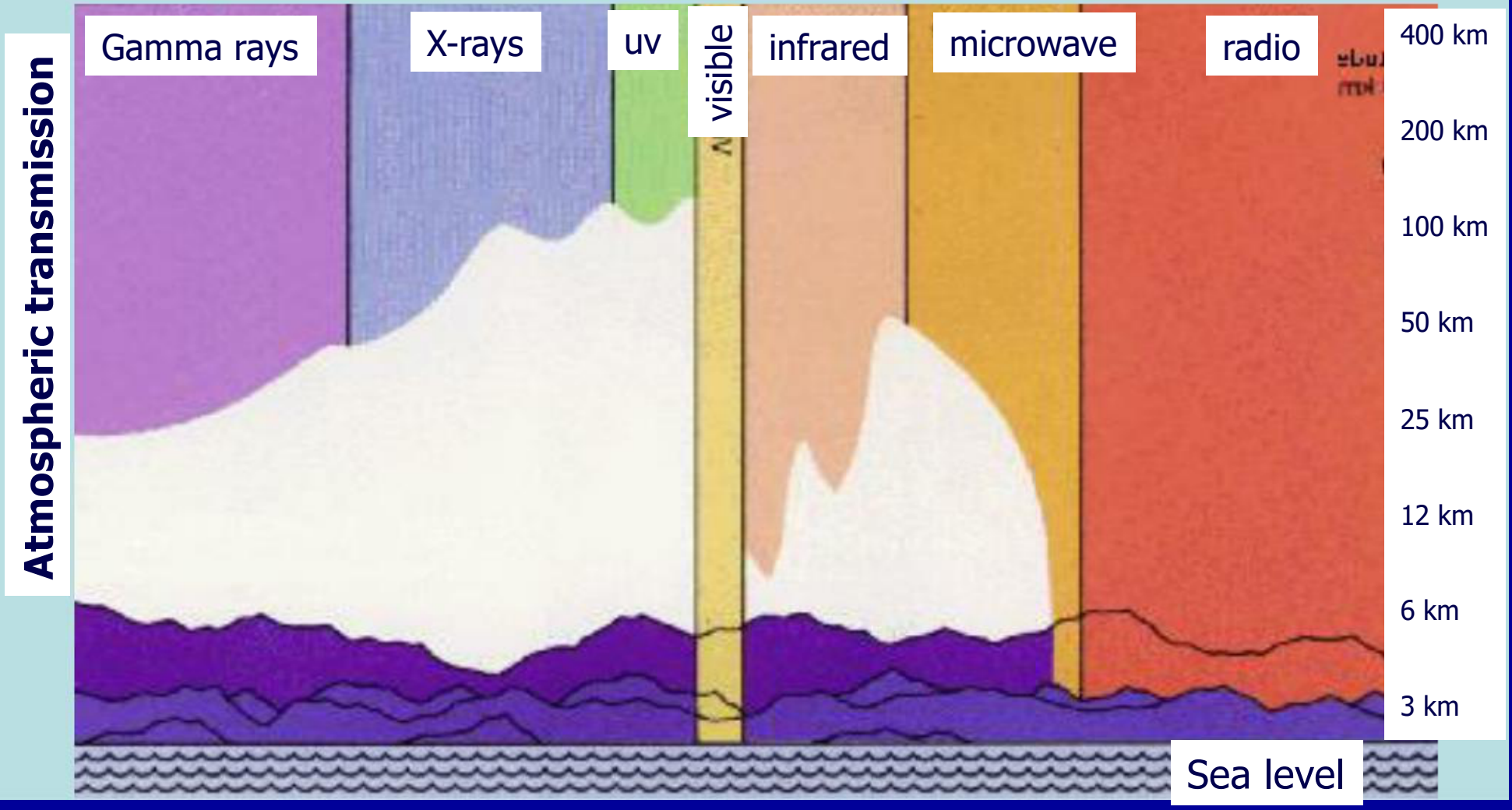
Without greenhouse effect: 255 Kelvin = -18°C = 0°F

Heat seeking missiles were developed in the early 1950s by the military.

They learned all about the absorption of infrared by atmospheric CO_2.

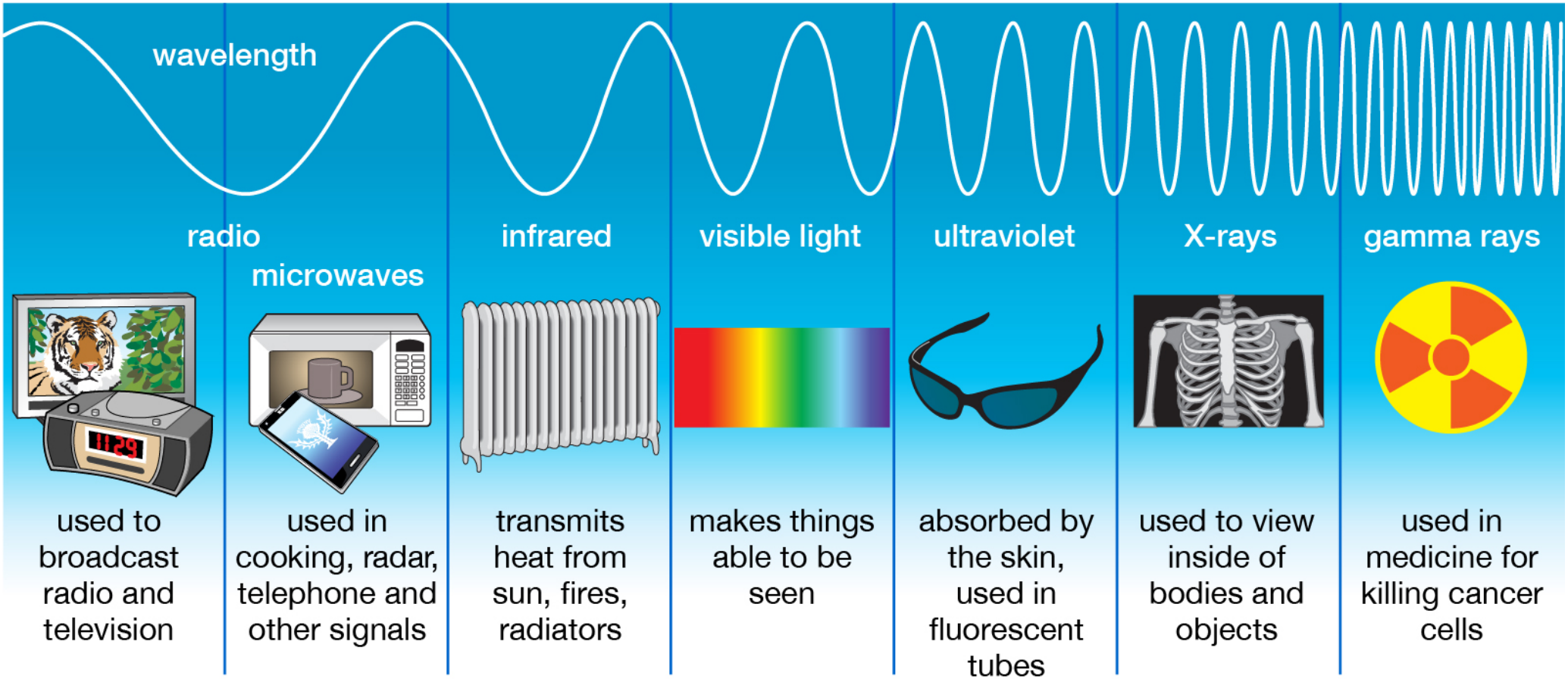


Penetration of different wavelengths of light through the atmosphere



Electromagnetic spectrum

Types of Electromagnetic Radiation



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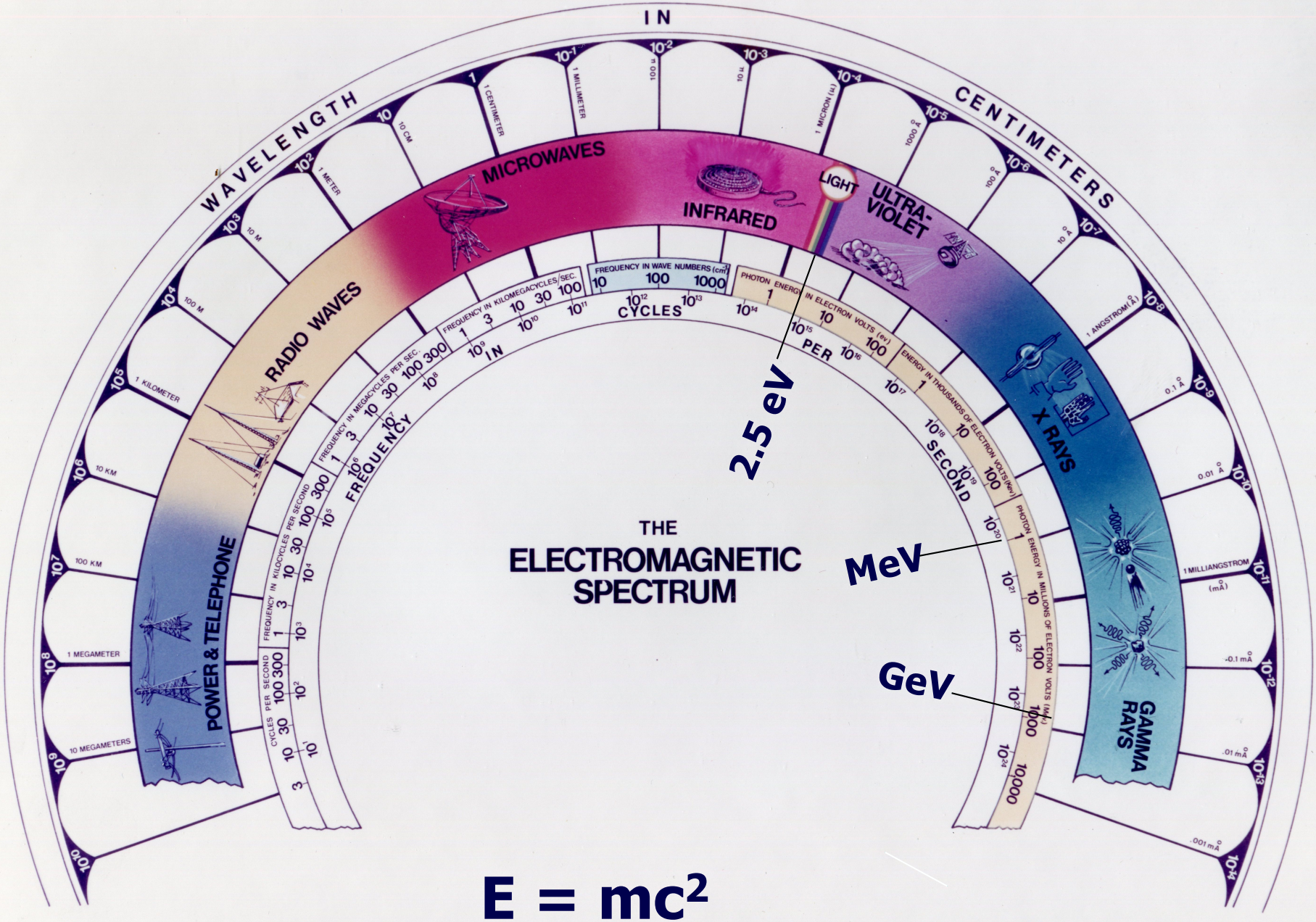
Which house has the gold?


THE
ELECTROMAGNETIC
SPECTRUM
WAVELENGTH IN CENTIMETERS
POWER & TELEPHONE
RADIO WAVES
MICROWAVES
INFRARED
LIGHT
ULTRA-VIOLET
X RAYS
GAMMA RAYS
FREQUENCY IN CYCLES PER SECOND
FREQUENCY IN KILOCYCLES PER SECOND
FREQUENCY IN MEGACYCLES PER SEC.
FREQUENCY IN KILOMEGACYCLES/SEC.
FREQUENCY IN WAVE NUMBERS (cm⁻¹)
PHOTON ENERGY IN ELECTRON VOLTS (ev)
ENERGY IN THOUSANDS OF ELECTRON VOLTS (Kev)
PHOTON ENERGY IN MILLIONS OF ELECTRON VOLTS (Mev)
CYCLES PER SECOND
2.5 eV
MeV
GeV

$$E = mc^2$$

Relationship between wavelength and frequency

Wavelength (λ) * frequency (ν) = c; c is the velocity of light
Einstein showed c is a universal constant

$\lambda\nu = c$, so $\lambda = c/\nu$ and $\nu = c/\lambda$

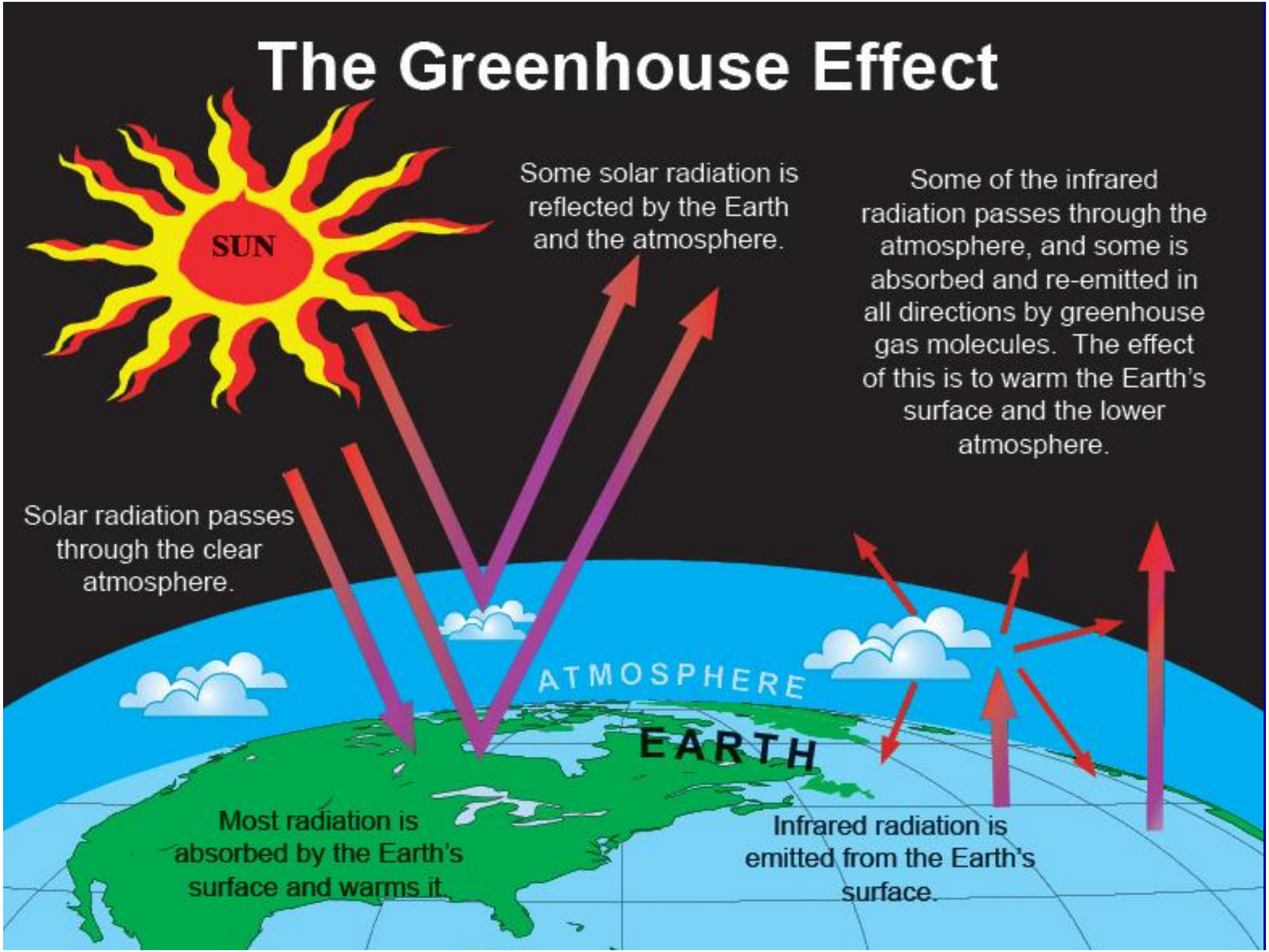
$h\nu = E$ E for energy,
h is another universal constant known as Planck's constant

Climate changes with changes in the radiation balance

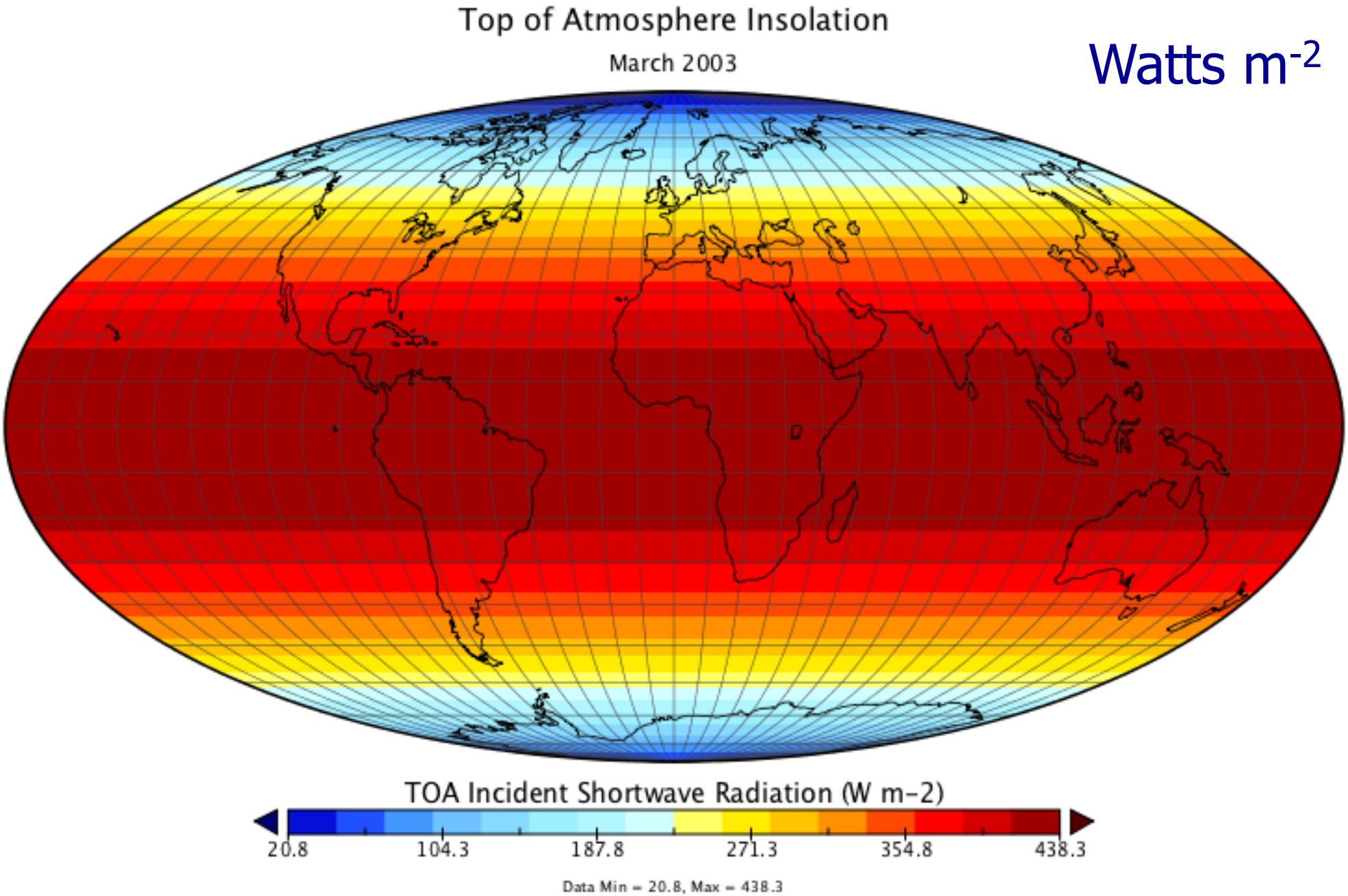
1. changing the incoming solar radiation
   - by changes in the Earth's orbit or in the Sun itself
2. changing the fraction of solar radiation that is reflected
   - the albedo can be changed, for example, by changes in ice coverage, aerosols or land cover
3. altering the heat energy radiated to space
   - by changes in greenhouse gas concentrations

Local climate also depends on how heat is distributed by winds and ocean currents. All of these factors have played a role in past climate changes.

The Greenhouse Effect

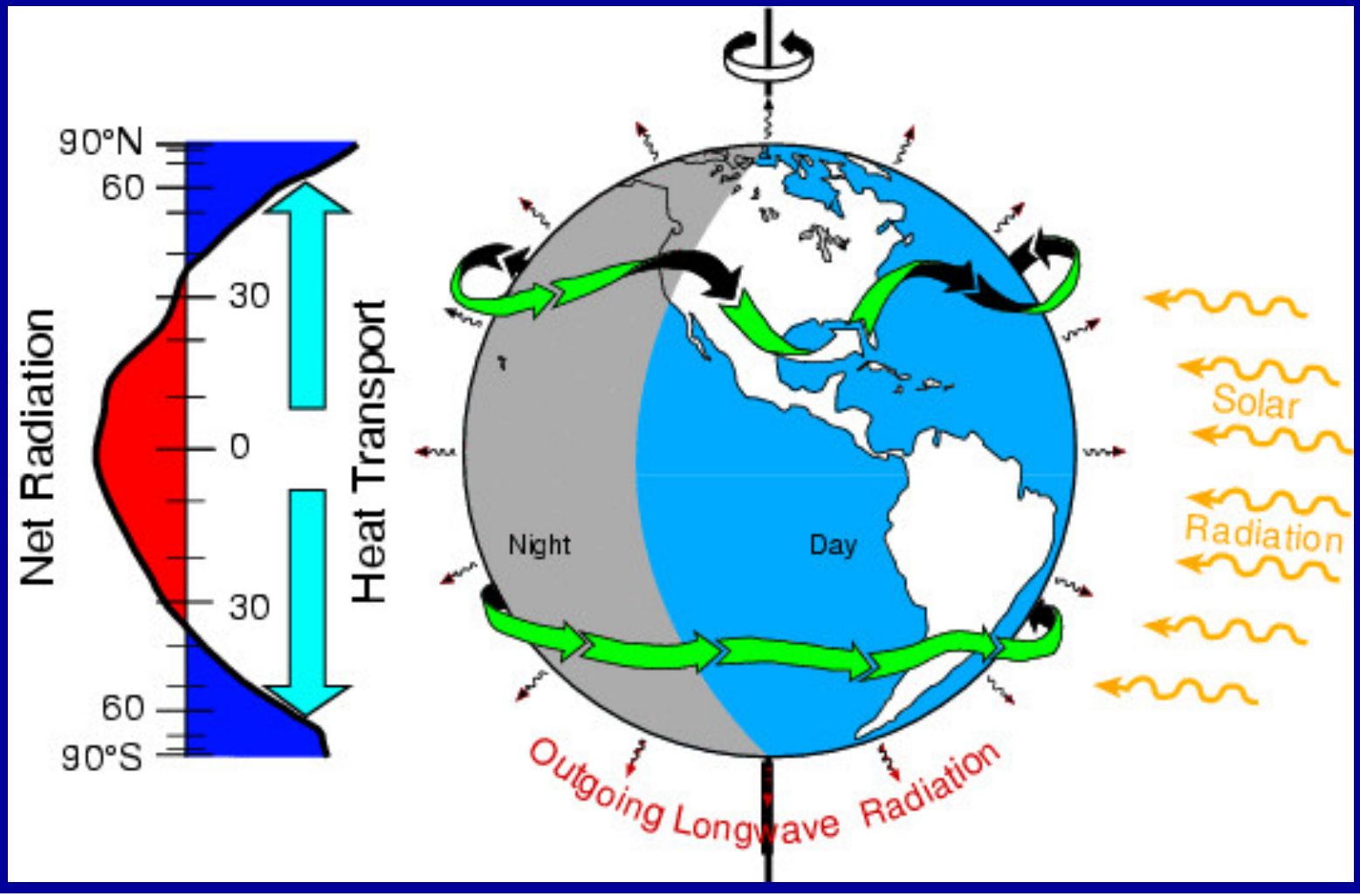


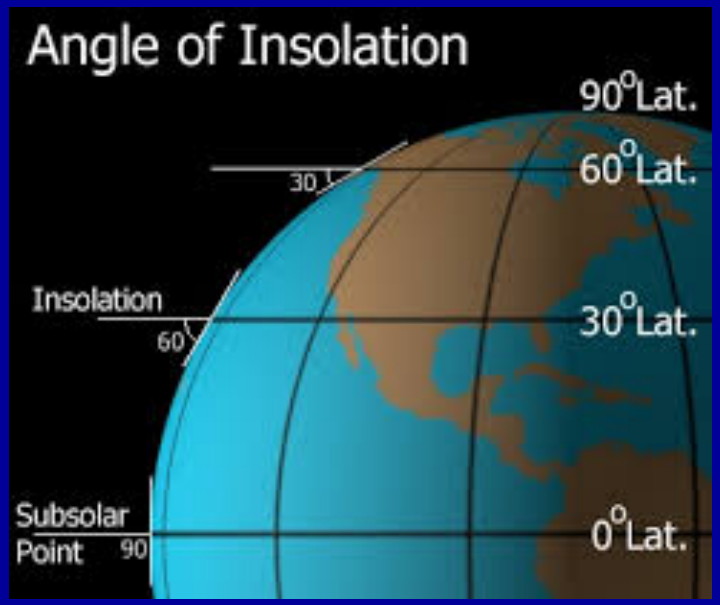
Insolation: incident solar radiation

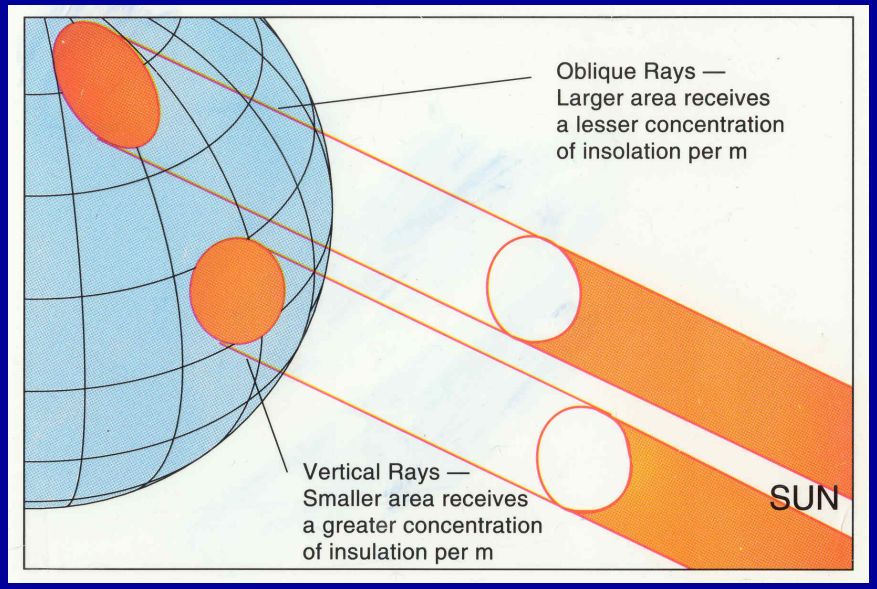


Energy Distribution

Incoming solar shortwave radiation is unevenly distributed reflecting to the geometry of the Earth-sun system. Outgoing longwave radiation is more uniform.



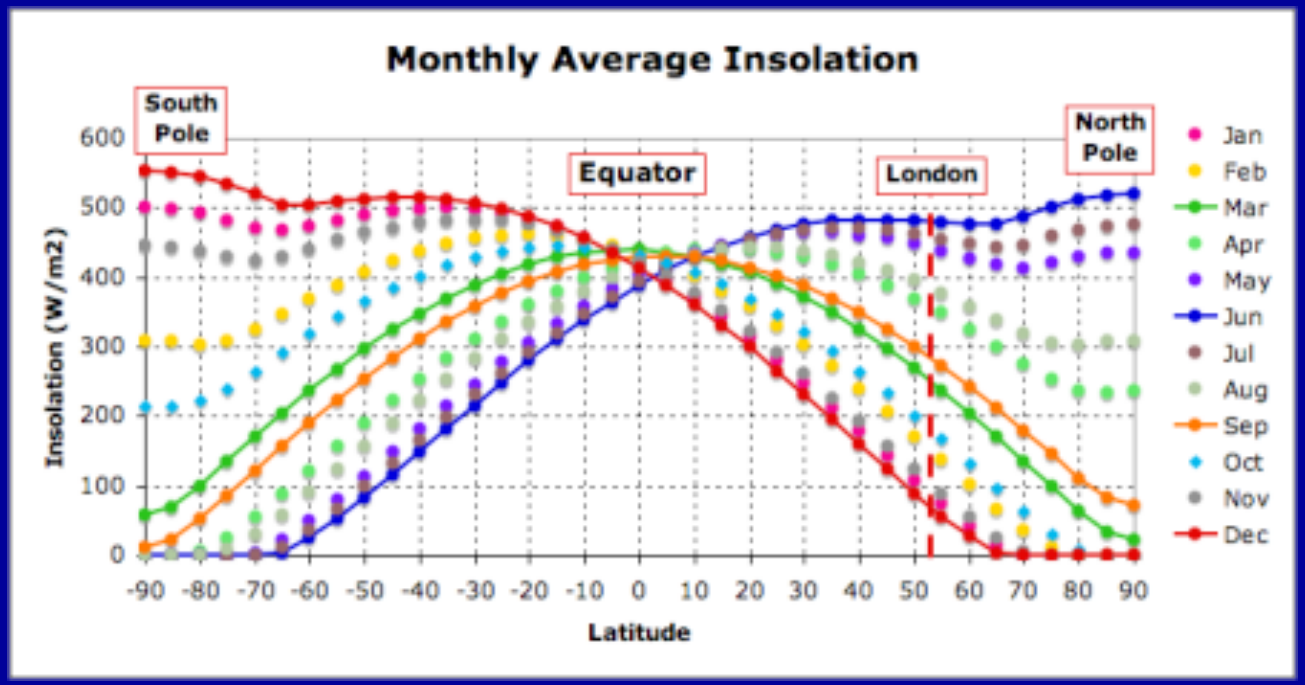


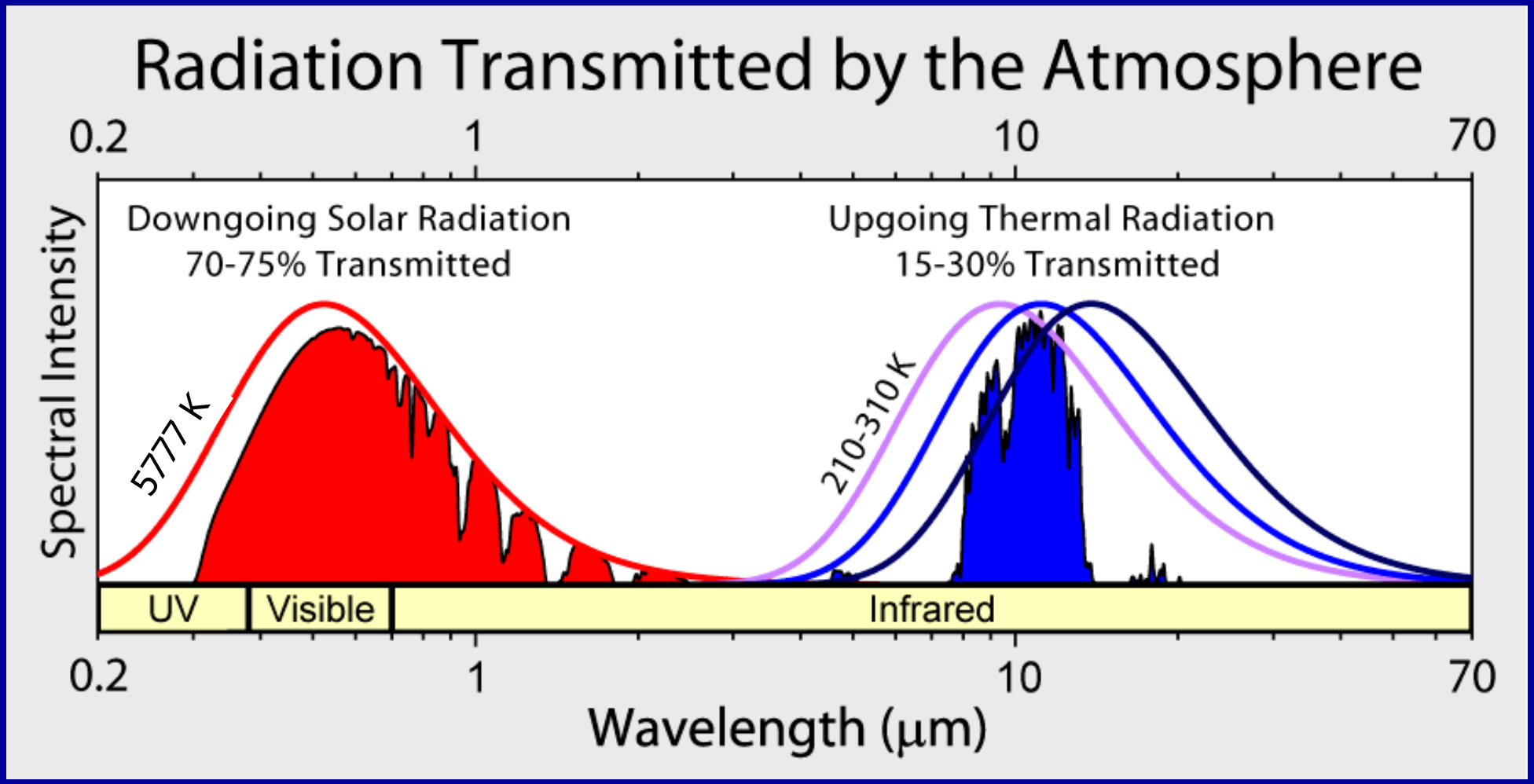


Denver 40 °NLat

Solar insolation

The term insolation comes from 'incident solar radiation'.





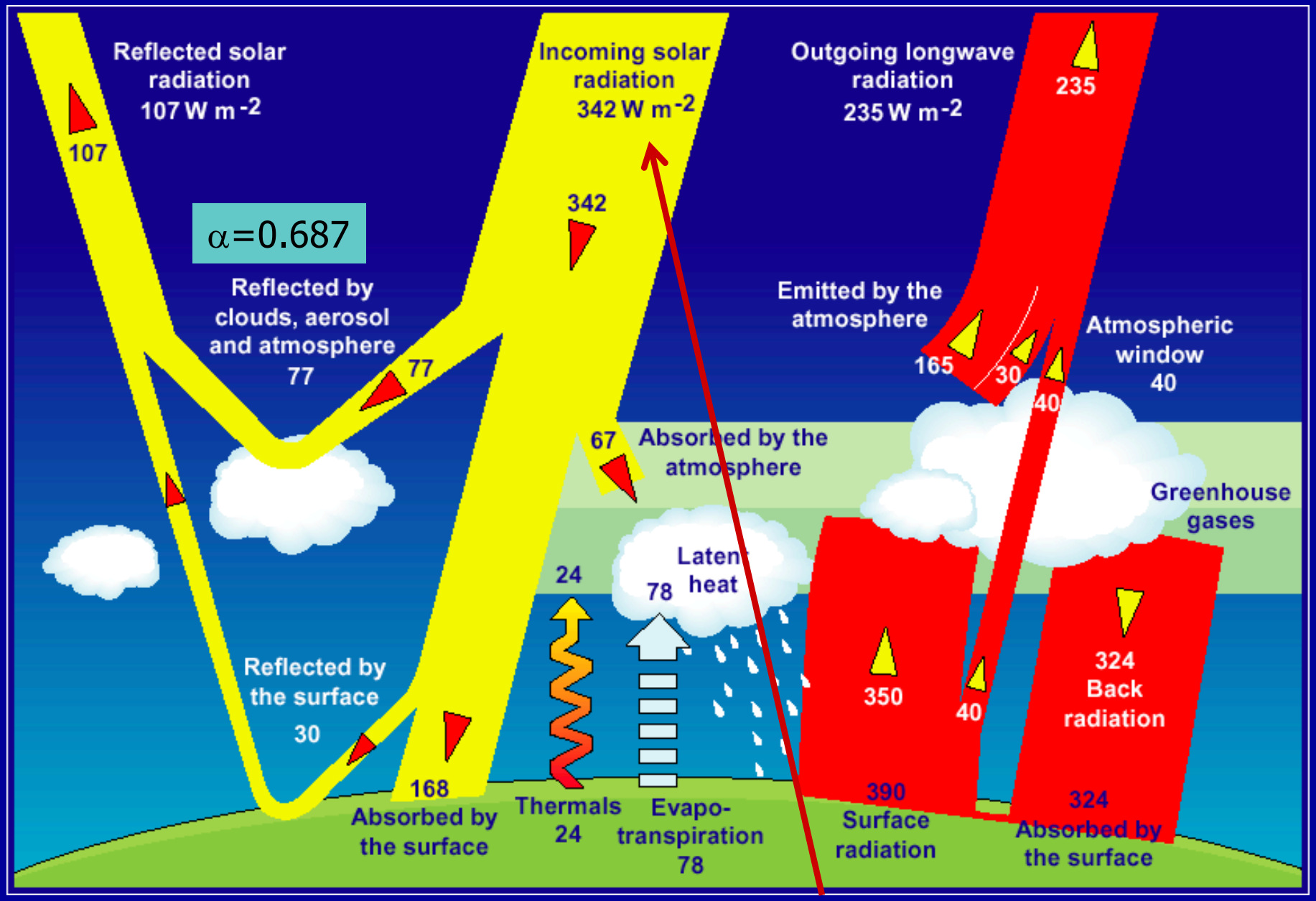
red λs come in

blue λs go out

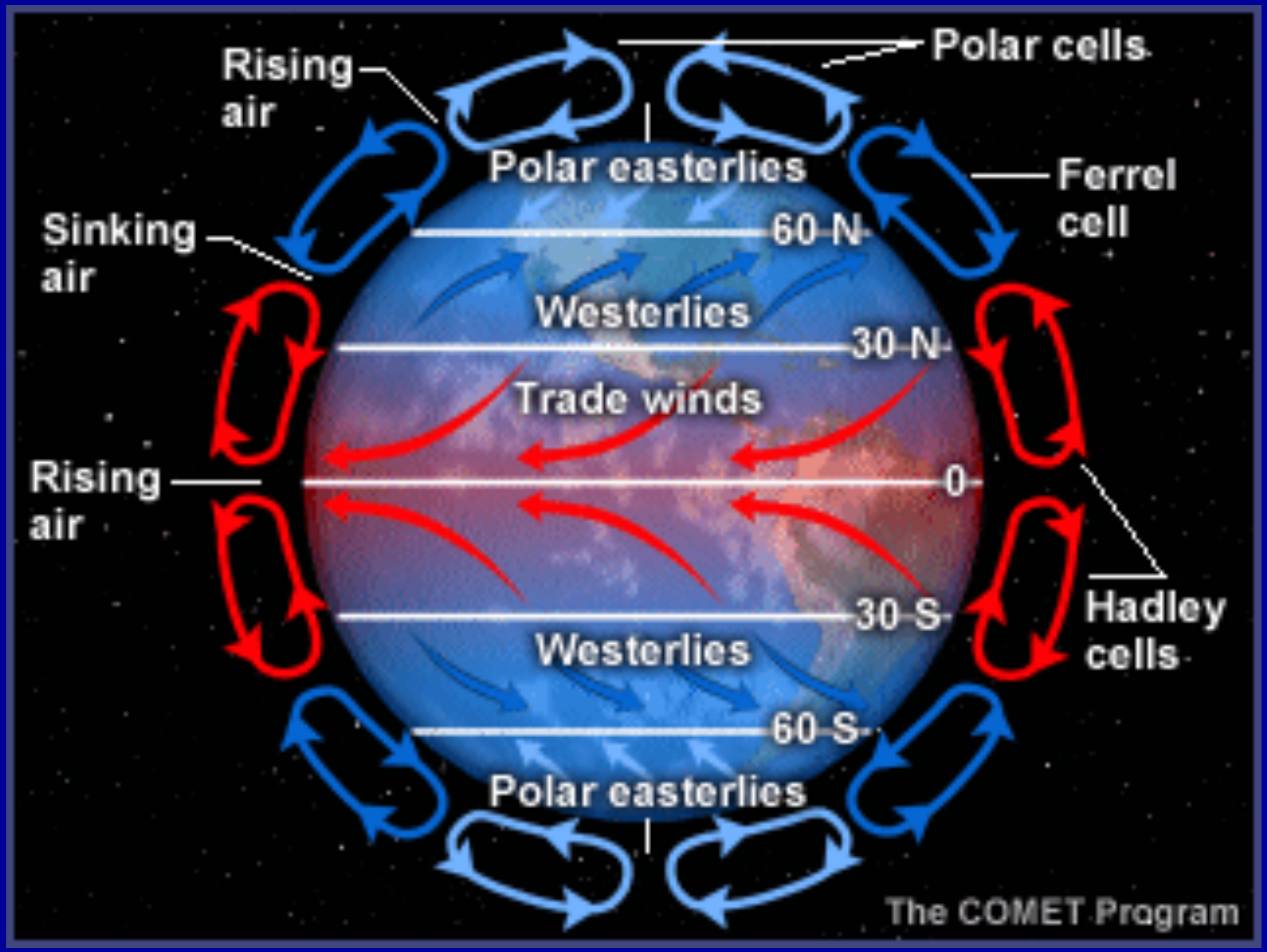
Global Radiation Budget

(1-α)

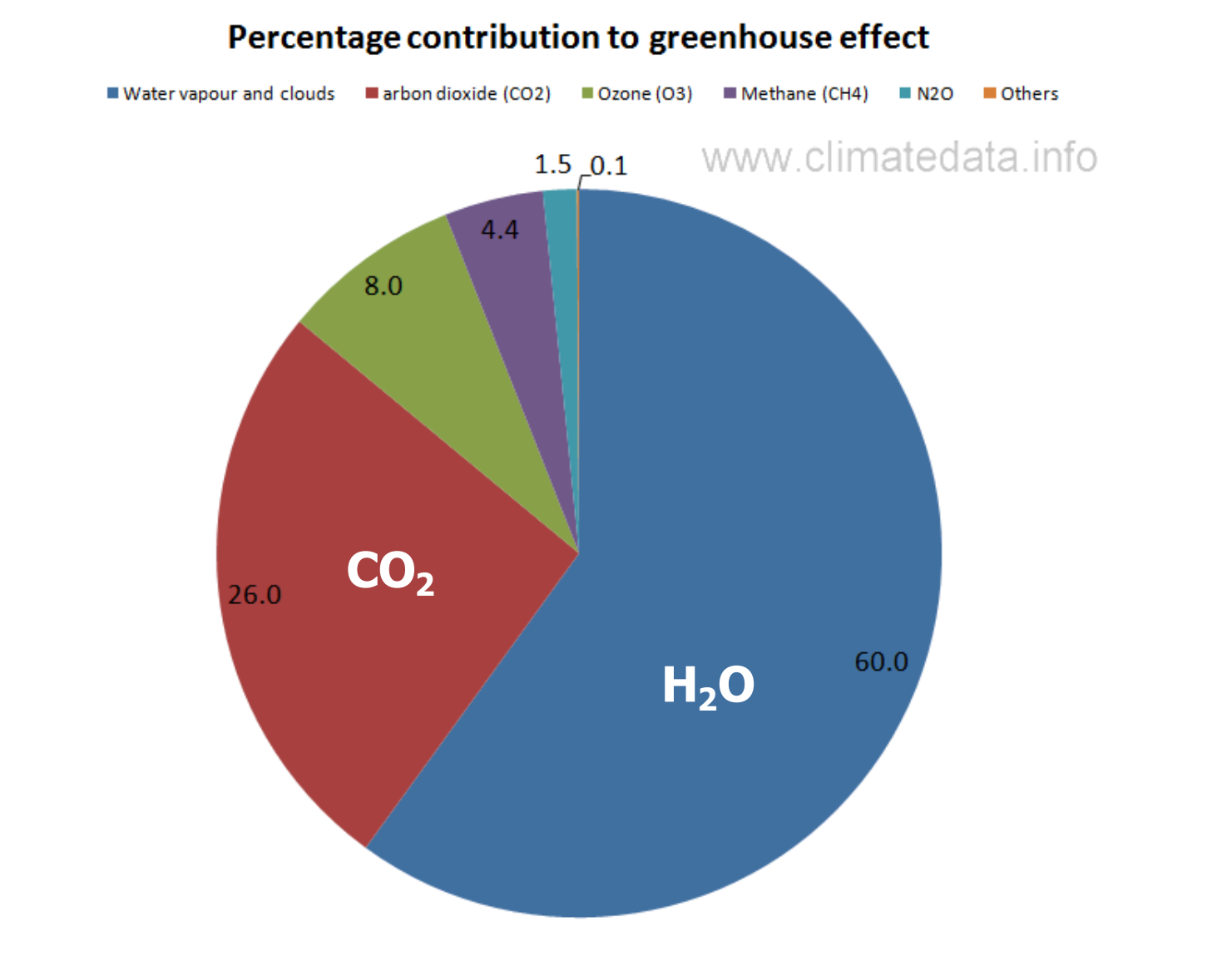
342-107 W m^{-2}
=235 W m^{-2}



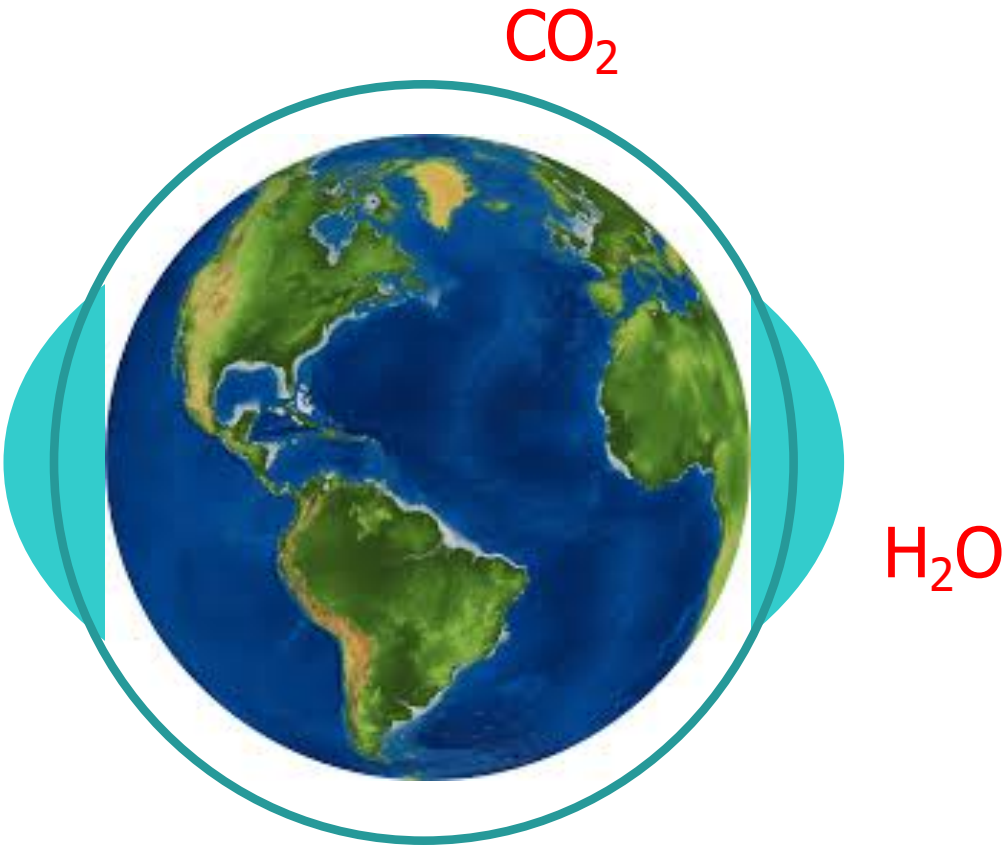
$S/4 = 1368\ W\ m^{-2}/4 = 342\ W\ m^{-2}$


Polar cells
Rising air
Polar easterlies
Ferrel cell
Sinking air
60 N
Westerlies
30 N
Trade winds
Rising air
0
Hadley cells
30 S
Westerlies
60 S
Polar easterlies
The COMET Program

Water contributes a lot

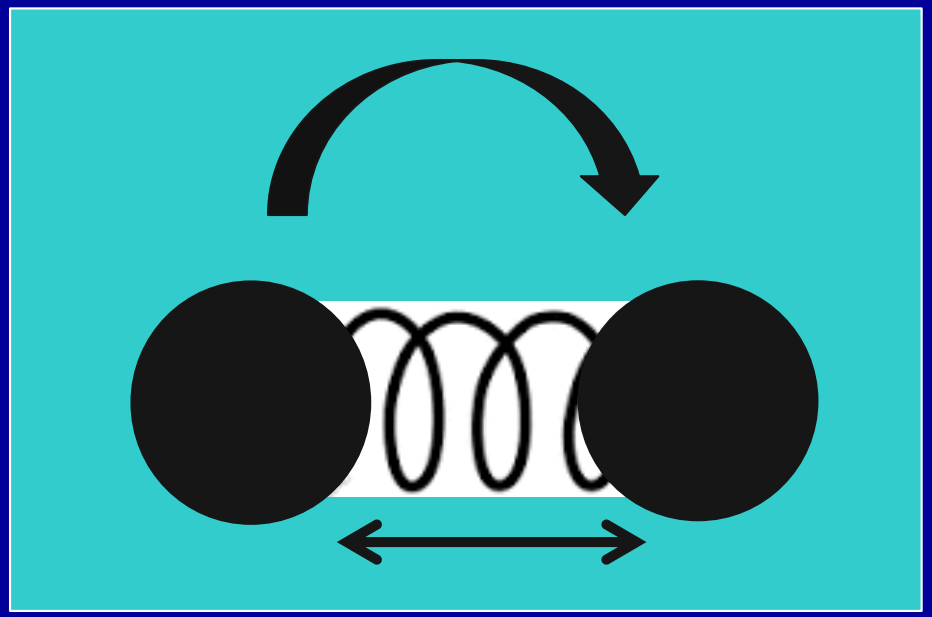


Distributions of Greenhouse gases



Internal molecular energy

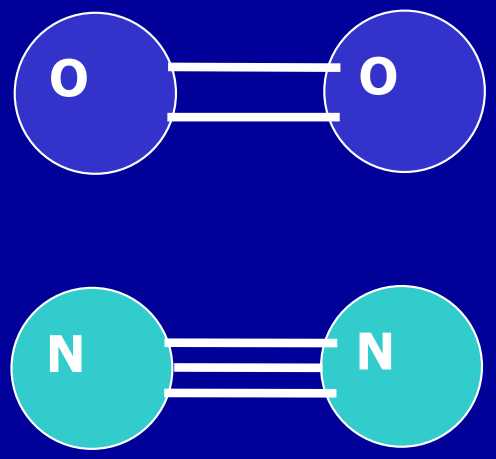
The whole system can rotate
Internal forces between molecules can cause oscillations



Simple oscillations of N_2 and O_2

Dancing Molecules and Heat Rays!

- Nearly all of the air is made of oxygen (O_2) and nitrogen (N_2) in which two atoms of the same element share electrons



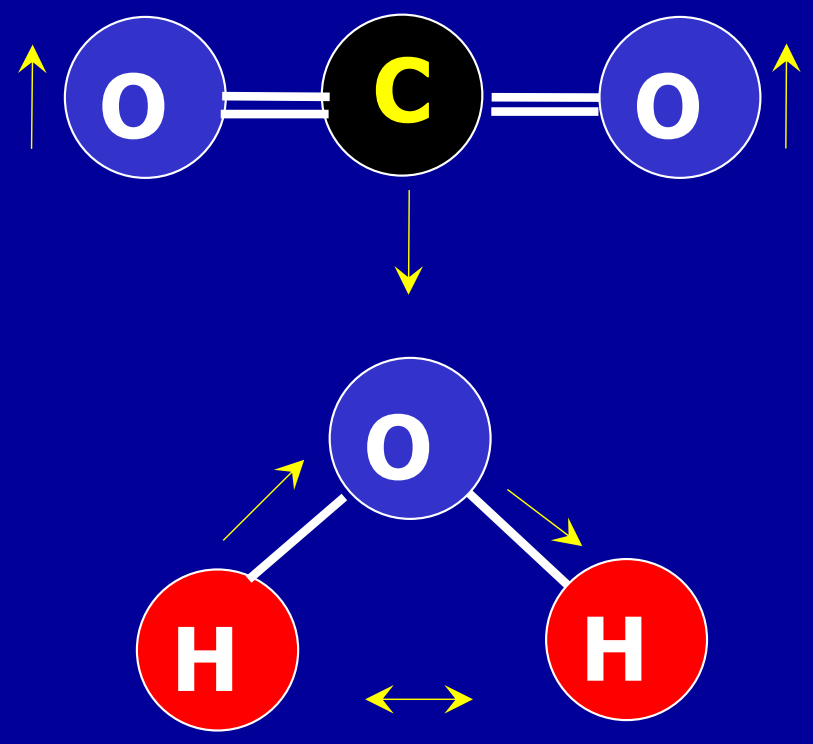
- Very little infrared (heat) energy radiated up from the surface can be absorbed by these molecules.

Diatomic molecules can vibrate back and forth like balls on a spring, but the ends are identical

Dancing Molecules and Heat Rays!

- Carbon dioxide (CO_2) and water vapor (H_2O) are different!

- They have many more ways to vibrate and rotate, so they are very good at absorbing and emitting infrared (heat) radiation

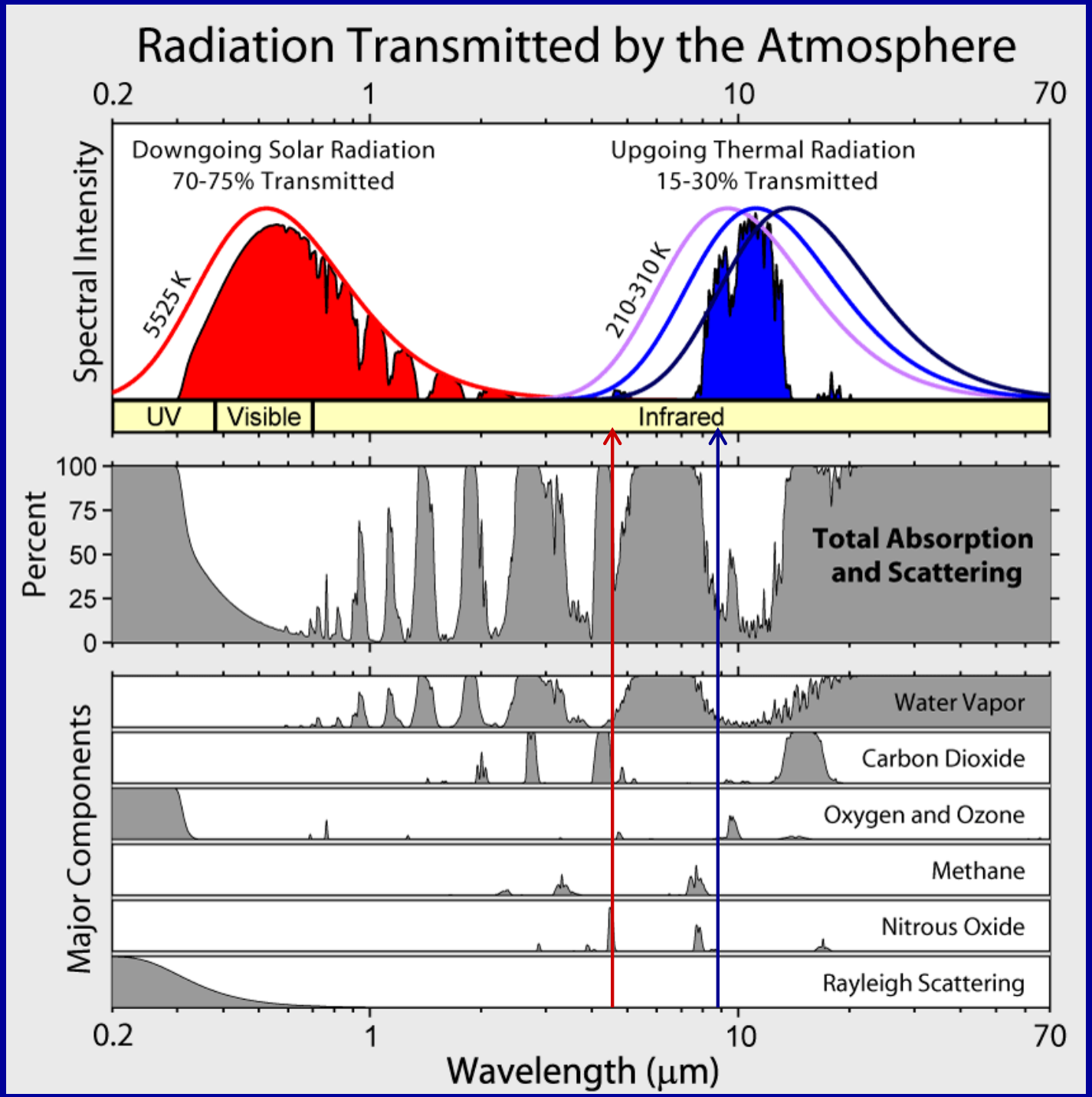


Molecules that have many ways to wiggle are called "Greenhouse" molecules

The absorption spectrum of CO_2 was measured by John Tyndall in 1863.

Prof. Scott Denning CSU

[redacted]



Raman lines

N_2

O_2