GEO409-FS2025 (3 credits)

Sep 8: Physical Foundations for Global Climatic Changes

- Physical Laws
- Radiative processes & Albedo (a)
- Energy balance of the Earth

Reading

Chen, J., C. Lei, and P. Sciusco, 2021. Modeling Ecosystem Global Warming Potentials. In *Biophysical Models and Applications in Ecosystem Analysis* (pp. 11-18; 120-126). MSU Press.

Topic for term paper due

Physical Foundation: Radiation & Heat Unit

Speed of light (c): c = 299,792,458 m/s

$\approx 3.0\times10^{8}$ m/s

≈ 300,000 km/s

≈ 186,282 miles/s

- Light takes about **8 min and 20 s** to travel from the Sun to Earth.
- Light can circle Earth **7.5 times** per second.
- It takes about **1.3 s** for light to travel from the Moon to Earth with a distance of 384,400 km or 238,855 miles.
- It takes about **3–22 min** to travel between Earth and Mars

https://ib.bioninja.com.au/standard-level/topic-4-ecology/44-climate-change/greenhouse-effect.ht

Physical Foundation: Radiation & Heat Unit

Energy

- Amount: Joule (J)
- Rate of energy use: Watt

- 1 W=1 J/s
- 1 Wh=3600 J
- A 60 W bulb on for 1 minutes:

$$E = 60\ W \times 60\ s = 3600\ J$$

Flux is the rate of energy transfer per unit area: $W{\cdot}m^{-2}$

Solar Constant: ≈ $1361\ W{\cdot}m^{-2}$

Latent heat of vaporization (L_v): To evaporate 1 gram of water at 100 °C and 1 atm: ~2260 $J \cdot g^{-1}$

$$L_v \approx 2260\ J/g = 2.26{\times}10^6\ J \cdot kg^{-1}$$

Question: how much energy is needed for 1 mm rain to completely evaporate?

$2.26\ MJ/m^2$

Blackbody Theory

Any object with a temperature higher than absolute zero (-273.15 °C) emits energy.

Stefan–Boltzmann Law

The total energy (E) radiated from an object is proportional to the 4th power of its temperature (T), with σ as the emissivity (i.e., Stefan–Boltzmann constant):

$$E = \sigma \cdot T^4$$

$$\sigma = 5.67\times10^{-8}\, W \cdot m^{-2} \cdot K^{-4}$$

Grey Body: actual emissivity (ε)

$$E = \underline{\varepsilon \cdot \sigma} \cdot T^4$$

- A perfect blackbody: $\varepsilon = 1$
- Real materials: $0 < \varepsilon < 1$

Planck's Radiation Law describes the electromagnetic radiation emitted by a black body in thermal equilibrium at a given temperature. This is described by :

$$E = \frac{h \cdot c}{\lambda}$$

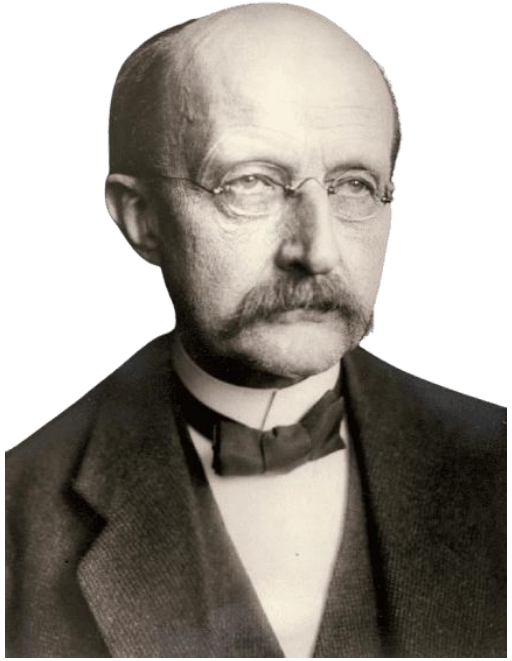
h = Planck's constant; 6.62607015×10^{-34} joule/s (J/s)

λ = frequency of radiation (nm)

c = speed of light (m/s)

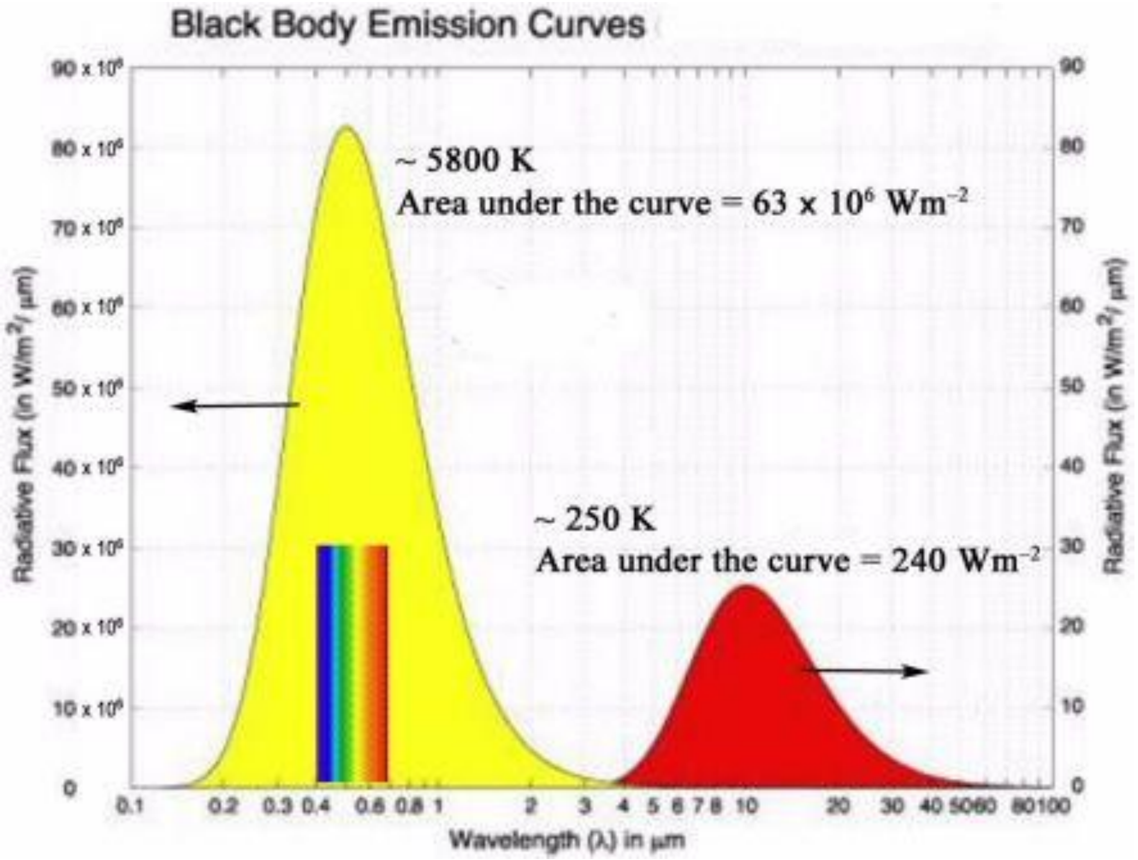
$$B(\nu, T) = \frac{2h\nu^3}{c^2}\frac{1}{\frac{hv}{ek_BT} - 1}$$

Planck's Law is a mathematical relationship formulated in 1900 by German physicist Max Planck to explain the spectral-energy distribution of radiation emitted by a blackbody (a hypothetical body that completely absorbs all radiant energy falling upon it, reaches some equilibrium temperature, and then reemits that energy as quickly as it absorbs it).



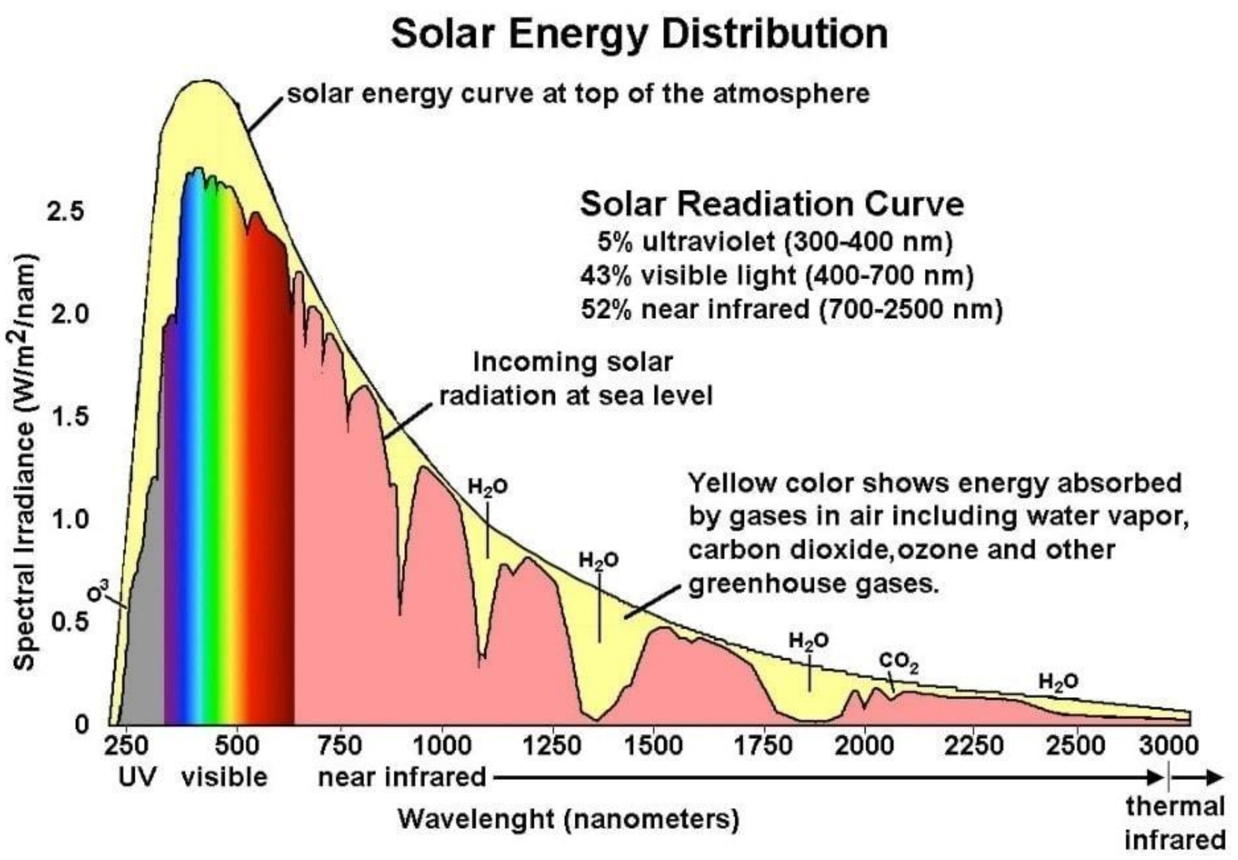
1) Radiant emittance from the sun (T = 6000 K) varies from 0.2 nm to 3.0 nm and peaks at spectra of ~0.55 nm, with most energy coming from a wavelength of 0.3-0.7 nm (>50%). These wavelengths are loosely called "shortwave radiation" or "visible light").

2) The Earth's (T = 288 K) peak emittance is 9.5-10.0 nm. In sum, Earth's temperature is mostly maintained by the balance of incoming shortwave radiation from the sun and outgoing longwave radiation from the Earth.



https://www.pinterest.com/pin/561964859722645297/

- Earth's atmosphere is composed of many gases and particles. Nitrogen (~78%) and oxygen (~21%) are the two major chemical species. Other species, including water, argon, carbon dioxide, neon, helium, methane, krypton, hydrogen, nitrous oxide, xenon, ozone, carbon monoxide, and ammonia, account for <1%.
- The atmosphere also contains a large amount of particulate matters and biological materials that can affect the energy balance of the Earth. For example, an increase in the amount of aerosol deposition on snow and glacier surfaces will reduce and, consequently, keep more energy within the Earth system. Volcanic eruptions, large-scale fires, and industrial production are major sources of aerosols at global scale.



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Sep 10: Greenhouse Effects on Global Climate & Change

- Physical Foundations for Global Climate Change (finishing up)
- What is greenhouse effect?
- Major Greenhouse Gases (GHG)

Reading

Chen, J., C. Lei, and P. Sciusco, 2021. Modeling Ecosystem Global Warming Potentials. In *Biophysical Models and Applications in Ecosystem Analysis* (pp. 121-126). MSU Press.