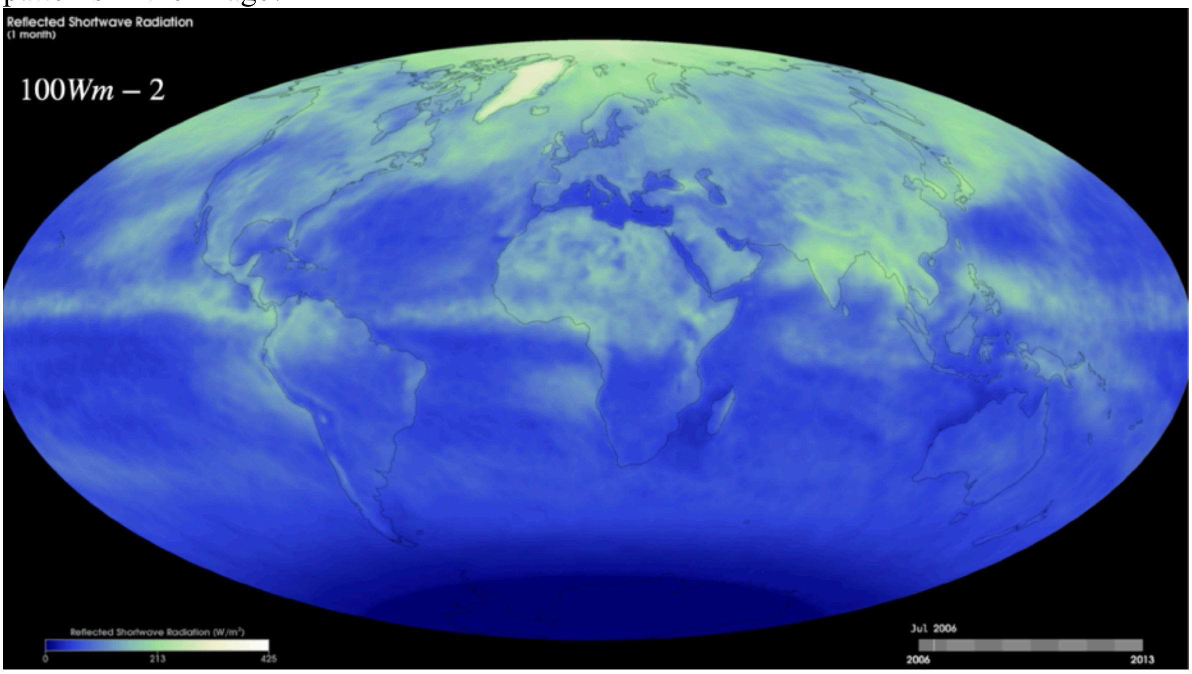
Class Exercise for CM615

1. A pollutant has a steady-state atmospheric burden (Q) of 1000 kg. Its removal rate (R) is 20 kg/day. Calculate the atmospheric lifetime (τ) of the pollutant in days.

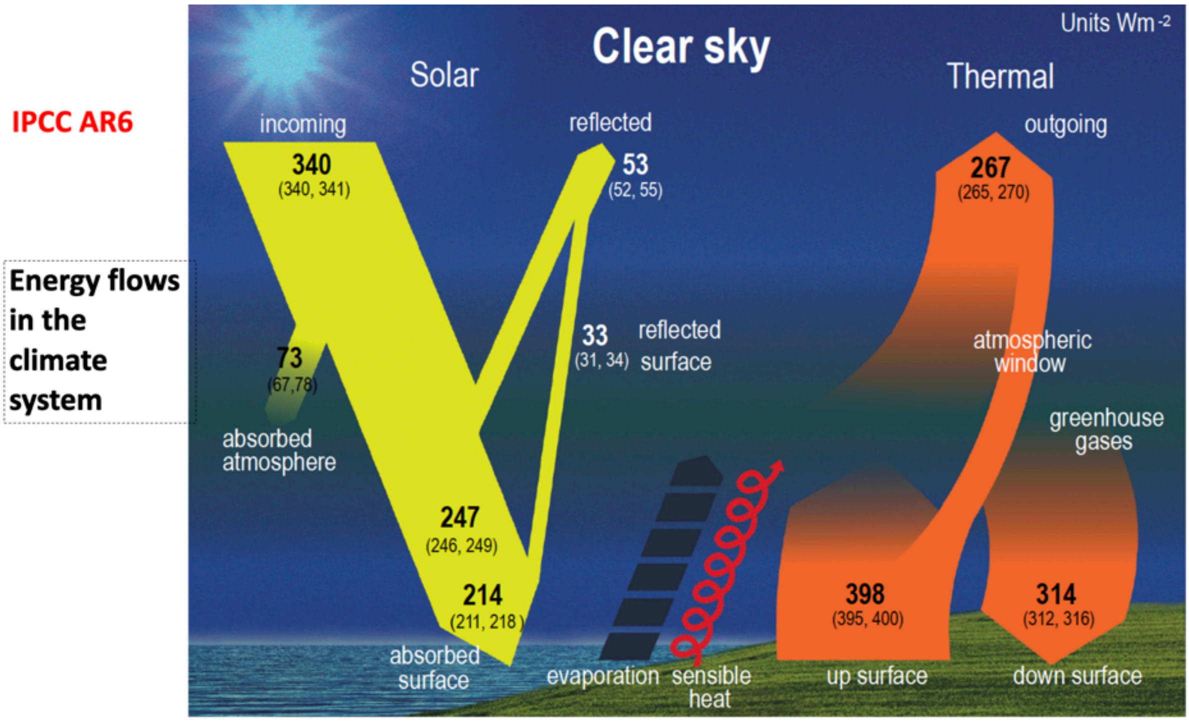
2. A chemical is produced in the atmosphere at a rate (P) of 500 tonnes per year. At steady state, its atmospheric lifetime (τ) is 10 years. Calculate the total atmospheric burden (Q) of the chemical in tonnes. What is the annual removal rate (R) of the chemical in tonnes/year?

3. A country reduces its emissions of a greenhouse gas by 50%. The gas has an atmospheric lifetime of 20 years. How long will it take for the atmospheric concentration of the gas to decrease by approximately 50% (assuming all other emissions remain constant)? Explain your reasoning, including any assumptions you make.

4. Why do some regions appear brighter (higher reflection) while others appear darker (lower reflection)? How do factors like cloud cover, surface albedo, and latitude influence the patterns in the image?



5. Use this figure to show that the energy budget at the top-of-the-atmosphere and at the surface have same energy imbalance.



6. Construct one-layer atmosphere. Atmosphere is perfectly transmissive to sunlight but a blackbody absorber in the infrared. Use this model to show under what condition(s) we will have surface temperature to be 288K.

7. For a homogenous atmosphere, derive an expression for pressure? For the same atmosphere, what would be the lapse rate

8. **In the 0-D climate system model**, the equilibrium surface temperature (T_s) is given by with $S_0 = 1361 Wm^{-2}$ and $\alpha = 0.3$:

$$T_s = (\frac{2(1-\alpha)S_0}{4\sigma})^{\frac{1}{4}}$$

A. If the surface temperature increases by **1 K**, estimate the increase in outgoing longwave radiation (OLR) assuming a blackbody response.

B. **Planck feedback** (λ_P) is defined as the change in OLR per unit temperature increase ($\lambda_P = \frac{dF_{OLR}}{dT_s}$). Derive an expression for λ_P and calculate its value at Earth's equilibrium temperature.

C. The total climate feedback parameter (λ_P) also includes contributions from water vapor, ice-albedo, and cloud feedbacks. If these additional feedbacks are estimated to reduce the net feedback parameter to λ= -1.2 W/m²K, calculate the equilibrium temperature change (ΔTs) for a forcing of **4 W/m²** (e.g., forcing when CO_2 is doubled). Compare this with the response under **Planck feedback alone.**