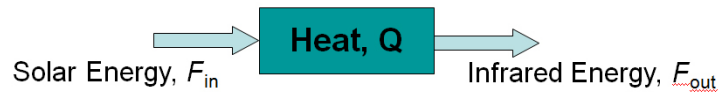


ENVS4450 Coursework - Atmosphere

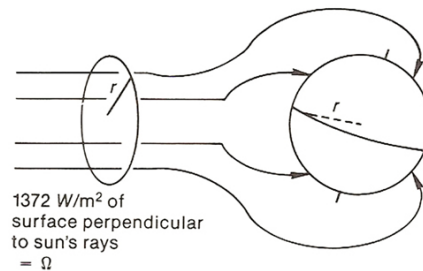
Complete 2 of the 3 parts (A, B, and C)

A. How Hot is Planet Earth?

Earth is continually receiving energy from the Sun and would get hotter and hotter if it did not radiate energy back to space. If the direct solar flux, Ω , is 1372 W/m^2 calculate the Earth's surface temperature using a simple input-output model below:



1. Formulate an expression for F_{in} the direct incoming solar flux received by the Earth.



[Hint: Calculate the ratio of the surface area of the Earth (a sphere) to the area of the disc, the input flux is then equal to Ω divided by this amount.]

2. F_{out} consists of two terms for the outgoing radiative flux, describe what we mean by SW and LW radiation.

$$F_{out} = SW_{out} + LW_{out}$$

Using the symbol ' a ' for albedo and ' Ω ' for solar flux write an expression for SW_{out} .

3. If $LW_{out} = \sigma T^4$ (Stefan-Boltzman law) write an expression for F_{out} which includes a , Ω , σ and T as the only variables.

4. Let $F_{in} = F_{out}$ and solve for T algebraically.

5. Solve for T using an albedo of 30 % and Stefan-Boltzman constant, $\sigma = 5.7 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-1}$.

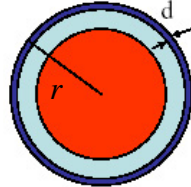
Discuss your answer relative to the Earth's true temperature (288 K). Why is your value for T lower than expected?

B. What is the total mass of ozone corresponding to 350 DU?

1. One Dobson unit is equal to the number of molecules of ozone required to create a layer of ozone 10 microns (μm) thick at standard temperature and pressure.

Show that the volume of ozone in the atmosphere is equal to $(4/3)\pi [r^3 + d^3 + 3rd^2 + 3r^2d - r^3]$ where r = radius of the Earth and atmosphere (red and light blue) and d = thickness of ozone (dark blue).

[Hint: Subtract the volume of a sphere radius r from the volume of a sphere of radius $(r+d)$]



2. Explain why the volume of ozone in the atmosphere can be simplified to $(4/3)\pi [3r^2d]$.

3. 350 DU of ozone is equivalent to how many meters of ozone?

4. Calculate the volume of ozone at concentration 350 DU using the equation derived above, $(4/3)\pi [3r^2d]$.

5. Use the ideal gas law to calculate the mass of ozone corresponding to 350 DU.

C. Gaussian Plume Model

A truck containing containers of concentrated herbicide crashes 200 m upwind of your garden in which you are growing prize-winning marrows for the summer show. (The velocity of the wind is 5 m s^{-1} and your garden is 25 m perpendicular distance to one side of the direct down-wind centerline).

One of the containers punctures and releases herbicide vapor at the rate of 0.1 kg s^{-1} . A quick back-of-the-envelope calculation on dosage reveals that your marrows are doomed if the herbicide concentration in the air around them rises above $2 \times 10^{-6} \text{ kg m}^{-3}$. For the sake of your marrows, are you thankful that today's weather condition is unstable rather than stable for dispersing of the herbicide vapor? Test your reasoning. What is the difference in the form of the plume in the two scenarios.

1. The standard expression for the Gaussian plume is as follows:

$$c(x, y, z) = \frac{Q}{2\pi\sigma_y\sigma_z u} \exp\left[-\frac{y^2}{2\sigma_y^2}\right] \left(\exp\left[-\frac{(z-H_e)^2}{2\sigma_z^2}\right] + \exp\left[-\frac{(z+H_e)^2}{2\sigma_z^2}\right] \right)$$

2. Compare this equation to the simplified form given to you in class. What are the similarities, what are the differences?

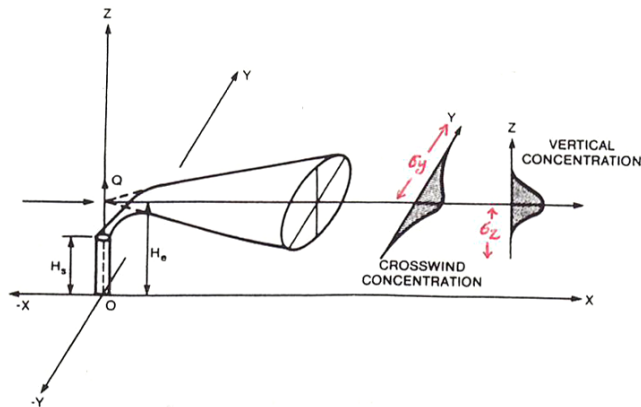
3. From direct manipulation of the equation, write down the expression for the 3-dimensional Gaussian plume concentration arising from emission of a pollutant at ground level.

Q = pollutant emission rate (kg s^{-1})

H_e = effective stack height ($= H + h$)

u = mean wind speed (m s^{-1})

σ_y, σ_z = standard deviation of plume width (x-dependent quantities)



[Hints: set $H_e = 0$, $e^a + e^a = 2e^a$]

2. From direct manipulation of the equation in Q3, write down the expression for the Gaussian plume concentration downwind at ground level ($z = 0$), but not on the centerline ($y \neq 0$).

[Hint: $e^0 = 1$]

4. Calculate the concentration of herbicide that reaches your garden for the unstable conditions where:

$$y = 25 \text{ m}, \sigma_y = 49.7 \text{ m}, \sigma_z = 49.7 \text{ m}$$

4. Calculate the concentration of herbicide that reaches your garden for the stable conditions where:

$$y = 25 \text{ m}, \sigma_y = 13.34 \text{ m}, \sigma_z = 2.58 \text{ m}$$

5. Comment on the shape of the two plumes, how can you tell which plume is larger?