December 19, 2008

Herkansing Tussentoets NS-255B: Klimaat, straling en thermodynamica

General remarks:
→ Read the text carefully!
→ Pay attention to the units! Do not use different units in a calculation. It is safest to use SI units.
→ It is ok to write in Dutch!
→ You may use textbook, lecture handouts, and calculator.
→ Some exercises are easier than others.

Exercise 1:

Briefly comment on following statements: (true, not true, explain why!!)

a. The colors of stars are related to their temperatures whereas the colors of the planets are not.

b. The equilibrium temperature of Venus is lower than that of Earth, even though Venus is nearer to the sun.

c. Low clouds emit more infrared radiation than high clouds of comparable thickness.

d. On a clear, still night (other factors being the same) the surface temperature drops more rapidly when the air above is dry than when it is moist, even before dew begins to form.

Exercise 2:

Measuring air pollution due to particles by mass can be quite misleading in terms of their ultimate impacts, for example health. For example, the results of some laboratory studies show that ultra fine particles cause inflammatory responses while larger particles with the same chemical composition do not. Calculate how many particles with diameter 0.2 μm would need to be collected on a "hi-vol" sampler (which is essentially just a filter on which the particles are trapped) to have the same mass as one particle of 20 μm. Assume they have the same chemical composition and hence equal density.

Exercise 3:

Consider a simplified planet-atmosphere system where a thin atmospheric layer is at some distance from the surface of the planet. The albedo of the planet's surface is A. The surface perfectly absorbs infrared radiation; i.e. it can be considered a blackbody in this wavelength region. There is no scattering of sunlight in the atmosphere, so the albedo of the atmosphere by itself is 0. The transmissivity of the atmosphere is τ_s for sunlight and τ_i for infrared radiation. The average incident solar radiation per surface area of the planet is Q. (For clarification: of the incident radiation Q the fraction $\tau_s Q$ is transmitted through the atmosphere, and the fraction $(1-\tau_s)Q$ is absorbed.). Start with accurate sketch of the model!

a) Show that the surface temperature T_0 of the planet is given by following relation:

$$\sigma T_0^4 = Q\left[\frac{1+\tau_s}{1+\tau_i}\right](1-\tau_s A)$$

b) Using the relation above show that for some choices of τ_s, τ_i, and A the surface temperature is lower than the equilibrium temperature T_E of the planet. (This would be a sort of negative greenhouse effect. HINT: $\sigma T_E^4 = Q$ – the fraction of Q that is reflected back into space). To understand the situation qualitatively, assume A=0 and explain in few words what is going on in this scenario.

Exercise 4:

Assuming that the atmosphere consists of a homogeneous layer of air from sea-level to 3 km with an extinction coefficient (i.e. the combined scattering and absorption coefficient) of 1×10^{-4} m^{-1}, another homogeneous layer from 3 to 10 km with an extinction coefficient of 3×10^{-5} m^{-1}, and a third homogeneous layer from 10 to 20 km with an extinction coefficient of 1×10^{-6} m^{-1}, what is the total column optical depth of the atmosphere? What fraction of the solar radiation penetrates to the surface at a solar zenith angle of 50°?

Exercise 5:

The amount of OH in the upper troposphere is dependent on the intensity of solar UV radiation in the tropopause region ([OH] is proportional to $I_{tropopause}$). The incoming radiation is reduced in the stratosphere because some of the sunlight is absorbed by ozone. Assume an optical depth of 2 for the stratosphere (due to ozone) and calculate the relative change of OH if the stratospheric ozone decreases by 10%.

Exercise 6:

CO2 in cloud water: Calculate the concentration of dissolved CO_2 (carbonic acid + bicarbonate + carbonate) in cloud water with a pH value of 8. The liquid water content is 1 g m^{-3}, the temperature 25 °C, total number of molecules 2.5 10^{25} molec m^{-3}, Henry's law constant 3.4 10^{-2} M/atm (1M = 1 mol/liter), first and second dissociation constant 4.4 10^{-7} M and 4.7 10^{-11} M, respectively. The cloud parcel is in equilibrium with a CO_2 mixing ratio of 380 ppm. What fraction of CO_2 is dissolved in cloud water?