November 4, 2008

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:
General questions/short exercises:
a.) Would you expect the total radiation emitted by an object to be proportional to (a) its surface area, (b) its volume, (c) its mass, (d) none of the above? Why?
b.) If the Earth were twice its distance from the Sun, by how much would its effective temperature decrease?
c.) In our calculation of the effective temperature of the Earth we viewed the Earth as a blackbody. However, we also accounted for the fact that the Earth absorbs only 72% of solar radiation (albedo = 0.28), so obviously the Earth is not a very good blackbody (which would absorb 100% of all incoming radiation). Nevertheless, the assumption that the Earth emits as a blackbody is correct to within a few percent. How can you reconcile these two results?
d.) A chemical species is removed from the atmosphere by chemical reaction with a lifetime of 2 years, and by deposition with a lifetime of 1 year. What is its atmospheric lifetime?

Exercise 2:
Briefly comment on following statements: (true, not true, 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.
e.) Objects viewed in direct sunlight, particularly around sunrise and sunset have a reddish color?
f.) Pressure in the atmosphere increases approximately exponentially with depth, whereas the pressure in the ocean increases approximately linearly with depth.

Exercise 3:
Mars is 2.3×10^8 km away from the Sun; its albedo is 0.15. Its only source of heat is solar radiation. Calculate the effective temperature of Mars. The temperature observed at the

surface of Mars is 220 K. Develop a one layer atmosphere model to simulate the situation. What fraction of the Martian radiation is absorbed by the atmosphere?

Exercise 4:

During the Mt Pinatubo eruption in 1991 large amounts of SO2 (about 17 million tons) were emitted into the stratosphere. After photochemical degradation to H2SO4 a stratospheric aerosol layer was formed that increased the optical depth of the stratosphere by a factor of 100 to an average value of ~0.08. Simulate this forcing by adding a thin stratospheric layer to the simple 1-layer atmosphere model. The stratospheric layer does not absorb terrestrial or solar radiation. There is no scattering of terrestrial radiation but solar radiation is scattered which results in the increased optical depth mentioned above. Use Fs=1370 W/m2, albedo A=0.3 (atmosphere surface), f=0.77.

a.) Calculate the albedo, A*, of the stratospheric layer before and after the eruption. [result: A^*_{before}=0.8E-3, A^*_{after}=0.077]

b.) Calculate the equilibrium temperature of the Earth's surface before and after the eruption. Since both values of A* are small you do not need to consider the effects of back and forth scattering between the 2 albedo layers.

Exercise 5:

It has been suggested hat hydrogen in the Earth's primitive atmosphere led to the production of CH_4 by the reaction

$$CO_2\ (g) + 4H_2\ (g) \underset{k_{backward}}{\overset{k_{forward}}{\rightleftharpoons}} CH_4\ (g) + 2H_2O\ (g)$$

a) The equilibrium constants k_{eq} for this reaction at 300 and 400 K are 5.2×10^{19} and 2.7×10^{12} bar^{-2}, respectively. If the partial pressures of H_2O, CO_2, and H_2 in the primitive atmosphere were taken to be 3.0×10^{-2}, 3×10^{-4}, and 5.0×10^{-5} bar, respectively, what are the equilibrium pressures of CH_4 at 300 and 400 K?

b) The equilibrium constants $k_{eq}=k_{forward}/k_{backward}$. At 400 K $k_{forward}$ is large, but at 300 K it is immeasurably small. Is it likely that this reaction was responsible for the conversion of much H_2 into CH_4 in the primitive atmosphere? Why, or why not?

Exercise 6:

The amount of OH in the upper troposphere is dependent on the intensity of solar UV radiation in the tropopause region. 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 and calculate the relative change of OH if the stratospheric ozone decreases by 10%.