

Answers to questions test 1 Climate Dynamics 17 April 2013.

Problem 1

Planetary albedo is defined in section 2.2 as one minus the ratio of top net Solar radiation and incoming Solar radiation at TOA. Therefore, you do not need need information of net Solar radiation at the Earth's surface. Information given figures 1 and 3 will suffice to compute the planetary albedo.

Problem 2

(a) Answer is given in section 2.2, eq. 2.2.

(b) Answer is given in section 2.3, eq. 2.10.

(c) In radiative equilibrium: $OLR - TOA = ASR$, i.e.

$$OLR - TOA = (1 - \epsilon)U + B = \frac{S_0}{4}(1 - \alpha) = \sigma T_E^4 = \frac{2 - \epsilon}{2} \sigma T_S^4 \quad (\text{see part b or eq. 2.10})$$

(c) Climate sensitivity is proportional to

$$\frac{\partial T_S}{\partial (OLR - TOA)} = \left(2(2 - \epsilon) \sigma T_S^3 \right)^{-1}.$$

It can easily be seen that climate sensitivity increases with increasing value of ϵ , because a larger increase of the surface temperature is required to accommodate a certain decrease of $OLR - TOA$ for a fixed increment of ϵ .

Problem 3

See the discussion of figure 2.21 in the lecture notes. In the upper half of the atmosphere, temperature is determined by atmospheric absorption and emission. If the absorption coefficient, or equivalently, the emission coefficient, ϵ , is very low, the radiative response time becomes comparable to or larger than one year (eq. 2.20). In other words, the upper atmosphere is unable to keep up with seasonal cycle of insolation. In the lower atmosphere, especially near to the Earth's surface, temperature is determined (also) by the temperature of the Earth's surface, which, since it is approximately a black body, responds almost instantaneously to insolation.

Problem 4

An absorption length of 10 m implies that radiation is attenuated by a factor $(1/e)$ while it travels a distance of 10 m (see Box 2.1). This is the same as saying that the optical path is 1 over a distance of 10 m.

Problem 5

If clouds have warming effect ASR increases faster than $OLR - TOA$ with increasing cloud cover fraction. So, we have to determine when the criterion

$$\frac{\partial(ASR)}{\partial A_c} > \frac{\partial(OLR - TOA)}{\partial A_c}$$

is satisfied. The above inequality becomes

$$\frac{S_0}{4}(\alpha_G - \alpha_C) > c = -1.7(T_S - T_C)$$

which leads to

$$(T_S - T_C) > \frac{S_0}{4 \times 1.7}(\alpha_C - \alpha_G) = \frac{1366}{4 \times 1.7}(0.45 - 0.1) = 70.31 \text{ K}.$$