Department of Physics and Astronomy, Faculty of Science, UU.
Made available in electronic form by the TBC of A–Eskwadraat
In 2007/2008, the course NS-MO429 was given by R.S.W. van de Wal.

Climate Dynamics (NS-MO429)
23 juni 2008

Question 1

The equation governing the global average, yearly average, T, of the Earth's surface is, according to Budyko,

$$C\frac{dT}{dt} = \frac{S_0}{4}(1-\alpha) - I_0 - bT$$

S_0 is the Solar constant; C is a heat capacity.

a) What physical processes are captured by this equation?

b) Empirically, Budyko obtained $I_0 = 205 Wm^{-2}$ and $b = 2.23 Wm^{-2}\ ^\circ C^{-1}$ What kind of measurements did Budyko use to obtain these values?

c) Assume that within a cartain range of temperatures $T_o < T < T_1$ the global average albedo, α, is temperature-dependent as follows (T is expressed in $^\circ C$):

$$\alpha = \begin{cases} \alpha_0 & \text{if } T \le T_0, \\ \alpha_0 + \frac{T-T_0}{T_1-T_0}(\alpha_1 - \alpha_0) & \text{if } T_1 \ge T > T_0, \\ \alpha_1 & \text{if } T \ge T_1. \end{cases}$$

The emperical parameters have the following values: $\alpha_0 = 0.6$; $T_0 = -10^\circ C$; $\alpha_1 = 0.25$; $T_1 = 0^\circ C$.

In other words, three temperatur eintervals can be ditinguished with different behaviour of the albedo. how many equilibrium states does the system have given that $S_0 = 1366 Wm^{-2}$?

d) Calculate the radiative equilibrium temperature in the middle temperature range ($T_1 > T > T_0$).

e) Can the equilibrium temperature calculated in (d) be sustained? In other words, is it a stable equilibrium?

Question 2

The equations governing the time-evolution of the number concentrations of the oxygen (O) atom (n_1) and the ozone (O_3) molecule (n_3) are

$$\begin{aligned} \frac{dn_1}{dt} &= 2j_a n_2 - k_b n_1 n_2 n + j_c n_3 - k_d n_1 n_3 \\ \frac{dn_3}{dt} &= k_b n_1 n_2 n - j_c n_3 - k_d n_1 n_3 \end{aligned}$$

a) Describe the reactions that form the basis of these equations.

b) The above system of two equations has 4 unkowns. Therefore, it cannot be solved. What equations would you use and assumptions would you make in order to solve the system?

Question 3

What does the Stommel model have to say about the role of the ocean in the climate on Earth?