Climate Dynamics
Summer Semester 2018

UNIVERSITÄT LEIPZIG

Homework 1
Due 25 April 2018

Problem 1 A very simple model of global warming

In this problem, we will build our first model. This is a very simple model – as we will see, too simple. But over the course of the semester, we will continually refine this model until it can reproduce many of the most interesting features of the real climate system.

(a) The sun radiates energy isotropically into space. At the mean sun–earth distance, the solar energy flux is $S_0 = 1360$ W m^{-2}. The solar irradiance measured at a point on earth depends on latitude, time of year, time of day, and of course atmospheric composition. However, the global-mean solar irradiance at the "top" of the atmosphere (TOA) is a very simple function of S_0. Determine its value.

(b) Let us ignore the land surface for the moment and consider the climate system to consist of the atmosphere and the upper, "mixed" layer of the ocean. What are the heat capacities of each? Assume 100 m as the mixed layer depth, 4 kJ kg^{-1} K^{-1} as the specific heat of water, 1000 kg m^{-3} as the density of water, 1 kJ kg^{-1} K^{-1} as the specific heat of air, 1000 hPa as the surface pressure, 10 m s^{-2} as the gravitational acceleration at the surface, and 6000 km as the earth radius.

(c) If the climate system was initially in equilibrium (i.e., no net energy loss or uptake), let us now consider what happens if we perturb it by $F = 4$ W m^{-2}, approximately the forcing of a doubling of the CO_2 concentration. Our climate model is simply this:

$$c\frac{dT}{dt} = FA, \tag{1}$$

where c is the heat capacity of the climate system, T is the surface temperature, and A is the earth's surface area. According to the heat capacity that you calculated in the previous problem, at what rate will the surface temperature increase?

(d) Considering only the processes we have included in this model, will the climate system reach a new equilibrium state? If not, what processes did we neglect?