EV20001: ENVIRONMENTAL SCIENCE

Assignment #2: Climate Change

(DUE 03 MARCH 2021)

1. In 2013, fossil fuels accounted for a global energy supply of 300 quadrillion kJ. (a) If all fossil fuels can be represented by the generic formula C_3H_5 with an average energy content of 40,000 kJ/kg, estimate the amount of CO_2 released to the atmosphere by burning fossil fuels in 2013. (b) If all the CO_2 entered the atmosphere (and none was assimilated), determine the increase in atmospheric CO_2 concentration, in parts per million (ppm) by volume. Assume that the atmosphere contains 5×10^{18} kg of air with a composition of 79% N_2 and 21% O_2, and has a molecular weight of 29 kg/kg mol. **[2½ + 2½ = 5]**

2. The simplest way to describe the change in the global energy budget is

$$\Delta Q = \Delta F - \lambda \Delta T$$

i.e., the difference between ΔF (W/m^2), the additional radiative forcing due to increased greenhouse gases and other atmospheric forcings, and the increased loss of energy to space that results from it, $\lambda \Delta T$ (assumed to be proportional to the global surface warming ΔT), equals the net energy uptake of the Earth ΔQ. The latter is dominated by ocean heat uptake, and is proportional to the warming according to the relation

$$\Delta Q = \kappa \Delta T$$

Based on the observed warming, ocean heat uptake, as well as models, $\kappa = 0.6$ W/m^{2}K and $\lambda = 1.4$ W/m^{2}K. The radiative forcing from the atmospheric CO_2 concentration c (ppm) relative to the preindustrial value of 280 ppm is given by

$$\Delta F = 5.35 \ln\left(\frac{c}{280}\right)$$

All values given above are approximate only.

(i) Assume a simple scenario where we continue to emit CO_2 at similar rates as in the past. Calculate the CO_2 concentration when we reach the internationally agreed temperature target of 2 °C above preindustrial. **[1]**

(ii) 2.1 Gt C (in the form of CO_2) corresponds to an increase in the atmospheric CO_2 concentration of 1 ppm. Of the anthropogenic emissions from fossil fuel use, land use and deforestation, about 50% remain in the atmosphere (while emissions continue); the rest is taken up by the ocean and biosphere. Calculate the emissions in Gt C that lead to the CO_2 concentration estimated in (i). **[1]**

(iii) The calculated emissions in (ii) give the total amount of carbon that can be emitted starting in preindustrial for the 2 °C target, but it ignores the non-CO_2 forcings. Assume that about 0.5 °C warming is caused by other forcings and as much as 540 Gt C have already been emitted so far. Estimate the remaining carbon budget. **[1]**

(iv) The budget estimated in (iii) is a best estimate, and therefore gives a 50% chance of being below 2 °C, and 50% above. For a higher certainty to actually remain below the target, e.g. 66%, we would have to assume a more pessimistic assumption for the climate feedbacks, e.g., $\kappa + \lambda = 1.8$ W/m^{2}K. Current global emissions are about 10 Gt C/yr. How many years at current emissions could we continue before we exceed the new budget? **[2]**