On admission to the examination room, you should acquaint yourself with the instructions below. You must listen carefully to all instructions given by the invigilators. You may read the question paper, but must not write anything until the invigilator informs you that you may start the examination.

You will be given five minutes at the end of the examination to complete the front of any answer books used.

DO NOT REMOVE THIS QUESTION PAPER FROM THE EXAM ROOM.

April 2015 **MTMG16/ 2014/15 A001**

Answer Book
Any bilingual English language dictionary permitted
Any non-programmable calculator is permitted

UNIVERSITY OF READING

Climate Change (MTMG16)

Two hours

Answer **ANY TWO** questions

The marks for the individual components of each question are given in [ ] brackets. The total mark for the paper is 100

1. (a) How did Earth's orbit around the sun differ 10,000 years ago compared to today? Explain whether the configuration 10,000 years ago was conducive to glacial or interglacial conditions based upon the mechanisms laid out by Milankovitch.

[10 marks]

(b) Explain why carbon dioxide is considered a forcing over the past hundred years and a feedback over the glacial cycles of the past million years.

[12 marks]

(c) Over the past 100 years there have been a number of explosive volcanic eruptions. Explain how these affect the climate system over the following years.

[8 marks]

(d) Following the eruption of the Mount Pinatubo volcano in 1991, observations show that mid to upper tropospheric specific humidity decreased by about 10% in response to a 0.5 K cooling of global average surface temperatures. Assuming a sensitivity of outgoing longwave radiation to increases in mid to upper tropospheric specific humidity of $-0.1\ Wm^{-2}$ per %, estimate the water vapour feedback parameter, Y_W.

[4 marks]

(e) Assuming that the total feedback parameter,

$$Y = \frac{\partial}{\partial Ts}\left(k{T_S}^4\right) + Y_W,$$

compute the equilibrium surface temperature response (ΔT_{eq}) to a constant radiative forcing of +4 Wm^{-2} where initially T_s = 289 K and constant k = 3.4x10 $^{-8}$ $Wm^{-2}K^{-4}$

[4 marks]

(f) Using your estimate of Y computed in (e), considering the transient climate change equation relating to a constant radiative forcing shown below, after how many years will it take for surface temperature (ΔT) to increase by more than 2^{o}C? Assume C_S = 30 $Wm^{-2}K^{-1}yr$. Draw a graph to illustrate this.

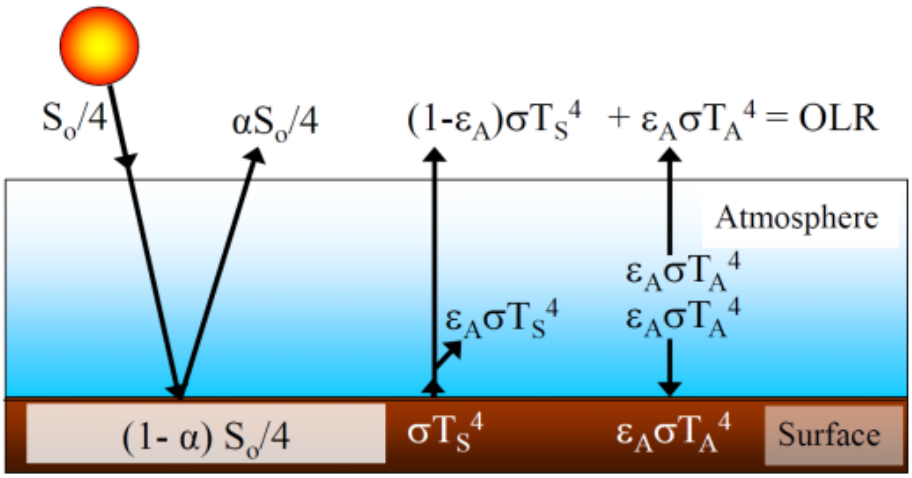
$$\Delta T(t) = \Delta T_{eq}(1 - e^{-tY/C_S})$$

[6 marks]

(g) Why are societies “committed” to continued sea level rise after greenhouse gas concentrations are stabilised?

[6 marks]

2. (a) The diagram below illustrates a simple global average energy balance representation of the climate system which assumes a zero heat capacity surface and atmosphere.



Explain what ALL terms in the diagram represent.

[15 marks]

(b) Based upon (a) write the energy balance equation at the surface and in the atmosphere.

[4 marks]

(c) Compute T_s from your answer to (b) assuming that S_o = 1361 Wm^{-2}, ε_A = 0.9, α = 0.3 and $\sigma = 5.67 \times 10^{-8}$ $Wm^{-2}K^{-4}$. How does this compare with current global average temperatures?

[4 marks]

(d) Comment on what important terms in the global annual average energy balance are missing from the simple energy balance model in (a).

[8 marks]

(e) Observations indicate that the net downward radiative flux at the top of Earth's atmosphere is about 0.6 Wm^{-2}. Assuming that this radiative imbalance remains constant and all of this energy flux accumulates evenly throughout the oceans, what rate of warming would be expected in K/century? Assume a specific heat capacity of sea water of 3900 $Jkg^{-1}K^{-1}$, a global surface area of 5.1×10^{14} m^2 and that the total mass of the oceans is 1.4×10^{21} kg.

[4 marks]

(f) What are the implications for climate change adaptation of the rate of temperature rise computed in (e)?

[4 marks]

(g) Explain why the estimated warming rate in (e) is likely to be unrealistic.

[6 marks]

(h) From your answer to (e) estimate the global rate of sea level rise in cm/century (assume a thermal expansivity of 1×10^{-4} K^{-1} and a mean ocean depth of 3600m). What additional contribution to sea level rise is not considered in this calculation?

[5 marks]

3. The Minister for Climate Change is too busy to read the Intergovernmental Panel on Climate Change summary for policy makers.

   (a) Describe to her in detail the evidence that backs up the following statement: “Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system.”

   [35 marks]

   (b) Summarize for the Minister what the following statement means: “Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.”

   [15 marks]

(End of Question Paper)