Candidates are admitted to the examination room ten minutes before the start of the examination. On admission to the examination room, you are permitted to acquaint yourself with the instructions below and to read the question paper.

Do 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.

April 2009

Answer Book
Data Sheet

Any bilingual English language dictionary permitted
Calculators and programmable calculators are permitted

UNIVERSITY OF READING

MSc/Diploma
Course in Atmosphere, Ocean and Climate
Course in Applied Meteorology
Course in Numerical Modelling of the Atmosphere and Oceans

Paper MTMG16

Climate Change

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) An expression for the global heat balance of the climate system is

$$\Delta Q = -Y\Delta T + \Delta F$$

where ΔQ is the net downward radiative flux at the top of the atmosphere, ΔT is the globally averaged surface temperature change from equilibrium, ΔF is the radiative forcing, and Y is the climate feedback parameter. With reference to the above, derive an expression for the surface temperature change at equilibrium, and show how one can derive the climate sensitivity in terms of Y from your expression. [6 marks]

(b) In general, for a feedback mechanism C_i,

$$Y_i = -(\partial Q/\partial C_i)(\partial C_i/\partial T)$$

Show using the above formulation that the climate feedback parameters associated with both water vapour column amount *q* and sea-ice fraction *F* are negative. What do these changes in Y imply for the climate sensitivity of the climate system? Using the above formulation explain why the uncertainty in the cloud feedback parameter is so large. [16 marks]

(c) For the following climate systems with the feedback parameters below, calculate the minimum and maximum values of the total feedback Y (which is the sum of the individual feedback parameters) and the minimum and maximum values of the climate sensitivity

(i) $Y_a = 3.0$, $Y_b = -1.0$, $Y_c = -0.5$ to $+0.5$
(ii) $Y_a = 3.0$, $Y_b = -2.0$, $Y_c = -0.1$ to $+1.0$
(iii) $Y_a = 3.0$, $Y_b = -1.0$ to -1.5, $Y_c = 0.3$

[9 marks]

Question 1 continued overleaf

Question 1 cont'd.

(d) (i) Name three different types of climatically important aerosols in the atmosphere.
(ii) Describe the difference between the direct and indirect effects of aerosol.
(iii) Explain why the geographical pattern of radiative forcing associated with anthropogenic black carbon aerosol is different to that associated with CO_2.
(iv) For a volcanic eruption, the maximum change in temperature following an eruption lags the maximum change in ΔF. Why is this?

[19 marks]

Turn over

2.

"They can't even forecast the weather for next week, so why should we believe all these predictions of global warming?"

This is a commonly repeated argument for dismissing predictions of climate change and global warming. Write a response to this statement which explains that, although deterministic weather forecasting is not possible beyond about a week, making forecasts of the climate many decades into the future is still a valid exercise. You should discuss the similarities as well as the differences between the two types of forecast and describe how the computer models used to forecast the weather must be adapted to make climate forecasts. State how we can test the skill of our climate models in order to have more confidence in their predictions, and how we can use climate models to make estimates as to the likelihood or probability of particular forecast outcomes. [50 marks]

Turn Over

3.

(a) The IPCC 4th assessment estimated that 21st century global average near-surface temperature increase is likely to be between 1.1 and 6.4K. Explain the three main types of uncertainty that contribute to future projections of global average temperature, and discuss their relative importance. Discuss, giving examples, whether improvements in climate modelling are likely to lead to increases or decreases in the range of projected 21st century warming.

[12 marks]

(b) Explain why the projected global average near-surface warming between present day and 2040 is almost identical for a wide range of different IPCC emissions scenarios. Discuss whether the relative importance of different sources of uncertainty for global average sea level rise during the 21st century will be the same as for surface warming. [8 marks]

(c) Stabilisation of greenhouse gas concentrations at 500ppmv (CO_2 equivalent) is likely to require significant cuts in annual emissions of greenhouse gases. Discuss four different mechanisms or technologies that might be used to achieve these emissions reductions, including the relative advantages and disadvantages.

[14 marks]

Question 3 continued overleaf

Question 3 cont'd.

(d) Assume that a country the size of the UK current emits 0.15 GtC per year. If these emissions were instantly reduced to zero for 50 years show that the resultant change in atmospheric CO_2 levels is approximately 1.8 ppmv. Assume that 50% of CO_2 emissions from today remain in the atmosphere for longer than it takes to stabilise temperature, the mass of the atmosphere is 5×10^{18} kg, and that the molar weights of C, CO_2 and air are 12, 44 and 29 respectively.

[6 marks]

What radiative forcing change is associated with this reduction in CO_2 concentration? Assume that $F=5.4 \ln((C)/C_0)$ where C is CO_2 concentration, and C_0 is 280 ppmv. Also assume a background future CO_2 concentration of 550ppmv. Approximately what equilibrium temperature change does this correspond to?

[8 marks]

Discuss the implication of this temperature change in the context of avoiding dangerous climate change. [2 marks]

(End of Question Paper)