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 2012

Answer Book
General Data Sheet
Any bilingual English language dictionary permitted
Only Casio-fx83 calculators are permitted

Final Examination for MSc

Course in Applied Meteorology
Course in Atmosphere, Oceans and Climate
Course in Data Assimilation and Inverse Modelling in Geosciences
Course in Applied Meteorology and Climate with Management

MTMG21

Oceanography

Two hours

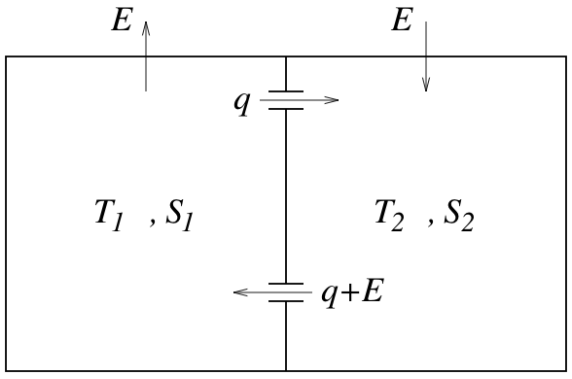
Answer **ANY TWO** questions

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

1. (a) A simple model of a hemispheric ocean basin consists of two well-mixed boxes. The temperatures of each box are maintained at their initial values through air-sea heat fluxes, but the salinities are allowed to vary in response the prescribed air-sea freshwater transports, E, sketched below and a thermohaline circulation whose strength is a linear function of the density difference between the boxes,

$$q = k\,(\alpha\,\Delta T - \beta\,\Delta S).$$

Here α and β are expansion coefficients for heat and salt, $\Delta T = T_1 - T_2$ is prescribed temperature difference, $\Delta S = S_1 - S_2$ is the unknown salinity difference, and k is a constant.



(i) By writing down a salt budget for either box, show that in a steady state:

$$|q|\,\Delta S \approx E\,S_0$$

where S_o is a mean salinity.

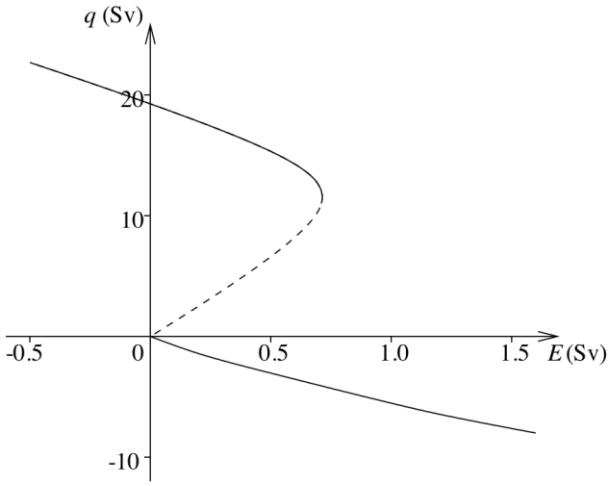
Why is there a modulus sign in this relation?

(ii) Thus show that the equilibrium transport is determined by the quadratic equation:

$$|q|\,q - k\,\alpha\,\Delta T\,|q| + k\,\beta\,E\,S_0 \approx 0.$$

[15 marks]

(b) The following graph shows solutions for the equilibrium transport, q, as a function of the freshwater transport, E. The dashed part of the curve corresponds to equilibrium solutions that are unstable.



(i) Estimate the transport of the thermohaline circulation in the state corresponding to the present-day North Atlantic, assuming $E = 0.5$Sv.

(ii) Why are increased levels of atmospheric CO_2 likely to lead to an increased freshwater transport, E?

(iii) Thus, using the graph, describe how the thermohaline circulation is likely to respond to increasing levels of atmospheric CO_2.

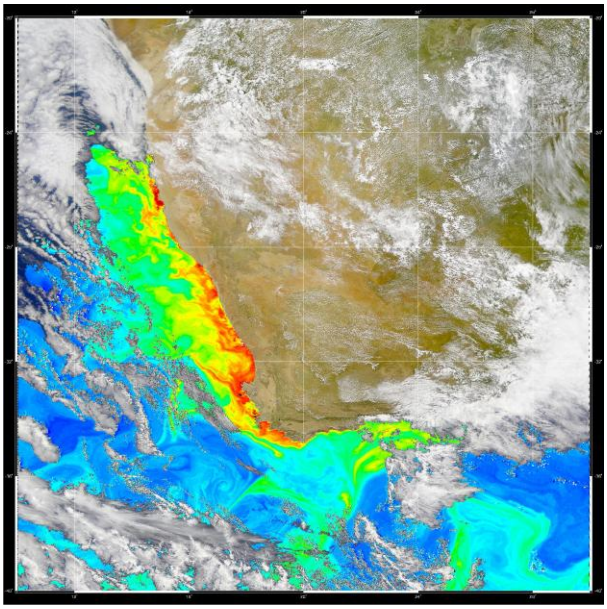
(iv) What is likely to happen to the thermohaline circulation if atmospheric CO_2 subsequently decreases to present-day values?

[20 marks]

(c) Describe how one might monitor the strength of the thermohaline circulation in the Atlantic. In your answer, discuss, the most appropriate choices of observations, the general methodology used to infer the circulation, and the most significant sources of uncertainty.

[15 marks]

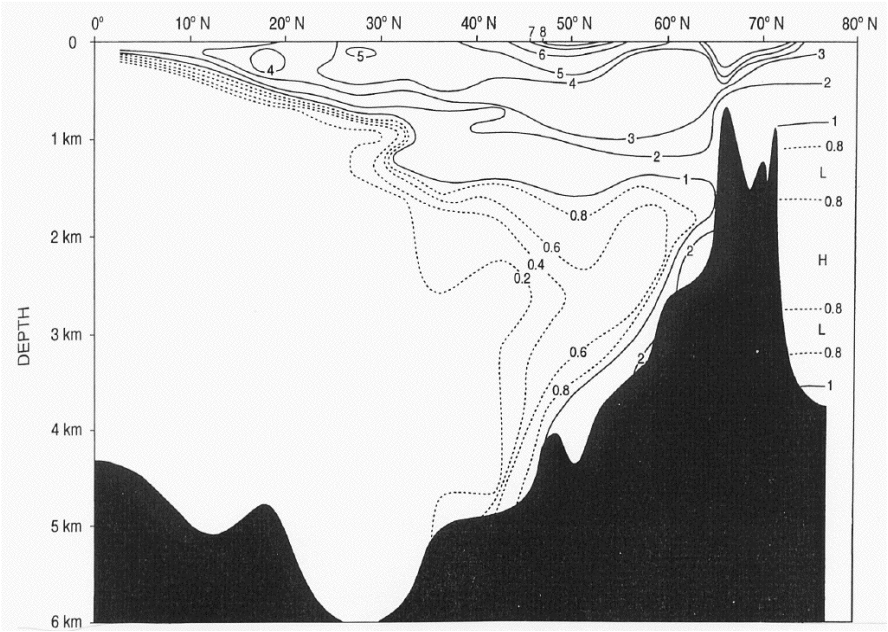
2. (a) The following figure shows surface chlorophyll off the west coast of South Africa.



Describe the physical processes that lead to this distribution.

[15 marks]

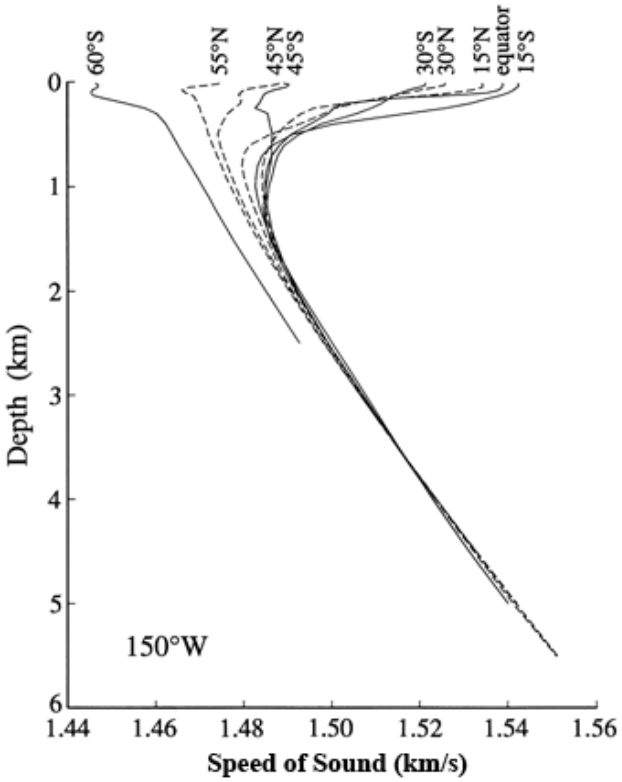
(b) This figure shows the distribution of Tritium on a meridional section through the North Atlantic in 1971.



What does this distribution tell us about the ocean circulation and why?
Explain how, when combined with observations of Helium-3, this data can be used to infer the "age" of a fluid parcel.

[15 marks]

(c) This figure shows the variation of the speed of sound with depth at various latitudes in the Pacific.



Describe, qualitatively, the reasons for the observed variations of the speed of sound with depth and latitude.

Briefly explain how the variation of the speed of sound gives rise to a sound channel in the ocean and how this sound channel might be exploited to monitor basin-scale temperature variations.

[20 marks]

3. (a) Give a brief physical explanation of why the depth-integrated circulation of the oceans is driven predominantly by surface winds rather than by buoyancy forcing.

[8 marks]

(b) Describe what is meant by the "thermohaline conveyorbelt" and sketch its present mode of operation.

Briefly outline the possible impacts of the thermohaline conveyorbelt on the climate of northwestern Europe.

[12 marks]

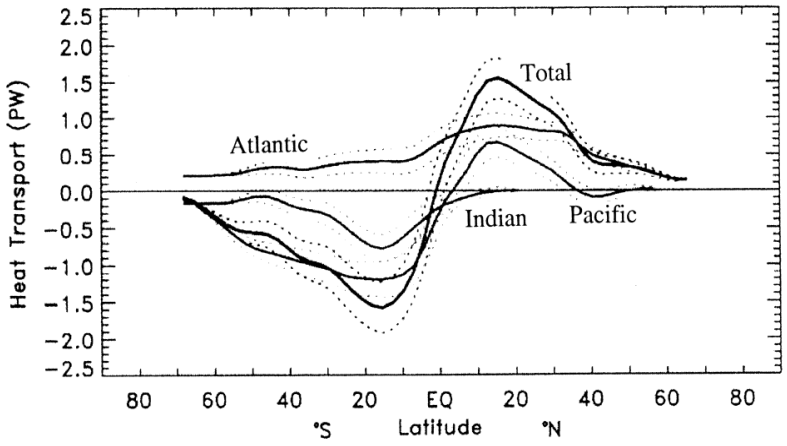
(c) Make rough estimates of the magnitudes and directions of the northward heat transports in the North Atlantic associated with (i) the wind driven subtropical gyre and (ii) the thermohaline conveyorbelt. Clearly state any assumptions that you make.

[8 marks]

(d) Describe how one might make observations in an ocean basin in order to estimate the northward heat transport. In your answer, discuss both the most appropriate choice of observations, the method used to calculate the heat transport, and the most significant sources of uncertainty.

[15 marks]

(e) The following figure shows estimates of the northward heat transports in the major ocean basins.



Briefly discuss the extent to which these distributions can be understood in terms of the wind-driven circulation and thermohaline conveyorbelt. [7 marks]

[End of Question paper]