prioriteit : 2

Faculteit Natuur- en Sterrenkunde
BOZ/Julius Instituut

Tentamenvoorblad
(gaarne zo volledig mogelijk invullen)

vak: NS-MO429M (climate dynamics)

tentamennr.*: 2006/2007 - 42

d.d.: donderdag 1 februari 2007

van 9.00 uur tot 12.00 uur

in gebouw*: BBL zaal*: 160

normering opgaven:

bijzonderheden:

open boektentamen: neen
formuleblad: neen

*) wordt door BOZ ingevuld

Exam

Climate Dynamics MO42gM

Thursday February, 1, 2007 9-12 hrs.

Answers may be given in Dutch or English

1 **Climate History:**

a. Which mechanisms explain the evolution of climate over the last 500 Myrs? Explain them briefly.

Climate over the last 3 Myr is dominated by the waxing and waning of ice sheets in the Northern Hemisphere.

b. How do we usually explain this?

c. Sketch a power spectrum of ice volume over the period 2-3 Myr before present, and one over the last Myr. Explain the difference in the two spectra.

d. Explain from a meteorological perspective why ice ages have a so-called saw teeth character.

e. Sketch sea level over the last 100 kyrs. Indicate separately the contributions from the ice following ice sheets: Greenland, North America, Eurasia, Antarctica.

f. Tomorrow there will be a new IPCC report with a chapter on climate projections for the next century. Explain why there is so much focus on thermal expansion, and why this does not play a major role in the ice age theories.

2. **Stable oxygen isotopes in paleoclimatology.**

a. Explain what fractionation is and why stable oxygen isotopes are widely used in paleoclimatology.

b. Explain the difference in the physical interpretation of marine benthic isotopes and oxygen isotopes in an ice sheet.

c. Sketch the observations of oxygen isotopes in an ice core and marine core over a full glacial cycle and explain your results.

d. Describe qualitatively what we know about the climate based on marine benthic isotopes over the last 60 Myrs.

3. Equator to pole temperature difference

Describe three physical effects/mechanisms that determine the equator to pole temperature difference at the Earth's surface.

4. The Hadley circulation

(a) What is the Hadley circulation?

(b) What drives the Hadley circulation according to the Hou-Held model?

(c) What important driving mechanism is neglected in this model?

5 Thermohaline circulation and climate

In the Stommel model of the thermohaline ocean circulation, the ocean is represented as two reservoirs of well-mixed water connected by "pipes" (see the figure below).

(Taylor, 2005)

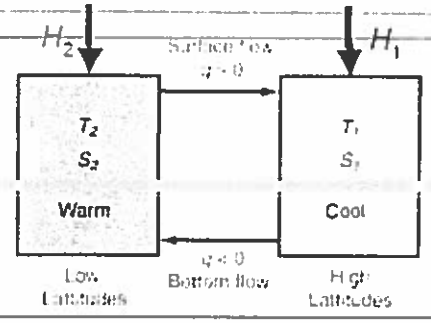

Fig. 11.6

The two reservoirs represent the polar and equatorial regions of the ocean at temperatures T_1 and T_2 (fixed for simplicity).The principle variable is the salinity of the water, S, which is affected by a "virtual" flux H of salt from the atmosphere. The flow of water q between the boxes is proportional to the density difference. Conservation salt is expressed by

$$\frac{dS_1}{dt} = H_1 + |q|(S_2 - S_1)$$

$$\frac{dS_2}{dt} = H_2 + |q|(S_1 - S_2)$$

The flux is given by

$$q = \frac{k}{\rho_0}(\rho_1 - \rho_2)$$

k is an unknown coefficient with the dimension [s^{-1}]. The equation of state for sea water is (approximately)

$$\rho = \rho_0(1 - \alpha T + \beta S)$$

α (>0) is the thermal **expansion** coefficient; β (>0) is the haline **contraction** coeffient. Therefore

$$q = \frac{k}{\rho_0}\Delta\rho = k(\alpha\Delta T - \beta\Delta S)$$

with

$$\Delta T = T_2 - T_1;\ \Delta S = S_2 - S_1$$

The atmosphere-ocean salt flux can be prescribed as follows

$$H_2 = -H_1 \equiv H > 0$$

(a) Why is H>0?

(b) How many steady state solutions does this model have for fixed parameter values?

(c) Which of these steady state solutions represents a salt driven circulation.

(d) Demonstrate that this salt driven steady state circulation is stable to small perturbations.

(e) Is the present day Atlantic thermohaline circulation salt driven?

(f) In which way is the Atlantic thermohaline circulation relevant for the climate on Earth.