EXAMINATION CLIMATE DYNAMICS

30 JUNE 2016 13.30-16.30

1. Paleo climate

1a. Explain which processes determine the $\delta^{18}O$ concentration in an ice core.

1b. Explain which processes determine the benthic $\delta^{18}O$ concentration of a marine sediment core.

1c. Explain why the changes in the benthic $\delta^{18}O$ concentration of a marine sediment cores are small with respect to the changes in an ice core.

1d. One can show that $\delta^{18}O$ concentrations of an ice core may be used as a proxy for temperature changes in the past. Which assumptions are usually made?

1e. Which processes play a role in the inception of the Antarctic ice sheet at the Eocene Oligocene boundary. Mention at least three.

1f. Calculate the ice age halfway the surface and the bottom for an ice sheet of 3000 m thick with an accumulation rate of 0.3 m/yr according to the Nye model concept.

1g. Explain a key shortcoming of the Nye concept.

1h. Sketch the vertical temperature profile in an ice sheet, which is in equilibrium at a position 100 km downstream of the ice divide and explain your sketch.

1i. Provide an explanation for the MPT without any additional external forcing.

2. Climate Sensitivity

Climate sensitivity (S) can be expressed as function of the temperature change (ΔT), the radiative forcing (ΔR) and the feedback strength (f):

$$S=(1-f)*\Delta T/\Delta R$$

It is also argued that climate sensitivity is state dependent.

2a. Explain that the climate sensitivity is state dependent even if we only have the Planck feedback (or Planck response) and no other feedbacks.

2b. Explain why it is important to know the feedback strengths as a function of temperature if you want to derive the climate sensitivity for the present-day climate based on paleo-data.

2c. Calculate the total feedback strength (f) if you may assume that feedbacks double the temperature response with respect to the case that there are no feedbacks.

For a warmer climate it seems reasonable to assume that the land ice feedback is smaller than during LGM conditions.

2d. Explain this.

3. Sea level rise

Assume a circular ice sheet on a flat surface situated around the South Pole, which is in equilibrium with the present climate. The ice sheet ends in the tundra. There is a balance between the accumulation and the ablation and the mass balance is dependent on the elevation.

The average ablation rate is twice the average accumulation rate.

3a. Calculate in terms of the radius (R) the position of the equilibrium line.

3b. What happens if the climate warms and the ablation rate increases and the accumulation rate stays constant in time.

3c. Explain where you expect the largest relative sea level rise.

The same ice sheet is now positioned on a cone with a constant slope in all direction and the highest point of the bedrock in the center of the ice sheet. The ice sheet ends in the ocean. There is no ablation, and the accumulation is balanced by the calving flux. After some time water temperatures increase and the calving flux increases.

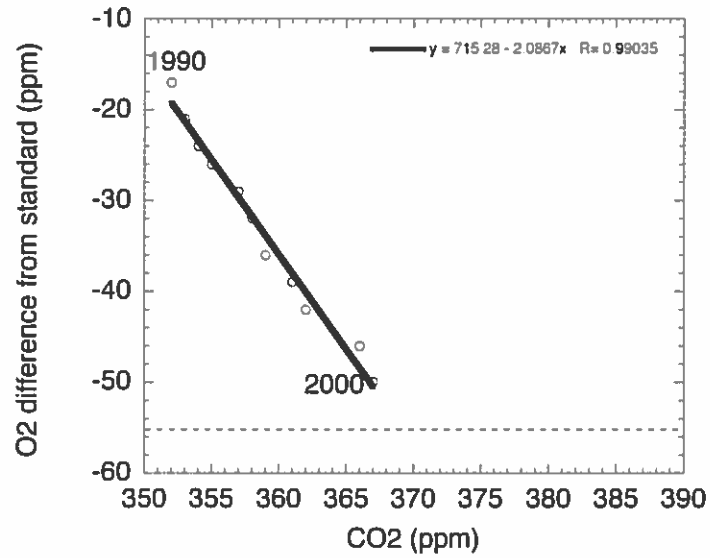
3d. Explain how the ice volume will evolve over time.

Climate change

As a consequence of fossil fuel burning CO_2 concentrations in the atmosphere increase and oxygen concentration decrease. Not all emitted CO_2 remains in the atmosphere, a fraction (f_{bio}=1/8) is used for production of biomass, which is constant over time and another fraction is taken up by the ocean (f_{oce}). The initial amount of CO_2 that is taken up by the biosphere equals the uptake of CO_2 by the oceans.

The equations are:

$$2C_8H_{18}+25O_2 > 16CO_2+18H_20$$
$$CO_2+H_2O>CH_2O+O_2$$



The figure above shows the concentration changes of CO_2 and O_2 over time in the atmosphere over the period 1990 (t_0) to 2000. Initial values for CO_2 and O_2 are respectively 352 ppm and -17 ppm (with respect to a standard).

4a. Explain why the observed change in CO_2 concentration in the atmosphere smaller is than what might be expected from the burning of fossil fuels.

4b. Explain why the observed change in O_2 concentration in the atmosphere smaller is than the amount used for fossil fuel burning.

4c. Derive an equation for the change of CO_2 as a function of the change in O_2 and the fraction taken up by ocean and biosphere.

As a consequence of increased levels of CO_2 in the atmosphere the pH of the ocean decreases and the uptake by the ocean decreases with an amount γ=1% per year. The amount of O_2 used for fossil fuel burning (ε) is equal to 4 ppm/yr.

4d. Calculate based on the information provided when the atmospheric CO_2 concentration reaches 400 ppm without ocean acidification and with ocean acidification and interpret your findings.