Final Exam

Paleoceanography and Climate Variability (GEO4-1405)

Educatorium Alfa: 17:00-19:00
(with medical certificate until 19:30)

The total of 100 points.

Question 1

Oxygen isotopes in foraminifera are one of the most important proxy methods in paleoceanography

1a) Explain the relationship between the oxygen isotopic composition of the seawater and of the foraminifera calcite. (5 Points)

1b) Explain the modern spatial variability in sea surface oxygen isotope composition. (5 Points)

1c) During the Early Cenozoic the world was essentially ice-free. Use a simple $\delta^{18}O$ mass balance to calculate the $\delta^{18}O$ (vs. SMOW) of the global ocean during the Early Cenozoic. Make educated guesses concerning the necessary $\delta^{18}O$ endmembers (ice, ocean) and the necessary volumes (hint: instead of volumes you can also work with ocean depth and sea-level equivalents). (5 Points)

1d) The $\delta^{18}O$ (vs. PDB) of benthic foraminifera during the Early Cenozoic were around 0 ‰ (vs. PDB). Using this value in combination with the value calculated above, estimate/calculate deep-sea temperatures for the Early Cenozoic. (5 Points)

Question 2

The last deglaciation

Give an overview of the sequence of events across the last deglaciation: consider in your description changes in atmospheric CO_2, sea-level, orbital forcing, temperature in northern and southern hemisphere, Southern Ocean circulation, sea-ice cover, dust, the biological pump and ice rafted debris in the North Atlantic. Mention in your description also proxies that can be used to reconstruct the above mentioned aspects. (20 Points)

Question 3

Ocean circulation

The following figure is from a recent *Nature* paper. The new datasets are presented in the blue and red lines.

Come up with a short title for this paper and write a short Nature style abstract that could accompany the study **(max. 200 words).** (10 Points)

Try to follow the typical structure of a *nature* style abstract.

- basic introduction with some background (2-3 sentences)
- general problem (1 sentence)
- one sentence with a summary of the results (starting with : "Here we show…")
- main results, and how they add to previous knowledge (2-3 sentences)
- broader perspective (1 sentence)

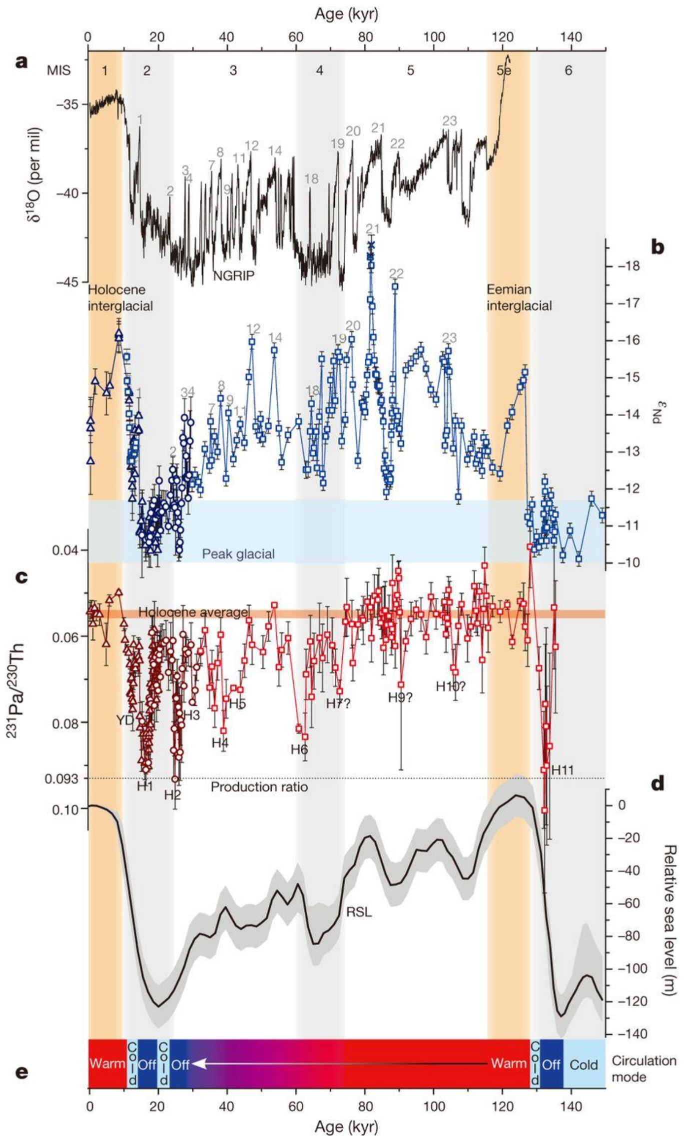

Figure caption: a Oxygen isotope record ($\delta^{18}O = (^{18}O/^{16}O)_{sample}/(^{18}O/^{16}O)_{VSMOW} - 1$) of the NGRIP ice core[29]. (VSMOW, Vienna Standard Mean Ocean Water.) Dansgaard–Oeschger interstadials corresponding to peaks of unradiogenic εNd signatures are labelled. **b**, εNd (axis reversed; errors, 2 s.d.; blue open squares) from the Bermuda Rise (also including data in dark blue from ref. 8 (open triangles) and ref. 27 (open circles)) constrain the appearances of the cold and off circulation modes and the arrival of SSW (southern sourced waters) in the North Atlantic to relatively short time periods during peak glacials (horizontal blue bar). Extremely unradiogenic leachate compositions around Dansgaard–Oeschger interstadials 21 have been reproduced using foraminiferal εNd data (crosses) following the method of ref. 8, confirming the reliability and comparability of both approaches. **c**, Bermuda Rise $^{231}Pa/^{230}Th$ data (axis reversed; error bars, 2 s.d.; open red squares, also including data from ref. 13 (dark red triangles) and ref. 23 (dark red circles)) display a low baseline (distinctly below production ratio) providing evidence for persistent export of ^{231}Pa as a consequence of an active deep AMOC. HS1–HS11 mark the timing of major iceberg surges in the North Atlantic[21] when $^{231}Pa/^{230}Th$ shifts towards the production ratio of 0.093. **d**, The movement of SSW into the North Atlantic has been tightly connected to relative sea level (RSL; the grey range covers minimal and maximal sea-level estimates[30]) suggesting that the available amount of meltwater and the location of Northern deep-water formation were crucial parameters for controlling the AMOC modes. **e**, Predominant AMOC modes (Fig. 1) as derived from the combined $^{231}Pa/^{230}Th$ and εNd records. Grey shadings (MISs 2, 4 and 6) mark glacial conditions, and orange shadings indicate interglacials (MISs 1 and 5e).

Question 4

Bottom water oxygenation

Bottom waters are increasingly becoming deoxygenated because of anthropogenic influences in the coastal zone. But also without influence of mankind dysoxic zone develop in the oceans.

a) Explain why the zone with lowest oxygen concentrations usually occurs at mid-depth. (5 points)
b) What proxies exist for the reconstruction of bottom water oxygenation and what are the underlying principles for these proxies. (5 points)
c) Explain why a basin with an anti-estuarine circulation is oxygenated versus the anoxic bottom-water conditions in a basin characterized by an estuarine circulation. (5 points)
d) Which 3 main factor today contribute towards increased dysoxia in the coastal zone? (5 points)

Question 5

Carbon 14

a) Explain the so-called reservoir effects and which factor potentially impact the reservoir effect. (5points)
b) Through time offsets are observed between true age and 14C ages. What processes are primarily responsible for these offsets and in which direction do the affect this offset? (5 points)

Question 6

The Indian summer monsoon is closely linked to insolation and global climate.

a) Explain what kind of relations you expect between the different components of insolation and the summer and winter monsoon? (5 points)
b) How would global climatic change affect the Indian summer monsoon? (5 points)
c) What tools would you use to study past changes in the Indian summer monsoon to test the above mention relationships? (10 points)