SIO 115 Ice in the Climate System

Final Exam 2017 Monday 20th March (due 3:00pm)

Please attempt all questions, I will count your best 10 answers. Please write your answers clearly and show your working for any mathematics problems. Please number all the questions and the question parts.

Email your exam to hafricker@ucsd.edu with the subject line "SIO115: Final Exam 2017" and name your file "Lastname-SIO115_Final2017.doc". The deadline is a ***strict deadline with no excuses****!*

1. General cryosphere

i. What are the components of the cryosphere?

ii. What are the three timescales that are usually involved in cryospheric changes?

iii. Why do some components of the climate system respond faster than others to climate changes?

iv. Which components of the cryosphere are still responding to historic changes (since the Last Glacial Maximum)?

v. State three components of the cryosphere that are responding to contemporary climate change, and discuss briefly how are they changing.

2. Milankovitch theory, albedo and isotopes

i. What are "Milankovitch cycles" and how are they used to explain why glaciation occurs?

ii. Which oxygen isotope(s) is/are used as a proxy for temperature and explain the principle behind this.

iii. How do we get a record of past climate from ice cores?

iv. How do we date the layers seen in ice core records?

v. Why is the gas that we sample in an ice core not exactly the same age as the surrounding ice?

3. Permafrost

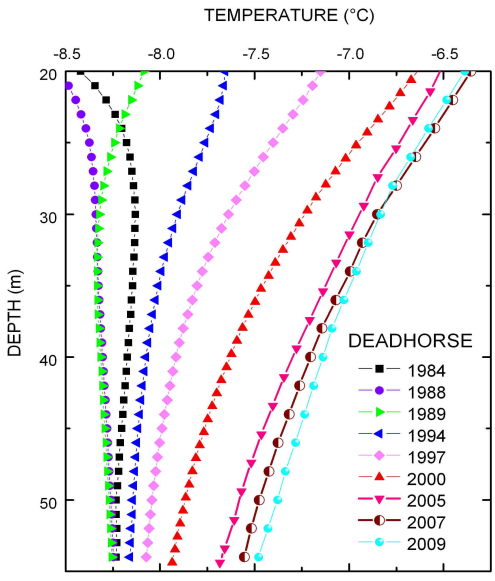
i. What is the "active layer" and what governs its thickness?

ii. Why is the thawing of permafrost such a concern for the Earth system?

iii. Describe how an ice wedge is formed.

iv. Describe what happens as an ice wedge melts.

v. The figure to the right shows a series of temperature profiles from our favourite site in Alaska (Deadhorse). Describe what is happening to the shapes of the temperature profiles through time, and explain why this is happening.



4. Sea-ice extent

i. What are the three reasons why sea ice is important to the physics of the Earth's climate system?

ii. What are the albedos of: a) sea-ice; and b) open ocean?

iii. Explain the "ice-albedo feedback"; is it a negative or positive feedback? Draw a sketch to show how this feedback works.

iv. What type of satellite instrument is used to determine sea-ice extent? Give two examples.

v. What are political and economical impacts of the disappearance of perennial sea ice in the Arctic?

5. Sea-ice thickness

i. Draw a sketch of a cross-section through a sea-ice floe, and annotate your sketch to show the following parameters:

- *sea-ice thickness*
- *ice freeboard*
- *ice draft*
- *ice free ocean surface*

ii. What is a typical value for thickness of first year ice in the Arctic?

iii. What type of satellite instrument is used to estimate sea-ice thickness? Give two examples.

iv. What is the parameter that is estimated to obtain ice thickness, and how is that parameter measured?

v. What additional information is required to estimate ice thickness from that measured parameter?

6. Glacier mass balance.

i. Define the acronym AAR, and describe what it represents.

ii. Define the acronym ELA, and describe what it represents.

iii. How is mass balance estimated *in situ*?

iv. Why is it not practical to use *in situ* methods to estimate mass balance over large glaciated regions?

v. What three satellite techniques are used to estimate mass balance over large glaciated regions? Give examples of instruments for each technique.

7. Glacier dynamics

i. How does a glacier move?

ii. Apply the relationship between basal stress, ice thickness and surface slope to calculate the basal shear stress with the following parameters and conclude if ice deforms or not:

a) $\alpha = 10^{\circ}$, H=7m b) $\alpha = 10^{\circ}$, H=70m

iii. A glacier has a surface profile given by $h = sqrt(cx)$ where h is the height in meters and x is the distance from the margin, in meters.

a) Differentiate this expression with respect to x to obtain surface slope, α.

b) Insert the result into the expression for basal drag, $\tau = \rho g h \alpha$ and show that τ is independent of

x.

c) Obtain a numerical value for τ in kPa using c = 16m.

8. Glacier hydrology

i. What are the differences between a channelized and a distributed (linked cavity) subglacial drainage system?

ii. Do you think the drainage of a subglacial lake in Antarctica would most occur via a channelized or distributed system? Explain.

iii. Does surface meltwater in Greenland cause a speed up or slow-down of the ice streams and outlet glaciers? Explain.

iv. Will the volume of supraglacial water in Greenland increase or decrease with climate change?

v. Will the volume of subglacial water in Antarctica increase or decrease with climate change?

9. Antarctic ice shelves

i. What is the "grounding line" of an ice sheet?

ii. Why is it important to know the location of the grounding line?

iii. Describe the thermohaline circulation under an ice shelf, making sure to explain what causes basal melting near the grounding line.

iv. If an ice shelf is losing mass through basal melting, does it mean that the ice shelf is under threat?

v. What is the other major loss process for ice shelves (apart from basal melting)?

10. Ice sheet changes

i. What are the two ice sheets on Earth today?

ii. What timescales are ice sheets traditionally thought to respond on?

iii. What timescales have ice sheets been observed to respond on in recent years?

iv. Explain what the "marine ice sheet instability (MISI)" is (a drawing will help you with this, remember to show the slope of the bedrock).

v. In which part of Antarctic is the MISI currently underway?

11. Ice sheets and sea-level change

Assume that the Earth is a sphere with radius of 6378 km, and 70% of its surface is covered by the ocean. Consider an ice sheet that is circular with a 2,000 km radius and an average thickness of 2 km average.

i. What is the total area of the global ocean?

ii. What is the volume of the ice sheet?

iii. If the ice sheet were to melt completely, by how much would it raise global sea level?

iv. In reality, why does sea level not rise uniformly across the ocean?

v. What are the other contributors to current sea level rise, apart from melting ice sheets?