Problem set 2 for EESCW4235 – Sea level change
Due on March 2nd per mail to Roger Creel (rcreel@ldeo.columbia.edu)

1. Inferring sea level from Pleistocene coral

The picture below shows a part of a fossil branch of an Acropora Palmata coral that was found in the Bahamas and dates to the Last Interglacial. The top of the coral was found at an elevation of 3.2m and the measurement precision of the GPS is 50cm. To investigate the indicative meaning, we can use data on the present living depth range of Acropora Palmata from the ocean biogeographic information system (OBIS). Show a histogram of the depths at which A. Palmata are found today using the provided data in the excel sheet. Use this data to calculate the relative water level and the indicative range for Acropora Palmata, which you can approximate as the mean and twice the standard deviation of this dataset. Using this information, estimate how high relative sea level (including uncertainty) was in the Bahamas during the Last Interglacial.

2. $\delta^{18}O$ balance

Use the oxygen isotope approach to estimate how much lower global mean sea level was during the last glacial maximum (LGM) compared to today. To estimate this you will need the values from the table below, the values from the Lisiecki and Raymo (2005) benthic oxygen stack (the first figure in lecture 10) and the equations we have used in class (during the breakout groups). Given that the Laurentide and Fennoscandian ice sheets were at a similar latitude than the present-day Greenland ice sheet, you can assume that excess ice during the LGM had the same $d^{18}O$ as the Greenland ice sheet does today.

Global mean sea level was around 120 – 130m lower during the last glacial maximum than it is today. How does this compare to your result and what are reasons for it to maybe differ?

	$\delta^{18}O$ (‰)	Mass (10^{18}kg)	Sea-level (m)
Ocean	3.2	1358	--
Greenland Ice Sheet	-35	2.66	7.3
West Antarctic Ice sheet	-41	2.75	4.3
East Antarctic Ice sheet	-56.5	21.55	53.3

3. Using spherical harmonics

Use spherical harmonics to calculate the mean ocean depth. To do that, follow these steps:

a) Load the topography provided for problem set 1 (etopo_15_ice) and construct the ocean function, which is defined as C(lon,lat) = 1 in the oceans and C(lon,lat) = 0 on land. Submit a figure showing a map of your ocean function.

b) Calculate the global average value of the ocean function using spherical harmonics. What does this number represent? Consider whether you need to interpolate your ocean function onto a Gauss Legendre grid before doing the spherical harmonic transform.

c) Calculate the mean ocean depth using spherical harmonics. To do so construct a new field that is equal to topography but 0 on land. Calculate the global average of this field and then use your result from (b) to account for the fact that you don't actually want the global average, but only the average in the ocean basins.

4. Earth's viscosity

A relative sea level curve for Richmond Gulf, Hudson Bay, has been established on the basis of the dating of shell specimens. The age-height pairs for these samples are listed below.

a) Determine the post-glacial decay time of Richmond Gulf using these data. Your answer should include a plot showing the data points and your best fitting curve. In addition to the data provided, consider that you also know the current relative sea level.

b) Using this decay time estimate the average mantle viscosity below Canada. You can assume the following values: Young's modulus of 10^{11} N/m^2, mantle density 3000 kg/m^3, depth of compensation L = 1200km. Over what depth in the mantle does this average apply?

Age (years)	Height (m)
6000	137
6230	154
6430	172
1790	22
2030	29
2760	44
3360	58

5. Earth' Maxwell time

a) What is the response (strain as a function of time) of a Maxwell viscoelastic material to the application of a constant stress σ_0? To answer this question it might help to first think about what the strain is at time t = 0 and then solve the constitutive equation with this initial condition and assuming constant stress σ_0.

b) Draw a diagram of strain (y axis) as a function of time (x axis) and mark the elastic portion and the viscous portion.

c) Identify the elastic and viscous strains as a function of time, and provide an equation for the time t_M at which these two are equal. What is the physical meaning of this time? Estimate this value for the Earth assuming a Young's modulus of 10^{11} N/m^2 and a viscosity of 10^{21} Pa*s.