Radiocarbon in Ecology and Earth System Science – 1st problem set

1. You send four samples (a foraminifera (single celled marine organism with a calcium carbonate shell), a leaf, and two pieces of wood) to a lab for measurement. They send you the following results:

	$\delta^{13}C$ (‰)	Fraction Modern
Foraminifera	+1.5	0.50
Leaf	-28.0	0.50
Wood 1	-25.0	0.25
Wood 2	-25.0	1.79

a. What are the **Radiocarbon Ages** of the three samples (see Lecture 1 notes for definitions)?

λ_{14} = ln(2)/5568 so 1/ λ_{14} = 5568/ln(2) = 8033 years

Radiocarbon age for samples = -8033*ln(FM)
Foram. Leaf = 5568 years (do you need to calculate to get this?)
Wood1 = 2 half-lives = 2*5568 years = 11,136 years
Wood2 = -5110 years! NEGATIVE, future age… this is by consensus reported as > Modern (i.e. post-1950, influenced by bomb radiocarbon)

b. Which of the samples has the most ^{14}C atoms per gram of sample carbon? (in other words, to which samples was ^{14}C added or subtracted to correct for mass dependent fractionation)?

Samples that are more enriched in ^{13}C (i.e. $\delta^{13}C$ > -25‰) had to have ^{13}C (and therefore ^{14}C) subtracted in order to report the fraction Modern. So the foram sample would have the greatest number of ^{13}C and ^{14}C atoms per gram of C. The two samples at -25 per mil had no correction made for reporting. The leaf sample had ^{13}C and ^{14}C added to reach -25 per mil equivalent, so it would have the least ^{13}C and ^{14}C atoms per gram of C.

c. Calculate the calibrated age ranges for these samples using one of the programs available on the web (e.g. **Calib**; http://calib.qub.ac.uk/calib/ or **Oxcal** http://c14.arch.ox.ac.uk/embed.php?File=oxcal.html). Try using error of ±25 years and ±50 years to see how that affects the calibrated age ranges.

5568 (2 sigma +/- 25) cal BC 4452- 4355
5568 (2 sigma +/- 50) cal BC 4494- 4336
11,136 (2 sigma +/- 50) cal BC 11149- 10893
negative age gives an error with INTCAL13, need to look at the bomb curve to assign an age (or use Oxcal, which gives you the option of using the bomb curve. The C fixed (in the northern hemisphere) is in 1963-1964.

d. What would be the $D^{14}C$ (see definition in notes; 1000*(FM-1)) and $\Delta^{14}C$ values for these samples - assume you measured them in 2016 – do you understand why they are different?

F	$D^{14}C$	F’	$\Delta^{14}C$
0.5	-500	0.496	-504
0.25	-750	0.248	-752
1.89	890	1.875	875

Comment [ST1]:

Delta

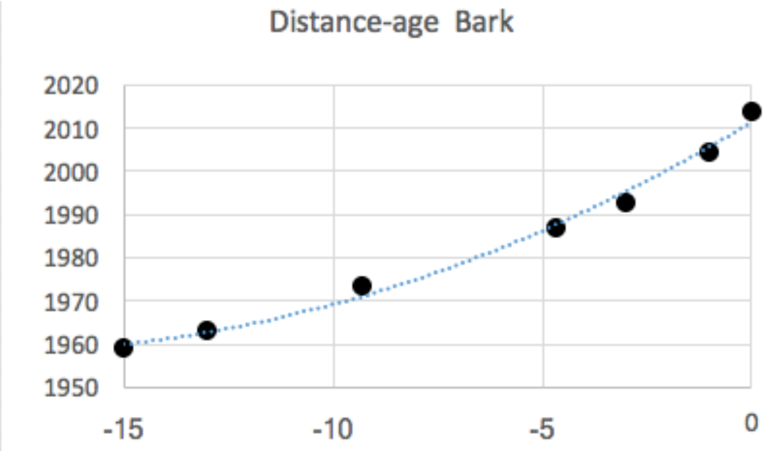
$$\Delta^{14}C = \left[\frac{\left.\frac{^{14}C}{^{12}C}\right]_{sample,-25}}{0.95 \left.\frac{^{14}C}{^{12}C}\right]_{OX1,-19} \exp^{\left((y-1950)/8267\right)}} - 1 \right] 1000$$

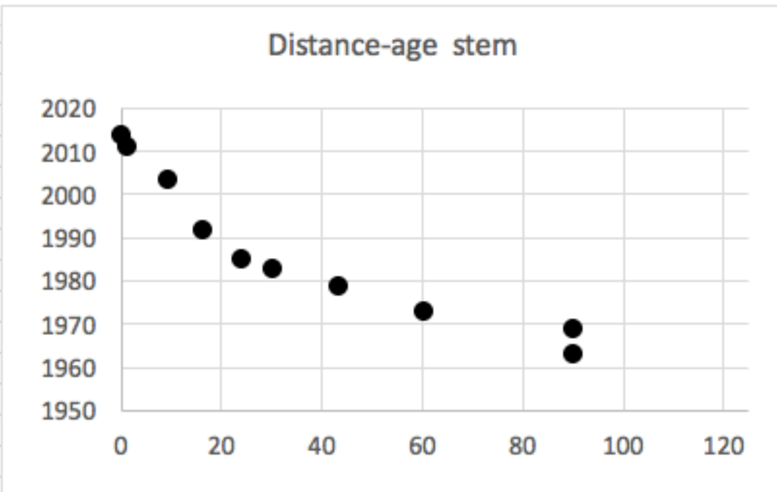
The year of sample collection and measurement is 2016, so the exponential factor (EXP((1950-2016)/8267) is 1.0080. The fraction modern is divided by this factor before we subtract 1 and multiply times 1000. (We refer to this in our book as F’, the “absolute” fraction modern).

If the year of sample collection and measurement is different, you need to account for this (an example will be in Problem set 2).

Problem 2. The spreadsheet (see link below) has data for FM 14C as a function of distance (from the cambium inward or the cambium outsward) from a tropical tree (see photo). Use a calibration program that allows you to use bomb radiocarbon to estimate the growth rates and ages of these two trees.

IDENT. (NAME)	FRACT. MOD.	±	DEL 14C	±	Year C fixed	±	Distance from cambium	
TanBark1_15mm	1.1578	0.0031	148.8	3.1	1959	0.5	-15	
TanBark3_13mm	1.3371	0.0045	326.6	4.5	1963	0.5	-13	
TanBark5_9.3mm	1.4296	0.0033	418.5	3.3	1973.5	0.5	-9.3	
TanBark8_4.7mm	1.1962	0.0042	186.8	4.2	1987	1	-4.7	
TanBark10_3mm	1.1375	0.0038	128.6	3.8	1993	2	-3	
TanBark11_1mm	1.0753	0.0025	66.9	2.5	2004.5	1.5	-1	
					2014		0	0
TanWood1_1mm	1.0449	0.0030	36.7	3.0	2011	1		1
TanWood2_9.4mm	1.0817	0.0027	73.2	2.7	2003.5	1.5		9.4
TanWood3_16mm	1.1432	0.0025	134.2	2.5	1992	2		16
TanWood4_24mm	1.2037	0.0027	194.2	2.7	1985	0.5		24
TanWood5_30mm	1.2449	0.0027	235.1	2.7	1983	1		30
TanWood6_43mm	1.3135	0.0035	303.2	3.5	1979	1		43
TanWood7_60mm	1.4370	0.0035	425.8	3.5	1973	1		60
TanWood8_90mm	1.5370	0.0037	525.0	3.7	1963	1		90
					1969	1		90


Distance-age Bark
2020
2010
2000
1990
1980
1970
1960
1950
-15
-10
-5
0


Distance-age stem
2020
2010
2000
1990
1980
1970
1960
1950
0
20
40
60
80
100
120

3) Corals that grew during the year 1900 off the coast of Hawaii, Galapagos, and the Great Barrier Reef contain ^{14}C Fraction Modern values of 0.945, 0.924 and 0.950, respectively.

a) Now calculate the $\Delta^{14}C$ values for the carbon in seawater from which these corals precipitated. (Use the true ^{14}C half-life of 5730 y in your calculations).

$$\Delta = \left[\frac{\left[\frac{^{14}C}{^{12}C}\right]_{\text{sample},-25} \exp^{\left((1950-1900)/8267\right)}}{0.95 \left[\frac{^{14}C}{^{12}C}\right]_{\text{OX1},-19}} - 1 \right] 1000$$

FM	Δ	Δ/1000+1	Res. Age
0.945	**-49.3**	**0.951**	**410yr**
0.924	**-70.4**	**0.930**	**590**
0.950	**-44.2**	**0.956**	**360**

b) Calculate the reservoir ages (equivalent to the radiocarbon age for the seawater carbon) for each of these coral sites. (Remember to use the Libby ^{14}C half-life of 5568 y in your calculations).

Use Δ/1000+1 from the table in part (a). This is the fraction Modern you WOULD have measured had you made the measurement in the year 1900. So the RESERVOIR AGE (this is the apparent radiocarbon age of carbon dissolved in seawater in 1900) – results are in the table above.