Problem Set 2

1. This is the radiocarbon super-problem.
   a. Given that the current cosmogenic production rate for ^{14}C is 2.5 atoms cm^{-2}s^{-1}, compute the global cosmogenic inventory of radiocarbon.
   b. Consider the schematic modern, preanthropogenic carbon cycle depicted in slide 9 of Lecture 11. There is a downward-pointing arrow missing between the land biota box and the soil/detritus box. What is its magnitude? The way the picture is drawn, the return flux from the soil/detritus box to the atmosphere is off (to the nearest GT/y) by how much?
   c. Using this schematic carbon cycle and treating the global ocean as a single box, use the following "facts" to determine how this isotope is partitioned between the ocean, land biota, soil/detritus, and atmospheric reservoirs. The "facts" are that the average oceanic Δ^{14}C is -170‰, the average radiocarbon age of the land biota is about 10 years, and the soil/detritus averages 30 years. According to this apportionment, what is the modern, preanthropogenic absolute atmospheric ^{14}C/^{12}C ratio?
   d. Splitting the ocean box between surface and deep reservoirs, and assuming the average surface Δ^{14}C is -50‰, calculate the CO_2 exchange rate in mol m^{-2} y^{-1} between the ocean and atmosphere. For the purposes of this calculation, assume a simple first order exchange model (*i.e.,* the flux is proportional to imbalance between ocean and atmosphere), that the average surface ocean "depth" is 100 m, and that the average TCO_2 concentration is 2.3 mol m^{-3}. Does this agree with our toy carbon cycle model?
   e. The Excel spreadsheet provided on our web site contains two columns: the calendar year BP (starting at 60,000 years before present and ending with "today"), and the estimated ^{14}C cosmogenic production rate in moles/year. Use this to build a multi-box model that emulates the history of Δ^{14}C for the atmosphere and surface ocean over the past 60,000 years. Qualitatively compare this to IntCal09 and Marine09 curves depicted in slide 11 of Lecture 11 (or consult the Reimer et al paper). Explain how your results (may) differ.

2. Given its relatively high mass (compared to He and Ne), the loss of atmospheric Ar to space can be considered negligible even over geologic time. Thus one may assume that the atmosphere accumulates all the radiogenic ^{40}Ar that has been outgassed from the solid earth over its history. Given an estimated bulk earth's potassium composition of 250 ppm (by weight), and the present day terrestrial ^{40}K abundance as 0.012% of potassium, calculate how much ^{40}Ar has been produced over the earth's history (be aware of the branching ratio!). How does this amount compare with the present day atmospheric inventory of ^{40}Ar and what conclusion can you draw from this? How might this relate to the ^{3}He story?

3. The cosmogenic production of ^{3}He in the upper atmosphere is nearly identical to that of tritium (^{3}H), that is ~0.25 atoms cm^{-2}s^{-1}. Tritium decays to ^{3}He in a time (12.3 years half-life) short compared to the residence time of He in the atmosphere, so the two can be combined as an effective cosmogenic ^{3}He production rate. How does this compare to the "primordial" ^{3}He outgassing rate?

4. Consider a simple model where the lower 75% of the world ocean is "ventilated" by 30 Sv (*i.e.,* 30 x 10^{6} m^{3}s^{-1}) by deep water formation. Calculate the expected helium isotope ratio anomaly (relative to the atmospheric ratio) in deep water that would result from the injection of the primordial ^{3}He, assuming that the average atmospheric He concentration in the ocean is 2 nmol kg^{-1} and the atmospheric ^{3}He/^{4}He ratio is 1.4 x 10^{-6}.

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