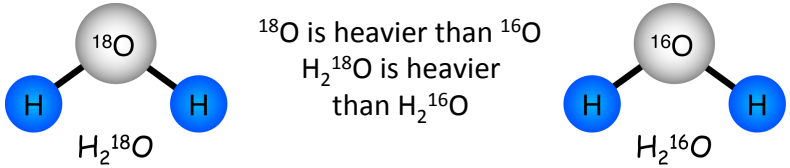
GEOG 401: Paleoclimate: Making sense of oxygen isotopes

Definitions: An isotope is simply a *mutation* of a typical molecule by having additional neutrons and thus atomic mass. In nature there are three stable isotopes of oxygen: oxygen-16 (99.8%), oxygen-17 (0.04%) and oxygen-18 (0.2%).



Here we focus on only oxygen-16 and 18. If we count all of the oxygen-16 and 18 molecules on Earth we'll find a 400:1 ratio. However, when we sample oxygen like you are doing currently, the ratios may be slightly different than 400:1. Thus we quantify the anomaly of oxygen-18 using:

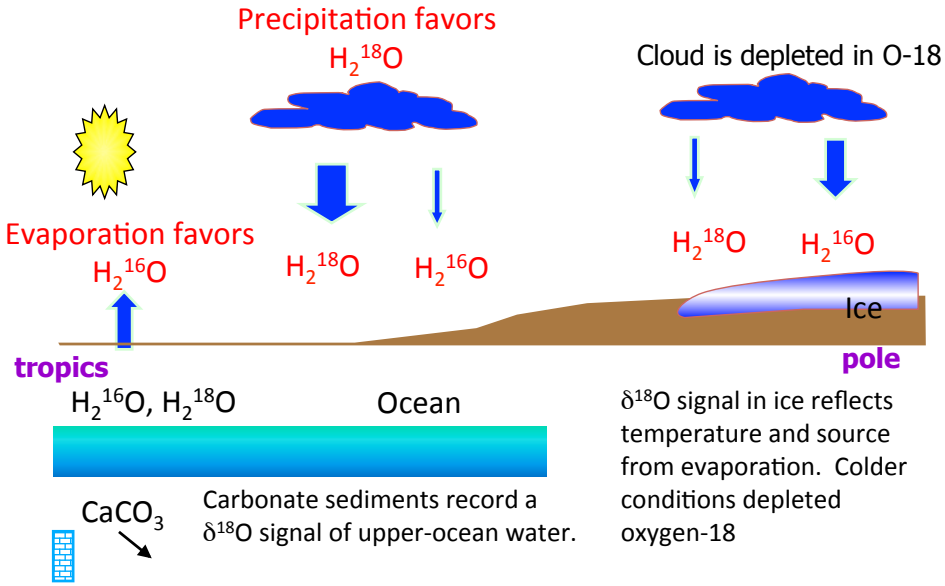
$$\delta^{18}O\ ‰ = \frac{{}^{18}O/{}^{16}O \text{ of sample} - {}^{18}O/{}^{16}O \text{ of standard}}{{}^{18}O/{}^{16}O \text{ of standard}} \times 1000$$

When the standard refers to standard mean ocean water, and deviations are expressed in parts per thousand (or per mil). There is a fixed number of oxygen molecules on Earth. This means that as areas increase their δ18O (enriched), other areas must have a corresponding decrease (depleted).

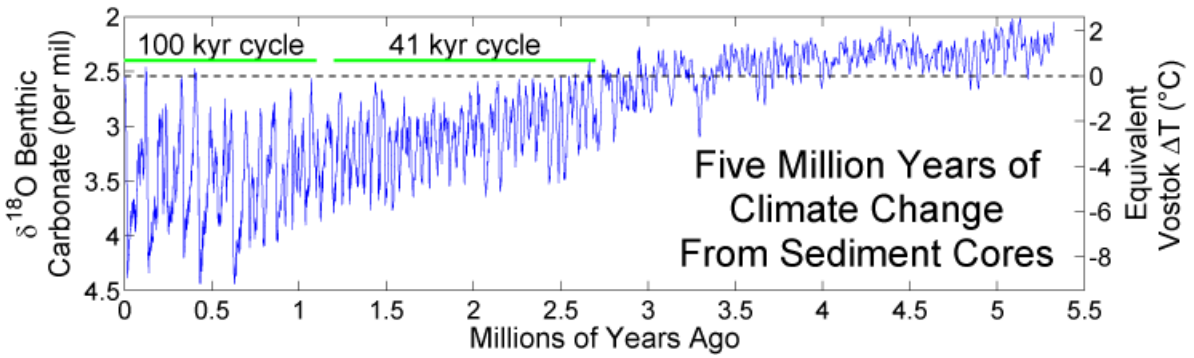
Fractionation: Natural processes that preferentially take up or remove isotopes. Oxygen-18 is heavier and thus preferentially precipitates out of clouds. By contrast, Oxygen-16 more readily evaporates. In the oceans, marine organisms preferentially take up oxygen-16 as water temperature increases.

General concepts

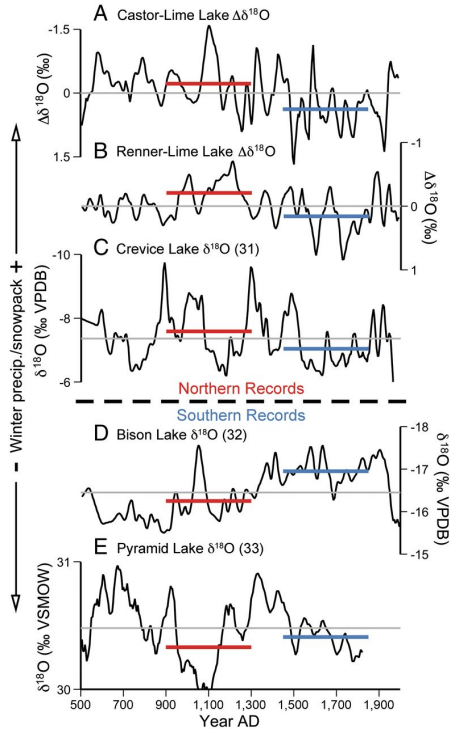
- Precipitation that makes it to the poles in generally very depleted in δ18O. Hence, ice sheets are home to depleted in δ18O.
- Heavier isotopes remain in the ocean and particularly the deep ocean, which is enriched 3-4 mil over standard ratio.
- As more ice is stored on land, more of the heavier isotopes remain in the ocean.
- Foraminifera preferentially take up heavier isotopes when waters cool. This compounds the signal from ice sheets.
- Every 1 per mil increase in deep ocean δ18O corresponds to a 4.2C decrease in ocean temperature where deep water forms.



Example Records



A record of benthic carbonate from ocean sediments for the past 5.5 million years. The more positive the values of δ18O the colder the ocean temperature were and the more ice was locked away in continental glaciers.



The record to the right shows δ18O records from five lakes located in the northwest (top three) and further south (bottom two). At the lake level, δ18O records provide a water balance proxy as during periods of drought where evaporation >> precipitation, the heavier isotopes should be left in the lake; whereas during pluvials, enhanced precipitation reduces δ18O of the lake.