

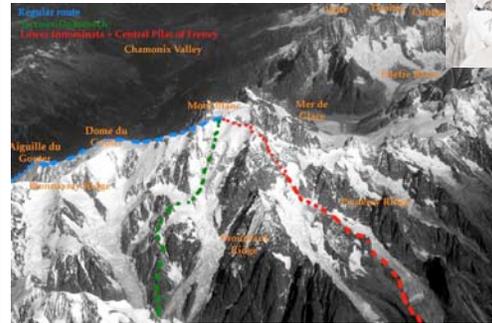
## Glacial Geology 563



Glaciation happens! -- Historical perspective  
It happens in cycles -- How do we know this?

- What are Milankovitch cycles?
- Sub-Milankovitch change
- Abrupt change

First investigations of glaciers and mountain geology, 1750-1800

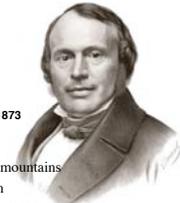


Observation of processes -- striations and ridges of mud and boulders



Father of Glacial theory

Jean L. R. Agassiz, 1807-1873



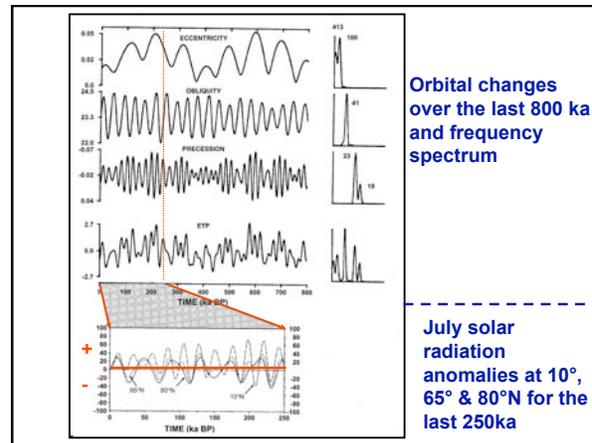
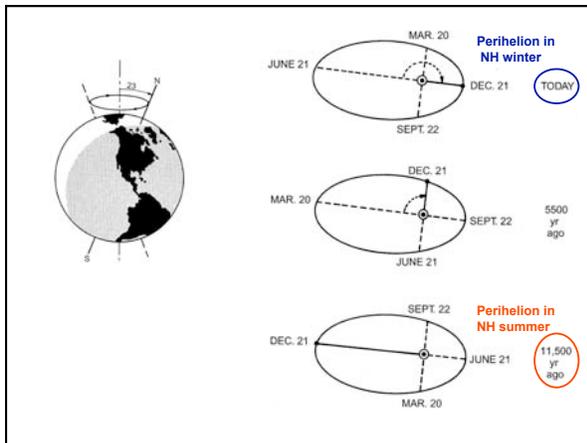
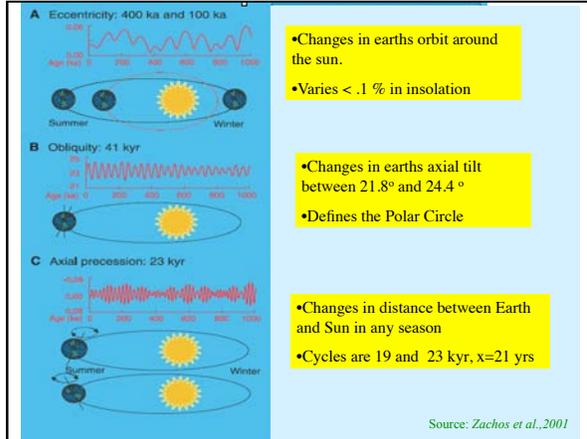
- 1795 -- James Hutton -- identified erratics in Jura mountains
- 1815 -- Perraudin, peasant, infers alpine glaciation
- 1821 -- Venet discussed Perraudin's ideas at Soc. Of Nat'l History
- 1833 -- Charles Lyell ("present is the key to the past") says striations were caused by boulder-ridden ice bergs in Noah's flood. (drift!)
- 1837 -- Agassiz lectures on the great ice age (Sherman Williams style)
- 1838 -- Buckland, convinced Britain was glaciated, renounces idea of the Noah's flood
- 1840 -- Agassiz publishes idea of glaciations
- 1841 -- Edward Hitchcock, State Geologists, gave lecture on Agassiz's ideas
- 1840-1860s -- glaciation recognized throughout Europe
- 1864 -- James Croll published Astronomical theory for ice ages

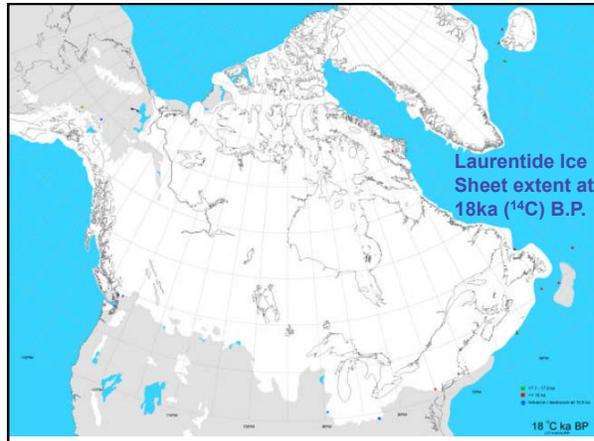
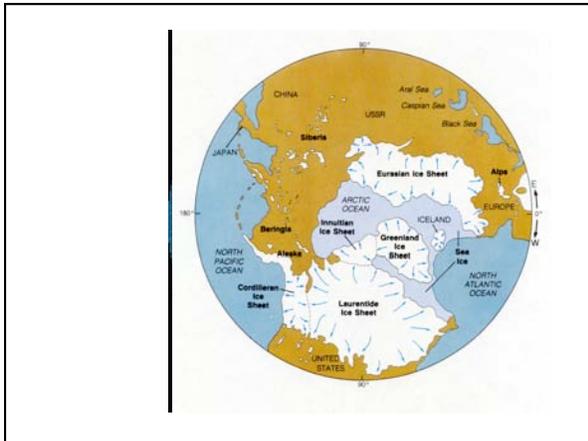
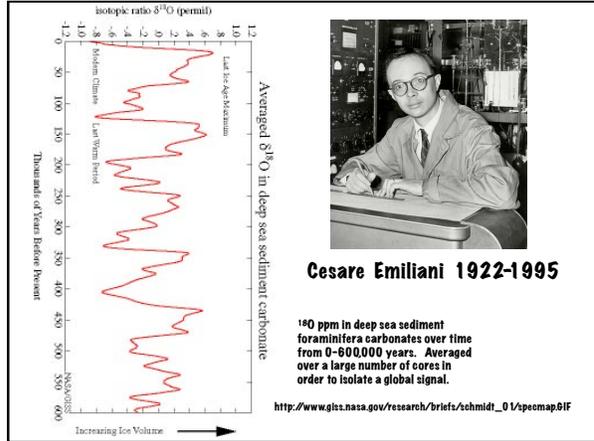
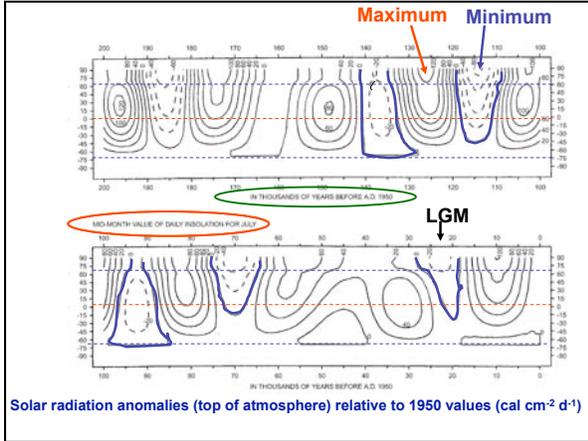
1920 -- Milutin Milankovitch, Serbian, published formulas calculating intensity of solar radiation based on Croll's ideas of orbital forcing

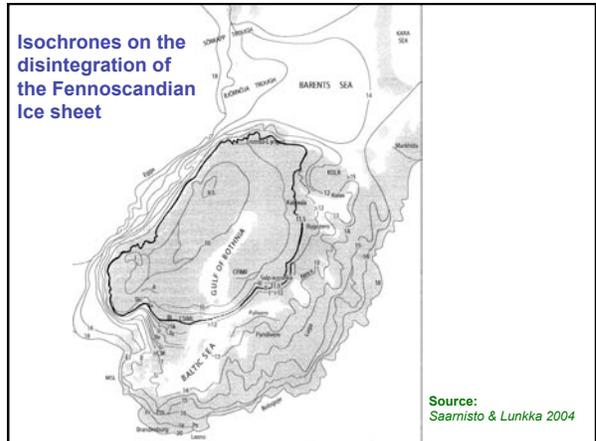
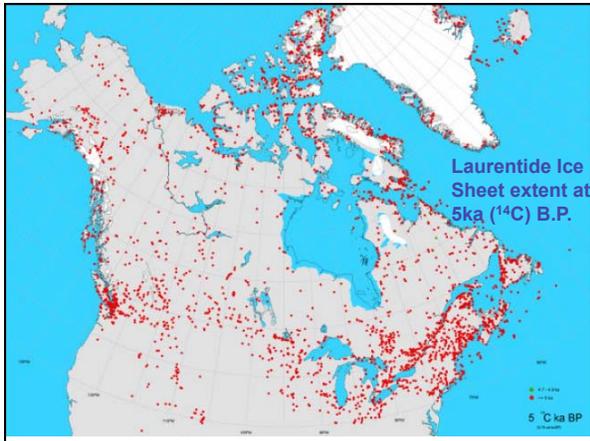
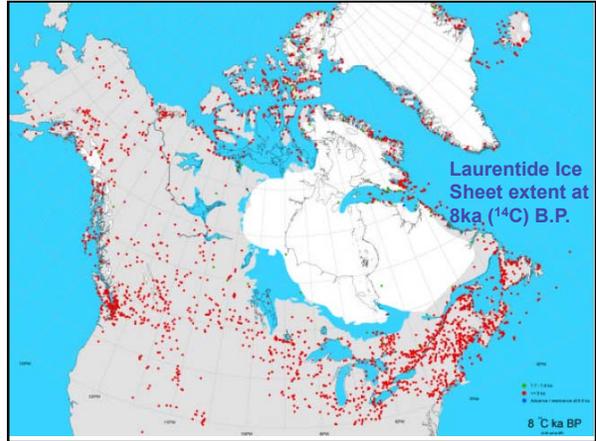
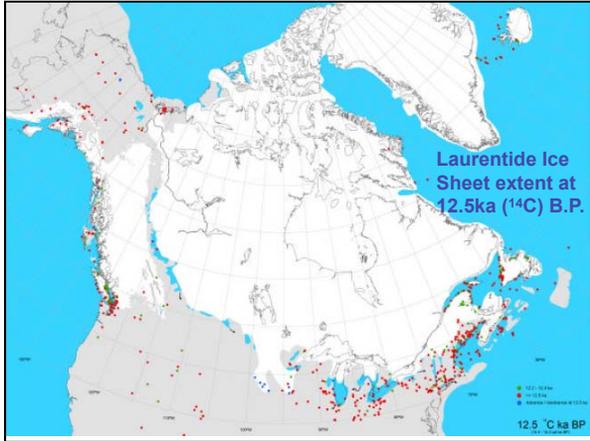


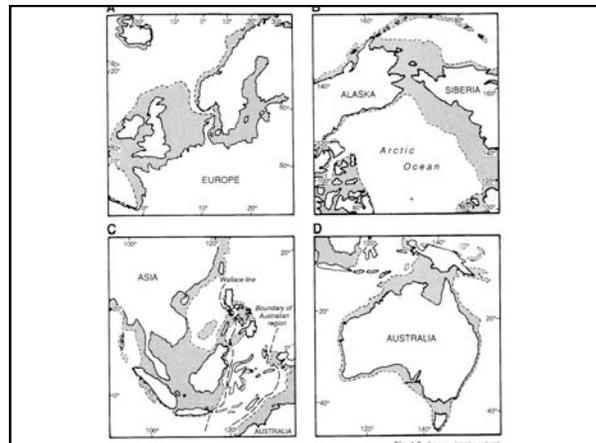
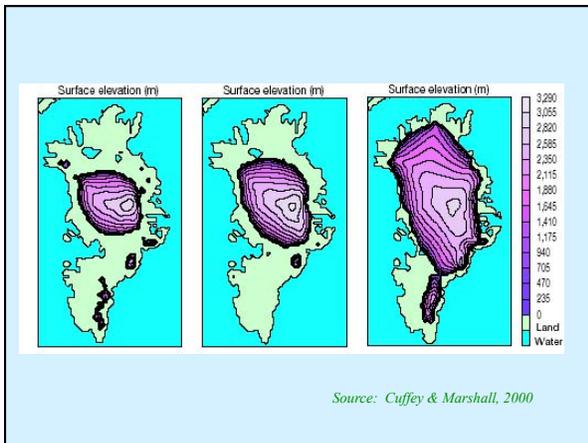
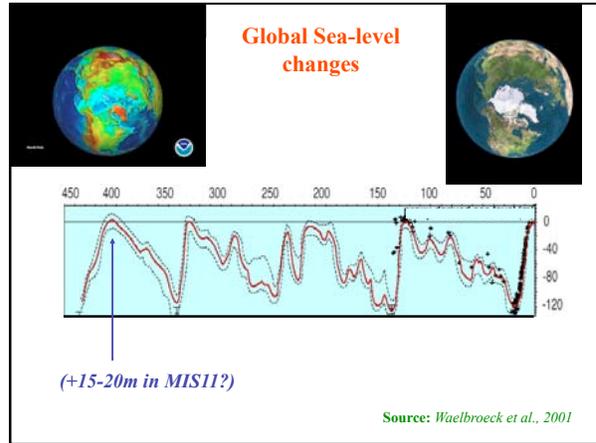
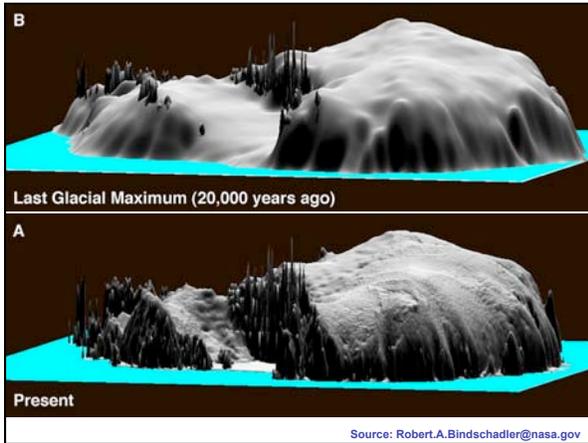
Milutin Milankovic's (1879-1958)

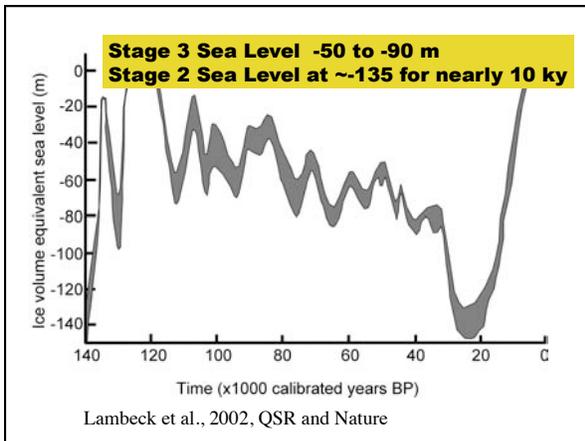
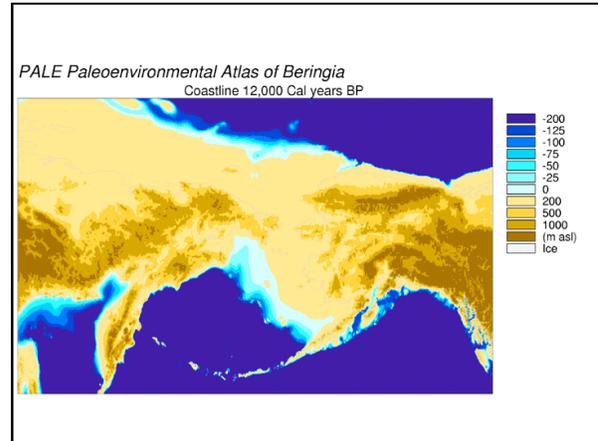
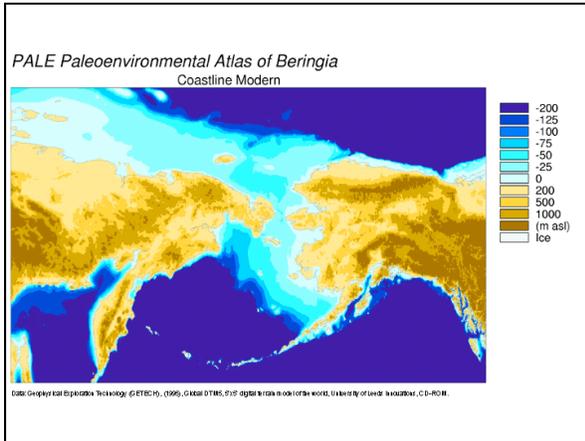
[http://en.wikipedia.org/wiki/Milankovitch\\_cycles](http://en.wikipedia.org/wiki/Milankovitch_cycles)











What do we know.....?

**With glaciation and the build up of ice sheets on land, sea level falls, usually about 120-140 m**

**With deglaciation, sea level rises as glaciers and ice sheets melt back into the sea.**

**If the climate gets warmer, more ice will melt and sea level will continue to rise.**

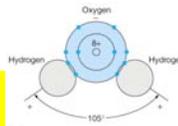
*How might such changes in the sea level and ice sheet size be recorded in the ocean?*

**Oxygen (8 protons)**

$^{16}\text{O}$	$^{17}\text{O}$	$^{18}\text{O}$
99.8%	0.04%	0.2%

**Hydrogen (1 proton)**

$^1\text{H}$	$^2\text{H}$ (Deuterium)	$^3\text{H}$ (tritium)
99.98%	0.016%	(?bombs)



So, can make 9 isotopic combinations of  $\text{H}_2\text{O}$ ,  
 e.g., 18 ( $^1\text{H}_2^{16}\text{O}$ ) to 22 ( $^3\text{H}_2^{18}\text{O}$ )  
 "light water" "heavy water"

In paleoclimate studies...  $^1\text{H}^1\text{H}^{16}\text{O}$  to  $^1\text{H}_2^{18}\text{O}$

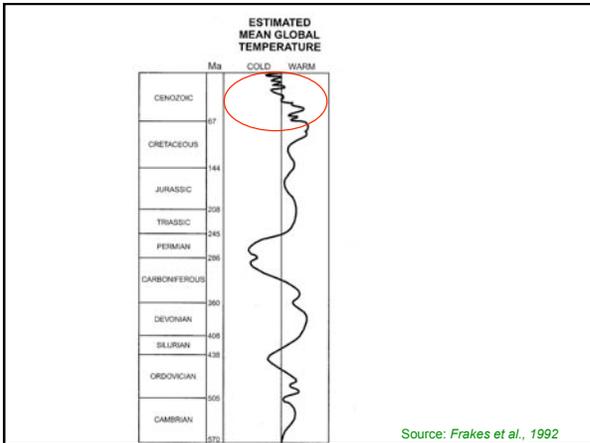
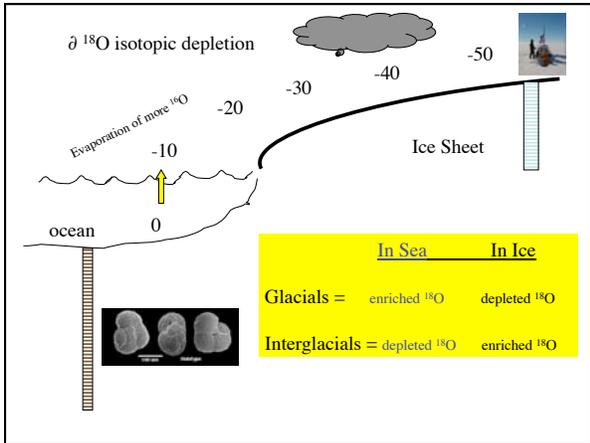
**General Equation:**

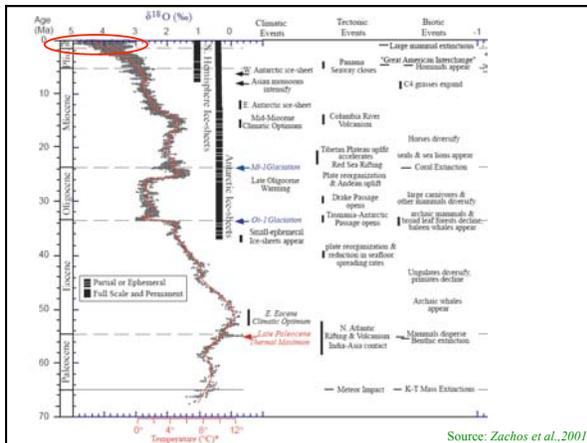
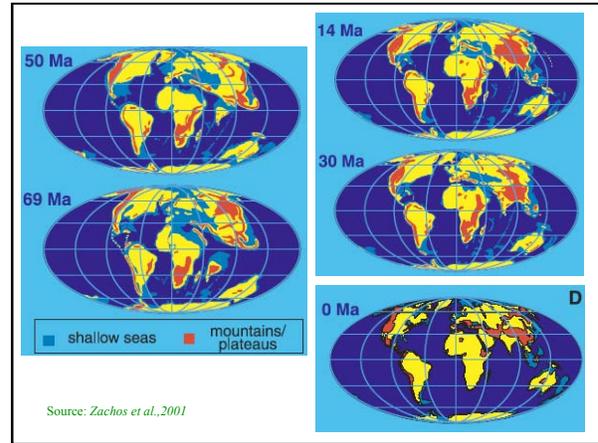
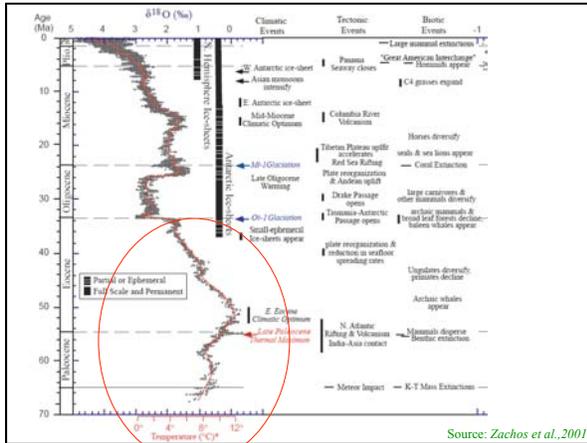
$$\delta^{18}\text{O} = \frac{^{18}\text{O}/^{16}\text{O}_{\text{sample}} - ^{18}\text{O}/^{16}\text{O}_{\text{standard}}}{^{18}\text{O}/^{16}\text{O}_{\text{standard}}} \times 1000$$

Expressed in per mille (‰)

Negative values = lower ratios = isotopically lighter  
 (less  $^{18}\text{O}$  than  $^{16}\text{O}$ )

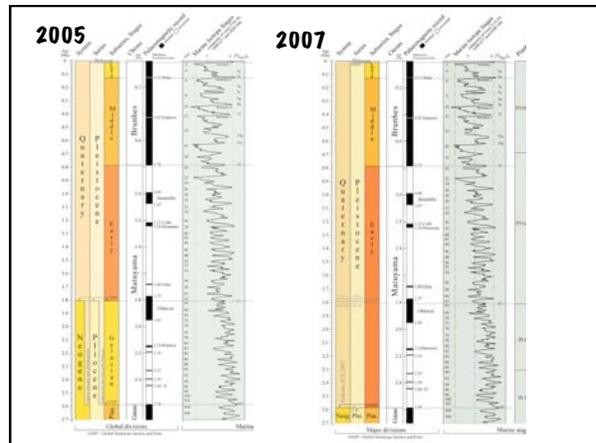
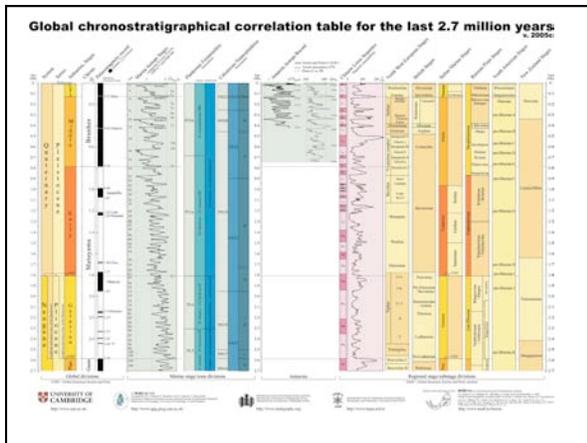
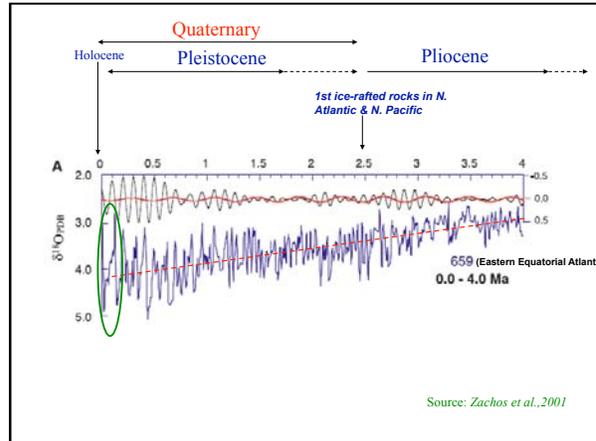
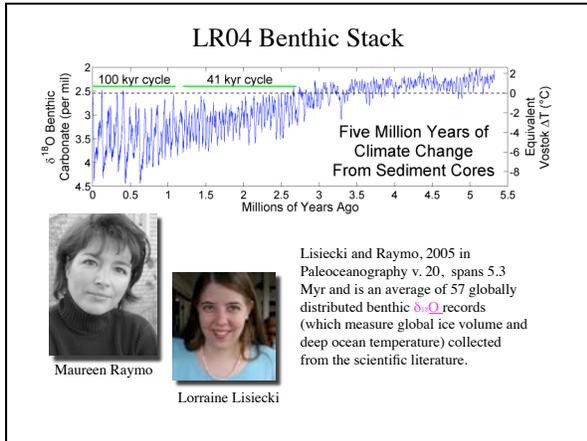
Positive values = higher ratios = isotopically heavier  
 (more  $^{18}\text{O}$  than  $^{16}\text{O}$ )

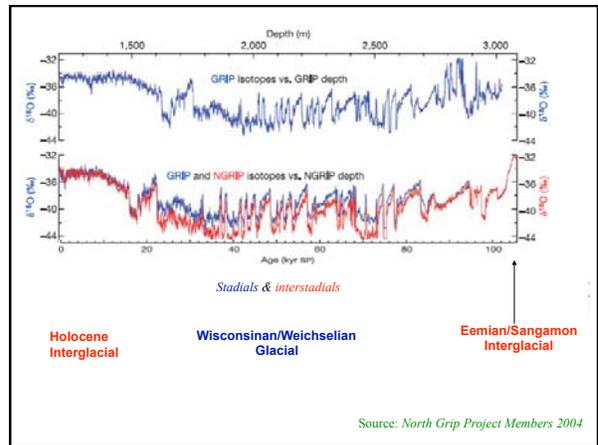
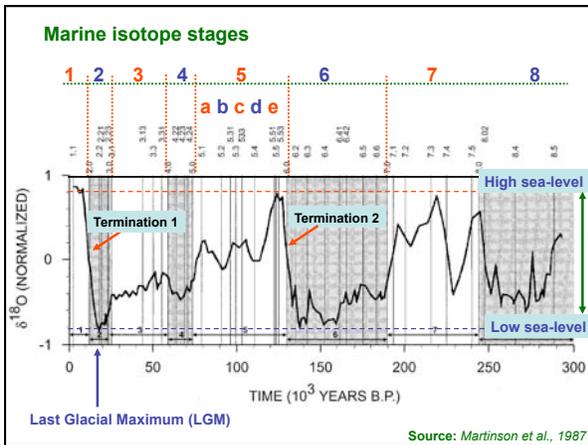
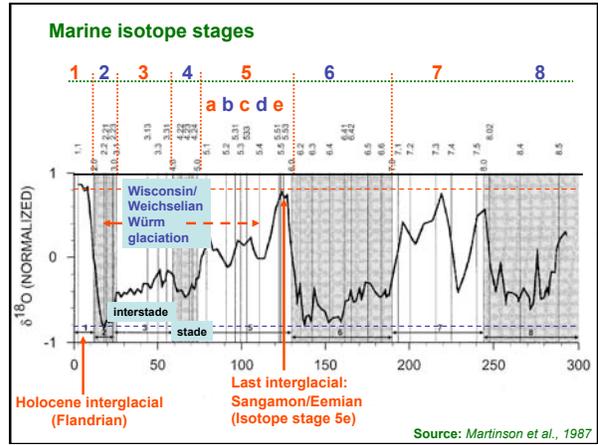
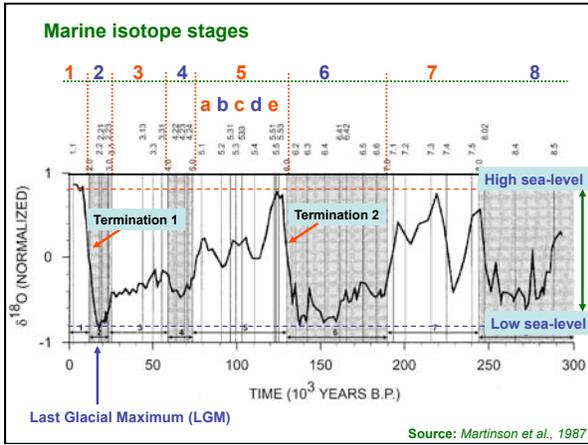


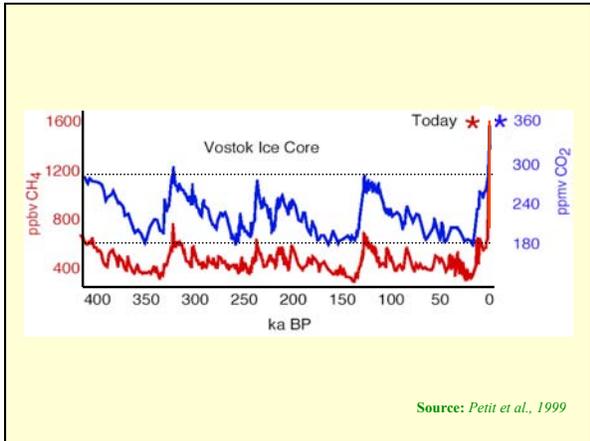


Changes in  $\delta^{18}\text{O}$  measured can be influenced by many factors!

<p><b>In marine sediments:</b></p> <p><b>Ice Volume (enrichment of oceans)</b></p> <p><b>Melt water</b></p> <p><b>Salinity</b></p> <p><b>Vital effects</b></p>	<p><b>In ice cores:</b></p> <p><b>Temperature at time of precipitation</b></p> <p><b>Distance of transport</b></p>
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➤ Are there thresholds, or feedbacks, in the climate system, beyond which climate will abruptly (& possibly irreversibly) change?

(..& how will increased levels of CO<sub>2</sub> affect these?)

