(lecture on 4/15/08)

Millennial Climate Oscillations - Preindustrial Climate

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Chapter 14 - Millennial Oscillations of Climate
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Millennial Oscillations

Climate oscillations of around a couple thousand years each, in contrast to the orbital frequency climate oscillations driven by precession (23,000 yr), tilt (41,000 yr), and eccentricity (100,000 yr) cycles, are recognized in records of glacial times.

Dansgaard-Oeschger Oscillations: high frequency oscillations in $\delta^{18}O$ in Greenland ice cores during glacial periods

Heinrich Events: ice-rafted debris events found in North Atlantic sedimentary strata; typically occur just prior to sudden large warming events indicated in the O isotopes

Bond (Oscillations): variation in the percentage of polar foraminifera found in North Atlantic sedimentary strata; parallels the cooling and warming indicated in Greenland ice core $\delta^{18}O$ oscillations

Similar high-frequency climate oscillations occurred in ***Europe*** during glacial times.
- Soil clay and carbon content varied (warmer/wetter = more chemical weathering = more clay; warmer/wetter = more vegetation = more carbon).
- Pollen varied between more cold adapted herbaceous (tundra) plants and more mild-adapted trees

Santa Barbara Basin: Millennial oscillations in
- planktonic foraminifera $\delta^{18}O$, indicating changing surface water temperature, similar to pattern in Greenland ice cores
- alternation of mixed (bioturbated = oxygenated) sediment layers vs. finely laminated (therefore anoxic) layers indicating alternation of downwelling - no downwelling

Antarctica vs. Greenland: Millennial oscillations also occur in Antarctic ice core $\delta^{18}O$ records. Using the atmospheric methane record preserved in Antarctic and Greenland air bubbles to correlate the levels in the Antarctic and Greenland cores, it is apparant that the climate oscillations appear to be nearly in direct opposition, i.e., cold in Greenland = warm in Antarctica.

Are the millennial oscillations regional in extent or do the northern and southern hemispheres pulse in opposition to one another?

Interglacial Times: Millennial oscillations were of large amplitude during glacial times, a large part of the total difference between glacial and interglacial values. They are small or non-existent in the record of interglacial times. Climate variations do occur, but it appears that they are local or regional. The whole or large parts of the Earth's climate system are not varying in lock step as it seems it may have when climate was under the strong influence of the polar ice caps.

Are Millennial oscillations cyclic? While a study, based on a particular climate proxy, may indicate a weak periodicity in climate variations, another study based on another proxy will find a different apparent periodicity. The conclusion for now is that they are not periodic but rather, quasi-periodic.

Possible Causes of Millennial Oscillations

Solar Variability: Changes in sunspot activity and solar wind change the amount of very high energy cosmic radiation striking Earth and therefore the amount of ^{14}C produced in the atmosphere by cosmic radiation. Variation in the production of ^{14}C has occurred with ~240 year cycles but no significant millennial cyclicity. So this is not likely the cause of millennial climate oscillations.

Greenhouse Gas Forcing: Methane variations follow (lag) the millennial variations in $\delta^{18}O$, so methane responds to and does not cause the millennial variations. The pattern for CO_2 variation is unclear at present.

Ice Sheet Instability: Perhaps cycles of glacial growth punctuated by rapid surges of ice into the North Atlantic (ice rafting events) could alter ocean circulation. Surges could be produced by gradual sinking of the crust, geothermal heating, sea level rise…

Bipolar Seesaw: Today, warm surface water from the southern hemisphere flow north with the Gulf Stream while cold North Atlantic Deep Water replaces it, upwelling in the South Atlantic. Could slowdown of the formation of NADW (possibly by surges of icebergs/meltwater into the North Atlantic) change the the heat distribution in the Atlantic so that when the Gulf Stream slows down, the North Atlantic cools, while more heat remains in the southern hemisphere so Antarctica warms.

Humans and Preindustrial Climate

Climate's Influence on Human Affairs

Bipedal hominins and ultimately humans evolved in Africa from tree-dwelling primates during the cool, dry climate of the ice ages as forest gave way to savanna and open grassland across much of Africa.

Savanna Hypothesis: One longstanding view is that primates took to bipedalism because of the gradual loss of forests and the need to travel and watch for predators in the tall grasses of the savanna. The timing of the drying and growth of grasslands is consistent with the hypothesis, though that doesn't make it right, and there are other hypotheses out there.

Noah's Flood: As the most recent ice caps receded from the glacial maximum, sea level rose. Eventually, about 7600 years ago, rising Mediterannean waters spilled over into the Black Sea basin. A deep gorge was cut and a giant waterfall stood where the waters gushed into the Black Sea. Water rose rapidly and day by day submerged villages causing the inhabitants of the region disperse widely, bringing their story of a great flood with them.

Human Influence on Climate - "Early Anthropogenic Hypothesis"

During the previous 4 interglacials, CO_2 and CH_4 concentrations gradually fell after peaking early in the interglacial.

CO_2 began falling but then started a steady rise beginning around 8000 years ago. The timing coincides with the rise of agriculture and clearing of forests for cropland. Growing forests pull CO_2 from the atmosphere and store it.

CH_4 began falling but then started a steady rise beginning around 5000-6000 years ago coincident with the beginning of rice paddy irrigation. Vegetation decays in rice paddies under low oxygen conditions thereby producing CH_4.

Climate models indicate that if CO_2 and CH_4 concentrations had continued to drop as in the previous 4 interglacials, the Earth would be at the onset of the next glaciation. (remember: we are currently at a northern hemisphere summer insolation low).