Astronomical Theory of Climate Change

The tilt of the earth relative to its plane of travel about the sun is what causes seasons. The hemisphere "pointing toward" the sun is in summer, while the opposite hemisphere is in winter. The earth makes one full orbit around the sun each year. The northern hemisphere is in summer in the left image, while 6 months later, the southern hemisphere has summer, as in the center image. If the earth's axis were "straight up and down" relative to the orbital plane, as in the right-hand image, there would be no seasons, since any given point at the top of the atmosphere would receive the same amount of sun each day of the year.

Changes in the "tilt" of the earth can change the severity of the seasons - more "tilt" means more severe seasons - warmer summers and colder winters; less "tilt" means less severe seasons - cooler summers and milder winters. The earth wobbles in space so that its tilt changes between about 22 and 25 degrees on a cycle of about 41,000 years. It is the cool summers which are thought to allow snow and ice to last from year to year in high latitudes, eventually building up into massive ice sheets. There are positive feedbacks in the climate system as well, because an earth covered with more snow reflects more of the sun's energy into space, causing additional cooling. In addition, it appears that the amount of Carbon Dioxide in the atmosphere falls as ice sheets grow, also adding to the cooling of the climate.

The earth's orbit around the sun is not quite circular, which means that the earth is slightly closer to the sun at some times of the year than others. The closest approach of the earth to the sun is called perihelion, and it now occurs in January, making northern hemisphere winters slightly milder. This change in timing of perihelion is known as the precession of the equinoxes, and occurs on a period of 22,000 years. 11,000 years ago, perihelion occurred in July, making the seasons more severe than today. The "roundness", or eccentricity, of the earth's orbit varies on cycles of 100,000 and 400,000 years, and this affects how important the timing of perihelion is to the strength of the seasons. The combination of the 41,000 year tilt cycle and the 22,000 year precession cycles, plus the smaller eccentricity signal, affect the relative severity of summer and winter, and are thought to control the growth and retreat of ice sheets. Cool summers in the northern hemisphere, where most of the earth's land mass is located, appear to allow snow and ice to persist to the next winter, allowing the development of large ice sheets over hundreds to thousands of years. Conversely, warmer summers shrink ice sheets by melting more ice than the amount accumulating during the winter.

What is The Milankovitch Theory? The Milankovitch or astronomical theory of climate change is an explanation for changes in the seasons which result from changes in the earth's orbit around the sun. The theory is named for Serbian astronomer Milutin

Milankovitch, who calculated the slow changes in the earth's orbit by careful measurements of the position of the stars, and through equations using the gravitational pull of other planets and stars. He determined that the earth "wobbles" in its orbit. The earth's "tilt" is what causes seasons, and changes in the tilt of the earth change the strength of the seasons. The seasons can also be accentuated or modified by the eccentricity (degree of roundness) of the orbital path around the sun, and the precession effect, the position of the solstices in the annual orbit.

What does The Milankovitch Theory say about future climate change?
Orbital changes occur over thousands of years, and the climate system may also take thousands of years to respond to orbital forcing. Theory suggests that the primary driver of ice ages is the total summer radiation received in northern latitude zones where major ice sheets have formed in the past, near 65 degrees north. Past ice ages correlate well to 65N summer insolation (Imbrie 1982). Astronomical calculations show that 65N summer insolation should increase gradually over the next 25,000 years, and that no 65N summer insolation declines sufficient to cause an ice age are expected in the next 50,000 - 100,000 years (Hollan 2000, Berger 2002).

References:
Milankovitch, M. 1920. Theorie Mathematique des Phenomenes Thermiques produits par la Radiation Solaire. Gauthier-Villars Paris.

Milankovitch, M. 1930. Mathematische Klimalehre und Astronomische Theorie der Klimaschwankungen, Handbuch der Klimalogie Band 1 Teil A Borntrager Berlin.

Milankovitch, M. 1941 Kanon der Erdbestrahlungen und seine Anwendung auf das Eiszeitenproblem Belgrade.
(New English Translation, 1998, Canon of Insolation and the Ice Age Problem. With introduction and biographical essay by Nikola Pantic. 636 pp. $79.00 Hardbound. Alven Global. ISBN 86-17-06619-9.)

Recent Calculations of Earth Orbital Parameters and Insolation by A. Berger are archived at the WDC Paleo.

For more detailed explanations of orbital variations with graphic representations, please see WDC Paleo's educational slide set "The Ice Ages".

See also the "Past Cycles: Ice Age Speculations" section of "The Discovery of Global Warming" from the American Institute of Physics for a history of the development of the astronomical theory of climate change.

 Paleoclimatology Educational Outreach Page

Last Updated Monday, 06-Apr-2009 09:37:48 EDT by paleo@noaa.gov
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