TOEFL iBT Sample
Listening

Answers/clues: color-coded, underlined and/or marked with asterisks (*)

Malinkovitch cycles

Narrator:
Now listen to part of a lecture in an astronomy class.

The earth is about 4.5 billion years old, and up to about 0.9 billion years ago there was actually very little ice covering its surface. From about 2.5 billion years ago, we've had several periods of glaciation. Although there are many concerns about global warming, we're actually in the middle of a cooling period now: the Holocene Epoch. Does that surprise you?

In any event, during periods of glaciation, temperatures dropped substantially everywhere, and much of the planet--some theories suggest at times nearly all of the planet--was covered by ice. There are several theories on the causes of this historic glaciation, including changes in land mass and ocean currents and levels of carbon dioxide.

Another factor—perhaps a decisive one--may have been the actual orbit of the earth. The contribution of changes in the orbit of the earth to glaciation was developed by Milutan Milankovitch and his theory is known as the Milankovitch cycles. His theory asserts something called <u>orbital forcing: changes in the orbit of the earth “forcing” changes in its climate.</u>

Let me provide the backdrop of this theory by restating facts that most of you probably already know: the earth is not a perfect sphere; it’s more of a somewhat egg-shaped body. You also know that the earth tilts on its axis. When a northern or southern earth hemisphere tilts toward the sun, it experiences warmer weather and when it tilts away, it experiences colder weather. That’s why when it’s summer in the United States, it’s winter in Argentina. You may also know that the orbit of the earth is not a perfect circle, as is often depicted in diagrams. To sum up, then, the earth is not a perfect sphere spinning on a perfectly vertical axis traveling in a perfectly circular orbit around the sun. Milankovitch took these facts and showed how their interactions could change the climate of our planet.

Firstly, Milankovitch noted that the orbit of the earth around the sun is eccentric. That is, it is neither wholly circular nor wholly elliptical. The orbit actually changes over a period of thousands of years, from somewhat circular to somewhat elliptical--a type of “stretched circle.” A more elliptical orbit will take it far from the sun at some points. When that happens, it receives less solar energy, or insolation. A more circular orbit will distribute insolation more broadly across the surface of the earth.

The second element of his theory is precession, or “wobble.” Have you ever seen a spinning top? After a few moments, it will stop spinning perfectly and start to wobble back and forth before falling. The rotation of earth has a similar wobble effect--although of course it will never “fall down.”

The last element of this theory is axial tilt, how the hemispheres of the earth “lean toward” or “lean away from” the sun. As I just mentioned, this leaning or “tilt” is what gives each hemisphere its season. Well, the degree of this tilt can vary. To be more precise, it will be “much” tilted toward or away from the sun or “not much” titled. When its tilt is minimized, summers at the lower hemispheric latitudes are colder and less insolation reaches the higher latitudes. In practical terms, low axial tilt means that summers in places such as the southern American states and central China will be cooler.

When orbital eccentricity, axial tilt and precession reduce the amount of insolation the earth receives, glaciation may occur. The most critical factor will be how much insolation the lower hemispheric latitudes receive during their summers. If they don’t receive much, the winter snow and ice may not melt. Instead, it may accumulate. It will also reflect insolation back into space instead of allowing the surface of the earth to absorb it. This reflection and retained precipitation creates a sort of cold weather feedback loop, eventually causing glaciation.

Research has shown that over the last 800,000 years, the temperature of the earth has approximately varied with changes in orbital eccentricity, axial tilt and precession that the Milankovitch Cycle theory predicts. This research is not only based on mathematical models, but the study of ice cores, pieces of ice that are sometimes hundreds of thousands of years old. Likewise, coral reefs in some oceans show evidence of periodic glaciation approximating what the Milankovitch cycles theory would indicate.

23. What is the lecture mainly about?

(A) A model of climate change
(B) A prediction of local weather
(C) An analysis of seasonal change
(D) An overview of the solar system

24. According to the professor, what was true of the earth 0.9 billion years ago?

(A) It gave off excessive heat.
(B) It contained faster-flowing currents.
(C) It had very little landmass change.
(D) It had a minimal amount of ice.

25. According to the professor, what may start a cold weather feedback loop leading to glaciation?

(A) Snow accumulation near the poles of the earth

(B) The melting of snow in higher hemispheric latitudes
(C) Persistence of precipitation in some areas of the globe
(D) Excessive insolation across all parts of the world

26. Why does the professor mention spinning tops?
(A) To illustrate how some bodies may rotate
(B) To show gravity may cause a wobble effect
(C) To prove that the earth spins almost perfectly
(D) To indicate the role of speed and force in an orbit

27. The Milankovitch cycles theory states that some features of earth movement through space may lead to significant changes to the surface of the planet. What evidence does the professor mention to support this? *Choose 3 answers.*

- Studies of discovered ice cores
- Verification through experiments
- Increasing worldwide sea levels
- Research on old coral reefs
- Changes in planetary size over time
- Data from sophisticated satellites

28. Listen to track (X).
Narrator
Listen again to part of the lecture. Then answer the question.
Professor

Although there are many concerns about global warming, we're actually in the middle of a cooling period now: the Holocene Epoch. Does that surprise you?

Why does the professor say this:
Does that surprise you?

(A) Several problems are resolved.
(B) New analysis is somewhat unclear.
(C) A current assumption is contradicted.
(D) A widely-held belief is clearly promoted.

Select Sources

Up to 0.9 billion years ago the
Earth was apparently mostly ice-free, despite low solar luminosity, although there is some evidence for a first glaciation approximately 2.5 billion years ago.

Cold winters, northern latittudes, feedback on cold earth

> Evidence supporting Milankovitch's theory of the precise timing of the ice ages first came from a series of fossil coral reefs that formed on a shallow ocean bench in the South Pacific during warm interglacial periods. As the ice ages came, more and more water froze into polar ice caps and the ocean levels dropped, leaving the reef exposed. When the ice melted, the ocean rose and warmed, and another reef formed. At the same time, the peninsula on which the reefs formed was steadily being pushed up by the motion of the Earth's shifting tectonic plates. Today, the reefs form a visible series of steps along the shore of Papua New Guinea. The reefs, the age of which was well-defined because of the decaying uranium in the coral, measured out the millennia between ice ages. They also defined the maximum length of each ice age. The intervals fell exactly where Milankovitch said they would.
>
> ▶ Explaining Rapid Climate Change

http://earthobservatory.nasa.gov/Features/Paleoclimatology_Evidence/

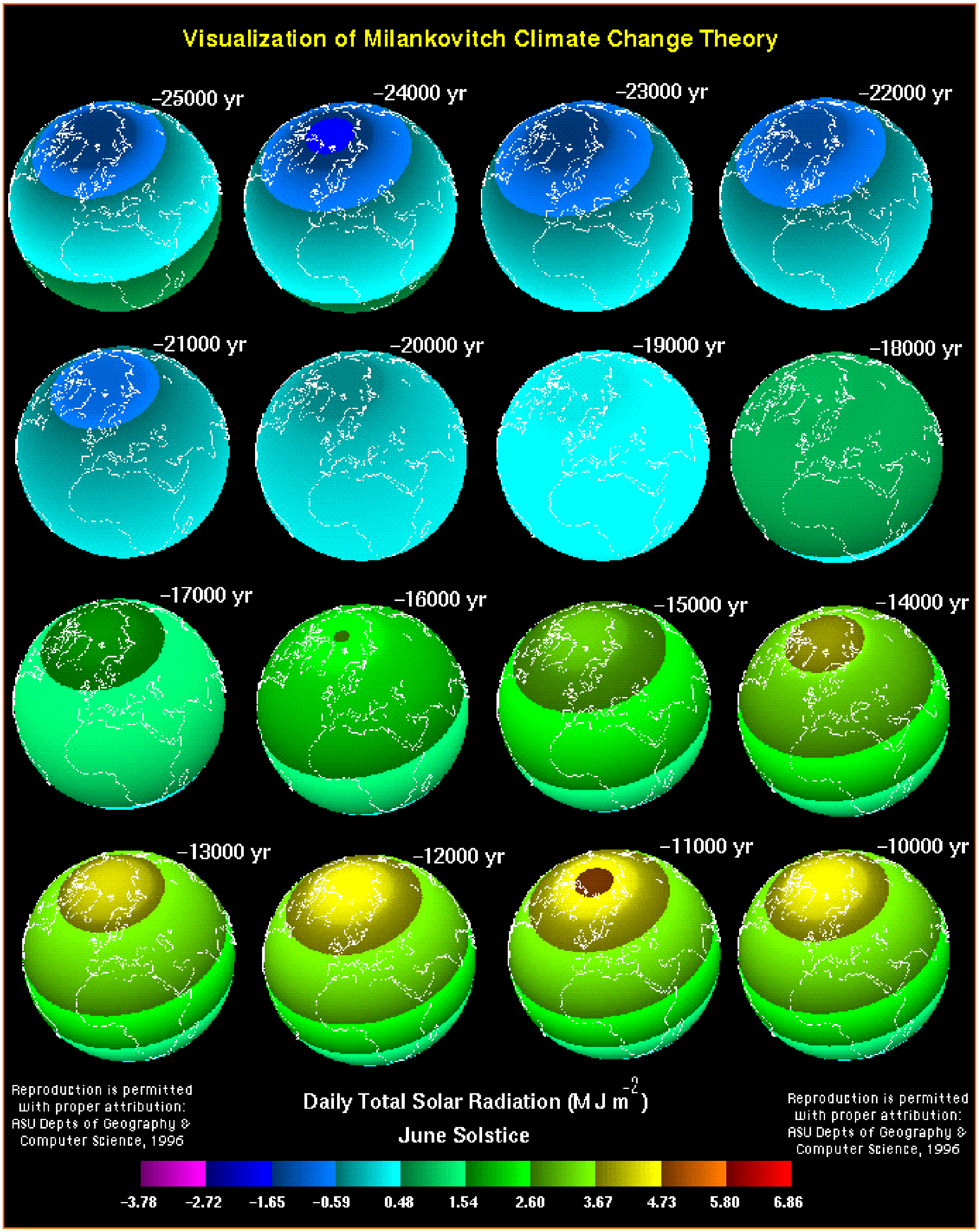
Do ice ages come and go slowly or rapidly? Records show that ice ages typically develop slowly, whereas they end more abruptly. Glacials and interglacials within an ice age display this same trend.

he Formation of Glacial Ice
Glaciers can only form at latitudes or elevations above the ***snowline***, which is the elevation above which snow can form and remain present year round. The snowline, at present, lies at sea level in polar latitudes and rises up to 6000 m in tropical areas. Glaciers form in these areas if the snow becomes compacted, forcing out the air between the snowflakes. As compaction occurs, the weight of the overlying snow causes the snow to recrystallize and increase its grain-size, until it increases its density and becomes a solid block of ice.

http://culter.colorado.edu/~saelias/glacier.html

One significant trigger in initiating ice ages is the changing positions of Earth's ever-moving continents, which affect ocean and atmospheric circulation patterns. When plate-tectonic movement causes continents to be arranged such that warm water flow from the equator to the poles is blocked or reduced, ice sheets may arise and set another ice age in motion.
Today's ice age most likely began when the land bridge between North and South America (Isthmus of Panama) formed and ended the exchange of tropical water between the Atlantic and Pacific Oceans, significantly altering ocean currents.
Glacials and interglacials occur in fairly regular repeated cycles. The timing is governed to a large degree by predictable cyclic changes in Earth's orbit, which affect the amount of sunlight reaching different parts of Earth's surface. The three orbital variations are: (1) changes in Earth's orbit around the Sun (eccentricity), (2) shifts in the tilt of Earth's axis (obliquity), and (3) the wobbling motion of Earth's axis (precession).
How do we know about past ice ages? Scientists have reconstructed past ice ages by piecing together information derived from studying ice cores, deep sea sediments, fossils, and landforms.

http://jrscience.wcp.muohio.edu/studentresearch/climate_projects_04/glacial_cycles/web/data.html



So: it looks as if in the last 800,000 years, variations in the Earth's temperature occur at periods that most closely match those of

obliquity (41 kiloyear) and eccentricity (100 kiloyear) cycles.
Variations in insolation are strongly a
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precession cycles, with period 20 kiloyears. But this
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The Earth has been cooling for at least 15 million years, with
glaciers in the Northern Hemisphere for at least 5 million years.
Irregular climate cycles have been getting stronger during this
time, becoming full-
edged glacial cycles roughly 2.5 million years
ago. These cycles lasted roughly 40,000 years at rst, and more
recently about 100,000 years.

Precession and changes in obliquity do not a
ect the yearly total
sunshine hitting the Earth. Changes in eccentricity do a
ect it, but
only a small amount: just 0.167%.
However, these changes dramatically a
ect the amount of sunshine
hitting the Earth at a given time of year at a given latitude. On
the summer solstice at 65 N, averaged over the whole day, the
insolation can vary between 440 and 560 watts per square meter!

http://math.ucr.edu/home/baez/glacial/glacial.pdf

http://www.museum.state.il.us/exhibits/ice_ages/why_glaciations1.html http://www.livescience.com/28219-holocene-epoch.html

GEOMETRY OF OCEAN BASINS

Another theory explaining these changes in climate involves the opening and closing of gateways for the flow of ocean currents. This theory suggests that the redistribution of heat on the planet by changing ocean circulation can isolate polar regions, cause the growth of ice sheets and sea ice, and increase temperature differences between the equator and the poles.

Ocean modeling experiments suggest that the ocean could not have carried enough heat to the poles to maintain the early warm climates. But atmospheric climate modeling experiments show that even if the ocean did transport enough heat up to the coast of Antarctica to maintain sea surface temperatures at 10 to 15 degrees Celsius, the interior conditions would still be much colder—and this is contrary to the geologic record. It is possible, however, that changes in heat transport caused by variations in ocean gateways may have played a significant role in cooling trends over the last 60 million years, and, in particular, may help explain some of the relatively sudden cooling events.

POSSIBLE EXPLANATIONS FOR THE PAST 60 MILLION YEARS OF COOLING

Climate change on ultra-long time scales (tens of millions of years) are more than likely connected to plate tectonics. Plate motions lead to cycles of ocean basin growth and destruction, known as Wilson cycles, involving continental rifting, seafloor-spreading, subduction, and collision. Several explanations of the latest cooling trend that involve a climate-tectonic connection are summarized below.

We are still in the midst of the third major cooling period that began around 3 million years ago.

Although the exact causes for ice ages, and the glacial cycles within them, have not been proven, they are most likely the result of a complicated dynamic interaction between such things as solar output, distance of the Earth from the sun, position and height of the continents, ocean circulation, and the composition of the atmosphere.

Ever since the Pre-Cambrian (600 million years ago), ice ages have occurred at widely spaced intervals of geologic time—approximately 200 million years—lasting for millions, or even tens of millions of years. For the Cenozoic period, which began about 70 million years ago and continues today, evidence derived from marine sediments provide a detailed, and fairly continuous, record for climate change. This record indicates decreasing deep-water temperature, along with the build-up of continental ice sheets. Much of this deep-water cooling occurred in three major steps about 36, 15 and 3 million years ago—the most recent of which continues today.

ATMOSPHERIC CARBON DIOXIDE

Changes in the concentration of carbon dioxide in the atmosphere are a strong candidate to explain the overall pattern of climatic change. Carbon dioxide influences the mean global temperature through the greenhouse effect. The globally averaged surface temperature for the Earth is approximately 15 degrees Celsius, and this is due largely to the greenhouse effect. Solar radiation entering earth's atmosphere is predominantly short wave, while heat radiated from the Earth's surface is long wave. Water vapor, carbon dioxide, methane, and other trace gases in the Earth's atmosphere absorb this long wave radiation. Because the Earth does not allow this long wave radiation to leave, the solar energy is trapped and the net effect is to warm the Earth. If not for the presence of an atmosphere, the surface temperature on earth would be well below the freezing point of water.

http://www.pbs.org/wgbh/nova/earth/cause-ice-age.html

http://www.skepticalscience.com/Milankovitch.html

http://www.tulane.edu/~sanelson/geol111/glaciers.htm

https://www.ncdc.noaa.gov/paleo/milankovitch.html

an be argued that lower obliquity favors ice ages for two reasons: the reduction in overall summer insolation and the additional reduction in mean insolation at high latitude.

A glacier is a permanent (on a human time scale, because nothing on the Earth is really permanent) body of ice, consisting largely of recrystallized snow, that shows evidence of downslope or outward movement due to the pull of gravity.

Glacial Ages

The term "ice age" typically invokes images of a frozen world, covered in snow and ice, in a time when woolly mammoths and sabre-toothed tigers roamed the Earth. However, scientists use the term ice age or **glacial age** to describe any geological period in which long-term cooling takes place and ice sheets and glaciers exist. That means we are currently in the midst of an ice age right now! More specifically, we are in an **interglacial** (warm period) within a glacial age. Cold periods within a glacial age are called **glacials** or**glaciations**, and are characterized by cooler temperatures and advancing glaciers.

http://serc.carleton.edu/eslabs/cryosphere/4a.html

Milankovitch Cycles

We know that Earth's climate has been highly variable over time, but what processes are behind these climatic swings?

Serbian astrophysicist Milutin Milankovitch is credited for developing one of the most significant theories relating changes in Earth's orbit to long-term changes in climate, including ice ages. Milankovitch's theory is based on cyclical variations in three aspects of Earth's orbit that result in changes to the seasonality and location of solar radiation reaching Earth:

1. **Changes in the obliquity (tilt) of Earth's axis**
2. Earth is slightly tilted—that's why we have seasons. As Earth orbits the sun, one hemisphere will be tilted toward the sun for a period of time (summer) and tilted away from the sun six months later (winter). Today, Earth's rotational axis is tilted at about 23.5 degrees from vertical. However, this tilt oscillates between 22.1 and 24.5 degrees on a 41,000-year cycle. Variations in the obliquity (tilt) of Earth's rotational axis result in changes in the severity of seasonal changes. When the tilt is larger, the extremes between summer and winter temperatures are greatest. When the tilt is smaller, the average temperature difference between winter and summer is less drastic. It is believed that it's actually these periods of smaller tilt that promote the growth of ice sheets. When Earth's axis is less tilted, winters are relatively warmer and summers are relatively cooler. This means that there is more moisture in the air in winter and therefore more snowfall. It also means that there is less summer melting, so more of the winter snow accumulation will last through the warmer months.
3.

4. **Variations in the shape of Earth's orbit (eccentricity)**
5. The gravitational pull of other planets orbiting the sun causes the shape of Earth's orbit to be elliptical rather than perfectly circular. Eccentricity (e), which ranges from 0 to 1, is a measure of how much an ellipse deviates from a perfect circle (how flattened the circle is). An orbit with an eccentricity of 0 is perfectly circular, and an orbit with an eccentricity of 1.0 is a parabola (no longer a closed orbit). The shape of Earth's orbit ranges from nearly circular (e = 0.005) to slightly elliptical (e = 0.058) and back again about every 100,000-400,000 years. Changes in eccentricity are important to determining periods of glaciation because they determine the distance between the Earth and sun, and therefore how much radiation is received at the Earth's surface during different seasons. When the orbit is nearly circular, the distance between the Earth and sun (and therefore the amount of solar energy reaching Earth) remains relatively constant throughout the year. However, when the orbit is more elliptical, the distance between the Earth and sun (and the amount of energy reaching Earth) fluctuates between seasons, resulting in slightly warmer or cooler temperatures. Today, Earth's orbit has an eccentricity of 0.017.
6.
7. **Changes in Earth's "Wobble" (Precession)**
8. Earth's axis of rotation behaves like a spinning top that is slowing down, wobbling in a circle over time. Earth's axis wobbles between pointing at Polaris (what we now call the North Star) and pointing at the star Vega (which would then be considered to be the North Star). Every year, this wobble causes Earth to travel slightly farther than one full orbit each year. This means that on today's date next year, Earth will be a little bit further in its orbit than it is right now. This is called precession. Earth's axis completes a full cycle of precession approximately once every 26,000 years. Because Earth's orbit isn't perfectly circular, the distance between the Earth and sun (and the average temperature) will be slightly different each year on the same date. Precession can cause significant changes in climate due to greater contrast in seasons. For example, when Earth's axis is pointed at Vega, the winter solstice in the northern hemisphere coincides with Earth being at its farthest distance from the sun (aphelion), and the summer solstice coincides with Earth being at its closest distance from the sun (perihelion). Just like with

variations in obliquity and eccentricity, the more drastic seasons brought on by precession will impact glaciation.

9.

As the Earth spins around its axis and orbits around the Sun, several quasi-periodic variations occur due to gravitational interactions. Although the curves have a large number of sinusoidal components, a few components are dominant.[2] Milankovitch studied changes in the orbital eccentricity, obliquity, and precession of Earth's movements. Such changes in movement and orientation alter the amount and location of solar radiation reaching the Earth. This is known as *solar forcing* (an example of radiative forcing). Changes near the north polar area, about 65 degrees North, are considered important due to the great amount of land. Land masses respond to temperature change more quickly than oceans, which have a higher effective heat capacity, because of the mixing of surface and deep water and the fact that the specific heat of solids is generally lower than that of water.

If the Earth were the only planet orbiting our Sun, the eccentricity of its orbit would not perceptibly vary even over a period of a million years. The Earth's eccentricity varies primarily due to interactions with the gravitational fields of Jupiter and Saturn. As the eccentricity of the orbit evolves, the semi-major axis of the orbital ellipse remains unchanged. From the perspective of theperturbation theory used in celestial mechanics to compute the evolution of the orbit, the semi-major axis is an adiabatic invariant.

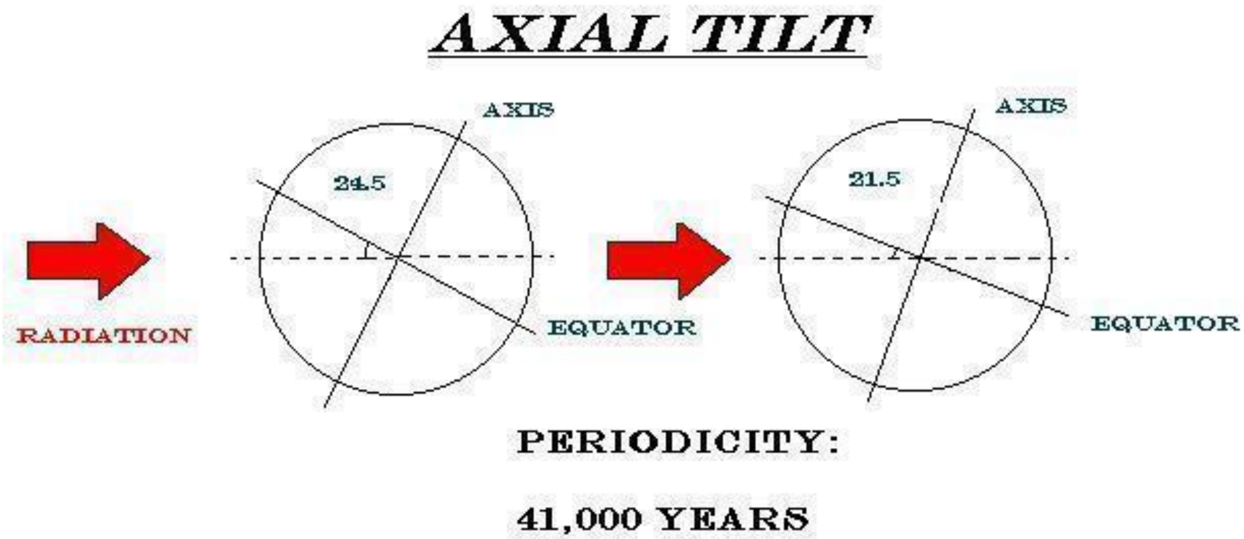
Eccentricity

t is of primary importance to explain that climate change, and subsequent periods of glaciation, resulting from the following three variables is **not due to the total amount of solar energy reaching Earth**. The three Milankovitch Cycles impact the **seasonality and location of solar energy** around the Earth, thus impacting contrasts between the seasons.

Today a difference of only about 3 percent occurs between aphelion (farthest point) and perihelion (closest point). This 3 percent difference in distance means that Earth experiences a 6 percent increase in received solar energy in January than in July. This 6 percent range of variability is not always the case, however. When the Earth's orbit is most elliptical the amount of solar energy received at the perihelion would be in the range of 20 to 30 percent more than at aphelion. Most certainly these continually altering amounts of received solar energy around the globe result in prominent changes in the Earth's climate and glacial regimes. At present the orbital eccentricity is nearly at the minimum of its cycle.

Axial Tilt

Axial tilt, the second of the three Milankovitch Cycles, is the inclination of the Earth's axis in relation to its plane of orbit around the Sun. Oscillations in the degree of Earth's axial tilt occur on a periodicity of 41,000 years from 21.5 to 24.5 degrees.



Today the Earth's axial tilt is about 23.5 degrees, which largely accounts for our seasons. Because of the periodic variations of this angle the severity of the Earth's seasons changes. With less axial tilt the Sun's solar radiation is more evenly distributed between winter and summer. However, less tilt also increases the difference in radiation receipts between the equatorial and polar regions.

Precession

The third and final of the Milankovitch Cycles is Earth's precession. Precession is the Earth's slow wobble as it spins on axis. This wobbling of the Earth on its axis can be likened to a top running down, and beginning to wobble back and forth on its axis. The precession of Earth wobbles from pointing at Polaris (North Star) to pointing at the star Vega. When this shift to the axis pointing at Vega occurs, Vega would then be considered the North Star. This top-like wobble, or precession, has a periodicity of 23,000 years.

Due to this wobble a climatically significant alteration must take place. When the axis is tilted towards Vega the positions of the Northern Hemisphere winter and summer solstices will coincide with the aphelion and perihelion, respectively. This means that the Northern Hemisphere will experience winter when the Earth is furthest from the Sun and summer when the Earth is closest to the Sun. This coincidence will result in greater seasonal contrasts. At present, the Earth is at perihelion very close to the winter solstice.
http://www.indiana.edu/~geol105/images/gaia_chapter_4/milankovitch.htm

Milankovitch argued that insolation
changes induce surface temperature changes and that long-term insolation changes are sufficient to produce ice ages by changing the geographic and seasonal distribution of sunlight received by the Earth.

Therefore astronomical theory is at a crossing point of geology, astronomy, physics, chemistry, biology, and geophysics. Moreover, it is related to processes of the solid Earth, the atmosphere, the hydrosphere, and the ocean.

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http://curry.eas.gatech.edu/Courses/6140/ency/Chapter10/Ency_Atmos/Ice_age.pdf