

Milankovitch Cycle Case Study

- Milankovitch cycles
- Eccentricity
- Obliquity
- Precession

WHAT YOU WILL LEARN

1. You will recognize how Milankovitch Cycles cause changes in the Earth's orbit and orientation.
2. You will recognize that cyclical conditions cannot explain the persistent change in global temperature increases.

How has global temperature changed over time?

The Earth's temperature has varied over the past four million years, and that at least 30 glacial periods have occurred. The graph below (Figure 1) shows data from ice core samples that chronicle the temperature and carbon dioxide levels over the past 400 thousand years. There is a direct correlation between the temperatures and the occurrence of ice ages. The carbon dioxide levels also correlate to the temperature which supports the idea that carbon dioxide levels contribute to warmer global temperatures.

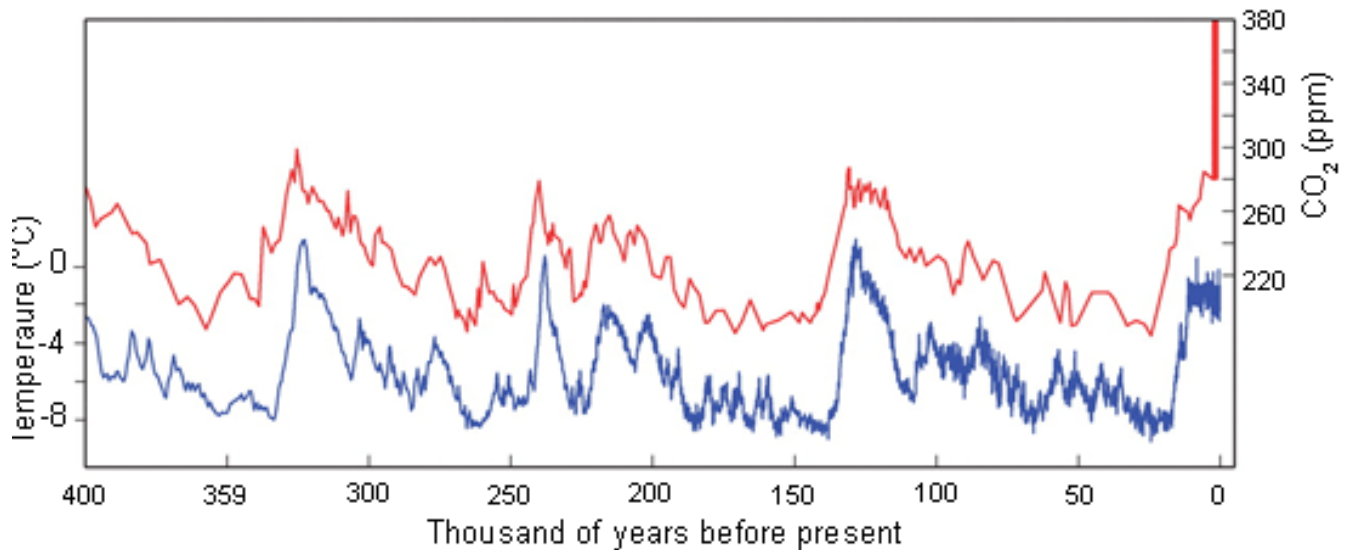


Figure 1. Variations in Temperature and CO₂ from the Volstok Ice Core

3. According to the data, how many cooling periods occurred during the past 400,000 years?

In the 1920's a Serbian scientist by the name of Milutin Milankovitch developed a theory to explain possible climate changes that could be caused by the Earth's changing patterns of orbit and tilt in relationship to the sun. Specifically, he tried to explain the occurrences of the ice ages. Milankovitch found that the changes in the Earth's orbit and tilt occur in cycles over very long periods of time—tens of thousands of years. These cycles are now known as the **Milankovitch Cycles**. Milankovitch's cycles were based on his mathematical calculations, and presented as a possible explanation for ice age events. His work was not considered seriously

until the 1970's when actual ice core data showed a possible connection between ice ages and the cycles Milankovitch had suggested. Scientists are now wondering if the Milankovitch Cycles could help explain the recent rise in the Earth's temperatures. Milankovitch studied three aspects of the Earth's orbit around the Sun that influences the amount of energy that the Earth receives from the Sun.

4. What did Milankovitch's theory originally try to explain?

The Earth's Tilt (OBLIQUITY)

Seasonal changes are caused by the tilt of the Earth (Figure 2). Today, the Earth's tilt is about 23.5° when compared against the Earth's orbit around the Sun. The first day of summer for the northern hemisphere occurs when the north pole of the Earth is tilted at the maximum 23.5° toward the Sun. On this day, the northern hemisphere receives the maximum amount of the Sun's radiant energy. This day also begins the first day of winter for the southern hemisphere.

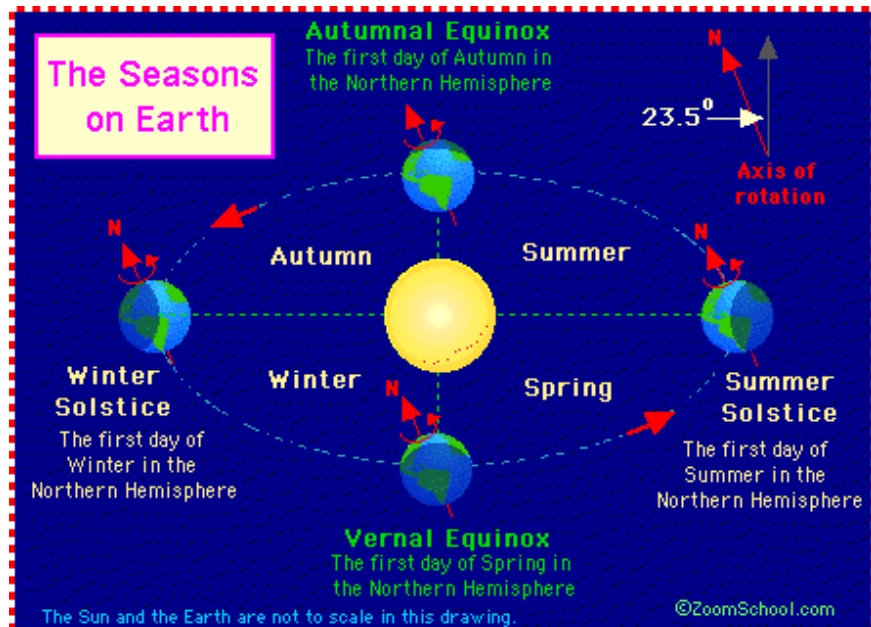


Figure 2. The Earth's Seasons

5. What causes the seasonal changes that we experience each year?

The shape of the Earth's Orbit (ECCENTRICITY)

The orbit of the Earth is not quite circular. The orbit is in the shape of an oval, and this shape is called an ellipse (Figure 3). This elliptical orbit causes the distance of the Earth from the Sun to continually change throughout the year. The Earth's average distance from the Sun is 93 million miles. At the Earth's closest point to the Sun, called the perihelion, the Earth is about 91.5 million miles from the Sun. This occurs in early January. The Earth reaches its furthest position away from the Sun, called the aphelion, in early July. At that time the Earth is about 94.5 million miles from the Sun. Some evidence exists that this elliptical orbit may make the northern seasons less severe than seasons in the Southern Hemisphere although the difference may be slight. The Northern Hemisphere has more land mass and therefore a greater chance of warming no matter the season. This fact may negate any difference in temperature caused by the Earth's changing distance from the Sun.



Figure 3. The Earth's Orbit. Source: Zoom Astronomy

The direction of the Earth's tilt (PRECESSION)

Currently the North Pole is pointing toward the North Star. This situation causes the Northern Hemisphere to tilt away from the Sun when the Earth is closest to the Sun (our winter) and tilt toward the Sun when the Earth is furthest from the Sun (our summer).

6. During which Northern Hemisphere season is the Earth actually closest to the Sun?

If these conditions of orbit and tilt continue as they now are set in a yearly repetition, then no change should be expected in the amount of solar heating taking place on Earth. The yearly cycle of solar heating should always continue to have the same effect on the Earth's atmospheric temperature. The Earth, however, does not follow the same pattern of orbit and tilt in relationship to the Sun over great expanses of time.

How might the Milankovitch Cycles be influencing present day global temperatures?

ECCENTRICITY

Milankovitch's first cycle has to do with **eccentricity**. Eccentricity is a measure of how much the ellipse of the Earth's orbit differs from a circle (Figure 4). The ellipse on the left is almost a circle. The ellipse on the right is more like an oval, therefore more eccentric than the ellipse on the left.



Figure 4. Different Earth Orbits.

If the Earth made a perfect circle around the Sun, it would be 93 million miles from the Sun all year around. However, because the Earth's orbit is an ellipse, the Earth travels closer and farther from the Sun at different times. Presently, the Earth's elliptical orbit varies from a circular shape by 3-million miles in distance from the Sun over a year's period of time. At an average distance of 93 million miles, this change is only about a 3% change. This amount of change does not seem too significant and it does not seem to cause temperature changes for the Earth. A more circular orbit will create less severe seasons and therefore less seasonal change. But, as Milankovitch discovered the shape of the ellipse changes and becomes more eccentric. This change could cause the Earth to be very much further away from the Sun at aphelion than the present day situation, and this large change in distance from the Sun could cause more severe seasons. Cooler summers could allow the buildup of snow and ice fields similar to the glacial period of the ice age. This cycle is estimated to repeat every 100,000 years.

7. How could a change in the earth's orbital eccentricity effect climate on the Earth?

8. How long does it take for this cycle to repeat?

OBLIQUITY

The second cycle Milankovitch proposed is referred to as **obliquity**, or the tilt of the Earth in relationship to the Sun. At present the tilt of the Earth is 23.5° in respect to the orbit around the Sun. This tilt is responsible for the changing seasons and their difference in temperature (Figure 5). Also, the degree of tilt changes over time. Over a 40,000 year period of time, the obliquity or tilt of the earth changes from a minimum of 22.1° to a maximum of 24.5° .

This change in tilt happens very slowly, but it could cause the seasons to be more severe during maximum tilt and less severe at minimum tilt. When the Earth is only tilted 22.1° , the summers and winters could be less severe. During such cooler summers, scientists speculate that winter snow and ice in the northern latitudes might not melt from year to year. In addition, the build up of snow and ice fields could cause sun's energy to be reflected back into space. This additional cooling could cause the build-up of glaciers and the potential for an ice age.

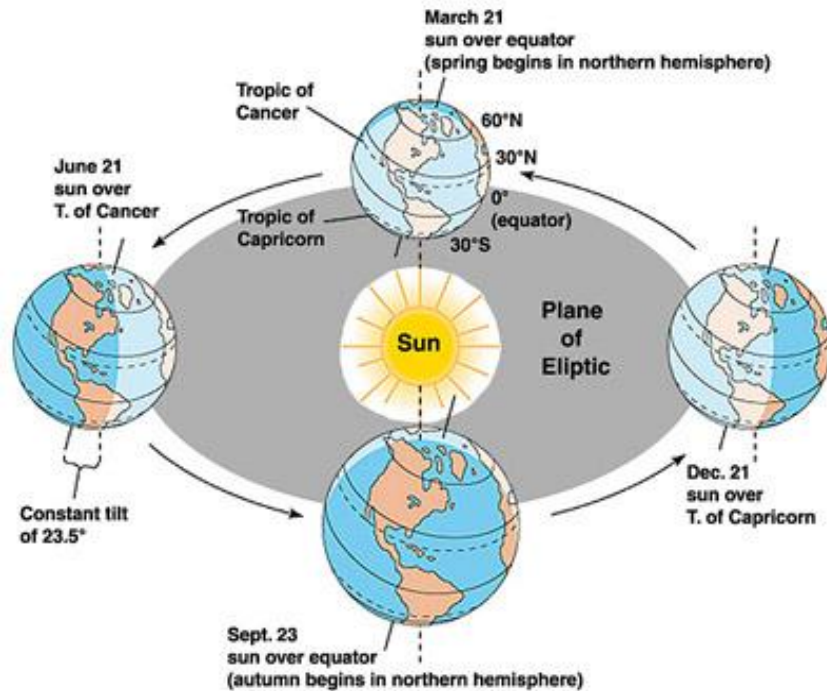


Figure 5. The Relationship between the Earth's Tilt and Orbit. Source: NASA

9. Will more tilt or less tilt cause more severe seasons?

10. How long does it take for the Earth to change from the maximum tilt to the minimum tilt?

PRECESSION

The third Milankovitch cycle deals with a process called **precession** (Figure 6). Currently, the Earth's axis is oriented so that it nearly intersects the star Polaris (the North Star), almost directly over the North Pole. However, this position of the Earth's axis is only accurate for the present time. Four thousand years ago, when the pyramids in Egypt were being built, the axis of the earth was oriented to the star Thuban, a star in the Draco Constellation. In other words, the Earth's tilt has shifted over time. This shift in the Earth's orientation is called precession. A similar movement can be observed as a top spins. The North Pole will draw a circle in the sky which will be completed in a 26,000 year cycle. So, 26,000 years from now, Polaris will once again be the North Star.

Today, the earth is nearest to the Sun (perihelion) during our winter and farthest away during our summer. This position of precession would be expected to cause less severe seasons—and that is what we may be experiencing now as the winters are warmer, and the summers are not markedly hotter. In about twelve thousand years, the precession cycle will move the Earth's perihelion so that it will occur during our summer. Therefore, in twelve thousand years, the earth will be nearest to the Sun during our summer and farthest away during our winter. This precession position is expected to cause greater severity in the seasons.

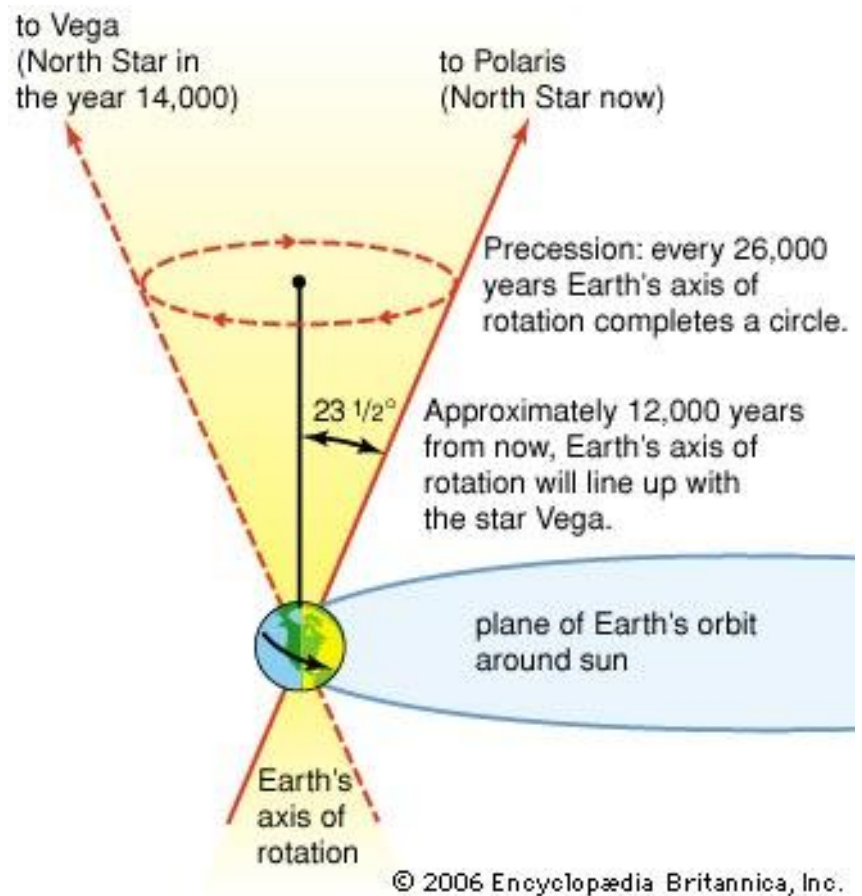


Figure 6. Precession of the Earth's Tilt.
Source: Encyclopædia Britannica

11. What process might bring the Earth closer to the Sun during our summer?

12. How long does it take for precession to complete one cycle?

How do these Milankovitch Cycles combine to affect climate?

Scientists speculate that the most likely scenario for a Northern Hemisphere ice age would be a combination of all three factors: a nearly circular shape of the Earth's orbit (minimum eccentricity), a minimum of 22.1° in the Earth's tilt (minimum obliquity), and a northern-hemisphere winter occurrence of the Earth's perihelion (precession). According to Milankovitch's theory, all of these factors combined would cause the four seasons to be less different from each other. The resulting seasonal temperature changes, even though very small, could allow northern areas to accumulate snow and ice and to form glaciers.

Scientists generally think that these cycles must favorably combine to produce either a cooling trend or a warming trend. At present, the earth's precession is such that perihelion occurs during our winter and scientists expect cooling to occur and the onset of a new ice age, but, the eccentricity and the obliquity of the Earth's orbit are not favorable for ice age conditions. Thus at the present, the cycles do not appear to be favorably combined to create either situation. At present, the Milankovitch Cycles cannot explain the current increase in global temperature.

13. Could the Milankovitch Cycles help explain the recent rise in temperatures here on Earth? Why or why not?

Conclusion

Climate and seasons on the Earth are primarily a function of how much solar radiation is absorbed and retained by the Earth. Many factors help determine exactly how solar radiation effects climate. Seasons are determined by the position of the Earth in respect to the orbit and the tilt of the Earth. The distance of the Earth from the Sun is also important. When the Earth is closer, the increased radiant energy will affect our climate. These factors also change over time within reoccurring cycles.

A correlation has been shown between the Milankovitch Cycles and the occurrence of ice ages. Using the Milankovitch Cycles of eccentricity, obliquity, and precession, ice ages should occur when all three of these factors encourage less severe seasons on Earth. At present, only one cycle, precession, is encouraging less severe seasons. The current precession of the Earth places it closest to the Sun during our winter and farthest away during our summer. This should make Northern Hemisphere seasons less severe, but conversely, Southern Hemisphere seasons more severe. The obliquity, or tilt, of the earth is, at present however, at neither extreme. The 23.5° of tilt at present is midway between the extremes of 22.1° and 24.5° . The eccentricity of the Earth's orbit is also not at an extreme. These cycles also repeat over periods that are 10's of thousands of years long. At present, the Milankovitch Cycles cannot explain the current increase in global temperature.

If temperatures are consistently rising with some variations occurring due to other cycles and events, then factors that persist need to be considered as serious factors. Greenhouse gasses, especially carbon dioxide, have been shown to be steadily rising as is shown by the graph below (Figure 7). This persistent, steady rise could explain the observed recent temperature increase.

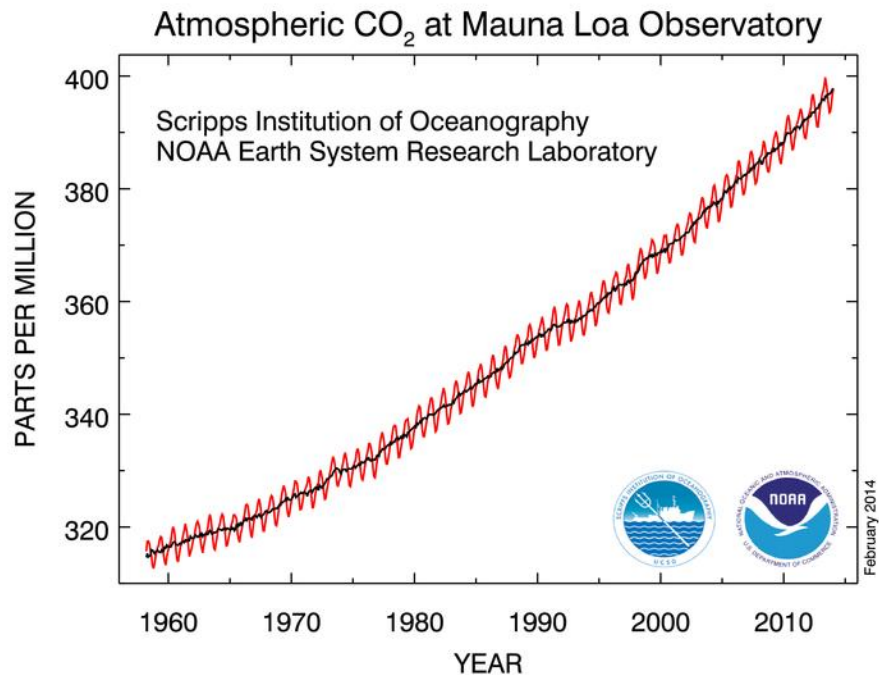


Figure 7. Atmospheric CO₂ levels. Source: NOAA.

Reflect on What You Have Learned

14. How might changes in the Earth's orbit (Milankovitch Cycle) affect the Earth's temperature?

15. How might the Milankovitch Cycle explain the recent increase in global temperature?