Milankovitch Cycles

Orbital effects on climate, the equinox, and seasons

By Matthew West — July 6, 2019

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Who was Milutin Milankovitch?

- Born May 28, 1879, Dalj, Austria-Hungary [now in Croatia]
- Died December 12, 1958, Belgrade, Yugoslavia [now in Serbia]
- Mathematician and geophysicist
- Best known for his work that linked long-term changes in climate to astronomical factors affecting the amount of solar energy received at Earth's surface.
- Published *Kanon der Erdbestrahlung und seine Anwendung auf das Eiszeitenproblem* (1941; *Canon of Insolation and the Ice-Age Problem*).

Who was Milutin Milankovitch?

- Mathematician who became interested in meteorology.
- Developed calculations to predict the temperature at *any* place and time on Earth.
- Collaborated with German meteorologist **Vladimir Köppen** and German geophysicist **Alfred Wegener** (of Continental Drift fame), who were then working on the causes of ice ages.

Who was Milutin Milankovitch?

- Extended his *longhand calculations* hundreds of thousands of years into the past to determine the effect of three astronomical parameters:
  - **Obliquity** (tilt) of Earth's axis of rotation
  - **Precession** (wobble) of the rotation axis
  - **Eccentricity** (circularity) of Earth's orbit

Who was Milutin Milankovitch?

- In the 1950s his calculations and the theory based on them fell out of favour. Most scientists believed that the changes were too slight to have the impact he predicted.

- He was vindicated in the 1970s when high-resolution studies of deep-sea cores confirmed that glacial periods, as reflected in seawater temperatures, precisely follow Milankovitch's predictions over the past one million years.

- Corroborated by Antarctic ice cores.

Who was Milutin Milankovitch?

- The cores provided evidence for cyclical climate change in the past with periods of approximately 100,000, 41,000, and 23,000 years.

- These coincide with the astronomical cycles in eccentricity, axial tilt, and precession, respectively.

- The variations in solar radiation are now known as **Milankovitch cycles**.

Why do Earth's orbital parameters change?

- Earth is not a perfect sphere.
- Earth rotational axis is tilted.
- Sun/Moon interactions.
- Pull from other solar system objects.
- Continentality and mass concentrations cause gravity to pull unevenly on the Earth.

What are Perihelion and Aphelion?

- All orbits are elliptical, not circular.
- Therefore orbits have points where the distance between objects is minimized and maximized.
- Perihelion is the minimum distance between the Earth and the Sun (early January). Maximum insolation (heating).
- Aphelion is the maximum distance between the Earth and Sun (early July). Minimum insolation (heating).

What effect does precession have?

- The change in orientation (wobble) of the Earth's rotational axis.
- Changes in axial precession alter the dates of perihelion and aphelion.
- This increases the seasonal contrast in one hemisphere and decrease the seasonal contrast in the other hemisphere.
- Occurs over a period of 23,000 years.

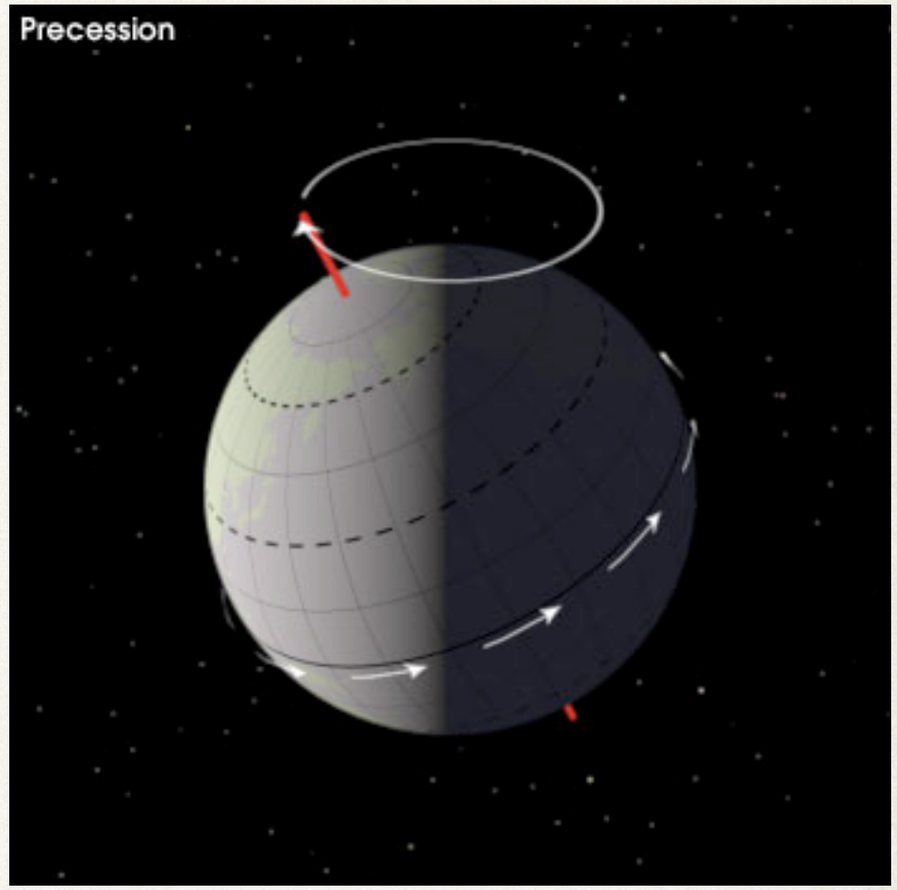


Image by Robert Simmon, NASA GSFC)

What effect does axial tilt (obliquity) have?

- The change in the tilt of the Earth's axis (obliquity).
- Affects the magnitude of seasonal change.
- At higher tilts the seasons are more extreme—warmer summers and colder winters.
- At lower tilts the seasons are more even—warmer winters and cooler summers can cause more snow accumulation in the winter and less melt in the summer.
- Tilt varies between 22.1 and 24.5 degrees.
- Occurs over a period of ~40,000 years.

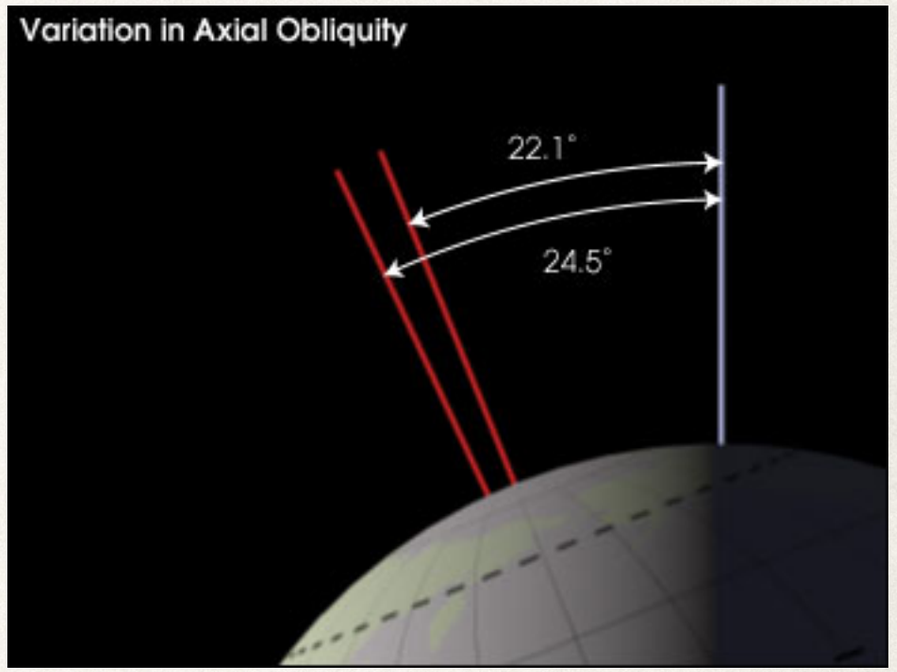
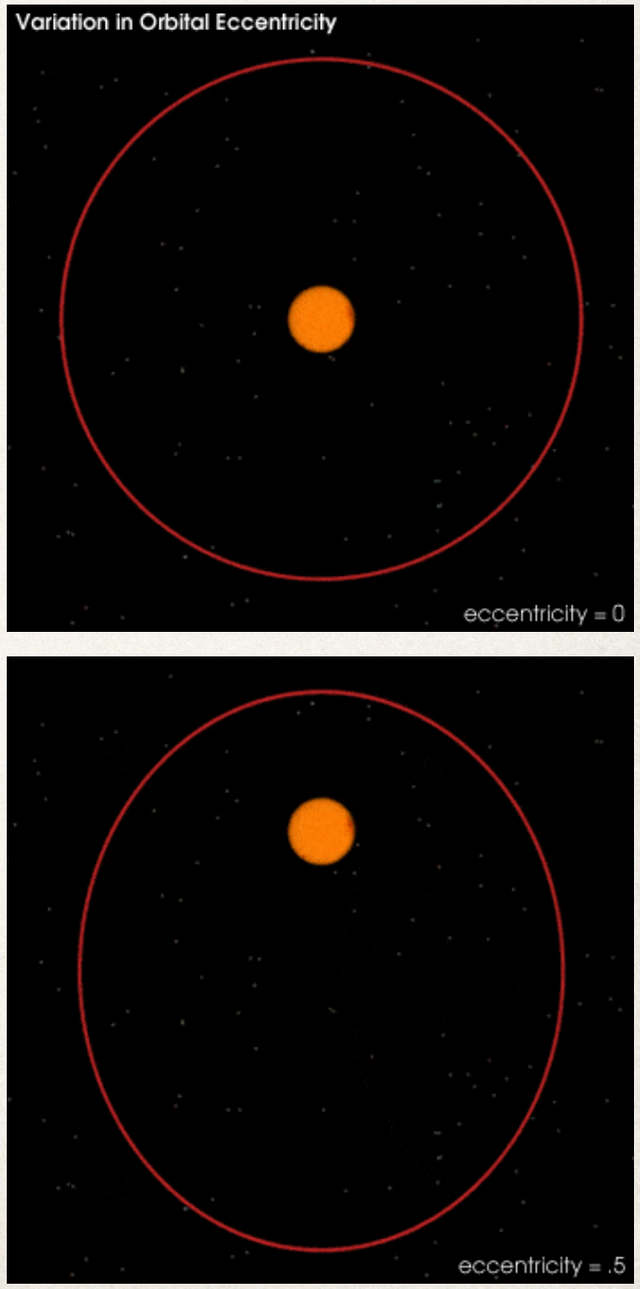


Image by Robert Simmon, NASA GSFC)

What effect does eccentricity have?

- The change in the eccentricity (circularity) of the Earth's orbital path.
- More eccentric (oval) means the difference perihelion and aphelion becomes greater.
- At greatest eccentricity, the amount of insolation received at perihelion would be on the order of 20 to 30 percent greater than at aphelion.
- Occurs over a period of 90,000 to 100,000 years.



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Demonstration: Milankovitch Cycles vs. the ice core record

- Putting it all together…

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