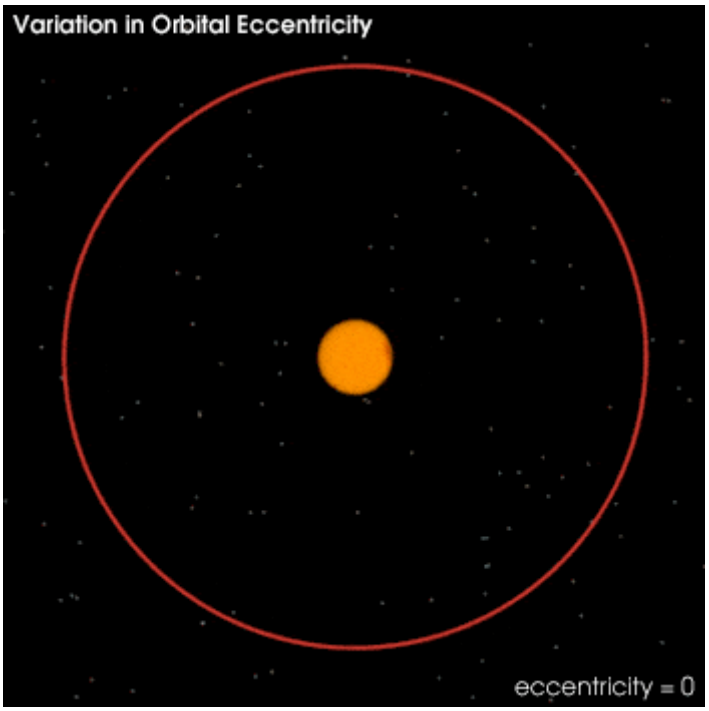
Milutin Milankovitch (1879-1958)

Orbital Variations

Changes in orbital eccentricity affect the Earth-sun distance. Currently, a difference of only 3 percent (5 million kilometers) exists between closest approach (perihelion), which occurs on or about January 3, and furthest departure (aphelion), which occurs on or about July 4. This difference in distance amounts to about a 6 percent increase in incoming solar radiation (insolation) from July to January. The shape of the Earth's orbit changes from being elliptical (high eccentricity) to being nearly circular (low eccentricity) in a cycle that takes between 90,000 and 100,000 years. When the orbit is highly elliptical, the amount of insolation received at perihelion would be on the order of 20 to 30 percent greater than at aphelion, resulting in a substantially different climate from what we experience today.

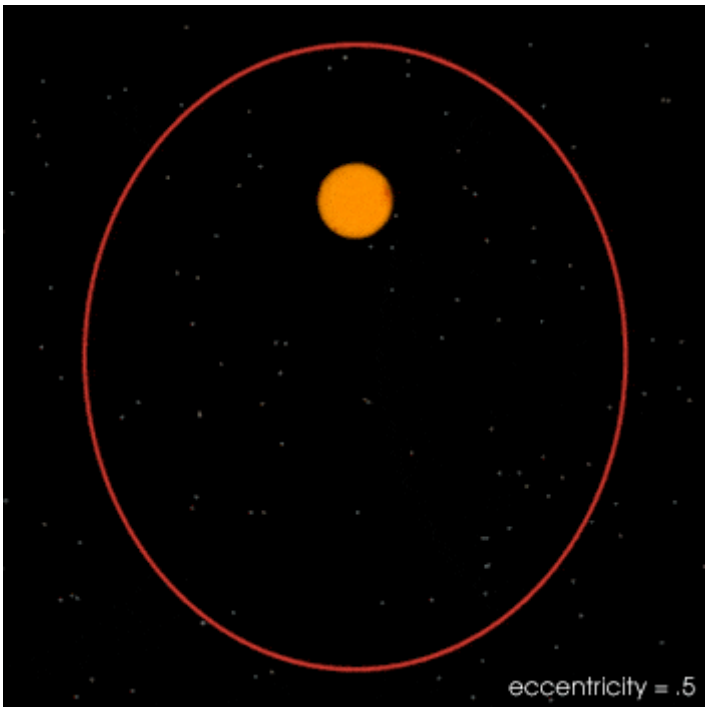


"As the axial tilt increases, the seasonal contrast increases so that winters are colder and summers are warmer."

On the Shoulders of Giants

More Giants

Left: The eccentricity of the

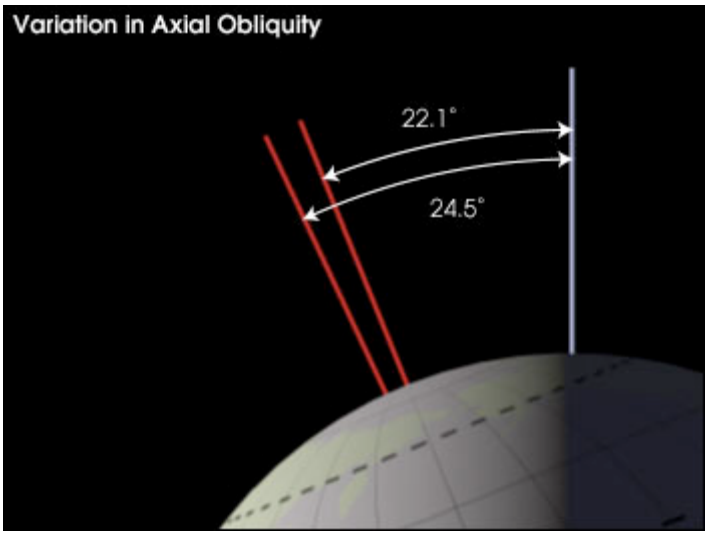


Earth's orbit changes slowly over time from nearly zero to 0.07. As the orbit gets more eccentric (oval) the difference between the distance from the Sun to the Earth at perihelion (closest approach) and aphelion (furthest away) becomes greater and greater. Note that the Sun is not at the center of the Earth's orbital ellipse, rather it is at one of focal points.

Note: The eccentricty of the orbit shown in the lower image is a highly exaggerated 0.5. Even the maximum eccentricity of the Earth's orbit—0.07—it would be impossible to show at the resolution of a web page. Even so, at the current eccentricity of .017, the Earth is 5 million kilometers closer to Sun at perihelion than at aphelion. (Images by Robert Simmon, NASA GSFC)

Obliquity (change in axial tilt)

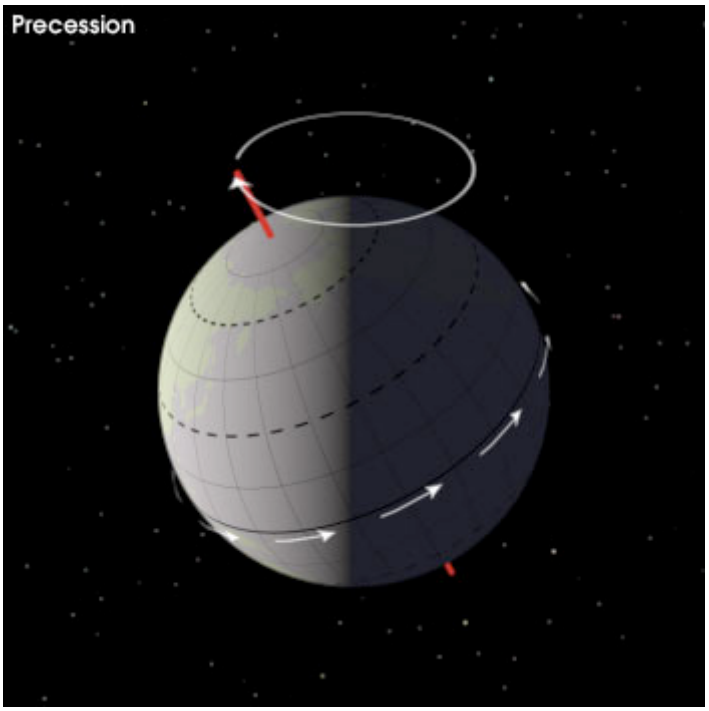
As the axial tilt increases, the seasonal contrast increases so that winters are colder and summers are warmer in both hemispheres. Today, the Earth's axis is tilted 23.5 degrees from the plane of its orbit around the sun. But this tilt changes. During a cycle that averages about 40,000 years, the tilt of the axis varies between 22.1 and 24.5 degrees. Because this tilt changes, the seasons as we know them can become exaggerated. More tilt means more severe seasons—warmer summers and colder winters; less tilt means less severe seasons—cooler summers and milder winters. It's the cool summers that 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.



Left: The change in the tilt of the Earth's axis (obliquity) effects the magnitude of seasonal change. At higher tilts the seasons are more extreme, and at lower tilts they are milder. The current axial tilt is 23.5°. Image by Robert Simmon, NASA GSFC)

Precession

Changes in axial precession alter the dates of perihelion and aphelion, and therefore increase the seasonal contrast in one hemisphere and decrease the seasonal contrast in the other hemisphere.



Left: Precession—the change in orientation of the Earth's rotational axis [this can be seen more clearly in an animation (small (290 kB QuickTime) or large (1.2 MB QuickTime))]—alters the orientation of the Earth with respect to perihelion and aphelion. If a hemisphere is pointed towards the sun at perihelion, that hemisphere will be pointing away at aphelion, and the difference in seasons will be more extreme. This seasonal effect is reversed for the opposite hemisphere. Currently, northern summer occurs near aphelion. (Image by Robert Simmon, NASA GSFC)

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