

Why is summer not caused by being closer to the Sun?

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When the Northern Hemisphere has summer, the Southern Hemisphere has winter. Both hemispheres belong to the same Earth at essentially the same distance from the Sun. This simple comparison already rules out a change in Earth's overall distance as the main explanation for their opposite seasons.

Distance does affect sunlight. The mistake is not believing that closer objects can receive more radiant energy. It is applying that correct principle to the wrong pattern. To explain the seasons, we must explain why the annual changes reverse between hemispheres, and why both the height of the midday Sun and the duration of daylight change together.

1. What the tilted axis changes

Earth rotates about an axis tilted relative to the perpendicular to its orbital plane. Over a year, its direction remains approximately fixed relative to distant stars. Consequently, the Northern Hemisphere is directed more towards the Sun during one part of the orbit and the Southern Hemisphere during the opposite part [1].

The word “towards” can mislead. The main benefit is not the tiny reduction in the surface's distance to the Sun. The tilt changes the angle at which sunlight reaches a horizontal area, and it changes how long that area remains illuminated during each rotation. These are changes in energy received per unit area and per day.

At the equator, the annual pattern differs from the familiar four-season story of temperate latitudes. Near the poles, the geometry can produce continuous daylight or darkness for part of the year. Seasons are therefore not a universal local schedule with identical temperature curves everywhere. A global geometrical cause generates different patterns at different latitudes.

2. The same beam can be spread over more ground

Imagine a beam with power F per unit area measured on a surface perpendicular to its direction. If a horizontal receiving area is tilted relative to that beam so that the Sun's zenith angle is z , the incident power per horizontal area is $F \cos z$. The zenith angle is measured from the upward vertical: overhead sunlight has $z = 0$.

The cosine is a projection factor. It does not mean each photon becomes intrinsically weaker when the Sun is lower. The same beam is spread over a larger horizontal footprint. Atmospheric absorption, scattering and clouds can then further modify what reaches the surface, but the geometrical projection exists before those complications are introduced.

For an illustrative latitude of 45° north and a chosen axial tilt of 23.5° , the ideal solar-noon zenith angles at the two solstices are 21.5° and 68.5° . Their cosine factors are approximately 0.930 and 0.367. Under identical incoming flux and without atmospheric effects, the summer-noon value is about 2.54 times the winter-noon value.

This calculation is deliberately local and instantaneous. It is not a prediction that summer air temperature is 2.54 times winter temperature. Temperature depends on energy storage and transfer, and ratios on the Celsius scale would be physically inappropriate for

that claim in any case. What the calculation establishes is the scale of a geometrical difference in received power.

3. The Sun also stays above the horizon longer

Let φ be latitude and δ the Sun's declination, its angular position north or south of the celestial equator. For a spherical Earth and a point-like Sun, the hour angle at sunrise or sunset satisfies $\cos H = -\tan \varphi \tan \delta$. Ignoring refraction and the Sun's finite apparent size, the daylight duration is $24H/\pi$ hours when H is expressed in radians.

At 45° north, using $\delta = +23.5^\circ$ gives about 15.4 hours of daylight. With $\delta = -23.5^\circ$, the result is about 8.6 hours. Thus the season with the higher noon Sun also provides a longer interval during which solar energy can arrive. Integrating the varying projection factor over daylight gives daily exposure; multiplying noon power by day length would only be a rough shortcut.

The formula has limits that reveal useful physics. At some combinations of latitude and declination, its right-hand side lies outside the range from -1 to $+1$. There is then no ordinary sunrise or sunset in this ideal model: the Sun remains above or below the horizon all day. That is a geometrical condition, not a failure of trigonometry.

Neither a calendar date nor the word summer alone determines local daily exposure. Latitude, orbital position and horizon conditions matter. The ideal calculation isolates two robust mechanisms, angle and duration, while leaving atmospheric and geographical effects to a more complete account.

4. Distance is a real secondary influence

Earth's orbit is slightly elliptical, so the distance to the Sun changes through the year. NASA notes that the closest approach occurs around January and the greatest distance around July [1]. Northern summer therefore occurs near the more distant part of the orbit, contrary to the usual distance-based explanation.

For a fixed solar luminosity, flux on a surface perpendicular to the rays varies as $1/d^2$, where d is distance. If distance increased by a hypothetical 2%, that flux would become $1/(1.02)^2$, about 0.961 of its original value. This is a model example, not a statement that Earth's actual annual distance change is exactly 2%.

A change in orbital distance affects the incoming flux at both hemispheres together. Axial tilt redistributes exposure between them. Both can operate simultaneously, but they leave different geographical signatures. Opposite seasons identify the redistribution as essential; they do not prove that the inverse-square effect is zero.

Longer-term changes in orbital geometry can also alter patterns of exposure. That is a separate timescale from the annual sequence considered here. One should not turn an explanation of ordinary seasons into a claim that Earth's orbit has no relevance to climate on other timescales.

5. Why the warmest day does not simply follow the highest Sun

The atmosphere, ground and ocean store and exchange energy. Their temperatures respond to the balance between incoming and outgoing energy, with transport between regions. A surface can continue warming after the annual maximum of incoming sunlight if its energy gains still exceed its losses.

This is the physical reason a temperature maximum need not coincide with the solstice. The exact delay and magnitude depend on the system being measured. A shallow soil

layer, the air over a continent and a large body of water need not respond alike. Clouds, circulation and evaporation further affect the seasonal temperature record.

Weather is a shorter-term variation superimposed on that annual framework. A cold summer day does not refute the tilt mechanism, just as one unusually warm winter afternoon does not establish a different orbital geometry. A meaningful comparison uses repeated observations and distinguishes the regular seasonal pattern from variability around it.

6. What we can establish without a climate model

Observations of shadow length and daylight duration across the year directly test the geometrical predictions. Comparing sites in opposite hemispheres tests their reversal. Measurements of Earth-Sun distance then test the competing distance explanation against the timing it actually predicts.

The basic cause of opposite hemispheric seasons is secure. Predicting the exact temperature or rainfall at one place is a larger problem, requiring atmospheric and surface processes. A correct geometrical explanation does not claim to solve that entire problem.

Summer comes mainly because a hemisphere receives sunlight at more favourable angles and for longer parts of each day. Distance modifies the amount available, but cannot by itself explain the opposing annual pattern. The common error is answering “what would make sunlight stronger?” before asking “what spatial and seasonal pattern must the explanation reproduce?”

Reference

[1] NASA Space Place. What Causes the Seasons? <https://spaceplace.nasa.gov/seasons/en/> (accessed 5 October 2026).