Journal of Physics Special Topics
An undergraduate physics journal

A3 7 Seasonal Orbit

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December 15, 2023

Abstract

In this paper, we determined how the intensity of solar radiation incident on Leicester changes over the year and investigate what effect Earth's elliptical orbit may have on influencing the intensity. We discovered that there is only a 6% increase on the intensity of sunlight the Earth receives when the Earth is at perihelion compared to it at aphelion. This small difference is drastically outweighed by the ≈70% difference caused by the Earth's tilt.

Introduction

As Earth's orbit around the Sun is elliptical, the solar radiation our planet receives varies throughout the year. This means that our planet receives less energy from the Sun when we are at aphelion, where we are furthest from the Sun, than at perihelion, where we are closest to the Sun. Therefore, at perihelion, we would expect to receive an increased proportion of solar radiation as the Earth is closer to the Sun.

However, there is another factor which affects the received intensity - the Earth's tilt. This tilt is a result of the Earth's axis of rotation being at an angle of 23.5° and is the dominant cause for the Earth's seasons [1]. The summer solstice occurs when the northern hemisphere is pointing directly towards the Sun at 23.5° and is when the northern hemisphere receives the maximum intensity. The reverse is applicable for the winter solstice.

Despite the Earth's tilt being the dominant factor contributing to the intensity of sunlight incident on Leicester, we investigated to what extent Earth's elliptical orbit plays an influence.

Perihelion vs Aphelion

To begin with, we calculated the intensity of solar radiation the Earth receives when it is at perihelion and aphelion. To do this, we used the inverse square law, seen below:

$$I = \frac{L_\odot}{4\pi R^2} \tag{1}$$

, where I is the intensity on the Earth's surface in $\mathrm{Wm^{-2}}$, $L_\odot$ is the luminosity of the Sun [2] and R is the radius of Earth's orbit, which can take the values $R_p = 147.1 \times 10^6$ km at perihelion and $R_a = 152.1 \times 10^6$ km at aphelion [3].

At perihelion, the intensity, I_p, is 1408 $\mathrm{Wm^{-2}}$. At aphelion, the intensity, I_a, is 1317 $\mathrm{Wm^{-2}}$, which is about 6% less than I_p. However, these values are not the intensity received in Leicester, but are for the equator. As a result, we must then take the Earth's tilt into account.

The Effect of the Earth's Tilt

To determine the energy incident on Leicester, the Earth's tilt and the latitude Leicester is located on are vital details, which are used in Equation 2 [4].

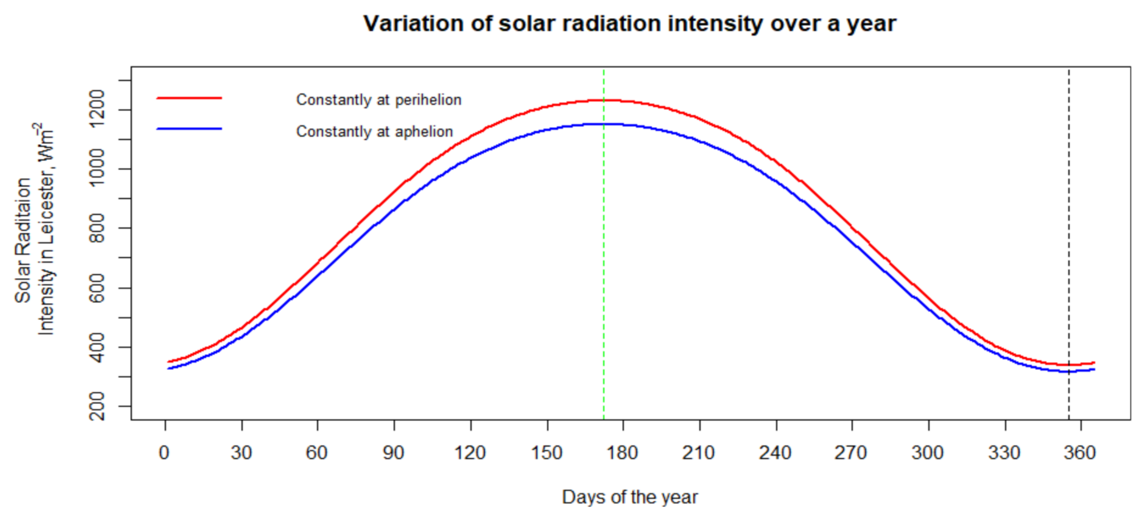

Figure 1: This graph shows minimal differences in intensity between perihelion and aphelion, emphasising the impact of Earth's tilt on seasonal changes. The green line represents maximum intensity (summer solstice), while the black line represents minimum intensity (winter solstice). The curve is defined by the time-varying δ in Equation 4.

$$I_{Leicester} = I \sin \alpha \tag{2}$$

, where $I_{Leciester}$ is the intensity incident on Leicester and where α is defined as [4]:

$$\alpha = 90^\circ - \phi + \delta \tag{3}$$

In Equation 3, α contains information for both the latitude, ϕ, and the Earth's tilt, δ. Leicester will experience a δ which will vary between $+23.5^\circ \leq \delta \leq -23.5$ over the year, as seen in the equation below [4]:

$$\delta = 23.5^\circ \times \sin\left(\frac{360}{365} \times (284 + d)\right) \tag{4}$$

, where d is the day of the year. Using Equations 2, 3 and 4, we were able to see how the intensity of solar radiation varies over a year and the difference between the intensities at perihelion and aphelion, seen in Figure 1.

Results

In Figure 1, the 6% difference between the perihelion and aphelion curves are noticeable, but the curves are dominated by the effect of the Earth's tilt as δ varies throughout the year. For example, when looking at perihelion, the highest intensity Leicester would receive is 1231 Wm^{-2}, whereas the lowest intensity is 338 Wm^{-2}. This is ≈70% decrease between the summer and winter months, far surpassing the 6% difference between perihelion and aphelion.

Discussion & Conclusion

Earth's climate and weather patterns are directly linked to the intensity of solar radiation incident upon it. It is clear that the effect of Earth's elliptical orbit is dwarfed by the effect of the Earth's tilt. This is reinforced by the fact that we reach perihelion in January [1], where no significant warming is observed in the northern hemisphere. This clearly demonstrates that the Earth's tilt is the dominant factor that determines Earth's climate.

References

[1] https://www.weather.gov/fsd/season [Accessed 4 December 2023]

[2] https://rb.gy/9hiwqd [Accessed 4 December 2023]

[3] https://rb.gy/73gppv [Accessed 4 December 2023]

[4] https://rb.gy/zx65vb [Accessed 4 December 2023]