Earth Temperature Based on Orbit Eccentricity

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1. Abstract

This project explains the change of habitability based on Earth's surface temperatures by the change of eccentricity of the Earth's orbit. The thought began with the expansion of the previous Earth-Orbit program. One of the questions mentioned the change of habitability of humans on Earth based on increased initial earth momentum and became the basis for the project idea.

2. Statement of the Problem

Assuming the Earth orbits in an elliptic pattern only affected by the gravitational force of the Sun, how will its eccentricity based on a fixed starting point change the surface temperature, and how will it affect the habitability for humans.

3. Methods

3.1 Creation of Elliptical Orbit

To make an accurate temperature model based on orbit, the orbit itself had to be closer to the model of Earth's orbit around the Sun. From the circular orbit base given, the next task was to create an eccentric orbit. The added change in Earth's momentum at the starting point brought a non-circular trajectory. In addition, with the changed gravitational force formula, the orbit now took account for the changing distance between the Sun and Earth instead of it being a constant. With different initial momentums brought different eccentricity results, which were solved using the formula $E = \frac{r_a - r_p}{r_a + r_p}$ in which E represents eccentricity, and r_a and r_p representing the distance between the Sun and Earth at aphelion and perihelion, respectively. The distances at the aphelion and perihelion were calculated using **if** statements with conditions regarding the maximum and minimum speed that would identify such point positions.

3.2 Solving for Surface Temperature

To find the Earth's surface temperature, the Stefan Boltzmann Law regarding the radiation of black bodies was used. Considering the Sun as a blackbody, the total energy emitted and received by the Earth's surface area was calculated. The effective temperature of the Earth was calculated using the formula ${T_E}^4 = \frac{{R_S}^2 {T_S}^4}{4a^2}$, in which T_E and T_S represent the surface temperature of the Earth and Sun respectively, a representing the distance between the Sun and Earth, and R_S representing the radius of the Sun. The energy used to calculate the temperature also accounts for the albedo of 0.3 that Earth reflects. This gives an effective temperature of 255K (-18°C), much lower than the average global temperature of 288K (15°C). The temperature difference is caused by the Greenhouse effect absorbing approximately 77% of terrestrial and atmospherically radiation to add a temperature factor of 33K to bring the surface temperature up to 288K.

3.3 Determining Human Habitability of Surface Temperature

Finally, to determine humans' habitability with a given surface temperature, the maximum temperature at a given day was used to determine whether human survival was possible. As Earth's initial position was at perihelion, the eccentricity was only increased in the experiment to keep the initial position as the perihelion point. According to NASA, a temperature of 323K

(50°C) at 10-25% humidity for 24 hours proved lethal for a human being. The code was able to test different initial momentum values to observe the relation between eccentricity and maximum temperature. We continued the experiment until a certain momentum resulted in a maximum temperature of over 323K.

4. Conclusion

In conclusion, the eccentricity showed linear regression with the maximum temperature calculated (Figure 1). The orbit's maximum eccentricity while keeping Earth's habitability is 0.1405, approximately 8.4 times larger than the original 0.0167 orbital eccentricities. At this value, the maximum temperature was at 323K (50°C). This differs from the initial hypothesis, predicting that the eccentricity would be extremely close to the original value as slight changes in orbit would massively affect the environment.

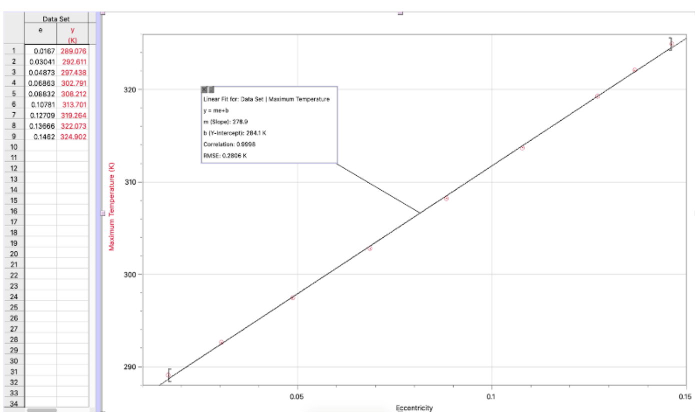
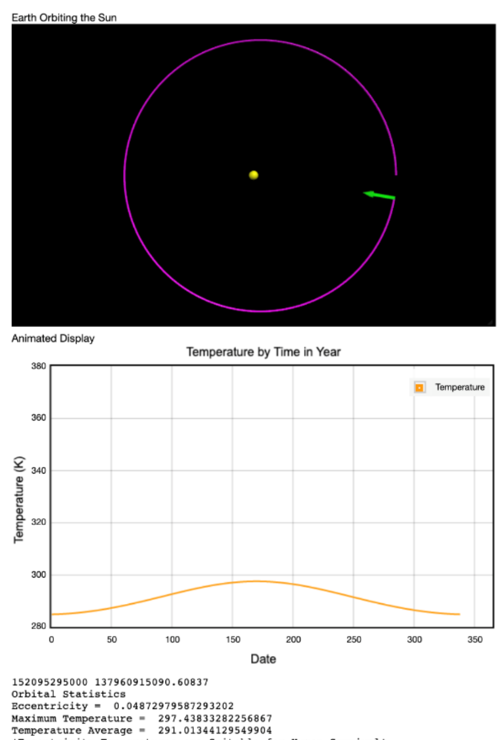


Figure 1. Plot of Orbital Eccentricity vs Maximum Surface Temperature (Above)

Figure 2. Orbit Diagram and Temperature Plot by Date (Right)



5. Contributions

I contributed to this project in multiple areas, including ideas, code, and the poster. I mainly put my effort into creating the code that calculated the orbits and temperatures from initial values. The code took approximately a couple of weeks of research in terms of concepts. Also, it took a lot of time to learn different coding functions and methods needed to model different experiment conditions and parts. In the poster aspect, I focused less on content and more on creating the poster itself in design, organization, and overall delivery.

6. References and Acknowledgments

- We would like to thank Professor Curtis Meyer for the physics education and for making this project possible.

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