Journal of Physics Special Topics

P3_2 An Extreme Solution to Global Warming

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November 17, 2012

Abstract
A brief investigation into the plausibility of solving the issue of global warming by moving the Earth further away from the Sun. It was found that the Earth would need to be moved to 1.23 AU to compensate for a 6.4 K per century increase in temperature.

Introduction

A large number of studies have been done into global warming and the possible human impact on the climate; these often focus on the annual temperature change and the relation to the concentrations of certain greenhouse gasses in the atmosphere, sometimes using models to predict future values. This article investigates the plausibility of one of the most unlikely solutions to the problem of increasing global temperatures, to move the planet further from the Sun as depicted in an episode of the TV series Futurama ("Crimes of the Hot").

Theory

Radiation from the Sun heats the Earth. As this occurs the Earth is also radiating energy into space, these two quantities are equal meaning that the overall temperature does not change. An increase in the concentration of greenhouse gases in the atmosphere insulates the planet so that less of the heat is radiated away, this then leads to a rise in the mean global temperature until a new equilibrium is reached. In reality the atmosphere is a much more complicated system, however an order of magnitude estimate will suffice to assess the plausibility of this method. To get an accurate number, the individual mechanisms and how these interact would need to be very precisely modelled.

The proposal is that it should be possible to compensate for this reduction in heat loss by increasing the Earth-Sun distance, this would in theory mean that less of the energy emitted by the Sun would be heating the planet so a lower temperature can be maintained despite the increase in greenhouse gas concentrations.

The luminosity of the Sun, L_{Sun}, is $3.84\text{x}10^{26}$ W [1], however only a small fraction of this will fall on the Earth, of that only a small amount goes into raising the temperature. The power from the Sun that hits the Earth is given by

$$P_E = \frac{R_E^{\ 2}}{4R_S^{\ 2}} L_{Sun} \quad , \qquad (1)$$

where R_E is the radius of the Earth. This is found by considering the area of the Earth that is visible from the Sun's point of view and comparing this to the entire area of a sphere at the distance of the Earth, R_S. This uses the assumption that the Earth is in a perfectly circular orbit around the Sun, as shown in figure 1. In reality this is not the case but it will be sufficient for this investigation since it only considers an order of magnitude estimate.

It is assumed that the only change that causes the rise in temperature is that the planet is being further insulated, while this is a gross oversimplification it should be suitable for this investigation. The amount of energy needed to raise the temperature can be calculated using

$$Q = mc\Delta T \quad , \qquad (2)$$

where Q is the total energy required to heat a body of mass m with a specific heat of c by a temperature ΔT. A power can then be calculated that would need to be supplied to heat the Earth by this amount over one century, t ($3.16\text{x}10^9$ seconds),

$$P_{\text{required}} = \frac{mc\,\Delta T}{t} \quad . \tag{3}$$

For the Earth to stay at a constant temperature, with a constant rate of greenhouse gas emissions, it must be moved a sufficient distance from the Sun to make up for this amount of energy being kept in the atmosphere that would otherwise escape. In other words equations 1 and 3 can be equated to give

$$\frac{-mc\,\Delta T}{t} = \left(\frac{R_E^{\,2}}{4R_1^{\,2}} - \frac{R_E^{\,2}}{4R_2^{\,2}}\right)\alpha\, L_{\text{Sun}} \quad , \tag{4}$$

where R_1 and R_2 are the radii of the current and new orbit as shown in figure 1. α is the fraction of the total power from the Sun that goes into heating the planet, 30% [2], the other symbols have their previous meaning. This is assuming that the ratios involved in the radiation budget of the Earth will remain largely unchanged and also that its insulation does not change. Equation 4 can be rearranged for R_2 and since we know R_1 a new quantity, ΔR, can be defined which is the distance the Earth needs to move.

The final equation used to calculate ΔR *was*

$$\Delta R = \left(\frac{1}{R_1^{\,2}} - \frac{4mc\,\Delta T}{R_E^{\,2}\, t\,\alpha\, L_{\text{Sun}}}\right)^{-\frac{1}{2}} - R_1 \quad . \tag{5}$$

The value for the specific heat was assumed to be close to that for water at room temperature and taken to be 4.2 $\text{kJkg}^{-1}\text{K}^{-1}$ [3]. A value of 6.4 K [4] was used for ΔT, the worst case prediction from climate modelling of greenhouse gas emissions. The mass, m, was taken to be $2.1\text{x}10^{21}$ kg which combines the mass of the atmosphere [5] and a fraction of the mass of the Earth [5] which corresponds to a depth of 1 km over 70% of the surface to account for the oceans. Finding a more accurate mass would require complex climate modelling, which would be beyond the scope of this article.

The final result was that the Earth would need to be approximately $0.35\text{x}10^{11}$ m further from the Sun to account for the temperature change predicted by the model used. This is the same as being roughly a fifth of its current distance further from the Sun or alternatively the new Earth-Sun distance would be 1.23 AU.

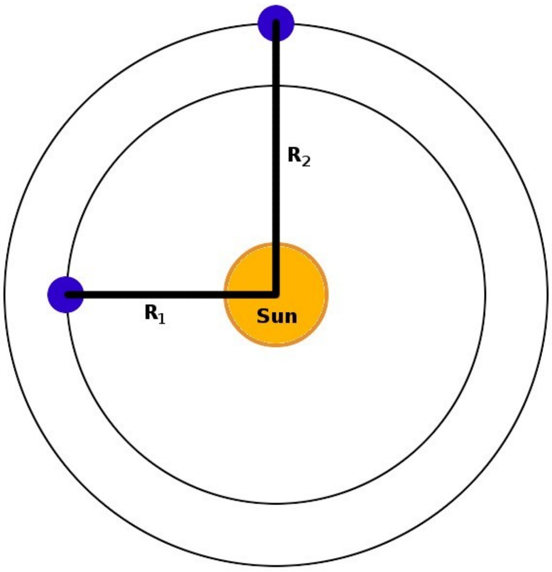

Figure 1: A diagram showing the simplified model of the Earth orbit used and the variables R_1 (initial radius) and R_2 (final radius) from equation 4.

Conclusion

While the distance may not immediately seem to make this proposal impossible, a consideration of the size of the forces and energy needed to accelerate something with a mass on the scale of a planet should. It is very clear that this is not a viable solution to climate change. There are also the other complications of an increased Earth-Sun distance to consider. This would however be a subject for further investigation.

References

[1] B. Carroll et al, *An Introduction to Modern Astrophysics* (Pearson Addison-Wesley, 2007) Appendix A.

[2] climatedata.info/Forcing/Forcing/albedo.html accessed on 22/10/12.

[3] www.engineeringtoolbox.com/water-thermal-properties-d_162.html accessed on 12/12/2012.

[4] G. Meehl et al, *IPCC Fourth Assessment Report: Climate Change* (2007) Chapter 10.

[5] nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html accessed on 18/11/2012.