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A4_8 Terraforming Mars – Orbital Mirrors: Operation

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Abstract

This paper looks at the temperature changes to the Martian surface of using orbital mirrors to heat it. It was found that net changes to the whole system would not be useful while localised temperature gains are enough to sublimate Martian ice to release water vapour and greenhouse gases.

Introduction

The Terraforming on Mars often seems like one of the logical steps in life within the solar system. This report will look into the warming of the Martian landscape using mirrors to reflect unused solar flux to the surface.

In the scope of the review the net effect on the temperature on Mars using a solar mirror as well as the local effect will be looked at, i.e. the sublimating of ice to release water and greenhouse gases. This review will look at a simplified case in which the mirror is a perfect reflector and a plane mirror.

Global Temperature Change

To calculate the change in the surface temperature of Mars it is necessary to find out how much energy is being added to the surface at any given time. This is calculated from the power incident, P_i, on the surface [1] from the combination of the solar power, P_s, and the mirror reflecting the Sunlight, P_m. Equation 1 gives the power where α is the albedo of the planet (0.15 [2]), a fraction of the energy that is reflected and not absorbed.

$$P_i = (1-\alpha)(P_s + P_m) \quad (1)$$

While energy is being added, it is also being radiated out by the planet back into the inter-stellar medium, P_e. The Stefan Boltzmann law, equation 2, gives this, where ε is the emissivity (0.96 [3]), σ is the Stefan-Boltzmann constant, A is the surface area of the planet and T_m is the surface temperature.

$$P_e = A\varepsilon\sigma T_m^4 \quad (2)$$

At any given time the power in and power out must be in equilibrium so equations 1 and 2 are set equal and rearranged to find a temperature for Mars. The power of the Sun and the mirror is equal to the luminosity of the Sun, L, multiplied by the area onto which it is incident (A for the Sun, area of the mirror for the mirror) divided by the area over the spherical distance to Mars and the mirror (allowing power from the sun to spread out).

$$T^4 = [(1-\alpha)L/(4D^2 A\varepsilon\sigma)](R_M^2 + r_m^2) \quad (3)$$

D is the distance between the Sun and Mars, R_m is the radius of Mars [4] and r_m is the radius of the Mirror. This equation was used to compare the temperature for a given radius of mirror, figure 1.

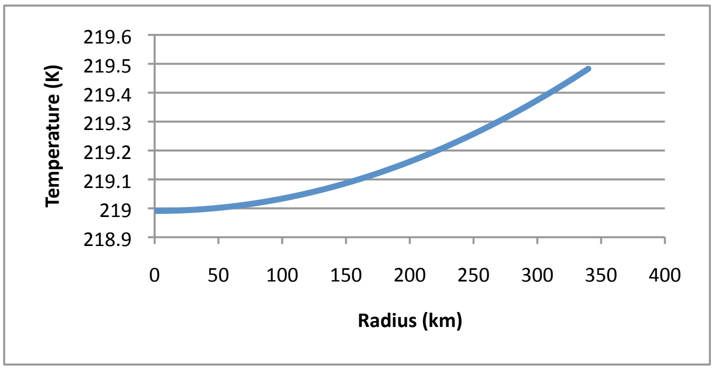

Figure 1. A graph show the relation between the surface temperature of Mars and the radius of the Mirror used to increases solar intensity on the surface.

As figure 1 shows the surface temperature of Mars increases with the radius of the mirror. However the increase is negligible and to increase the temperature to a more comfortable level for humans (273 K) would require a mirror of radius 4260 km, which is larger than Mars.

Local Changes

For local variations it is necessary to know the area of the planet that is shadowed by the mirror, y'. Equation 4 is the magnification by a mirror where s' is the distance to the surface of Mars [5].

$$y' = -(s'/D)y \quad (4)$$

Using this radius of the image on Mars, equation 3 is altered for A to be the area on the surface Mars seen by the mirror and R_m is also replace with the radius of the mirror image, resulting in equation 5.

$$T^4 = \frac{(1-\alpha)L}{4D^2\varepsilon\sigma}\left(1+\frac{r_m^2}{\pi(\frac{s'}{D}y)^2}\right) \quad (5)$$

Using this equation it is possible to observe the effects of height and radius on the instantaneous temperature of the area that mirror is illuminating. These effects are seen in figure 2.

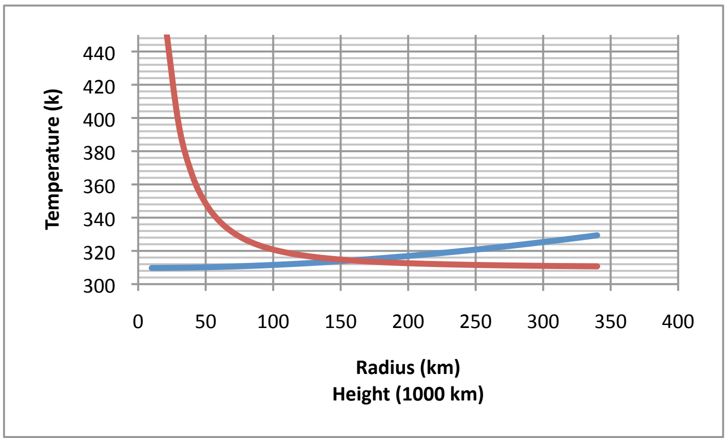

Figure 2. A graph to show the local changes in temperature on the surface of Mars for a given radius (blue) or height (red) while keeping the over factors constant

Figure 2 shows that as altitude of the mirror increases, then the instantaneous temperature in the area exposed to the mirrors light decreases, due to the power being dissipated over a larger region. Whilst increasing the radius slowly increases temperature, due to the mirrors power increasing, but the magnification of its image on the surface of Mars does not increase.

The average surface temperature at the poles of Mars is 190 K [6]; small seasonal changes raise this and cause a small layer of dry ice to sublimate into the atmosphere until the Martian winter. The temperature increase in a given area is seen to be over 100 K for a typical mirror of radius 125 km, and height 214,000 km [7]. This would be more than enough to melt the ice caps and with the values just given for the attitude of the mirror, and then the magnification is large enough to encompass the entire size of the southern pole, 650 km.

Ice trapped in the regolith is another target to release water and carbon dioxide. If the rock were porous enough to allow out gassing then the temperature increase would be enough to release a significant amount of trapped ice.

Conclusion

This paper has found that a mirror at Mars orbit would not produce energy for a net global change to melt polar ice and aid in creating a liveable environment for humans. However for a given area on the surface of Mars the temperature change would be enough to induce sublimation that can release carbon dioxide and water into the atmosphere from both the ice caps and ice trapped in porous regolith. This released gas would to some degree start a greenhouse effect warming the entire planet at once. Unfortunately more atmospheric gas increases the surface pressure, which in turn increase the temperature needed for sublimation and may have the effect of slowing the process.

The temperature increases quoted are slightly higher than would be observed, as the mirror would not be a perfect reflector and when aimed to an area of the planet the effective area observed by the Sun would be smaller reducing the additional power to the surface. However it is still believed that enough extra energy would be supplied to start the process of creating a more liveable Martian environment. A concave mirror could be used to focus the energy more and drastically increase the temperature of a specific smaller area.

References

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