How to Implement the Alternate Solution to Global Warming

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Abstract

Solar geoengineering is vital in global warming as results can reverse trends and reduce the probability of a tipping point from occurring. As well, the pace and depth of implementing the GHG solution is tenuous. It is of interest in this paper to focus on the implementation of a solar geoengineering solution to global warming. It is obvious that an albedo solution is in theory possible. However, research in this area seems stagnant and implementing even urban heat island cool roofs on a unified worldwide global level has not gone forward. In particular, in this paper we provide some basic modeling and insight into "Earthly components" that one could focus on to increase opportunity for reducing climate change. Modeling illustrates that by solar geoengineering selecting hotspot areas, the effective area could be roughly 13 times smaller than a nominal non-hotspot areas in influencing global warming.

1 Introduction

We provide follow-on work from of our original paper on geoengineering an albedo solution [1]. In this paper, implementation is discussed. When we talk about climate change solutions, in the race against time, it is advantageous to look at the known alternate solutions. Although there are a number of suggested approaches to global warming mitigation, there are really only two solutions, reduction of GHGs and albedo change. These are the root causes. In view of the slow progress that is being reported in terms of greenhouse gas reduction, and the continual increase in the Earth's average yearly temperature increase, it is important to revisit the alternate albedo solution. There have been a number of geoengineering solutions proposed in this area [2-4]. Prior to greenhouse gas reemission, short wavelength absorption must first occur. If this can be reduced, then there are multiple advantages. Once absorption occurs, initial temperature rise has occurred to the Earth, and then part of this energy is reradiated back to Earth by GHGs. It is important to view the benefit of the albedo solution this way. Inclusion of the re-radiation factor is important in calculations.

As well, GHGs are not easily reversible, it takes about 30 years to reduce 50% of any increase; and reducing GHG emissions only slows global warming from occurring, that is, it has much less of an effect in terms of reversing trends including feedback problems. This is especially true with the pace of deforestation. Lastly, an absorption solution now appears to be the only way to stop the potential tipping point which we do not believe has occurred to date [5].

Furthermore, not all absorptions areas on the Earth are equal. In this paper we will look at the following types of target areas having:

- high solar irradiance
- large heat capacities
- low albedo
- ability to amplify nature's albedo

To clarify the last factor, we infer that cooling down certain areas, may prompt natural compounding albedo changes to occur such as increases in snow fall and ice formations.

In terms of short wavelength absorption, these factors are likely the most important. The leading factor is the albedo itself, it is possible to mitigate, since it's a surface effect. Each factor amplifies solar radiation absorption compared to a nominal land area. Although the task is highly challenging, it is easier to do geoengineering of reflectivity surfaces compared with building cities. Therefore, one key strategy is to study Solar Amplified Areas (SAA) relative to Nominal Land Albedo (NLA) areas (30% albedo) and determine if it is possible to make a significant impact on global warming. The goal is to change a SAA to one with a target albedo surface (TAS).

2. Data and Methods

In our initial paper on geoengineering the albedo solution to global warming [1], we identified key parameters and simple expressions for geoengineering the required percentage of area $\%\Delta\alpha$ needed to provide an adequate solution.

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The simplified expressions (also see Appendix A and B) and estimates for a 1.5% area are

$$P_{\text{Rev\_surface}} = -\lambda_{\%\Delta\alpha\Delta T}\ \ \%\Delta\alpha\ (1+f)\ A/T = P_T\ (1+f)\ A/T = 3.83W/m^2 \tag{1}$$

and

$$\Delta T_{\text{Rev}} = -1\text{W/m}^2/\%\text{ x }1.5\%\text{ x }1.6\text{ x }2\,x\,f_2 x 1/\lambda_o\ /1.25 = -0.7°K \tag{2}$$

where,

$P_{\text{Rev surface}}$ is the reverse power per unit area
$\lambda_{\%\Delta\alpha\Delta T}$ = albedo-plank parameter, 1Watt/m^2/%ΔAlbedo [1,5] (also see Appendix C)
f= the re-radiation parameter about 0.63 [1,5] (also see Appendix A)
A is an estimate of the anticipated GW amplification reduction, about 2
T is a climate transient value about 1.25 [13]
P_T is the reverse forcing from the target area related to a target albedo change (described below)
λ_o is the Planck parameter about 3.3 W/m^2/°K

This simple assessment provides a rough goal that we can use in this paper for the alternate solution.

2.1 Albedo Modeling

We can write the short wavelength solar absorption as

$$P = \frac{Q}{A} = \frac{S_N}{4}\sum_i \frac{A_i}{A}(1-\alpha_i) + \frac{S_N}{4}\mathrm{H}_{T-N}\frac{A_T}{A}(1-\alpha_T) \tag{3}$$

Here A_i is the i^{th} area having an albedo α_I, $S_N=1361W/m^2$ and A is the surface area of the Earth. We consider a change to a hotspot target area A_T with albedo α_T. In addition, because we select a particularly problematic solar absorbing target area compared to a nominal area (N), it has hotspot amplification potential $\mathrm{H}_{\text{T-N}}$, a function of the heat capacity, mass, temperature storage, and solar irradiance, This hotspot amplification potential is described and enumerated in Appendix C. The overall equation for the unaltered area is subject to the constraints

$$P = 240W/m^2 \ \ and\ \ A = \sum_i A_i + \mathrm{H}_{T-N}A_T \tag{4}$$

We now alter the albedo of the target area so that

$$P' = \frac{Q'}{A} = \frac{S_N}{4}\sum_i \frac{A_i}{A}(1-\alpha_i) + \frac{S_N}{4}\frac{A_T}{A}\mathrm{H}_{T-N}(1-\alpha'_T) \tag{5}$$

Using an example goal of 1.5W/m^2 change by altering the target area, the heat absorbed is

$$\Delta P_T = P - P' = \frac{S_N}{4}\frac{A_T\mathrm{H}_{T-N}}{A}\left[(1-\alpha_T)-(1-\alpha'_T)\right] = 1.5W/m^2 \tag{6}$$

However, the same results can be obtained by changing the albedo of a nominal area, so in this case $\mathrm{H}_{T-N}=1$, the equivalent change for the nominal area is

$$\Delta P_{T-N} = \frac{S_N}{4}A_N\left\{(1-\alpha_N)-(1-\alpha'_N)\right\} = 1.5W/m^2 \tag{7}$$

3 Results and Discussion

Comparing the target to the nominal changes, we have

$$\frac{\Delta P_T}{\Delta P_N} \approx \frac{A_T \mathrm{H}_{T-N}\left[(1-\alpha_T)-(1-\alpha_T')\right]}{A_N\left[(1-\alpha_N)-(1-\alpha_N')\right]} = 1 \tag{8}$$

As an example, assume $\mathrm{H}_{T-N} \approx 10$ and α_N=0.3, α_T=0.1, α_N'=α_T'=.9 we obtain

$$\frac{A_N}{A_T} = \frac{\mathrm{H}_{T-N}\left[(1-\alpha_T)-(1-\alpha_T')\right]}{\left[(1-\alpha_N)-(1-\alpha_N')\right]} = \frac{10\left[(1-.1)-(1-.9)\right]}{\left[(1-.3)-(1-.9)\right]} = \frac{10(0.8)}{0.6} = 13.3 \tag{9}$$

This indicates that the nominal area would have to be 13.3 times larger than the target area for the equivalent results. In assessing our goal, we have for this example from Eq. 6

$$\Delta P_T = 340\frac{A_T 10}{A}\left[0.8\right] = 1.5W/m^2 \tag{10}$$

Then

$$\frac{A_T}{A} = 0.00055 = 0.055\% \tag{11}$$

In this model, we would need to change a relatively small portion of the Earth. We can compare this to the total urbanized area. Estimates of Urbanization vary, extrapolated values to 2019 from Schneider [7] is about 0.188% [5] while studies from GRUMP [9] is 0.953% [8]. Therefore, compared to these 2019 estimates for urban heat island and surrounding areas, the required area change is

- 3.4-17.3 times smaller

It is of course still a highly challenging task to alter this much area. Yet considering that man is capable of building complex cities compared to geoengineering an albedo change, it is far less complex.

3.1 Advantages of UHI

UHIs meet a lot of the requirements. Estimates for amplification factors have suggested by Feinberg [5] and they vary between 3.1 and 8.4. Furthermore, the albedo is about 0.12 [9]. Reversing just warming due to UHI would require changing the albedo to 0.2 [5]. This is not a lot of change, but can pose difficulties as this would be an effective albedo for the entire UHI. Nevertheless, certainly much higher reflective surfaces can be realized. Furthermore, roof surfaces allow for more stable albedo maintenance over time compared to other areas like mountain regions.

3.2 Some Hotspot Target Areas:

Hotspot areas are likely targets for albedo change. Desserts would be highly difficult to maintain any albedo change. However, mountains and UHI cool roofs in cities might be good targets areas. Some interesting known hotspots include

- Flaming Mountains, China
- Bangkok, Thailand (planet's hottest city)
- Death Valley California
- Titat Zvi, Israel
- Badlands of Australia
- Urban Heat Islands

We note that mountain areas in cool regions should not be excluded as such changes may prompt natural compounding albedo changes to occur from increases of snow fall and ice formations. Albedo changes could be done in summer months, and then in winter months, any compounding effects can be assessed.

4 Conclusions

The alternate solution to global warming is viewed as vital in mitigating global warming. Today, technology has numerous advances that include drone technology, artificial intelligence, and advances in materials that may be helpful. Mankind has addressed many technological challenges successfully. It is not illogical to consider a global albedo solution while time permits prior to a potential tipping point.

Furthermore, as we described, an albedo solution has many advantages over greenhouse gases improvements. It is earlier in the chain of events and offers larger benefits over greenhouse gases (see Appendix A) due to reemission. It can reverse global warming trends, where greenhouse gas improvements have less impact.

In this paper we have provided a number of important estimates that include:

- Changing the albedo has 160% benefit due to GHG reemission
- A reasonable target albedo goal forcing reduction of 1.5W/m^2
- Selecting proper target areas can reduce the required area to 3.3-17.3 times smaller than current occupied urbanized area estimates
- Likely target areas may include problematic hot cities and mountains

Appendix A Reemission Percent

This is detailed in Feinberg [1]. However, we provide a simplistic view for 1950 by assuming no forcing at that time. Looking at typical energy budget diagrams, blackbody portion of the budget is about 240W/m^2 where the total increase to obtain the 1950 temperature is about 385W/m^2. This implies the reemission must be

$$240\text{W/m}^2 \,/\, 385\text{W/m}^2 = 62\%$$

Appendix B Amplification Factor

In this appendix we suggest the candidate amplification factor $H_{T\text{-}N}$ described in Section 2. We provide it in this appendix since it is a rough overview to aid the reader in clarifying our suggested method in Section 2. Using this methodology, it is likely more rigorous solutions can be developed. Such solutions are outside the scope of this paper.

In this keeping with the suggested method in Section 2, we consider a ratio for a target (T) area compared to a nominal (N) area. Then the sensible heat storage q due to a mass *m*, having specific heat capacity *Cp* experiencing a heat day-night change *ΔT* then the suggested amplification factor $H_{T\text{-}N}$ has the form

$$H_{T-N}=\frac{q_T}{q_N}x\frac{I_T}{I_N}=\frac{m_T C_{PT}\Delta T_T}{m_N C_{PN}\Delta T_N}x\frac{I_T}{I_N} \tag{B-1}$$

where we also including irradiance ratio I.

As a numeric example, first consider a 90% irradiance target area (compared to the equator) with a nominal mid-latitudes (45°) roughly 70%, compared to say the Arctic and Antarctic Circles 40% [10]. Then the irradiance ratio is

$$\frac{I\%_T}{I\%_N}=\frac{90\%_T}{70\%_N}=1.3 \tag{B-2}$$

For the sensible heat numeric portion we consider a target rocky (such as Flaming mountain) area compared with a nominal vegetative land area. As a rule of thumb, most rocks have a density of 2.65 g/cm3 soil, about 50% difference compared to a nominal soil area of 1.33 g/cm3 [11]. The heat capacity of rocks compared with vegetated land is 2000 to 830J/Kg/^{o}K [12]. Then ΔT is estimated from tables for a day-night cycle [13].

$$\frac{q_T}{q_N}=\frac{m_T C_{PT}\Delta T_T}{m_N C_{PN}\Delta T_N}=\frac{\rho_T C_{PT}\Delta T_T}{\rho_N C_{PN}\Delta T_N}=\left(\frac{2.65}{1.33}\right)_{\rho}\left(\frac{2000}{830}\right)_{C_P}\left(\frac{23(\Delta 10C)}{14.84(6.9)}\right)=2x2.4x1.66=6.72 \tag{B-3}$$

Then including irradiance

$$H_{T-N}\approx 9 \tag{B-4}$$

Appendix C Planck-Albedo Feedback Parameter

This parameter comes about from the following assessment [1,5]

$$\lambda_{\%\Delta\alpha} = \frac{\Delta E_o}{\frac{\alpha_1 - \alpha_2}{\alpha_1}100} = \frac{E_o\left(\alpha_1 - \alpha_2\right)}{\frac{\alpha_1 - \alpha_2}{\alpha_1}100} = E_o\alpha_1 / 100 = 1W / m^2 / \%\Delta albedo \qquad \text{(C-1)}$$

where Eo=340 W/m^2 and we see the closer that α_1 is to 29.4118%, the nearer a value of 1W/m^2/Δ%albedo is obtained. We note the value 29.4118% (100/340) is listed in AR5 [6]. This value relates for a 1°K change [1,5] where

$$\lambda_{\%\Delta\alpha\Delta T} = 1W / m^2 / \%\Delta albedo / {}^\circ K \qquad \text{(C-2)}$$

Therefore, one can estimate the feedback parameter

$$\lambda_\alpha = \lambda_{\%\Delta\alpha}\ x\ \%\Delta\alpha \qquad \text{(C-3)}$$

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