

The Alternate Solution to Global Warming

Alec Feinberg

Key Words: Albedo Modeling, Albedo solution to global warming, solar amplification, hotspots mitigation

Abstract In this paper we provide an overview on why the alternate solution to global warming has numerous advantages over greenhouse gas (GHG) reduction. This is initially evident in considering that prior to greenhouse gas reemission, LWR must first occur. In the chain of events, initially we have incoming short wave radiation, absorption, long wave emission, then re-radiation from GHGs. In theory, we can focus on any event in order to mitigate climate change. However, reducing absorption also prevents a second event, greenhouse gas (GHG) reemission. Therefore, in comparison, the greenhouse gas effect is less dynamic. As well the pace and depth of the GHG solution is tenuous. It is of interest in this paper to look at the absorption part in the chain of events. 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 global level has not gone forward. In particular, in this paper we provide some basic modeling and provide insight into “Earthly components” that one could focus on to increase opportunity for reducing climate change.

1 Introduction

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 [1-3]. 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 turns out this is about 60% [4] (Appendix A). Thus, there is a major advantage for the albedo type solution. If we use the 60% reemissions estimate, this means that a

- reduction in absorption equates to a 160% benefit
- while a 100% GHG reduction equates to only a 60% benefit by comparison

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. Lastly, an absorption solution is the only way to stop the potential tipping point.

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

One key parameter that helps to quickly obtain a reverse forcing goal is the Albedo-Planck Parameter [4,5]. This value is $1\text{Watt/m}^2/\% \Delta \text{Albedo}$ [4,5] (also see Appendix B). For example, using the IPCC global albedo [6] of 0.294118, a 1.5% change to 0.29853 would have an impact of 1.5 Watts/m² warming reduction.

64
65
66
67
68
69

Using the 1.6 reemission factor, this is $2.4W/m^2$ improvement. With a reduction in water-vapor feedback, often a factor of 2, the resulting effect could be as high as $4.8W/m^2$. This simple assessment provides a rough goal that we can use. It also offers motivation to revisit the alternate solution.

70 2.1 Albedo Modeling

71
72
73

We can write the short wavelength solar absorption as

$$74 \quad P = \frac{Q}{A} = \frac{S_N}{4} \sum_i \frac{A_i}{A} (1 - \alpha_i) + \frac{S_N}{4} H_{T-N} \frac{A_T}{A} (1 - \alpha_T) \quad (1)$$

75 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
76 change to a hotspot target area A_T with albedo α_T . In addition, because we select a particularly problematic solar
77 absorbing target area compared to a nominal area (N), it has amplification potential H_{T-N} , a function of the heat
78 capacity, mass, temperature storage, and solar irradiance, This amplification potential is described and enumerated
79 in Appendix C. The overall equation for the unaltered area is subject to the constraints

$$80 \quad P = 240W/m^2 \text{ and } A = \sum_i A_i + H_{T-N} A_T \quad (2)$$

81 We now alter the albedo of the target area so that

$$82 \quad P' = \frac{Q'}{A} = \frac{S_N}{4} \sum_i \frac{A_i}{A} (1 - \alpha_i) + \frac{S_N}{4} \frac{A_T}{A} H_{T-N} (1 - \alpha'_T) \quad (3)$$

83
84
85
86
87

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

$$88 \quad \Delta P_T = P - P' = \frac{S_N}{4} \frac{A_T H_{T-N}}{A} [(1 - \alpha_T) - (1 - \alpha'_T)] = 1.5W/m^2 \quad (4)$$

89

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

$$92 \quad \Delta P_N = \frac{S_N}{4} A_N \{(1 - \alpha_N) - (1 - \alpha'_N)\} = 1.5W/m^2 \quad (5)$$

93 3 Results and Discussion

94 Comparing the target to the nominal changes, we have

95

$$96 \quad \frac{\Delta P_T}{\Delta P_N} \approx \frac{A_T H_{T-N} [(1 - \alpha_T) - (1 - \alpha'_T)]}{A_N [(1 - \alpha_N) - (1 - \alpha'_N)]} = 1 \quad (6)$$

97 As an example, assume $H_{T-N} \approx 10$ and $\alpha_N=0.3$, $\alpha_T=0.1$, $\alpha'_N=\alpha'_T=.9$ we obtain

98

$$99 \quad \frac{A_N}{A_T} = \frac{H_{T-N} [(1 - \alpha_T) - (1 - \alpha'_T)]}{[(1 - \alpha_N) - (1 - \alpha'_N)]} = \frac{10[(1 - .1) - (1 - .9)]}{[(1 - .3) - (1 - .9)]} = \frac{10(0.8)}{0.6} = 13.3 \quad (7)$$

100

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

$$103 \quad \Delta P_T = 340 \frac{A_T 10}{A} [0.8] = 1.5W/m^2 \quad (8)$$

104 Then

$$105 \quad \frac{A_T}{A} = 0.00055 = 0.055\% \quad (9)$$

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

110
 111
 112
 113
 114
 115
 116
 117
 118
 119
 120
 121
 122
 123
 124
 125
 126
 127
 128
 129
 130
 131
 132
 133
 134
 135
 136
 137
 138
 139
 140
 141
 142
 143
 144
 145
 146
 147
 148
 149
 150
 151
 152
 153
 154
 155
 156
 157
 158
 159
 160
 161
 162
 163
 164
 165

- 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

UHI meet a lot of the requirement. 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 surface allow for more stable albedo maintenance over time compared to other areas like mountain refions.

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 $1.5\text{W}/\text{m}^2$
- 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 [5]. 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 $240\text{W}/\text{m}^2$ where the total increase to obtain the 1950 temperature is about $385\text{W}/\text{m}^2$. This implies the reemission must be

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

166 Appendix B Amplification Factor

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

171
 172 In this keeping with the suggested method in Section 2, we consider a ratio for a target (T) area compared to a
 173 nominal (N) area. Then the sensible heat storage q due to a mass m , having specific heat capacity C_p experiencing a
 174 heat day-night change ΔT then the suggested amplification factor H_{T-N} has the form

$$175 \quad H_{T-N} = \frac{q_T}{q_N} \times \frac{I_T}{I_N} = \frac{m_T C_{pT} \Delta T_T}{m_N C_{pN} \Delta T_N} \times \frac{I_T}{I_N} \quad (\text{B-1})$$

177 where we also including irradiance ratio I .

178
 179 As a numeric example, first consider a 90% irradiance target area (compared to the equator) with a nominal mid-
 180 latitudes (45°) roughly 70%, compared to say the Arctic and Antarctic Circles 40% [10]. Then the irradiance ratio is

$$181 \quad \frac{I\%_T}{I\%_N} = \frac{90\%_T}{70\%_N} = 1.3 \quad (\text{B-2})$$

183
 184 For the sensible heat numeric portion we consider a target rocky (such as Flaming mountain) area compared with a
 185 nominal vegetative land area. As a rule of thumb, most rocks have a density of 2.65 g/cm³ soil, about 50%
 186 difference compared to a nominal soil area of 1.33 g/cm³ [11]. The heat capacity of rocks compared with vegetated
 187 land is 2000 to 830J/Kg/°K [12]. Then ΔT is estimated from tables for a day-night cycle [13].

$$188 \quad \frac{q_T}{q_N} = \frac{m_T C_{pT} \Delta T_T}{m_N C_{pN} \Delta T_N} = \frac{\rho_T C_{pT} \Delta T_T}{\rho_N C_{pN} \Delta T_N} = \left(\frac{2.65}{1.33} \right)_\rho \left(\frac{2000}{830} \right)_{C_p} \left(\frac{23(\Delta 10C)}{14.84(6.9)} \right) = 2 \times 2.4 \times 1.66 = 6.72 \quad (\text{B-3})$$

190
 191 Then including irradiance

$$192 \quad H_{T-N} \approx 9 \quad (\text{B-4})$$

193 Appendix C Planck-Albedo Feedback Parameter

194 This parameter comes about from the following assessment [4,5]

$$195 \quad \lambda_{\% \Delta \alpha} = \frac{\Delta E_o}{\alpha_1 - \alpha_2} \times \frac{100}{100} = \frac{E_o (\alpha_1 - \alpha_2)}{\alpha_1 - \alpha_2} \times \frac{100}{100} = E_o \alpha_1 / 100 = 1W / m^2 / \% \Delta \text{albedo} \quad (\text{C-1})$$

198
 199 where $E_o=340 \text{ W/m}^2$ and we see the closer that α_1 is to 29.4118%, the nearer a value of $1W/m^2/\Delta\% \text{albedo}$ is
 200 obtained. We note the value 29.4118% (100/340) is listed in AR5 [6]. This value relates for a 1°K change [4,5]
 201 where

$$202 \quad \lambda_{\% \Delta \alpha \Delta T} = 1W / m^2 / \% \Delta \text{albedo} / ^\circ K \quad (\text{C-2})$$

203
 204 Therefore, one can estimate the feedback parameter

$$205 \quad \lambda_\alpha = \lambda_{\% \Delta \alpha} \times \% \Delta \alpha \quad (\text{C-3})$$

208 References

- 209 1. D. Dunne, (2018), Six ideas to limit global warming with solar geoengineering, CarbonBrief,
 210 <https://www.carbonbrief.org/explainer-six-ideas-to-limit-global-warming-with-solar-geoengineering>
- 211 2. A. Cho (2016), To fight global warming, Senate calls for study of making Earth reflect more light, Science,
 212 [https://www.sciencemag.org/news/2016/04/fight-global-warming-senate-calls-study-making-earth-reflect-](https://www.sciencemag.org/news/2016/04/fight-global-warming-senate-calls-study-making-earth-reflect-more-light)
 213 [more-light](https://www.sciencemag.org/news/2016/04/fight-global-warming-senate-calls-study-making-earth-reflect-more-light)
- 214 3. Levinson, R., Akbari, H. Potential benefits of cool roofs on commercial buildings: conserving energy,
 215 saving money, and reducing emission of greenhouse gases and air pollutants. *Energy Efficiency* 3, 53–109
 216 (2010). <https://doi.org/10.1007/s12053-008-9038-2>
- 217 4. Feinberg, A., Global Warming Re-Radiation Model with New Albedo-Planck Parameter

- 218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
5. Feinberg, A., Urban Heat Island Amplification Estimates on Global Warming Using an Albedo Model, *Vixra* 2003.0088, DOI: 10.13140/RG.2.2.32758.14402/15
 6. Hartmann, D.L., A.M.G. Klein Tank, M. Rusticucci, L.V. Alexander, S. Brönnimann, Y. Charabi, F.J. Dentener, E.J. Dlugokencky, D.R. Easterling, A. Kaplan, B.J. Soden, P.W. Thorne, M. Wild and P.M. Zhai, 2013: Observations: Atmosphere and Surface. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
 7. Schneider, A., M. Friedl, and D. Potere, 2009: A new map of global urban extent from MODIS satellite data. *Environmental Research Letters*, 4(4), 044003, doi:10.1088/1748-9326/4/4/044003
 8. Global Rural Urban Mapping Project (GRUMP) 2005, Columbia University Socioeconomic Data and Applications Center, Gridded Population of the World and the Global Rural-Urban Mapping Project (GRUMP).
 9. Sugawara, H., Takamura, T. Surface Albedo in Cities (0.12): Case Study in Sapporo and Tokyo, Japan. *Boundary-Layer Meteorol* 153, 539–553 (2014). <https://doi.org/10.1007/s10546-014-9952-0>
 10. Simmon, R, NASA, Earth Observatory, <https://earthobservatory.nasa.gov/features/EnergyBalance/page2.php>
 11. Bulk Density, USDA-NRCS, https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053260.pdf
 12. NASA, Heat Capacity and Energy Storage, <https://www.e-education.psu.edu/earth103/node/1005>
 13. List of cities by average temperature, https://en.wikipedia.org/wiki/List_of_cities_by_average_temperature