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The Optimum Solution to Global Warming

In the Control of CO_2, Hotspots, & Hydro-Hotspots Forcing Due to the GHG-Albedo Interaction

Alec Feinberg
DfRSoft Research, email: dfrsoft@gmail.com

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Abstract

In this paper we consider the (Greenhouse Gas) GHG-albedo interactions and show that the albedo solution is the optimum way to mitigate global warming when considering three known types of forcing and current trends in climate change. These considerations also indicate that focusing solely on CO_2 solutions have many associated risks compared with the albedo solution. The GHG-albedo interaction strength is also modeled.

1. Introduction

There have been a number of proposed albedo solutions [1-5] to reduce climate change. The main problem with the reflectivity (albedo) solution is that it remains relatively unknown and historically it has been overshadowed by CO_2 concerns. Furthermore, since Global Warming (GW) has come to the forefront, there has been widespread disregard for albedo controls compared with CO_2 legislation and other efforts. This lack of controls has increased the strengths overtime of these historically known additional forcing problems that also have needed attention. By assessing GHG-albedo interactions for all forcing issues and using historical information, we illustrate why albedo solutions are optimum compared to CO_2 methods in climate control. We also assess the GHG-albedo interactive strength. Therefore, it is concluded that albedo methods and solutions to reduce climate change pose much less risk in their ability to prevent the tipping point when compared to CO_2 reduction methods. Then, a goal of this paper is to point out the major risks involved with focusing solely on the CO_2 effort and to promote urgently needed additional government funding work on albedo controls and implementing reflectivity solutions [5].

2. Method

We first consider GHG-albedo interactions and associated historical information for three types of known GW forcing issues:

- CO_2 (ignoring other GHGs)
- Hotspots (such as Urban Heat Islands and Roads)
- Hydro-hotspots

Here a hydro-hotspot [6] is a solar hot impermeable surface common in cities and roads that creates atmospheric moisture in the presence of precipitation. This moisture increase can act as a local greenhouse gas. This mechanism includes warmer expanded air-surface temperatures due to the initial hotspot, and then during precipitation, evaporation increases the local atmosphere humidity GHG (as warm air holds more water vapor). The level of hydro-hotspot significance in climate change is currently unknown.

However observations of this effect are reasonably well established. For example, Zhao et al. [7] observed that Urban Heat Islands (UHI) temperatures increase in daytime ΔT by $3.0^{o}C$ in humid climates but decrease ΔT by 1.5°C in dry climates. They found a strong correlation between ΔT increase and daytime precipitation. Their results concluded that albedo management would be a viable means of reducing ΔT on large scales.

Since GHGs need long wavelength radiation to work, changing a hotspot surface's reflectivity is associated with the greenhouse gas mechanism. Therefore, we know the following ***Interactive GHG-albedo Statements to be true****:*

1. *Increasing the reflectivity of a hotspot surface reduces its greenhouse gas effect*
2. *Decreasing the reflectivity of a hotspot surface increases its greenhouse gas effect*
3. *The Global Warming (GW) change associated with a reflectivity hotspot change is given by the albedo-GHG radiation factor having an approximate inherent value of 1.6 (Sec. 2.2).*

Interactive Statements 1 and 2 provide the basis for the fact that the albedo solution [1-5] is proficient, having strong interactions with all three types of forcing mechanisms. ***Statement 3*** (see Sec. 2.2) details the strength of the GHG-albedo interaction. From Statements 1 and 2, we can deduce:

- CO_2 mitigation primarily only reduces its forcing effect
- CO_2 mitigation has somewhat weak interactions with hotspot forcing (9-26% [8]) (compared with tropospheric hotspot atmospheric water vapor GHG interactions)
- CO_2 mitigation has no direct interaction with hydro-hotspots forcing
- The albedo solution has strong mitigation interactions with hotspots, hydro-hotspots and CO_2 forcing
- Enhanced albedo mitigation can also compensate for increases in CO_2 effects and would be proficient in condensing out increases in atmospheric water vapor and offsetting arctic snow and ice albedo feedback losses

We also note from Statement 3, that because of the hotspot-albedo interaction, hotspot forcing has an increased GHG additional heat exchange. For example, based on our modeling (see Equations 20 and 21)

- a change in hotspot forcing would require approximately 1.6 times as much GHG forcing to have the same GW effect (see also Table 1)

This new hotspot GW heat exchange is largely with water vapor and clouds GHG (approximately 36-72% [8]). We see from these simple arguments, that the albedo solution is likely optimum and pose less risk in mitigate global warming. As well, many climatologists have possibly underestimated hotspot forcing, considering it to be negligible. Additionally, since little is known about hydro-hotspot forcing, these both need more consideration in forcing estimates [9, 10].

The assumption that hotspot forcing does not contribute significantly to global warming has been contested by many authors as it relates to UHIs. This is described by these authors' measurements [11-21] and more recently in modeling [4, 22]. One key work often referred to is by McKitrick and Michaels [11, 12] who found that the net warming bias at the global level may explain as much as half the observed land-based warming. This study was criticized by Schmidt [23] and defended by Mckitrick [12] over many years. In modeling, Feinberg [4, 22] assessed UHI amplification factors (solar area, heat capacity, canyon effect, etc.) with the help of UHI footprint and dome estimates that extended the UHI effect beyond its own area and used an albedo model to verify significance.

Little is understood about hydro-hotspot GW forcing significance. We do know that since the industrial revolution, impermeable surfaces have increased at an alarming rate (like CO_2) correlated to population growth [22] and thus, GW increases. Furthermore, there has been a lack of hotspot controls in terms of solar considerations in their construction of UHIs, rooftops, roads, parking lots, cars colors, and so forth. More studies on amplification effect of hydro-hotspots similar to Zhao et al. [7] would be helpful. In terms of amplification effects, it is likely that hydro-hotspots would have both local water-vapor GHG interactions and the additional 1.6 warming influence on GW (with UHI heat capacities also playing an important role). Therefore, hydro-hotspots may play a significant role in climate change as water vapor is a major GHG. Thus, hydro-hotspots should be recognized by GW experts and in IPCC reports.

- Consequently, there is a reasonable probability that focusing on CO_2 solutions creates reasonable associated risks in climate change mitigation as governments are now solely depending on such methods

Furthermore, there are growing concerns regarding

- slow progress reported in CO_2 reduction and this solution's ability to prevent the tipping point
- the yearly increases in reports on large desertification and deforestation occurring [24]
- lack of hotspot and hydro-hotspot controls [6]

Therefore, the only way to reduce these risks are by adopting, at least in parallel, ***albedo solutions since according to interactive albedo-GHG statements 1-3, it would guarantee success in mitigating all three types of forcing*** and offset the slow progress in CO_2 mitigation.

Currently, there remains little educational effort on albedo solutions [1-5] and they have not received any worldwide support compared to the CO_2 effort. This oversight is unfortunate as it hurts the potential business and governmental support of reflectivity solutions.

- Uneducated politicians are now totally invested in CO_2 solutions and there is a reasonable probability this puts our planet at great risk given the uncertainty existing in CO_2 mitigation.

Regarding ***Interactive Statement 3***, it is next important to determine the albedo-GHG re-radiation 1.6 interaction [4, 22] strength and its change since the pre-industrial revolution. Such values relate to the effective emissivity constant of the planetary system. Because of its importance to the albedo-GHG interactive mechanism, it is a primary focus in the next sections as it supports potential albedo geoengineering solutions.

2.1 Albedo-GHG Radiation Factor

When initial solar absorption occurs, part of the long wavelength radiation given off is re-radiated back to Earth. In the absence of forcing we denote this fraction as f_1. This presents a simplistic but effective model

$$P_{\Pr e-Industrial} = P_\alpha + P_{GHG} = P_\alpha + f_1 P_\alpha = P_\alpha\left(1+f_1\right) = \sigma T_S^4 \text{ where } P_\alpha = \frac{S_o}{4}(1-\alpha) \tag{1}$$

and T_s is the surface temperature, $P_{\text{pre-industrial}}$, P_α, and P_{GHG} are the total pre-industrial warming, albedo warming and GHG warming in W/m^2, respectively. As one might suspect, f_1 turns out to be exactly β^4 in the absence of forcing, so that f_1 is a redefined variable taken from the effective emissivity constant of the planetary system. We identify $1+f_1=1.618034$ (see Section 2.2) as the pre-industrial albedo-GHG radiation factor (Table 1).

We identify the re-radiation 2019 having a value of $1+f_2=1.6276$ (Table 1). That is, in 2019, due to increases in GHGs, an increase in the re-radiation fraction occurs

$$f_2 = f_{2019} = f_1 + \Delta f = \beta_1^4 + \Delta f \approx \beta_2^4 + \Delta f \tag{2}$$

In this way $f_{2019} = f_2$ is a function of f_1. The RHS of Eq. 2 indicates that $\beta_1 \approx \beta_2$ (see verification results in Eq. 18 and 19). We find that $\Delta f = 0.0096$ is relatively small compared to $(1+f_1)$ which we show can fairly accurately be assessed in geoengineering.

2.2 Estimating the Pre-industrial Albedo-GHG Interaction Strength

In geoengineering, we are working with absorption and re-radiation, we define

$$P_{Total} = \sigma T_S^4 = \sigma \left(\frac{T_e}{\beta} \right)^4 \text{ and } P_\alpha = \sigma T_\alpha^4 = \sigma \left(\beta T_S \right)^4 \tag{3}$$

The definitions of $T_\alpha = T_e$, T_S and β are the emission temperature, surface temperature and typically $\beta \approx 0.887$, respectively. Consider a time when there is ***no forcing issues*** causing warming trends. Then by conservation of energy, the equivalent power re-radiated from GHGs in this model is dependent on P_α with

$$P_{GHG} = P_{Total} - P_\alpha = \sigma T_S^4 - \sigma T_\alpha^4 \tag{4}$$

To be consistent with $T_\alpha = T_e$, since typically $T_\alpha \approx 255^o K$ and $T_s \approx 288^o K$, then in keeping with a common definition of the global beta (the proportionality between surface temperature and emission temperature) for the moment $\beta = T_\alpha / T_s = T_e / T_S$.

This allows us to write the dependence

$$P_{GHG} = \sigma T_S^4 - \sigma T_\alpha^4 = \frac{\sigma T_\alpha^4}{\beta^4} - \sigma T_\alpha^4 = \sigma T_\alpha^4 \left(\frac{1}{\beta^4} - 1 \right) = \sigma T_\alpha^4 \left(\frac{1}{f} - 1 \right) \tag{5}$$

Note that when $\beta^4 = 1$, there are no GHG contributions. We note that f, the re-radiation parameter equals β^4 in the absence of forcing.

We can also define the blackbody re-radiated by GHGs given by some fraction f_1 such that

$$P_{GHG} = f_1 P_\alpha = f_1 \sigma T_\alpha^4 \tag{6}$$

Consider $f = f_1$, in this case according to Equations 5 and 6, it requires

$$P_{GHG} = \sigma T_\alpha^4 \left(\frac{1}{f_1} - 1 \right) = f_1 \sigma T_\alpha^4 \tag{7}$$

This dependence leads us to the solution of the quadratic expression

$$f_1^2 + f_1 - 1 = 0 \text{ yielding } f_1 = 0.618034 = \beta^4 \text{, } \beta = \left(0.618034 \right)^{1/4} = 0.886652 \tag{8}$$

This is very close to the common value estimated for β and this has been obtained through energy balance in the planetary system providing a self-determining assessment. In geoengineering we can view the re-radiation as part of the albedo effect. Consistency with the Planck parameter is shown in Section 3.1. We note that the assumption $f = f_1$ only works if planetary energy is in balance without forcing. In the next section, we double check this model in another way by balancing energy in and out of our global system.

2.3 Balancing Pout and Pin in 1950

In equilibrium the radiation that leaves must balance P_α, the energy absorbed, so that

$$\begin{aligned} Energy_{Out} &= (1-f_1)P_\alpha + (1-f_1)P_{Total} = (1-f_1)P_\alpha + (1-f_1)\{P_\alpha + f_1 P_\alpha\} \\ &= 2P_\alpha - f_1 P_\alpha - f_1^2 P_\alpha = Energy_{In} = P_\alpha \end{aligned} \tag{9}$$

This is consistent, so that in 1950, Eq. 9 requires the same quadratic solution as Eq. 8. It is also apparent that

$$P_\alpha = f_1 P_{Total\_1950} = \beta_1^4 P_{Total\_1950} \tag{10}$$

since

$$P_\alpha = f_1(P_\alpha + f_1 P_\alpha) \;\; or \;\; 1 = f_1(1+f_1) \tag{11}$$

The RHS of Eq. 11 is Eq. 8. This illustrates f_l from another perspective as the fractional amount of total radiation in equilibrium. As a final check, the application in the Section 3, in Table 1, illustrates that f_l provides reasonable results.

2.4 Re-radiation Model Applied to 2019

In 2019 due to global warming trends, to apply the model we assume that feedback can be applied as a separate term and we make use of some IPCC estimates for GHG forcing as a way to calibrate our model. In the traditional sense of forcing, we assume some small change to the albedo and most of the forcing due to IPCC estimates for GHGs where

$$P_{Total\,2019} = P_{\alpha'} + P_{GHG'} = P_{\alpha'}(1+f_2) \tag{12}$$

Then we introduce feedback through an amplification factor A_F as follows

$$P_{Total\,2019\,\&\,Feedback} = P_{1950} + (\Delta P)\,A_F = P_{1950} + (P_{2019} - P_{1950})\,A_F = \sigma T_S^4 \tag{13}$$

Here, we assume a small change in the albedo denoted as P_α' and f_2 is adjusted to the IPCC GHG forcing value estimated between 1950 and 2019 of 2.38W/m^2 [10]. Although this value does not include hydro-hotspot forcing assessment described in the introduction, it possibly may be effectively included since forcing estimates also relate to accurate GW temperature changes. Then the feedback amplification factor, is calibrated so that T_S=T_{2019} (see Table 1) yielding A_F =2.022 [also see ref. 24]. The main difference in our model is that the forcing is about 6% higher than the IPCC for this period. Here, we take into account a small albedo decline of 0.15% that the author has estimated in another study due to likely issues from UHIs [22] and their coverage. We note that unlike f_1, f_2 is not a strict measure of the emissivity due to the increase in GHGs.

3 Results Applied to 1950 and 2019 with an Estimate for f_2

In 1950 we will simplify estimates by assuming the re-radiation parameter is fixed and reasonable close to the pre-industrial level of f_l=0.618034. Then, to obtain the average surface temperature T_{1950}=13.89^{o}C (287.04^{o}K), the only adjustable parameter left in our basic model is the global albedo (see also Eq. 1). This requires an albedo value of 0.3008 (see Table 1) to obtain the T_{1950}.=287.04^{o}K. This albedo number is reasonable and similar to values cited in the literature [26].

In 2019, the average temperature of the Earth is T_{2019}=14.84^{o}C (287.99^{o}K) given in Eq. 15. We have assumed a small change in the Earth's albedo due to UHIs [22]. The f_2 parameter is adjusted to 0.6276 to obtain the GHG forcing shown in Column 7 of 2.38W/m^2 [10]. Therefore the next to last row in Table 1 is a summary without feedback, and the last row incorporates the A_F=2.022 feedback amplification factor.

Table 1 Model Results

Year	**T_S(°K)**	**T_α(°K)**	***f_1, f_2***	**α, α'**	**Power Absorbed W/m^2**	**$P_{GHG'}$, P_{GHG}**	**P_{Total} W/m^2**
2019	287.5107	254.55	0.6276	30.03488	238.056	149.4041	387.4605
1950	287.04	254.51	0.6180	30.08	237.9028	147.024	384.9267
Δ2019-1950	0.471	0.041	0.0096	(0.15%)	0.15352	2.38	2.53
$\Delta_{Feedback}$ A_F=2.022	0.95	0.083	-	-	0.3104	4.81	5.12

From Table 1 we now have identified the reverse forcing at the surface needed since

$$P_{Total\,2019\_Feedback\,Amp} = P_{1950} + \left(P_{2019} - P_{1950}\right) A_F = 384.927 W/m^2 + (2.5337 W/m^2) 2.022 = 390.05 W/m^2 \quad (14)$$

and

$$\Delta T_S = T_{2019} - T_{1950} = \left(390.05/\sigma\right)^{1/4} - 287.04°K = 287.9899°K - 287.04°K = 0.95°K \quad (15)$$

as modeled. We also note an estimate has now been obtained in Table 1 for f_2=0.6276, A_F=2.022, and $\Delta P_{Total\_Feedback\_amp}$=5.12W/m^2.

3.1 Model Consistency with the Planck Parameter

As a measure of model consistency, the forcing change with feedback, and resulting temperatures T_{1950} and T_{2019}, should be in agreement with expected results using the Planck feedback parameter. From the definition of the Planck parameter λ_o and results in Table 1, we estimate [27]

$$\lambda_o = -4\frac{\Delta R_{OLW}}{T_S} = -4\left(\frac{237.9028 W/m^2}{287.041°K}\right)_{1950} = -3.31524 W/m^2/°K \quad (16)$$

and

$$\lambda_o = -4\frac{\Delta R_{OLW}}{T_S} = -4\left(\frac{238.056 W/m^2}{287.99°K}\right)_{2019} = -3.306 W/m^2/°K \quad (17)$$

Here ΔR_{OLW} is the outgoing long wave radiation change. We note these are very close in value showing miner error and consistency with Planck parameter value, often taken as 3.3W/m^2/°K.

Also note the Betas are very consistent with Eq. 8 for the two different time periods since from Table 1

$$\beta_{1950} = \frac{T_\alpha}{T_S} = \frac{T_e}{T_S} = \frac{254.51}{287.041} = 0.88667 \textit{ and } \beta_{1950}^4 = 0.6180785 \quad (18)$$

and

$$\beta_{2019} = \frac{T_\alpha}{T_S} = \frac{T_e}{T_S} = \frac{254.55}{287.5107} = 0.88526 \textit{ and } \beta_{2019}^4 = 0.6144 \quad (19)$$

3.2 Hotspot Versus GHG Forcing Equivalency

From Equation 1 and 12 we can estimate the effect in a change in hotspot forcing as

$$\left(\frac{dP_{Total}}{dP_\alpha}\right)_{1950} = \left(1 + f_1\right) = 1.618 \text{ and } \left(\frac{dP_{Total}}{dP_\alpha}\right)_{2019} = \left(1 + f_2\right) = 1.6276 \quad (20)$$

However, we note a change in GHGs is only a factor of 1 by comparison

$$\frac{dP_{Total}}{dP_{GHG}} = \frac{d\left(P_\alpha + P_{GHG}\right)}{dP_{GHG}} = 1 \tag{21}$$

This indicates that hotspot forcing has a larger effect due to GHG amplification. Alternately, 1 W/m^2 of albedo forcing generally would require 1.628 W/m^2 of GHG forcing to have the same global warming effect. This is an important result and should be factored into albedo forcing estimates.

4 Summary

In this paper we have initially argued the importance of the albedo solution using the fundamental concepts of GHG-albedo interactions. From the basic concept of the GHG-albedo interaction and the reality of today's challenges, it appears to indicate that the albedo solution would be the optimum safest way to mitigate climate change. This is also due to the fact it is the only logical method to fully mitigate global warming when three types of forcing are all considered as significant. As well we know CO_2 solutions may be too slow to prevent a tipping point (especially with desertification and deforestation occurring).

The GHG-albedo interaction strength due to the re-radiation factor has been fully described in application to two time periods. Results show that the re-radiation factor for 1950 when taken as a pre-industrial value is 1.6181 which is directly given by β^4 (the emissivity constant of the planetary system). However in present day, this factor has increase to 1.6276 due to the increase in GHGs. In order to make the present day assessment, we assumed a small planetary albedo decrease from 1950 of 0.15% and GHG forcing of about 2.38 W/m^2 (in accordance with IPCC estimates). In terms of geoengineering albedo modification estimates, the interactive value of 1.62 should to be a good approximation.

Below we provide suggestions and corrective actions which include:

- Albedo guidelines for both UHIs and roads similar to on-going CO_2 efforts
- Guidelines for future albedo design considerations of cities
- Government money allocation for geoengineering and implement albedo solutions
- Recommend an agency like NASA to be tasked with finding applicable albedo solutions and implementing them
- Recommendation for cars to be more reflective. Although world-wide vehicles likely do not embody much of the Earth's area, recommending that all new manufactured cars be higher in reflectivity (e.g., silver or white) would help raise awareness of this issue similar to electric automobiles that help improve CO2 emissions.

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