Optimum Solution to Global Warming Using a Greenhouse Gas-Albedo Hotspot Theorem In the Control of Three Types of Forcing

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Abstract

In this paper we suggest that a fundamental GHG-albedo hotspot surface theorem, when applied to the reality of today's climate challenges, appears to indicate that the albedo solution is the optimum and safest way to mitigate climate change. The theorem also indicates that CO_2 solutions have an associated risk in stopping climate change when considering three types of forcing described. The albedo-GHG factor is also detailed.

1. Introduction

Since GHGs need long wavelength radiation to work, then changing a hotspot surfaces albedo is associated with the greenhouse gas mechanism. Therefore, we can devise *a greenhouse gas (GHG) albedo hotspot surface theorem* stating*:*

- *Increasing the reflectivity of a hotspot surface has the same effect as reducing greenhouse gases*
- *Decreasing the reflectivity of a hotspot surface has the same effect as increasing greenhouse gases*
- *The inherent global warming change associated with a reflectivity hotspot change is given by the albedo-GHG radiation factor having an approximate value of 1.6.*

This fundamental theorem is important because it leads one to the reality that conservatively, the albedo solution [1-5] is our fastest and safest method to stop climate change. From the theorem we can deduce:

- CO_2 mitigation is not optimum in reducing hotspots effects and has no effect on hydro-hotspots
- The albedo solution is effective in reducing hotspots, hydro-hotspots and CO_2 effects

Here we assume three dominant types of forcing due to

- CO_2 (ignoring other GHGs)
- Hotspots
- Hydro-hotspots

Carbon climatologist apparently assume that hotspot forcing is negligible and little is known about hydro-hotspot forcing where

- UHI and other impermeable surfaces create hydro-hotspots [6] which contribute to global warming. However, the level of hydro-hotspot significance is currently unknown. A hydro-hotspot is a solar hot surface that creates atmospheric water vapor in the presence of precipitation. Such surfaces create excess moisture in the atmosphere promoting a local greenhouse effect. For example, Zhao et al. [7] observed that UHI temperatures increase in daytime ΔT by 3.0^{o}C in humid climates but decreasing ΔT by 1.5^{o}C in dry climates.

The assumption that hotspots do not contribute significantly to global warming has been contested by many authors as it relates to UHIs. This is now fully described both with measurements [8-19] and more recently in modeling [4,20]. Furthermore, humankind has a lack of hotspot controls in the construction of UHIs and impermeable surfaces which are increasing with population [20] growth at an alarming rate. In this view, we have three dominate forcing issues, hotspots, hydro-hotspots and CO_2.

- Thus, maintaining the carbon climatologist's argument that hotspots and hydro-hotspots forcing are not significant, so that CO_2 must dominates, promotes associated risk in climate change mitigation

Finally, there is no well-established scientific proof that CO_2 plays such a dominate role. One could argue that hydro-hotspot increases are possibly more dominant in terms of greenhouse gas changes since the industrial revolution. Therefore, the only way to reduce this risk is by adopting, at least in parallel, ***albedo solutions since according to this theorem, it guarantee success in mitigating all three types of forcing***.

Furthermore, we have growing concerns regarding

- slow progress reported in CO_2 reduction
- the yearly increases in reports on large desertification and deforestation occurring [21]
- Lack of hotspot and hydro-hotspot control [6]

One aspect of this theorem of interest is to demonstrate the albedo-GHG radiation 1.6 factor [4, 20] and its change since the pre-industrial revolution. This factor must take into account all GHG increases including hydro-hotspot changes. Such values relates to the effective emissivity constant of the planetary system β^4. Because of its importance as it relates to the albedo-GHG mechanism, it is a primary focus in the rest of this paper.

2. Method: Albedo-GHG Radiation Global Warming Pre-Industrial 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

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

and T_s is the surface temperature. 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 $1+f_1=1.618034$ 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 varication 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 accurate be assessed in geoengineering.

2.1 Basic Re-radiation Model and Estimating f_1

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_α=T_e, T_S and β are the emission temperature, surface temperature and typically β≈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_α=T_e, since typically T_α≈255°K and T_s≈288°K, then in keeping with a common definition of the global beta (the proportionality between surface temperature and emission temperature) for the moment β=T_α/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 β^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

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

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.

2.2 Balancing Pout and Pin in 1950

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

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

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

$$P_\alpha = f_1 P_{Total\_1950} = \beta_1^4 P_{Total\_1950} \quad (10)$$

since

$$P_\alpha = f_1(P_\alpha + f_1 P_\alpha) \;\; or \;\; 1 = f_1(1+f_1) \quad (11)$$

The RHS of Eq. 11 is Eq. 8. This illustrates f_1 from another perspective as the fractional amount of total radiation in equilibrium. As a final check, the application in the next Section in Table 1, illustrate that f_1 provides reasonable results.

2.3 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

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

Then we introduce feedback through an amplification factor A_F as follows

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

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 [22]. Then the feedback amplification factor, is calibrated so that T_S=T_{2019} (see Table 1) yielding A_F =2.022 [also see ref. 23]. 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 [20] and their coverage. We note that unlike f_1, f_2 is not a strict measure of the emissivity due 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 at the pre-industrial level of f_1=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. This requires an albedo value of 0.3008 (see Table 1) to obtain T_{1950}.=287.04^{o}K. This albedo number is reasonable and similar to values cited in the literature [24].

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 [20]. The f_2 parameter is adjusted to 0.6276 to obtain the GHG forcing shown in Column 7 of 2.38W/m^2 [23]. Therefore the next to last row in Table 1 is a summary without feedback, and the last row incorporated the A_F=2.022 feedback amplification factor.

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

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

and

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

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.

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

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 [25]

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

and

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

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 $3.3 W/m^2/°K$.

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

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

and

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

4 Summary

In this paper we have devised a greenhouse gas albedo surface theorem. The theorem includes a re-radiation factor which has been fully described and applied to two time periods. Results show that the re-radiation factor for 1950 is taken as a pre-industrial value of 1.6181 while in present day the factor has increase to 1.6276 due to the increase in GHGs.

We suggest the theorem, when applied to the reality of today's challenges, appears to indicate that the albedo solution would be the safest and fastest way to mitigate climate change. Furthermore, the theorem indicates that focusing solely on the CO2 solution is unrealistic and puts our planet at risk when three types of forcing are considered.

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