Quantifying the Advantage of the Albedo/GHG GW Solution Using a Re-Radiation Model And a New Albedo-Planck Parameter

Alec Feinberg,
DfRSoft Research,
(Please feel free to provide any helpful preprint comments to dfrsoft@gmail.com)

Key Words: Re-Radiation Model, Global Warming Modeling, Planck Parameter, Planck-Albedo Parameter

Abstract In this paper, we model global warming (GW) using a re-radiation factor and use the Planck's feedback parameter to verify consistency. The re-radiation factor is important in quantifying the fact that for the same percent change in the Earth's albedo compared to greenhouse gases (GHG), the albedo affect has a 2.6 times larger impact on global warming. In our simple model, we additionally define a handy Planck-albedo feedback parameter having a convenient value of $1W/m^2/^oK/\Delta\%$albedo. An alternate way to assess the Planck parameter was also found.

1 Introduction

Although global warming is highly complex, often it is helpful to work with a simplified model. We create a model that uses a re-radiation factor which helps to quantify significant differences between changes in the global albedo versus greenhouse gas forcing. We use the Planck's feedback parameter to verify model consistency. This model illustrates a reasonable way to view the Earth's energy budget; it is likely useful as a teaching aid, it provides a number of useful insights in climatology sensitivity estimates and demonstrates the relative advantage of solar geoengineering solutions over GHG reduction in GW mitigation [1]. In working the model, we also find a handy Planck-albedo parameter that may be useful to climatologists [2].

2. Data and Method

In order to introduce the re-radiation surface model, it is helpful to initially look at the Planck feedback parameter as it plays a key role in verifying modeling.

2.1 Overview of Planck Feedback Parameter

Estimates on Planck's feedback parameter are varied, typically between $-3.8W/m^2/^oK$ and $-3.21W/m^2/^oK$ with some values as large as $-7.1W/m^2/^oK$ [3]. The IPCC AR4 [4] list a value of $-3.21W/m^2/^oK$. Numerous authors have developed different expressions [3]. A typical estimate uses

$$F_{TOA} = (1-\alpha)\,S_o/4 - \sigma(\beta T_S)^4 = (1-\alpha)\,S_o/4 - R_{LWR} \tag{1}$$

where $S_o=1361W/m^2$, F_{TOA} is the radiation budget at the top of the atmosphere, R_{LWR} is the outgoing long wave radiation (a function of surface temperature and albedo), σ is the Stefan-Boltzmann constant and β is described below. Then the Planck parameter λ_o can be calculated as

$$\lambda_o = \partial F_{TOA}/\partial T_S = -\partial R_{LWR}/\partial T_S \tag{2}$$

This result is

$$\lambda_o = -4\beta^4\sigma T_S^3 = -4\beta\sigma T_{TOA}^3 \tag{3}$$

where β varies from 0.876 to 0.887 (averaging=0.8815) and Ts=288°K [4]. This yields $-3.37W/m^2/^oK<\lambda_o<-3.21W/m^2/^oK$. However, from Eq. 3, β is often taken as the ratio

$$\beta = T_{TOA}/T_S = 255°K/288°K = 0.8854 \tag{4}$$

A common assessment uses $T_{TOA}=255^oK$, so that $\lambda_o=-3.33W/m^2/^oK$. Another expression developed by Schlesinger [5] is dependent on the albedo and surface temperature as

$$\lambda_o = S_o(1-\alpha)/T_S \tag{5}$$

When $S_o=1361$, $0.294118<\alpha<0.3$, and Ts=288 °K then $-3.308W/m^2/^oK > \lambda_o > -3.3358W/m^2/^oK$, respectively.

2.2 Estimating Planck's Parameter with an Albedo Method

Consider a global albedo change corresponding to 1°K rise from solar absorption. Since we are only concerned with an albedo change that corresponds to the surface temperature we can write

$$F_{TOA} = 0 = (1-\alpha)E_o - \sigma(T_S)^4 \tag{6}$$

where $E_o = S_o/4$. Then a 1°K change is

$$\Delta T_S = T_2 - T_1 = \left(\frac{E_o}{\sigma}(1-\alpha_2)\right)^{1/4} - \left(\frac{E_o}{\sigma}(1-\alpha_1)\right)^{1/4} = 1°K \tag{7}$$

Here we will use the AR5 albedo starting value of 0.294118 [6]. We find that the corresponding albedo change is 0.28299 when E_o=340W/m^2. This corresponds to an absorption of

$$\Delta E_o = E_o\left\{(1-\alpha_2)-(1-\alpha_1)\right\} = E_o(\alpha_1-\alpha_2) = 3.784W/m^2 \tag{8}$$

Since this is for a 1°K rise, then it can also be written as

$$\lambda_{1K}=3.784\text{W/m}^2/°\text{K} \tag{9}$$

We note this is related to the surface value, then

$$\lambda_{1K} = -4\sigma T_s^3 \tag{10}$$

By comparison to above we have

$$\lambda_o=\lambda_{1K}\,\beta = -3.784\text{W/m}^2/°\text{K}=-3.349\text{W/m}^2/°\text{K} \tag{11}$$

This is very close to the -3.33 W/m^2/°K value obtained in the traditional manner.

2.3 Top of the Atmosphere and Beta

From Eq. 1

$$R_{LWR} = \sigma(\beta T_S)^4 = \sigma(T_S)^4 \tag{13}$$

giving

$$\beta^4 R_{TOA,T_S} = R_{TOA,T_{TOA}} \tag{14}$$

We will need this expression later when showing model consistency with the Planck feedback parameter.

2.4 Re-radiation GHG GW Model

Global warming can be modeled by looking at two different time periods. We assume no GW in 1950 compared to 2019 as

$$P_{Total\_1950} = P_\alpha + P_{GHG} \text{ and } P_{Total2019} = P_{\alpha'} + P_{GHG'+Feedback} \tag{15}$$

where

$$P_\alpha = S_o\left\{0.25x(1-Albedo)\right\} \tag{16}$$

where S_o=1361W/m^2. Here $P_{GHG'+Feedback}$ includes GHG increase comprising also of water-vapor increase, lapse rate effect and other effect such as an increase in snow-ice albedo change that are hard to separate out. That is some of this feedback is related to GHG increases and some is related to albedo change. Pa′ represents any albedo change due to UHI absorption increases, cloud absorption change, ice and snow melting and so forth that can be discerned.

The re-radiation model connects the absorption to re-radiation effects since absorption must occur prior to re-radiation and feedback. Therefore, we can write

$$P_{GHG} = f_{1950}P_\alpha \ and\ P_{GHG'+Feedback} = f_{2019}P_{\alpha'} \tag{17}$$

To be clear, *f* is then primarily a GHG re-radiation parameter. It is a function of GHGs and many feedback effects. However, it primarily affects is GHGs re-radiation since $P_{GHG} \approx P_{GHG'+Feedback}$. We then write

$$P_{Total} = \sigma T^4 \ and\ P_\alpha = \sigma T_\alpha^4 \tag{18}$$

3.0 Results and Discussion

The GHG re-radiation parameter *f* is adjustable and is set so that T_{1950}=13.89°C (287.038°K) and T_{2019}=14.84°C (287.99°K) .

Consider now a small change might have occurred of say 0.2% in the albedo from 1950 to 2019. This will also help demonstrate a number of changes. This might have occurred due to albedo forcing such as increases in UHIs and ice and snow changes. Then allowing for this small change we set $Albedo_{1950}$=29.6118 and the realized change is $Albedo_{2019}$=29.4118

We then note if the re-radiation parameters for 1950 and 2019 is adjusted to f_{1950}=0.6072 and f_{2019}=0.624, the results yields $P_{Total1950}$=384.9177 W/m^2 and $P_{Total1950}$=390.0464 W/m^2. We find that

$$\Delta P_{Total} = P_{2019} - P_{1950} = 5.13W/m^2 \tag{19}$$

and

$$\Delta T_{Total} = T_{2019} - T_{1950} = 0.95°C \tag{20}$$

which is the observed surface temperature increase since 1950.

The table below summarizes model results for the specified albedos and setting the model to the observed Earth's surface temperatures.

Table 1 Model results

Year	**T(°K)**	**T_α(°K)**	**f**	**α, α'**	**P_α, $P_{\alpha'}$**	**P_{GHG}, $P_{GHG+feedback}$**	**P_{Total}**
2020	288.0389	255.11	0.62512	29.4118	240.176	150.139	390.315
1950	287.0388	254.93	0.60722	29.6118	239.496	145.427	384..92
Δ2020-1950	1.00	0.18	**1.79%**	-0.2 **(0.68%)**	0.681	4.712	**5.39**
"What If - 1°K From Albedo Change"							
2020	288.039	255.11	0.62512	**29.4118**	**240.176**	150.139	390.315
1950	287.0391	254.1	0.62835	30.5248	236.389	148.535	384.925
Δ2020-1950	**1.00**	**1.00**	-0.323	-1.113 (3.65%)	3.787	1.6	5.39

To show model consistency, the forcing change 5.39 W/m^2 resulting in a 0.95°K rise, should agree with what is expected from Planck's feedback parameter. From Eq. 14 it is evident that

$$\beta^4 \Delta R_{TOA} = 5.25 \text{ x } \beta^4 = 3.2W/m^2 \tag{21}$$

This illustrates the consistency of the simple re-radiation model. Then Planck's feedback parameter temperature rise is in agreement

$$3.2W/m2 \text{ x } (1/3.3)°K/W/m2 = 0.95°K \text{ at } T_s \tag{22}$$

3.1 Why the Re-radiation Parameter is Significant

In Table 1 a 1.79% change in re-radiation increase is found. This is significance. It indicates an estimate of climate change from a different perspective, a measure of GHG increase and feedback effects and is generally helpful in looking at how our climate is working. We note that the GHG re-radiation parameter averages 61.62%. This is helpful to use an average between 1950 and 2020, since some of the feedback occurs due to the albedo change and some occurs due to GHGs. In the chain of events, prior to GHG re-radiation, blackbody absorption must occur. Therefore, all of the GHG re-radiation originates from the Earth's blackbody radiation. This indicates that an albedo change corresponds to about 161.62% impact on global warming. Specifically, the GHGs contribution compared to absorption is about

$$\frac{\bar{f}+1}{\bar{f}} \approx \frac{1.6162}{0.6162} = 2.62 \tag{23}$$

Alternately we can assess this factor directly noting the change, ΔP_{Total}, with a one-percent change of GHG versus a similar albedo percent change. Then in the albedo case

$$\frac{\Delta P_{Total}}{\%\Delta Albedo} = \frac{5.39W/m^2}{0.68\%} = 7.926W/m^2/\%\Delta Albedo \tag{24}$$

and for a GHG

$$\frac{\Delta P_{Total}}{\%\Delta GHG} = \frac{5.39 W/m^2}{1.79\%} = 3.011 W/m^2/\%\Delta GHG \tag{25}$$

We see that a one-percent change in GHG versus the equivalent percent albedo change, shows the albedo is a factor of 2.63 larger

$$\frac{7.926 W/m^2/1\%}{3.011 W/m^2/1\%} = 2.63 \tag{26}$$

This is as expected in agreement with Eq. 23. This factor may be slightly larger, but we cannot separate out some of the feedback occurring due to albedo change versus GHG issues.

In general, albedo forcing has a higher impact per percent change in climate forcing and is a key reason that UHIs, cloud coverage, snow and ice melting, can create significant climate effects. In this view, an albedo solution is advantageous having significant potential for reversing global warming. Therefore, while the GHG solution is important, certainly an albedo approach is advantageous. It reduces both initial absorption and its potential re-radiation. Its impact rating can be taken as 161.6% compared to GHG with a 61.6% impact by comparison according to Table 1, yielding a 2.6 times higher advantage. It is important to realize that because the albedo solution can highly impact GW and reverse trends, it is also vital in preventing a tipping point from occurring.

3.2 Planck-Albedo Feedback Parameter

There are two albedo changes in Table 1, they are: $\Delta\alpha = -0.2$ *or* $\%\Delta\alpha = 0.68\%$ and $\Delta\alpha = 0.1113$ *or* $\%\Delta\alpha = 3.42\%$. The albedo ΔP_α changes in Table 1 are 0.681W/m^2 and 3.787 W/m^2, respectively. We note that we can define a unique Planck-albedo parameter $\lambda_{\%\Delta\alpha} = \Delta P_\alpha / \%\Delta albedo$. To illustrate from Table 1

$$\lambda_{\%\Delta\alpha} = 1\ \mathrm{W/m^2/\Delta\%albedo} = 0.681/.68\% \text{ and } 1.04\ \mathrm{W/m^2/\Delta\%albedo} = 3.767/3.65 \tag{27}$$

This parameter can also be expressed per degree since in both case we have about a 1^{o}K change, then

$$\lambda_{\%\Delta\alpha\Delta T} \approx 1 W/m^2/\Delta\%albedo/{}^\circ K \tag{24}$$

The parameter was first noted in Feinberg 2020 [2] but is featured here as a modeling tool. We term it the Planck-albedo parameter, since it relates to blackbody (P_α) absorption. This interesting parameter arises from the basic assessment

$$\lambda_{\%\Delta\alpha} = \frac{(\Delta E_o)_\alpha}{\frac{\alpha_1-\alpha_2}{\alpha_1}100} = \frac{E_o(\alpha_1-\alpha_2)}{\frac{\alpha_1-\alpha_2}{\alpha_1}100} = E_o\alpha_1/100 \approx 1 W/m^2/\%\Delta albedo \tag{28}$$

where E_o=340 W/m^2 and when α_1 is 29.4118%, the value 1.000W/m^2/Δ%albedo is obtained. We note the value 29.4118% (100/340) is given in AR5 [6]. The parameter's relationship to λ_α is

$$\lambda_\alpha = \lambda_{\%\Delta\alpha\Delta T}\ x\ \%\Delta\alpha \tag{29}$$

and the feedback parameter including GHG re-radiation is in 2019

$$\lambda_\alpha^\dagger = \lambda_{\%\Delta\alpha\Delta T}\ x\ \%\Delta\alpha\ x 1.62 \tag{30}$$

4.0 Conclusion

In this paper we provided a simple re-radiation global warming model. The model shows consistency with the Planck parameter. We noted that the re-radiation parameter increased by about 1.8% due to global warming from 1950 to 2019, illustrating the warming from a different perspective. From the model, the albedo effect was quantified having an impact rating of 161.6% compared to GHG with 61.6% per one-percent of change of each. The albedo effect then yields a 2.6 times higher advantage when comparing these. These results strongly support moving forward with solar geoengineering solutions [2, 7-9].

We also found a handy parameter that we termed the Planck-albedo parameter which is about $\lambda_{\%\Delta\alpha\Delta T} \approx 1 W/m^2/\Delta\%albedo/{}^\circ K$. This can be helpful in quickly estimating the effect of an albedo change on global warming and in assessing λ_α. For example, Feinberg 2020 [1] suggested a goal of 1.5% geoengineering albedo change. Using this parameter, an impact of 1.5 Watts/m^2 warming reduction should result. Given a 1.6 GHG reemission factor, this is 2.4W/m^2 improvement. With a reduction in water-vapor feedback, often estimated by a factor of 2 [10], provides an overall resulting effect that could be as high as 4.8W/m^2. Feasibility is discussed in more detail in Feinberg's 2020 paper [1] and other solutions have been proposed [6-9].

References

1. Feinberg, A., The Alternate Solution to Global Warming (2020), Vixra
2. Feinberg, A., Urban Heat Island Amplification Estimates on Global Warming Using an Albedo Model, preprint: Vixra 2003.0088 (2020),, DOI: 10.13140/RG.2.2.32758.14402/15 (submitted).
3. Kimoto, K. On the Confusion of Planck Feedback Parameters, Energy & Environment (2009)
4. Soden, B.J. and Held I.M., 2006: An Assessment of Climate Feedbacks in Coupled Ocean Atmosphere Models. J. Climate,Vol.19,3354–3360
5. Schlesinger, M.E. 1986: Equilibrium and transient climatic warming induced by increased atmosphericCO2.ClimateDynamics,Vol.1,35–51
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. D. Dunne, (2018), Six ideas to limit global warming with solar geoengineering, CarbonBrief, https://www.carbonbrief.org/explainer-six-ideas-to-limit-global-warming-with-solar-geoengineering
8. A. Cho (2016), To fight global warming, Senate calls for study of making Earth reflect more light, Science, https://www.sciencemag.org/news/2016/04/fight-global-warming-senate-calls-study-making-earth-reflect-more-light
9. Levinson, R., Akbari, H. Potential benefits of cool roofs on commercial buildings: conserving energy, saving money, and reducing emission of greenhouse gases and air pollutants. *Energy Efficiency* **3,** 53–109 (2010). https://doi.org/10.1007/s12053-008-9038-2
10. Dessler A. E. ,Zhang Z., Yang P., Water-vapor climate feedback inferred from climate fluctuations, 2003–2008, *Geophysical Research Letters*, (2008), https://doi.org/10.1029/2008GL035333

Appendix:

Quantifying the Advantage of the Albedo/GHG GW Solution in Layman's Terms

Consider the Earth as a greenhouse. Initially we open the roof. Sunlight comes in and some is absorbed and heats the floor. Let's say this is 10 units of energy. The heat rises so the 10 unit leaves but the floor keeps absorbing and re-radiating 10 units from new sunlight so the floor stays warm. We measure the temperature of the floor it is 255^{o}K. This temperature is the result of 10 units. Now we close the glass roof and it allows only 4 units to escape at a time so 6 units on average stay and 4 units leave. The temperature of the floor rises to 288^{o}K due to the 6 additional units. What is the contribution from the floor? It is 10 units and 6 from the glass roof. Without the floor absorption, the roof would do nothing and without the glass roof, the floor is only 10. So the floor is responsible for 16 units while the glass top is responsible for 6. Results is

16/6=2.666

Now what if the roof increases so we get 1% more. 1% increase is 6.06

6.06
(10+6.06)/6.06=2.65016

Result is now

(10+.1+6)/6.01=2.65

Now says the floor increase by 1% we get

Advantage is 2