The Advantage of the Albedo Solution to Global Warming using a Re-Radiation Model with New Albedo-Planck Parameter

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Abstract In this paper, we show how global warming can be modeled 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 gas, the albedo change will have a 2.6 times larger impact on global warming forcing. In our simple model, an alternate way to assess the Planck parameter was also found. As well, we define a handy Plank-albedo feedback parameter that has a convenient value of $1W/m^2/\Delta\%albedo/^oK$.

1 Introduction

Although global warming models are highly complex, often it is helpful to use a simple model and relate it to the top of the atmosphere using the Planck's feedback parameter. The model described here uses a re-radiation factor that helps to quantify significance difference between changes in the global albedo versus greenhouse gas forcing. In working with the model, we find a handy Planck-albedo parameter that may be useful to climatologists [1]. This model illustrates a reasonable way to view the Earth's energy budget, it is likely useful as a teaching aid, and provides a number of useful insights in climatology sensitivity estimates and for alternate albedo solutions to global warming [2].

2. Data and Method

In order to introduce the re-radiation surface model, it is helpful to 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 $3.21W/m^2/^oK$ and $3.8W/m^2/^oK$ with some values as high 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

$$\lambda_o = \partial F_{TOA}/\partial T_S = -\partial R_{LWR}/\partial T_S = -4\sigma(\beta T_S)^4 \tag{2}$$

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 (average 0.8815) and Ts=288^{o}K [4]. This yields $3.21W/m^2/^oK<\lambda_o<3.37W/m^2/^oK$. However, from Eq. 3, β is taken as the ratio

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

Here we take T_{TOA}=255^{o}K, so that λ_o =3.33W/m^2/^{o}K. Another expression developed by Schlesinger [5] dependent on the albedo and surface temperature, given by

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

When S_o=1361, $0.294118<\alpha<0.3$, and Ts=288 ^{o}K then $3.3358W/m^2/^oK > \lambda_o > 3.308W/m^2/^oK$ 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 a surface temperature change 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

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

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

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

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

At the top of the atmosphere we obtain

$$T_{TOA} = \beta T_S \tag{12}$$

and

$$F_{TOA} = S_o(1-\alpha_1) - \sigma T_{TOA}^4 \tag{13}$$

giving

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

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

2.4 Re-radiation GW Model

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

$$P_{Total\_1950} = P_\alpha + P_{GHG} \text{ and } P_{Total\,2019} = P_{\alpha'} + P_{GHG+Feedback} \tag{15}$$

where

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

where S_o=1361W/m^2. Note that the 2019 model has a feedback added subscript due to forcing and α' indicates that some warming occurring due to albedo changes possibly from UHIs and ice and snow melting.

The re-radiation model is simply

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

We then write

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

3.0 Results and Discussion

The 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 of 0.2% albedo change from 1950 to 2019, related to events on Earth such as increases in UHI and ice and snow melting, so we set

$Albedo_{1950}$=29.6118 and $Albedo_{2019}$=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 yield

$P_{Total1950}$=384.9177 W/m^2 and $P_{Total1950}$=390.0464 W/m^2

We find that

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

and

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

which is the observed temperature increase.

The table below summarizes the model results for the specified albedos and setting the temperatures to those observed at the surface.

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 - 1K 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, we need to see how the 5.39 W/m^2, resulting from a 0.95°K change, agrees with what is expected from Planck's feedback parameter. We recall that

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

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

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

3.1 Why the Re-radiation Parameter is Significant

In Table 1 a 1.79% change in re-radiation increase is observed. This provides an estimate of climate change from a different perspective and can be helpful in looking at how our climate is working. We note that the re-radiation parameter averages 61.62%. This is significance. It indicates how much of the blackbody portion is re-radiated back to Earth. We note in the chain of events, prior to GHG re-radiation, blackbody absorption must occur. This indicates that an albedo change corresponds to about 161.62% impact on global warming. Specifically, the GHGs contribution compared to absorption is

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

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 for the albedo one-percent change we find

$$\frac{\Delta P_{Total}}{\%\Delta Albedo} = \frac{5.39W/m^2}{0.68\%} = 7.926W/m^2/1\% \tag{24}$$

and for a GHG one-percent change

$$\frac{\Delta P_{Total}}{\%\Delta GHG} = \frac{5.39W/m^2}{1.79\%} = 3.011W/m^2/1\%\Delta GHG \tag{25}$$

We see that a 1% change of GHG versus albedo change, shows the albedo is a factor of 2.63 larger

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

As expected, in agreement with Eq. 23

Therefore, one would conclude an albedo approach to slowing and even potentially reversing global warming is highly advantageous. While the GHG solution is important, certainly an albedo approach will have a maximum impact. It reduces both initial absorption and the re-radiation, effectively have a 162% impact. It is important to realize that because the albedo solution can highly impact global warming 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 power changes ΔP_α 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

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

This parameter can also be expressed per degree since in both case we have a 1°K change, then

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

The parameter was first noted in Feinberg 2020 [1] but is featured here as a modeling tool. We term it the Plank-albedo parameter, since it relates to blackbody P_α absorption. This interesting parameter arises from the basic assessment

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

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

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

4.0 Conclusion

In this paper we provided a simple re-radiation 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. The re-radiation parameter was quantified averaging 61.62% of blackbody radiation is re-emitted to Earth. One can conclude that given the same percent change in albedo compared to GHG, the albedo change has a 2.6 times larger impact on forcing. We also found a handy parameter that we termed the Planck-albedo parameter which is about $\lambda_{\%\Delta\alpha\Delta T} \approx 1W/m^2/\Delta\%albedo/°K$. This can be helpful in quickly estimating the effect of an albedo change on global warming and in determining λ_α.

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