Global Warming 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 verifying consistency. The re-radiation factor is important in quantifying the fact that albedo versus a greenhouse gas change will have more impact on global warming. In our simple model we also found an alternate way to assess the Planck parameter. As well we define a handy Plank-Albedo feedback parameter that has a convenient value of 1 $W/m^2/\Delta\%albedo/^oK$.

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 plank feedback parameter. The model uses a re-radiation factor that helps to quantify significance in albedo versus greenhouse gas changes. 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 3.21 to 3.8 with some values as high as 7.1 [3]. The IPCC AR4 [4] list a value of 3.21. 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 3.21<λ_o<3.37. However, from Eq. 3 β is taken as the ratio

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

Where we take T_{TOA}=255^{o}K, so that λ_o =3.33. 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<α<0.3, and Ts=288 ^{o}K then 3.3358 >λ_o>3.308 respectively.

2.2 Estimating Planck's Parameter with an Albedo Method

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

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

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

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

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

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

Since this is for a 1°K rise then let

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

We note this is related to the surface value, then

$$\lambda_{1K}=-4\sigma T_s^3 \quad (10)$$

By comparison to above we have

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

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

$$T_{TOA}=\beta T_S \quad (12)$$

and

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

giving

$$\beta^4 F_{TOA,T_S}=F_{TOA,T_{TOA}} \quad (14)$$

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

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

where

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

where S_o=1361 W/m^2. Note that the 2019 model has a Feedback added factor due to forcing and a' indicates that warming is also occurring due to albedo change from urbanization and ice and snow melting.

our re-radiation model is simply

$$P_{GHG}=f\,P_\alpha \;\; and \;\; P_{GHG+Feedback}=f\,P_{\alpha'} \quad (17)$$

We then write

$$P_{Total}=\sigma T^4 \;and\; P_\alpha=\sigma T_\alpha^4 \quad (18)$$

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.

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 we set the re-radiation parameters for 1950 and 2019 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

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

and

$$\Delta T_{Total} = T_{2019} - T_{1950} = 0.95°C \quad (20)$$

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

Table 1 Model Summary

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**	1.68	-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 1K change, agrees with what is expected from Planck's feedback parameter. We recall that

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

This illustrates the consistency of the simple re-radiation model. Then Planck's feedback temperature rise finds an increase of

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

3.1 Why is the Re-radiation Parameter Significant?

First we see from Table 1 that a 1.8% change in re-radiation increase is occurring. This provides an estimate of the 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 is about 60%. This shows significance in climatology as well. It indicates how much of the black body portion is re-radiated back to Earth. We note in the chain of events, prior to GHG re-radiation, black body absorption must occur. This indicates that an albedo change corresponds to about 160% impact on global warming. However, a 100% GHG change only impacts global warming by about 60%. Therefore, one would conclude an albedo solution to global warming has a larger impact and it more advantageous. As well, an albedo solution has other major advantages, as it can reverse global warming and possibly 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 as $\lambda_{\%\Delta\alpha} = \Delta P_\alpha / \%\Delta albedo$. To illustrate from Table 1

$$\lambda_{\%\Delta\alpha} = 1 \text{ W/m}^2/\Delta\%\text{albedo} = 0.681/.68\% \text{ and } 1.04 \text{ W/m}^2/\Delta\%\text{albedo} = 3.767/3.65 \quad (23)$$

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

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

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 black body P_α absorption. This interesting parameter arises from the basic assessment

$$\lambda_{\%\Delta\alpha} = \frac{\Delta E_o}{\frac{\alpha_1-\alpha_2}{\alpha_1}100} = \frac{E_o(\alpha_1-\alpha_2)}{\frac{\alpha_1-\alpha_2}{\alpha_1}100} = E_o\alpha_1/100 \approx 1W/m^2/\%\Delta albedo \quad (25)$$

where E_o=340 W/m^2 and we see the closer that α_1 is to 29.4118%, the nearer a value of 1W/m^2/Δ%albedo is obtained. We note the value 29.4118% (100/340) is given in AR5 [6]. We note the parameter's relationship to

$$\lambda_\alpha = \lambda_{\%\Delta\alpha\Delta T}\ x\ \%\Delta\alpha \quad (26)$$

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% illustrating the warming from a different perspective. The re-radiation parameter was quantified showing about 60% of black-body radiation is re-emitted to Earth. One can conclude that an albedo change in global warming has a 160% impact. Furthermore, one can conclude that GHG change impact is only 60% by comparison. We also found a handy parameter that we termed the Planck-albedo parameter which is about $\lambda_{\%\Delta\alpha\Delta T} \approx 1W/m^2/\Delta\%albedo/°K$ and can be helpful in estimating λ_α.

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