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Abstract

The objective of this work is to apply the Dynamic-Atmosphere Energy Transport (DAET) climate model to a study of the Earth's semi-opaque troposphere. In this analysis the concept of previous authors has been followed and the Earth's climate is treated as a single integrated structured system of solar energy collection, thermal energy retention and energy distribution across the Earth's surface. Unlike previous authors the hemispheric duality of the Earth's surface is modelled with two separate energy environments of a day lit hemisphere of net energy collection and a dark night surface of net energy loss as fundamental to the design. Using worked examples, it is shown how the Greenhouse Effect results from the summation of two separate physical atmospheric processes, both of which are mathematically equivalent and which together create an energy reservoir within the Earth's troposphere. These processes are the thermal radiant opacity blocking of radiative physics, and the process of adiabatic convection and conserved energy delivery to far distance of mass-motion physics. Both these processes involve the mathematical infinite summation of halves-of-halves of energy flux and are completely saturated at a surface atmospheric pressure of 1 Bar. It is concluded that the two fundamental controls on terrestrial planetary climate for a given solar system orbit are the downwelling high frequency energy reflection filter of planetary Bond Albedo, and the upwelling low frequency energy bypass to space filter of the Atmospheric Window.

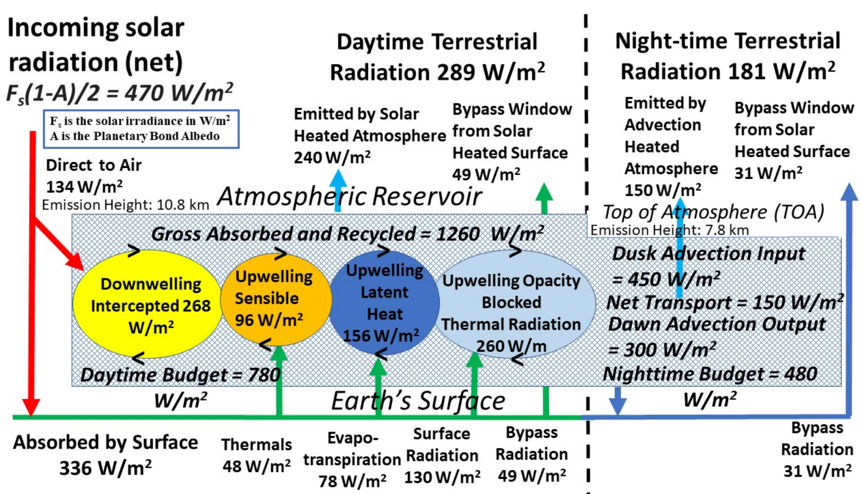

Figure 1: Figure 3 The Thermal Radiant Opaque Atmospheric Reservoir Energy Recycling Process

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The Application of the Dynamic Atmosphere Energy Transport Climate Model (DAET) to Earth's Semi-Opaque Troposphere

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Abstract: The objective of this work is to apply the Dynamic-Atmosphere Energy Transport (DAET) climate model to a study of the Earth's semi-opaque troposphere. In this analysis the concept of previous authors has been followed and the Earth's climate is treated as a single integrated structured system of solar energy collection, thermal energy retention and energy distribution across the Earth's surface. Unlike previous authors the hemispheric duality of the Earth's surface is modelled with two separate energy environments of a day lit hemisphere of net energy collection and a dark night surface of net energy loss as fundamental to the design. Using worked examples, it is shown how the Greenhouse Effect results from the summation of two separate physical atmospheric processes, both of which are mathematically equivalent and which together create an energy reservoir within the Earth's troposphere. These processes are the thermal radiant opacity blocking of radiative physics, and the process of adiabatic convection and conserved energy delivery to far distance of mass-motion physics. Both these processes involve the mathematical infinite summation of halves-of-halves of energy flux and are completely saturated at a surface atmospheric pressure of 1 Bar. It is concluded that the two fundamental controls on terrestrial planetary climate for a given solar system orbit are the downwelling high frequency energy reflection filter of planetary Bond Albedo, and the upwelling low frequency energy bypass to space filter of the Atmospheric Window.

Keywords: Adiabatic DAET Climate Model, Thermal Radiant Opacity, Lossy Surface Atmospheric Window

1. Introduction

The Earth's planetary climate consists of a gravitationally bound, mobile-fluid mass-transport and energy delivery system powered by high-frequency solar radiant energy. The climate system dynamic is composed of oceanic water and atmospheric air, organised in the form of closed loops or cells, that advects mass and energy across the planetary surface from tropical regions of net energy surplus to polar regions of energy deficit. In this paper the role of the oceans is not considered because, although the oceans are by far the major mobile fluid in terms of mass and energy content, the liquid ocean surfaces are everywhere covered by atmospheric air. It is the overlying atmosphere that mediates the critical role of solar energy capture by modulating the planetary albedo; thermal energy retention by modulating the atmospheric thermal radiant opacity, and subsequent exhaust to space from the planet of low-frequency thermal radiant energy.

Global atmospheric energy balance is the fundamental tenet of Climate Science. The energy balance concept posits that the high-frequency solar radiation intercepted by the Earth's lit hemisphere is the predominant source of energy that powers the atmosphere. This intercepted energy is subsequently lost to space as thermal radiant energy emitted from the full surface area of the planetary globe, and that on average these two flows of radiant energy are in balance. In order to study this balance a considerable body of work has been amassed in the scientific literature, amongst these works *Earth's Annual Global Mean Energy Budget* [1] has been cited 2,056 times (as of December 2022) and this paper is the basis on which the analysis herein is developed.

The Vacuum Planet Equation is an algorithm used in Astronomy to calculate the thermal radiant emission temperature of a terrestrial body using the Stefan-Boltzmann relationship and has the following form as exemplified in Sagan and Chyba [2]: -

"The equilibrium temperature T_e of an airless, rapidly rotating planet is: -

Equation 1: $$T_e \equiv [S\ \pi\ R^2(1\text{-}A)/4\ \pi\ R^2\ \varepsilon\ \sigma]^{1/4} \quad (1)$$

where σ is the Stefan-Boltzmann Constant, ε the effective surface emissivity, A the wavelength-integrated Bond albedo, R the planet's radius (*in metres)*, and S the solar constant (*in Watts/m^2*) at the planet's average distance from the sun."

The Vacuum Planet Equation contains several key assumptions. These include:

That all planets intercept solar energy at their orbital distance as if they are a disk with a cross-sectional area that is equal to the planet's radius (i.e., $\pi\ R^2$). However, due to daily rotation and seasonal tilt, planets emit surface radiation from all parts of their surface over the course of each year.

Therefore, the total surface area of the planet that emits thermal radiation to space is four times the surface area of its intercepting disk (i.e., $4\pi\ R^2$).

2. Reprise of the Standard Climate Model

The accepted concept at the core of modern climate science theory is that solar insolation flux which impacts the atmosphere is averaged over the annual solar orbital cycle of the planet. The numerical process which encapsulates this feature of climate modelling is the dilution of the incoming planetary disk solar flux to a quarter (the divide by 4 dilution process) and is exemplified by the work of Kiehl and Trenberth [1]. This feature of climate modelling is shown in Figure 1 [1; Figure 3] where the Incoming Solar Radiation is recorded as 342 W m^{-2} which is one quarter of the average insolation of 1,368 W m^{-2} that the Earth intercepts at its mean orbital distance from the Sun.

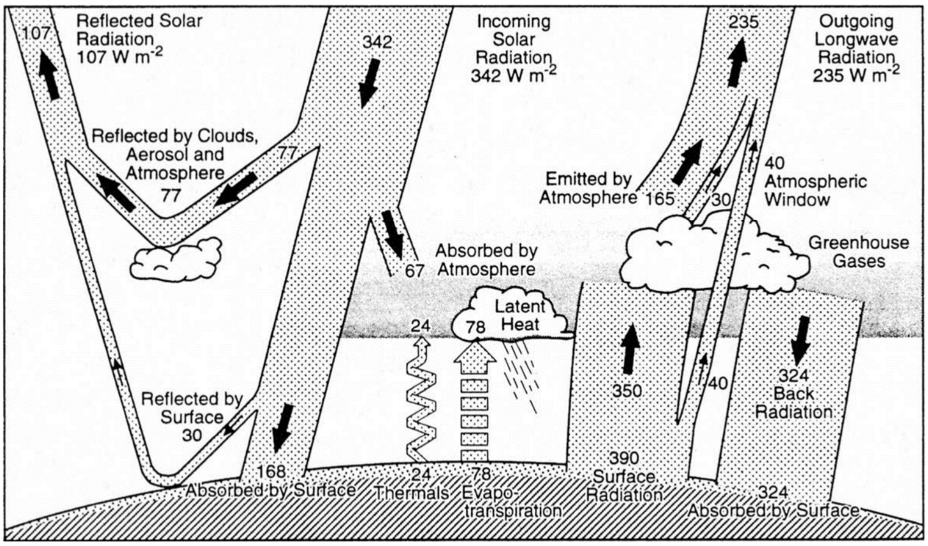

Figure 1. *Earth's Annual Global Mean Energy Budget [1].*

Table 1 arranges the numerical elements shown in Figure 1 using the rationale of infinite limit fractional recycling as discussed in [3].

Table 1. *Earth's Annual Global Mean Energy Budget [3] including the elements of the atmospheric recycling process.*

Items recorded in W/m^2	Insolation	Albedo bypass losses	Absorbed Insolation	Emitted by surface (Losses)	Air Absorption (Incoming & Outgoing)	Halves-of-Halves Infinite Recycled Limit	Energy Lost to Space (Concept)	Energy Lost to Space (Diagram)
Incoming Solar Radiation	342.00							
Reflected by Clouds, Aerosol and Atmosphere		77.00						Total Bond Albedo 0.313
Reflected by Surface		30.00						
Insolation Absorbed by Atmosphere			67.00		67.00	67.00	67.00	Total Intercepted Energy 235 W/m^2
Insolation Absorbed by Surface			168.00					
Surface Radiation (part absorbed by air)				26.00	26.00	26.00	26.00	

Items recorded in W/m^2	Insolation	Albedo bypass losses	Absorbed Insolation	Emitted by surface (Losses)	Air Absorption (Incoming & Outgoing)	Halves-of-Halves Infinite Recycled Limit	Energy Lost to Space (Concept)	Energy Lost to Space (Diagram)
Surface Thermals				24.00	24.00	24.00	24.00	
Surface Evaporation				78.00	78.00	78.00	78.00	
Atmospheric Window Loss				40.00			40.00	40.00
Emission by Atmosphere								165.00
Emission by Clouds								30.00
Totals	342.00	107.00	235.00	168.00	195.00	195.00	235.00	235.00

Table 2 demonstrates how the global average air temperature (GAT) of 15°C is achieved from the divide-by-4 flux dilution of the standard irradiance model using a process of flux enhancement radiative feedbacks (as shown in Table 1) and surface flux energy losses to generate the required flux to air of 390 W m^{-2}.

It is clear from the way that the Vacuum Planet Equation is formulated with its requirement for rapid diurnal rotation and annual globally averaged insolation, that it cannot be applied to a terrestrial planet that is tidally locked to its parent sun. To address this climate model structural limitation a planetary climate model with universal applicability was designed based on the concept of a tidally locked world [4].

Unlike the standard model based on the concept of an airless rapidly rotating planet [2], in the new model called "Noonworld" the only mechanism by which captured solar energy can be transferred to the unlit dark side is by the meteorological processes of convection and advection within the atmosphere, rather than by the rapid planetary surface rotation of the standard concept.

Table 2. *Key Energy Budget Metrics [3].*

Key Energy Budget Metrics from Figure 3: Kiehl and Trenberth [1]	Power Intensity % of Unfiltered Sunlight	Power Intensity W/m^2	System Gain by Component w.r.t. 235 W/m^2	Temperature Kelvin	Temperature Celsius	Comments
Raw Planet Filtered Insolation (post-Albedo)	68.71%	235.00		254	-19	Solar Heating Potential
Raw Surface Absorbed Insolation	49.12%	168.00		233	-40	Effective Surface Solar Heating
Air Absorption (Incoming and Outgoing)	57.02%	195.00				
Recycled Atmospheric Energy	57.02%	195.00				
Total Enhanced Surface Power Intensity	163.16%	558.00	2.37	315	42	Available Energy Including Feedbacks
1) Direct Surface Radiation (Loss)	7.60%	26.00				
2) Surface Thermals (Loss)	7.02%	24.00				
3) Surface Evaporation (Loss)	22.81%	78.00				
4) Atmospheric Window to Space (Loss)	11.70%	40.00				
Remaining Surface Radiant Power Intensity	114.04%	390.00	1.66	288	15	Global Average Air Temperature (288K-273K)
Radiant Exhaust	68.71%	235.00	1.00	254	-19	Energy Lost to Space

3. DAET Model Formulation

The modelling process devised to study the climate of Noonworld is called the Dynamic-Atmosphere Energy-Transport (DAET) climate model. To ensure that the model can separately address the issue of atmospheric thermal radiant opacity it was first stipulated that the model atmosphere consist only of thermally transparent nitrogen gas, thereby removing this confounding variable from the initial phase of the study. The new model was then applied to a study of the planet Venus, because this terrestrial planet is the closest approximation to a tidally locked planet that can be observed within the solar system [4].

The Noonworld climate model when applied to the planet Venus has several very interesting properties that inform the science of planetary climate in various unexpected ways. The first discovery was that in its fundamental form, where the solar energy captured by the tidally locked lit hemisphere of the model is equipartitioned (50%: 50%) between the nitrogen atmosphere and direct surface to space thermal radiative loss, the Noonworld climate model fully matches the computations of the standard Vacuum Planet Equation (VPE) for Venus.

The average thermal radiant loss to space from the surface of Noonworld through the transparent nitrogen atmosphere is therefore a direct analogy to the energy loss to space from the top of the Venusian atmosphere of the standard opaque model. In essence for a fully thermally radiant transparent atmosphere the Noonworld climate model describes a diabatic process of energy transfer between the solar illuminated and heated surface and the overlying basal contact of the heated atmosphere. This is in contradistinction to the observed meteorological processes of adiabatic energy transfer which are known to take place at the base of a semi-transparent atmosphere such as exists on planet Earth and are part of the fundamentals of the science of meteorology.

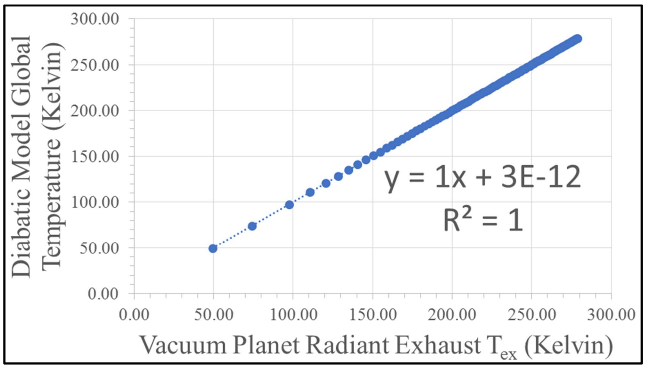

Figure 2. *The Direct Equivalence of the Vacuum Planet Equation Top of Atmosphere Radiant Exhaust Temperature (Astronomy) with the Diabatic Climate Model Surface Atmospheric Temperature (Meteorology).*

The critical analysis which demonstrates that the VPE is a diabetic equation and therefore does not incorporate fundamental meteorological processes of mass-motion energy transfer is shown in the following graphical relationship between the diabatic DAET model and the Vacuum Planet Equation using Earth irradiance parameters (Figure 2).

This graph proves that the Vacuum Planet Equation (VPE), the foundation concept of the standard climate model, is an incomplete description of surface atmospheric energy transfer because it is based solely on radiative flux transfer processes for the top of the atmosphere, and fails to adequately incorporate the mass-motion energy transfer processes that are fundamental to the science of meteorology [5].

3.1. DAET Model Application to Earth's Semi-Opaque Atmosphere

The Dynamic-Atmosphere Energy-Transport (DAET) climate model has as its fundamental premise the stipulation that solar energy is only ever captured by the lit hemisphere of a planetary globe, and that all energy transfer between the lit and unlit dark surface is mediated by the dynamic meteorological processes of energy retention and mass-motion within the body of the atmosphere. In order to validate the use of this model to the semi-opaque atmosphere of the Earth, previous work was reviewed [6] and these parameters (Table 3) were used as the basis for the comparison with the parameters shown in Figure 1, as published in the canonical paper of Kiehl and Trenberth [1].

Table 3. *Earth Climate Metrics derived from [1] and used to constrain the diabatic DAET climate model in the first phase of this study.*

Earth Climate Metrics		
Earth's Top of Atmosphere (TOA) Solar Irradiance	1368.00	W/m^2
Earth Bond Albedo (specifically 107/342)	0.313	Variable
Dimmed Intercepted Beam at Solar Zenith	940.00	W/m^2
Disk Silhouette Intercept of Lit Hemisphere	100%	
Total Surface Area of Lit Hemisphere	100%	
Lit Hemisphere Power Intensity Dilution Divisor	2	
Average Daily Lit Hemisphere Illumination	470.00	W/m^2
Earth's Annual Surface Temperature	15	Celsius
Moist Adiabatic Lapse Rate	8.0	K/km
Dry Adiabatic Lapse Rate	9.8	K/km

When applied in its diabatic form and using Earth insolation parameters the DAET model has a lit hemisphere surface thermal air flux of 313.33 W m^{-2} and a dark hemisphere surface thermal air flux of 156.67 W m^{-2}. These two values combine to produce a global average air flux of 235 W m^{-2}. This global average flux then converts using the Stefan-Boltzmann relationship to a Global Average Air Temperature for the Earth of 253.73 Kelvin (-19.27°C) (Table 4).

Table 4. *Testing the Whole Earth Diabatic DAET Model.*

Cycle Number	**Incoming Captured Radiation W/m^2**	**Heating the Lit side W/m^2**	**Adiabatic Lit side Radiant Loss from Surface W/m^2**	**Adiabatic Lit side Thermal Export to Dark Side W/m^2**	**Diabatic Darkside Radiant Loss to Space W/m^2**	**Diabatic Darkside Thermal Return to Lit side W/m^2**	**Radiant Energy Exiting to Space W/m^2**
	Target Annual Temperature 288 Kelvin (15°C)		50.0000%	50.0000%	50.0000%	50.0000%	
0	470.0000					0.0000	
1	470.0000	470.0000	235.0000	235.0000	117.5000	117.5000	352.5000
2	470.0000	587.5000	293.7500	293.7500	146.8750	146.8750	440.6250
3	470.0000	616.8750	308.4375	308.4375	154.2188	154.2188	462.6563
2997	470.0000	626.6667	313.3333	313.3333	156.6667	156.6667	470.0000
2998	470.0000	626.6667	313.3333	313.3333	156.6667	156.6667	470.0000
2999	470.0000	626.6667	313.3333	313.3333	156.6667	156.6667	470.0000
3000	470.0000	626.6667	313.3333	313.3333	156.6667	156.6667	470.0000
Infinity	470.00	626.67	313.33	313.33	156.67	156.67	470.00

Cycle Number	Incoming Captured Radiation W/m^2	Heating the Lit side W/m^2	Adiabatic Lit side Radiant Loss from Surface W/m^2	Adiabatic Lit side Thermal Export to Dark Side W/m^2	Diabatic Darkside Radiant Loss to Space W/m^2	Diabatic Darkside Thermal Return to Lit side W/m^2	Radiant Energy Exiting to Space W/m^2
Stefan-Boltzmann σ	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08
Kelvin	301.7	324.24	272.65	272.65	229.27	229.3	301.7
Celsius	28.7	51.2	-0.3	-0.3	-43.7	-43.7	28.7
Statistic	Available Energy Temp	Mean Air Temp	Mean Exit Temp	Lit-side Power W/m^2	Dark-side Power W/m^2	Total System Power W/m^2	
Energy Flux W/m^2	470.00	235.00	235.00				
Stefan-Boltzmann σ	5.67E-08	5.67E-08	5.67E-08				
Kelvin	301.74	253.73	253.73	626.66667	313.333	940.000	
Celsius	28.74	-19.27	-19.27				
	Atmospheric Response		Lit Surface Thermal Enhancement (Celsius)	Lapse rate K/Km	Tropopause Height (km) Delta K	Km	
	Lit Hemisphere		22.5	9.8	51.59	5.26	
	Dark Hemisphere			9.8	43.38	4.43	

This temperature value of 253.73 Kelvin (Table 4) exactly matches the computation performed by the Vacuum Planet equation (Table 5) which demonstrates the validity of the DAET concept.

Table 5. *The relationship between the Diabatic DAET Model and the Vacuum Planet Equation for the Earth at various values of Bond Albedo.*

Bond Albedo	Post Albedo Power Intensity (W/m^2)	Vacuum Planet Expected T_e (Kelvin)	Lit Hemisphere Diabatic Equation (W/m^2)	Diabatic Model Global Temperature (Kelvin)	Temperature Difference (Kelvin)
0	342.00	278.7	684.00	278.7	-0.0045
0.105	306.09	271.1	612.18	271.1	-0.0044
0.205	271.89	263.1	543.78	263.1	-0.0043
0.306	237.35	254.4	474.70	254.4	-0.0041
0.313	235.00	253.73	470.00	253.73	-0.0041
0.405	203.49	244.8	406.98	244.8	-0.0040
0.505	169.29	233.8	338.58	233.8	-0.0038
0.605	135.09	220.9	270.18	220.9	-0.0036
0.705	100.89	205.4	201.78	205.4	-0.0033
0.805	66.69	185.2	133.38	185.2	-0.0030
0.905	32.49	154.7	64.98	154.7	-0.0025
0.999	0.342	49.6	0.684	49.6	-0.0008

3.2. DAET Model Sensitivity Analysis

The next stage of this analysis is to establish the surface energy partition ratio for a lit hemisphere covered by a semi-opaque atmosphere. Using the DAET model in its diabatic form the energy partition ratio of the lit hemisphere can be adjusted to match the elements of the Earth's semi-opaque troposphere as used by Kiehl and Trenberth [1] (Figure 1). Table 6 shows the components of this process.

This organisation of the data shows that surface radiation processes account for 28.09% of the planetary surface energy loss, while the remaining 71.91% of the surface energy loss involves mass-motion processes. Using the energy partition ratio of Radiation Component 28.09% and Mass-Motion Components 71.91%, these values can now be used in the DAET model, be applied to the lit surface, and used to compute the global average surface air temperature.

Table 6. *Kiehl and Trenberth [1] Surface Energy Partition Distribution using Key Energy Budget Metrics.*

Kiehl and Trenberth [1] Budget Components	Power Intensity W/m^2	% Distribution	Flux Components	Power Intensity W/m^2	Lit Globe Average Energy Partition Distribution	Comments
1. Surface Thermal Radiation (Opacity Blocked)	26.00	11.06%	Planetary Surface Solar Radiation Losses	66.00	28.09%	Equivalent to Radiant Partition Component of DAET Model
2. Atmospheric Window to Space (Transparency Pass Through)	40.00	17.02%				
3. Insolation Absorbed by Atmosphere (Thermal Gain)	67.00	28.51%	Solar Energy Thermal Components that Heat the Troposphere	169.00	71.91%	Equivalent to Thermal Partition Component of DAET Model
4. Surface Thermals (Convection Gain)	24.00	10.21%				
5. Surface Evaporation (Latent Heat Gain)	78.00	33.19%				
Top of Atmosphere Thermal Radiant Exhaust	235.00	100.00%		235.00	100.00%	Lit Surface Partition

In this scoping analysis it is assumed that the unlit hemisphere in the DAET model still retains a diabatic surface energy partition ratio of 50% radiation to space: 50% retention by the air. The concept being applied here is that of the three solar energy interception processes of 1. Direct sunlight absorbed by the atmosphere, 2. Solar driven convection thermals and 3. Evapotranspiration, do not happen at night.

Using these assumptions, the DAET model computes a global average surface air temperature of 16.06°C (Table 7).

The process of applying an adiabatic energy flux partition ratio derived from the canonical climate model [1] to the lit surface of the DAET model has generated a global average air temperature of 16.06°C. This temperature is a close approximation to the required 15°C value, however there is a fundamental problem with this modelling scenario. The application of a distinctly different partition ratio, the 50%: 50% diabatic energy flux partition ratio to the dark side surface in this model can be justified only if the nighttime atmosphere is completely thermal radiant transparent and consequently that all the radiant energy loss to space takes place from the Earth's surface.

Table 7. *Applying the Lit Surface Flux Partition of Kiehl and Trenberth [1] to create a semi-Adiabatic DAET Model.*

Cycle Number	**Incoming Captured Radiation W/m²**	**Heating the Lit side W/m²**	**Adiabatic Lit side Radiant Loss from Surface W/m²**	**Adiabatic Lit side Thermal Export to Dark Side W/m²**	**Diabatic Darkside Radiant Loss to Space W/m²**	**Diabatic Darkside Thermal Return to Lit side W/m²**	**Radiant Energy Exiting to Space W/m²**
	Target Annual Temperature 288 Kelvin (15°C)		28.0851%	71.9149%	50.0000%	50.0000%	
0	470.000					0	
1	470.000	470.0000	132.0000	338.0000	169.0000	169.0000	301.0000
2	470.000	639.0000	179.4638	459.5362	229.7681	229.7681	409.2319
3	470.000	699.7681	196.5306	503.2375	251.6187	251.6187	448.1493
2997	470.000	733.8870	206.1130	527.7741	263.8870	263.8870	470.0000
2998	470.000	733.8870	206.1130	527.7741	263.8870	263.8870	470.0000
2999	470.000	733.8870	206.1130	527.7741	263.8870	263.8870	470.0000
3000	470.000	733.8870	206.1130	527.7741	263.8870	263.8870	470.0000
Infinity	470.00	733.89	206.11	527.77	263.89	263.89	470.00
Stefan-Boltzmann σ	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08
Kelvin	301.7	337.30	245.54	310.61	261.19	261.2	301.7
Celsius	28.6	64.1	-27.6	37.5	-12.0	-12.0	28.6
Statistic	Available Energy Temp	Mean Air Temp	Mean Exit Temp	Lit-side Power W/m²	Dark-side Power W/m²	Total System Power W/m²	
Energy Flux W/m²	630.83	395.83	235.00				
Stefan-Boltzmann σ	5.67E-08	5.67E-08	5.67E-08				
Kelvin	324.77	289.06	253.73				
Celsius	51.77	16.06	-19.27	733.887	527.774	1261.661	
			Lit Surface Thermal Enhancement (Celsius)	Lapse rate	Tropopause Height (km)		
	Atmospheric Response			K/Km	Delta K	Km	
	Lit Hemisphere		35.6	8.0	91.75	11.47	
	Dark Hemisphere			9.8	49.42	**5.04**	

While a case can be made that the high elevation winter icecap surface of Antarctica is just such an environment, where the ice surface radiant energy loss to space through the thin dry atmosphere generates an atmospheric surface inversion, this polar icecap surface environment is not typical of the Earth as a whole.

3.3. DAET Model Uniform Partition Ratio Analysis

The next stage of the scoping analysis is to apply a uniform energy partition ratio to both the lit day and the dark nighttime surfaces of the DAET model in order to model the realistic expectation that the Earth's troposphere is globally uniform in thermal radiant opacity. In this scenario the 28.09% radiant energy and 71.91% mass-motion flux partition was again used being applied uniformly to both hemispheres and the DAET model returned a global average air temperature of 48°C for the planetary surface (Table 8).

Clearly this value of 48°C greatly exceeds the 15°C expected value and the cause of this difference is two-fold. The first cause of error is that the energy flux partition ratio is weighted too heavily in favour of energy retention by the mobile mass of the fluid atmosphere, this causes the model to overheat. The second component of error is that the DAET model does not filter the by-pass loss directly to space of the atmospheric window [7], rather it incorporates this flux into the model and incorrectly recycles and so feedbacks its value. It is the process of devising an application of the atmospheric window to the DAET model that informs the rest of this paper.

Table 8. *Applying a Uniform Flux Partition to form an Adiabatic DAET Model.*

Cycle Number	**Incoming Captured Radiation W/m^2**	**Heating the Lit side W/m^2**	**Adiabatic Lit side Radiant Loss from Surface W/m^2**	**Adiabatic Lit side Thermal Export to Dark Side W/m^2**	**Adiabatic Darkside Radiant Loss from Surface W/m^2**	**Adiabatic Darkside Thermal Return to Lit side W/m^2**	**Radiant Energy Exiting to Space W/m^2**
	Target Annual Temperature 288 Kelvin (15°C)		28.0851%	71.9149%	28.0851%	71.9149%	
0	470.000					0.0000	
1	470.000	470.0000	132.0000	338.0000	94.9277	243.0723	226.9277
2	470.000	713.0723	200.2671	512.8052	144.0219	368.7833	344.2890
3	470.000	838.7833	235.5732	603.2101	169.4122	433.7979	404.9854
2997	470.000	973.4380	273.3911	700.0469	196.6089	503.4380	470.0000
2998	470.000	973.4380	273.3911	700.0469	196.6089	503.4380	470.0000
2999	470.000	973.4380	273.3911	700.0469	196.6089	503.4380	470.0000
3000	470.000	973.4380	273.3911	700.0469	196.6089	503.4380	470.0000
Infinity	470.00	973.44	273.39	700.05	196.61	503.44	470.00
Stefan-Boltzmann σ	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08
Kelvin	301.7	361.98	263.51	333.34	242.66	307.0	301.7
Celsius	28.7	89.0	-9.5	60.3	-30.3	34.0	28.7
Statistic	Available Energy Temp	Mean Air Temp	Mean Exit Temp	Lit-side Power W/m^2	Dark-side Power W/m^2	Total System Power W/m^2	
Energy Flux W/m^2	585.02	601.74	388.41				
Stefan-Boltzmann σ	5.67E-08	5.67E-08	5.67E-08				
Kelvin	318.71	320.96	287.69	973.438	700.047	1673.485	
Celsius	45.71	47.96	14.69				
			Thermal Enhancement (Celsius)	Lapse rate	Tropopause Height (km)		
	Atmospheric Response			K/Km	Delta K	Km	
	Lit Hemisphere		60.2	8.0	98.47	12.31	
	Dark Hemisphere			9.8	90.68	9.25	

4. Whole Earth Adiabatic DAET Model with Lossy Surface Atmospheric Window

The DAET climate model is predicated on the assumption of a mathematical process which is the fractional series retention of energy in an infinite series of recycled loops, this process lies at the core of the Noonworld concept [4] and is exemplified by the meteorological structure of a Hadley Cell [8]. It is well established that the Earth's troposphere is semi-opaque to thermal radiation [9],[10] and that there is within the atmosphere a transparency bypass window that permits the direct transmission to space of surface thermal radiant energy [7]. In order to capture this process of a bypass energy leak to space and to incorporate it into the structure of the DAET model, a refinement was made predicated on the assumption that the bypass leak is a constant fraction of the energy flux that interacts with the planetary surface.

Starting with the assumption from the canonical climate model that the atmospheric window for the Earth is 40 W m^{-2} (Figure 1) it necessarily follows that using the DAET model concept of a single lit hemisphere the atmospheric window value must be doubled to 80 W m^{-2} (Table 9) because the process of surface thermal radiant loss to space will take place throughout the course of the 24-hour day and so apply to both hemispheres. Indeed this night time surface thermal loss is the prerequisite for atmospheric thermal inversion and associated winter frost. However, the warmer daylit surface will accordingly emit a larger percentage of this total 80 W m^{-2} flux to space than the colder night surface does.

In order to establish this proportionality of surface energy loss a further assumption was made that a fixed percentage of the lit surface energy budget is lost to space during each iteration cycle of the DAET model, and that this percentage results in the required total aggregate energy loss to space of 80 W m^{-2} post feedbacks (Table 9).

Table 9. *DAET model Earth Climate Metrics incorporating the Lossy Surface Global Atmospheric Window (1997 Data).*

Earth Climate Metrics		
Earth's TOA Solar Irradiance	1368.00	W/m^2
Earth Bond Albedo	0.313	Variable
Dimmed Intercepted Beam at Solar Zenith	940.00	W/m^2
Disk Silhouette Intercept of Lit Hemisphere	100%	
Total Surface Area of Lit Hemisphere	100%	
Lit Hemisphere Power Intensity Dilution Divisor	2	
Average Daily Lit Hemisphere Illumination	470.000	W/m^2
Lit Surface Direct to Space Radiant Loss	30.08	W/m^2
Fractional Bypass Leak (Lit Surface Radiant Energy Loss/Daily Lit Hemisphere Illumination)	6.40%	Ratio
Total Global Atmospheric Window Bypass Loss to Space	80.00	W/m^2
Earth's Annual Surface Temperature	15	Celsius
Lit side Moist Adiabatic Lapse Rate	8.0	K/km
Dark side Dry Adiabatic Lapse Rate	9.8	K/km

By adding the presence of a surface-to-space leaky thermal radiation atmospheric window to the structure of the DAET model, it was established by sensitivity testing that once a common bypass leak is in place for both the lit and dark surfaces of the DAET model the required fractional bypass leak (the pre-feedbacks value) can be determined by inverse modelling.

In making this structural change to the DAET model the troposphere is assigned to be opaque to thermal radiation, it then follows that all the remaining solar energy captured by the lit hemisphere will be doubled in the atmospheric reservoir by the opaque radiative recycling process of infinite fractional summation - the halves of halves summation concept of the standard model [3] (Figure 3).

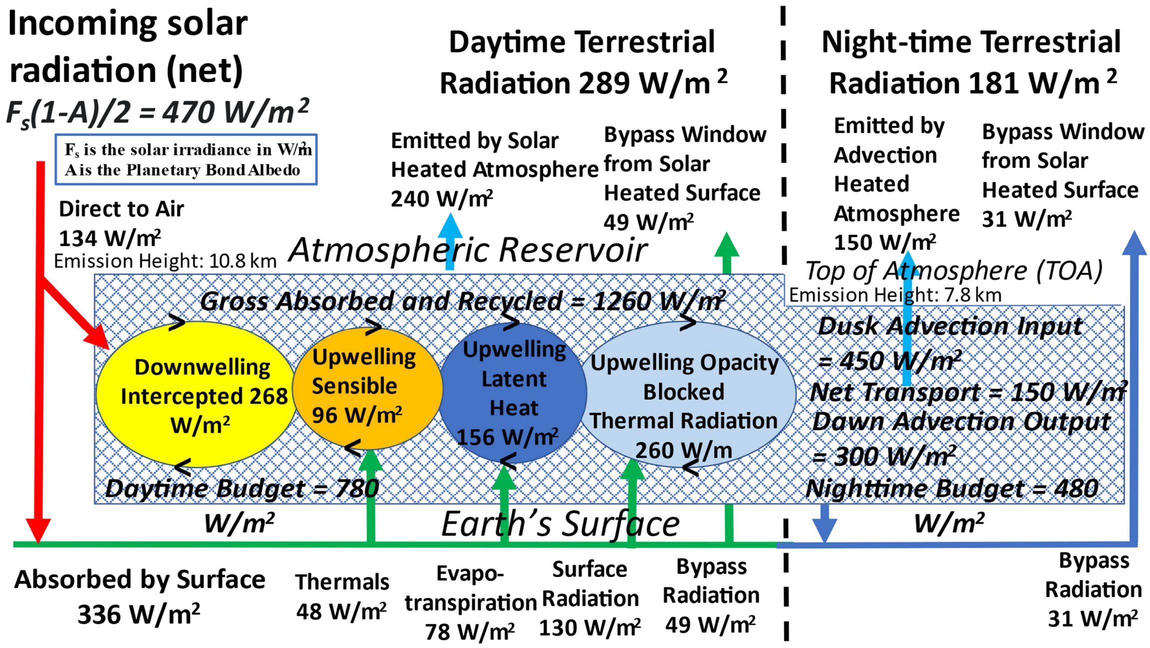

Figure 3. *The Thermal Radiant Opaque Atmospheric Reservoir Energy Recycling Process.*

4.1. Discussion of the Thermal Radiant Opaque Atmospheric Reservoir Energy Recycling Process

In establishing the parameters displayed in Figure 3 (which are derived from Figure 1 and Table 10) the following assumptions have been made:

1) The downwelling solar flux values used in Figure 1 from Kiehl and Trenberth [1] have been doubled in the DAET model to account for the increase power of the insolation collected over the surface of the illuminated hemisphere.
2) The upwelling surface thermal and radiative fluxes have also been doubled to account for the increased downwelling solar energy flux.
3) Critically however the upwelling surface Evapotranspiration flux has not been doubled. The justification for this is that the Evapotranspiration flux used by Kiehl and Trenberth [1] is derived by back calculation of global surface average annual precipitation and therefore is a fixed global flux quantity that cannot be increased.
4) All fluxes leaving the Earth's surface are solar energy derived.
5) The Atmospheric Window bypass flux leaving the surface goes straight out to space and therefore does not impact on the energy content of the Atmospheric Reservoir above the surface. This energy flux sums to 80 Wm^{-2} in this example realisation and is apportioned within the model between the two surfaces with a bias towards loss from the warmer lit surface.
6) All remaining upwelling thermal fluxes including evapotranspiration with its attendant Latent Heat transport are blocked by the opacity of the troposphere.
7) The justification for including Latent Heat transport, a none radiative process, in the context of opacity blocking is that latent heat release during condensation is a thermal emission activity that takes place over the full depth of the troposphere.
8) The standard process of radiative flux doubling [3] can therefore be applied to all upwelling lit surface fluxes used in the conceptual DAET opacity model.
9) The lit hemisphere atmospheric reservoir therefore receives its flux capacity by the standard process of thermal radiant opacity blocking.

The key feature of the revised DAET concept is that the meteorological process of Hadley cell convection is applied to allow for the transport of solar heated air from the lit to the unlit dark surface of the model. It is of critical importance to understand that in the presence of a gravity field vertical adiabatic air motion is a non-lossy process that delivers energy to distance via mass-motion. The process of adiabatic convection involves the interchange of potential and kinetic energy as air rises and falls in a gravity field [11]. Potential Energy is the property of mass at a given location and potential energy cannot be lost by thermal radiative emission; a mass can lose kinetic energy by radiative means, but not its potential energy. It is for this reason that the adiabatic mass-motion transport of energy flux that occurs within a gravity field is described here as being a non-lossy or “transparent” process.

The formulation of the DAET model established that mass-motion transport of energy within a global atmosphere is itself a process of infinite summation of halves of halves [4], but this is not a radiative opacity process. It has also been established above that the diabatic form of the DAET model is an energy equipartition process (Figure 2). Therefore, a doubling of the transported energy by the Hadley cell mass transport process is justified within the revised DAET opacity model as the air is endlessly circulated between the two surfaces in the model. To achieve this flux doubling a fixed flux energy partition ratio of 1/3 Top of the Atmosphere Radiant Loss to space and 2/3 Thermal Retention within the troposphere was applied to both the lit and dark hemisphere surfaces of the model for the circulating mass of the global atmosphere.

The resulting application of the Adiabatic DAET opacity model using the above parameters is shown in Table 10.

Table 10. *Whole Earth Adiabatic Opacity Model with Lossy Surface Atmospheric Window Applied (1997 Data).*

Cycle Number	**Incoming Lit Hemisphere Intercepted Radiation W/m^2**	**Powering the Lit side W/m^2**	**Lit Surface Bypass Reduction W/m^2**	**Lit side Radiant Topside Loss to Space W/m^2**	**Lit side Thermal Export to Darkside W/m^2**	**Dark Surface Bypass Reduction W/m^2**	**Darkside Radiant Topside Loss to Space W/m^2**	**Darkside Thermal Return to Lit side W/m^2**	**Total Radiant Energy Exiting to Space W/m^2**
	Target Annual Temperature 288 Kelvin (15°C)		6.4000%	33.3333%	66.6667%	6.4000%	33.3333%	66.6667%	
0	470.000							0	
1	470.000	470.0000	439.9200	146.6400	293.2800	274.5101	91.5034	183.0067	286.9933
2	470.000	653.0067	611.2142	203.7381	407.4762	381.3977	127.1326	254.2651	398.7416
3	470.000	724.2651	677.9121	225.9707	451.9414	423.0171	141.0057	282.0114	442.2537
2997	470.000	769.7044	720.4433	240.1478	480.2955	449.5566	149.8522	299.7044	470.0000
2998	470.000	769.7044	720.4433	240.1478	480.2955	449.5566	149.8522	299.7044	470.0000
2999	470.000	769.7044	720.4433	240.1478	480.2955	449.5566	149.8522	299.7044	470.0000
3000	470.000	769.7044	720.4433	240.1478	480.2955	449.5566	149.8522	299.7044	470.0000
Infinity	470.00	769.70	720.44	240.15	480.30	449.56	149.85	299.70	235.00
Stefan-Boltzmann σ	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08
Kelvin	301.7	341.3	335.7	255.1	303.4	298.4	226.7	269.6	253.7
Celsius	28.7	68.3	62.7	-17.9	30.4	25.4	-46.3	-3.4	-19.3
Statistic	Available Energy Temp	Mean Air Temp	Mean Exit Temp						
Energy Flux W/m^2	625.00	390.00	235.00	Lit-side Power W/m^2	Lit Bypass Window Power Loss W/m^2	Dark-side Power W/m^2	Dark Bypass Window Power Loss W/m^2	Total System Power W/m^2	Total Power Loss to Space W/m^2
Stefan-Boltzmann σ	5.67E-08	5.67E-08	5.67E-08						
Kelvin	324.02	287.99	253.73	769.70	49.26	480.30	30.74	1250.00	470.00
Celsius	51.02	14.99	-19.27						
	Atmospheric Response		Thermal Enhancement (Celsius)	Lapse rate K/Km	Tropopause Height (km) Delta K	Km			
	Lit Hemisphere		39.6	8.0	86.2	10.8			
	Dark Hemisphere			9.8	76.6	7.8			

Having established that the flux partition ratio to be applied in the DAET opacity model is 1/3 Radiant loss and 2/3 thermal retention, and that the gross atmospheric window loss is 80 W m^{-2}; the Goal Seek inverse modelling tool within the Excel spreadsheet can now be used to establish the relative ratio of upwelling surface energy loss to space to the downwelling solar flux that is sacrificed to power this process. For this example of the DAET opacity model built on the parameters of Kiehl and Trenberth the solar flux to atmospheric window loss ratio that generates 80 W m^{-2} of energy leak bypass to space is 6.4% (Table 9).

It should be noted here that although the Adiabatic DAET opacity model was tuned to deliver 80 W m^{-2} of Atmospheric Window loss to space, the flux partition ratio of 1/3 Radiant to 2/3 Thermal was chosen from first principles, and so the Mean Air Temperature of 14.99°C (Table 10) delivered by the model using this partition ratio and input irradiance parameter is a full validation of the model design.

4.2. Discussion of the Adiabatic DAET Opacity Model

The Adiabatic DAET Opacity Model presented here is a development of the original Noonworld modelling concept [4] and contains three fundamental changes from the previous DAET modelling study of the Earth [6]. The first change corrects a conceptual error in the DAET model design whereby previously the global average air temperature (GAT) was calculated by averaging the air temperature of the two sides of the model. This procedure of averaging temperature is not physically appropriate and this error has now been corrected by applying the process of averaging energy flux for the two sides of the model prior to conversion to average air temperature using the Stefan-Boltzmann equation.

The most significant consequence of this algorithm change is that in its diabatic form the temperature output from the DAET model now fully matches the equivalent irradiance computation of the Vacuum Planet Equation [3]. This direct equivalence is shown in Figure 2 using Earth system parameters where there is a drift of only $3*10^{-12}$ between the two computational outputs and a mismatch of less than -0.0041 Kelvin using the Earth's irradiance data (Table 5).

The second change applies a direct surface to space radiant energy bypass loss to the DAET model as a proxy for the Atmospheric Window [7]. This is achieved by placing two filter columns within the structure of the model, one for the lit and one for the dark surface. Both filters reduce the circulation of energy being calculated by the iterative infinite summation process that is fundamental to the model design. This diminution of energy being retained by the atmospheric circulation process reduces the output temperature of the model and is part of the explanation that accounts for the drop in global average air temperature observed between Table 8 (47.96°C) and Table 10 (14.99°C).

The third algorithm change introduced here involves the stabilisation of the energy flux partition ratio as 1/3 radiant energy loss and 2/3 thermal energy retention for both surfaces of the DAET model (Table 10). This ratio of 1 to 2 captures the required mass-motion energy flux doubling process of the infinite summation of halves of halves and is identical to the radiant flux doubling of the standard climate model. However, the critical difference is that the energy doubling applied here is a fundamental property of an atmospheric Hadley cell and is a dynamic mass motion process and not a radiative process.

The revised Adiabatic DAET Opacity Model for the Earth has one extrinsic variable and just two intrinsic variables. These are:

1) The power of the insolation received by the planet at its given average orbital distance (Extrinsic variable).
2) The planetary Bond Albedo (Intrinsic variable).
3) The size of the Atmospheric Window (Intrinsic variable).

In the case of the Bond Albedo, the presence in the atmosphere of reflective clouds of water vapour and ice crystals provides a fundamental control on the amount of solar energy captured by the planetary atmosphere, while the size of the Atmospheric Window determines the amount of energy retained within the atmospheric reservoir. So, a low planetary albedo will generate a warm Earth climate, while a broad atmospheric window will generate a cold Earth climate.

The authors have previously suggested that the size of the global Atmospheric Window is a function of terrestrial surface elevation [6]. Analysis of CERES data shows that high land surface elevation terrains, such as the Tibetan Plateau, have an intrinsically higher surface to space energy loss through the reduced overlying atmospheric mass at this location than occurs at sea level. The generally accepted view that the size of the atmospheric window is a function of electromagnetic wavelength fails to consider the clear relationship between pressure and atmospheric clarity that supplies an additional opportunity for radiant energy to leak to space from the Earth's high elevation mountain ranges and icecaps.

5. Sensitivity Study and Applications of the Adiabatic DAET Opacity Model

Following the validation of the corrected and revised Adiabatic DAET Opacity Model against the work of Kiehl and Trenberth [1] using their parameters of insolation and Bond Albedo (inferred from their published work to be 107/342 = 0.313), the modern NASA Earth System parameters [12] will be used to provide a direct comparison link to previously published work [6] (Table 11).

Table 11. *DAET Model Earth Climate Metrics incorporating the Lossy Surface Global Atmospheric Window (NASA 2021 Data).*

Earth Climate Metrics		
Earth's TOA Solar Irradiance	1361.00	W/m^2
Earth Bond Albedo	0.306	Variable
Dimmed Intercepted Beam at Solar Zenith	944.53	W/m^2
Disk Silhouette Intercept of Lit Hemisphere	100%	
Total Surface Area of Lit Hemisphere	100%	
Lit Hemisphere Power Intensity Dilution Divisor	2	
Average Daily Lit Hemisphere Illumination	472.267	W/m^2
Lit Surface Direct to Space Radiant Loss	30.65	W/m^2
Fractional Bypass Leak (Lit Surface Radiant Energy Loss/Lit Hemisphere Illumination)	6.489%	Ratio
Total Global Atmospheric Window Bypass Loss to Space	81.375	W/m^2
Earth's Annual Surface Temperature	15	Celsius
Lit side Moist Adiabatic Lapse Rate	8.0	K/km
Dark side Dry Adiabatic Lapse Rate	9.8	K/km

The modest increase in post-albedo insolation from 470 W m^{-2} (Table 9) to 472.267 W m^{-2} (Table 11) means that more energy is now being carried internally by the DAET model. Consequently, in order to maintain the GAT at 15°C for purposes of comparison, the total global atmospheric window bypass loss to space must be increased from 80 W m^{-2} to 81.375 W m^{-2}, which is a bypass energy loss of 6.489% pre feedbacks (Table 12).

N. B. In the DAET model Table 12 and those that follow a Kelvin to Celsius bias conversion of -273.15 has been applied, whereas in the prior DAET tables published above the previous workers practice of using -273.0 as the bias [1] was followed.

Table 12. *Adiabatic DAET Model with Lossy Surface Atmospheric Window Applied (NASA 2021 Data).*

Cycle Number	Incoming Lit Hemisphere Intercepted Radiation W/m^2	Powering the Lit side W/m^2	Lit Surface Bypass Reduction W/m^2	Lit side Radiant Topside Loss to Space W/m^2	Lit side Thermal Export to Darkside W/m^2	Dark Surface Bypass Reduction W/m^2	Darkside Radiant Topside Loss to Space W/m^2	Darkside Thermal Return to Lit side W/m^2	Total Radiant Energy Exiting to Space W/m^2
	Target Annual Temperature 288 Kelvin (15°C)		6.4890%	33.3333%	66.6667%	6.4890%	33.3333%	66.6667%	
0	472.267							0	
1	472.267	472.2670	441.6216	147.2072	294.4144	275.3098	91.7699	183.5399	288.7271
2	472.267	655.8069	613.2515	204.4172	408.8343	382.3050	127.4350	254.8700	400.9368
3	472.267	727.1370	679.9530	226.6510	453.3020	423.8872	141.2957	282.5915	444.5455
2997	472.267	772.4806	722.3543	240.7848	481.5695	450.3204	150.1068	300.2136	472.2670
2998	472.267	772.4806	722.3543	240.7848	481.5695	450.3204	150.1068	300.2136	472.2670
2999	472.267	772.4806	722.3543	240.7848	481.5695	450.3204	150.1068	300.2136	472.2670
3000	472.267	772.4806	722.3543	240.7848	481.5695	450.3204	150.1068	300.2136	472.2670
Infinity	472.27	772.48	722.35	240.78	481.57	450.32	150.11	300.21	235.45
Stefan-Boltzmann σ	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08
Kelvin	302.1	341.6	336.0	255.3	303.6	298.5	226.8	269.8	253.8
Celsius	29.0	68.5	62.8	-17.9	30.4	25.4	-46.3	-3.4	-19.3
Statistic	Available Energy Temp	Mean Air Temp	Mean Exit Temp						
Energy Flux W/m^2	627.03	390.89	195.45	Lit-side Power W/m^2	Lit Surface Bypass Power Loss W/m^2	Dark-side Power W/m^2	Dark Surface Bypass Power Loss W/m^2	Total System Power W/m^2	Total Power Loss to Space W/m^2
Stefan-Boltzmann σ	5.67E-08	5.67E-08	5.67E-08						
Kelvin	324.28	288.15	242.30	772.48	50.13	481.57	31.25	1254.05	472.27
Celsius	51.13	15.00	-30.85						
	Atmospheric Response		Thermal Enhancement (Celsius)	Lapse rate	Tropopause Height (km)				
				K/Km	Delta K	Km			
	Lit Hemisphere		39.5	8.0	86.4	10.8			
	Dark Hemisphere			9.8	76.7	7.8			

5.1. Atmospheric Window Sensitivity Test

A sensitivity study of the impact on global average air temperature of a variation in the size of the Earth's atmospheric window was conducted. In this analysis it was assumed that both the insolation power flux and the planetary Bond albedo are held constant at their present measured values.

Table 13 records the modelling data from this sensitivity study and Figure 3 displays these data in graphical form.

Table 13 demonstrates that for an Earth with a completely blocked atmospheric window the global average air temperature will rise to a maximum value of 29°C. It is suggested that this scenario will be able to account for the Cretaceous Hothouse World [13]. During the Cretaceous Period the global average surface elevation of the continents was lower than now and so the overlying atmospheric opacity was uniformly high. A significant role for topography as a component driver of a global atmospheric window is inferred, and because of the lack in the Cretaceous of high surface elevation thermal radiant leak points, such as the modern world's Tibetan Plateau [6], the global average air temperature was therefore much higher.

Table 13. *Lossy Surface Atmospheric Window Sensitivity Study.*

Fractional Bypass Leak (Lit Surface Radiant Energy Loss/Lit Hemisphere Illumination)	Lit Surface Bypass Power Loss W/m^2	Dark Surface Bypass Power Loss W/m^2	Total Surface Bypass Power Loss to Space W/m^2	Lit side Thermal Export Powering the Darkside W/m^2	Darkside Thermal Return to Lit side W/m^2	Lit side Power Determined Thermal Equivalent Export to Darkside (Celsius)	Darkside Power Determined Thermal Equivalent Return to Lit side (Celsius)	Average Power Determined Global Air Temperature (Celsius)
0.00%	0.00	0.00	0.00	566.72	377.81	43.04	12.56	28.95
1.00%	8.37	5.52	13.89	552.26	364.49	41.00	10.01	26.70
2.00%	16.48	10.77	27.25	538.33	351.71	39.00	7.49	24.50
3.00%	24.35	15.75	40.10	524.90	339.44	37.04	5.01	22.32
4.00%	32.00	20.48	52.47	511.94	327.64	35.10	2.56	20.18
5.00%	39.43	24.97	64.40	499.43	316.30	33.20	0.14	18.08
6.00%	46.66	29.24	75.90	487.34	305.40	31.33	-2.24	16.00
6.49%	50.13	31.25	81.37	481.57	300.21	30.43	-3.40	15.00
7.00%	53.70	33.29	87.00	475.64	294.90	29.49	-4.60	13.96
8.00%	60.56	37.15	97.71	464.33	284.79	27.67	-6.93	11.94

Fractional Bypass Leak (Lit Surface Radiant Energy Loss/Lit Hemisphere Illumination)	Lit Surface Bypass Power Loss W/m^2	Dark Surface Bypass Power Loss W/m^2	Total Surface Bypass Power Loss to Space W/m^2	Lit side Thermal Export Powering the Darkside W/m^2	Darkside Thermal Return to Lit side W/m^2	Lit side Power Determined Thermal Equivalent Export to Darkside (Celsius)	Darkside Power Determined Thermal Equivalent Return to Lit side (Celsius)	Average Power Determined Global Air Temperature (Celsius)
9.00%	67.26	40.80	108.06	453.37	275.04	25.88	-9.24	9.95
10.00%	73.79	44.28	118.07	442.75	265.65	24.12	-11.52	7.99
11.00%	80.17	47.57	127.74	432.46	256.59	22.37	-13.78	6.05
12.00%	86.41	50.70	137.11	422.47	247.85	20.65	-16.02	4.13
13.00%	92.52	53.66	146.18	412.77	239.41	18.95	-18.24	2.23
14.00%	98.49	56.47	154.96	403.35	231.26	17.27	-20.44	0.36
15.00%	104.35	59.13	163.48	394.20	223.38	15.61	-22.62	-1.49
16.00%	110.09	61.65	171.73	385.30	215.77	13.96	-24.78	-3.33
17.00%	115.71	64.03	179.74	376.64	208.41	12.34	-26.92	-5.14
18.00%	121.24	66.28	187.52	368.21	201.29	10.73	-29.06	-6.94
19.00%	126.67	68.40	195.07	360.00	194.40	9.13	-31.17	-8.72
20.00%	132.00	70.40	202.40	352.00	187.73	7.55	-33.27	-10.49
21.00%	137.24	72.28	209.53	344.20	181.28	5.98	-35.36	-12.24
22.00%	142.41	74.05	216.46	336.59	175.03	4.43	-37.44	-13.98
23.00%	147.49	75.71	223.19	329.17	168.97	2.88	-39.50	-15.70
24.00%	152.49	77.26	229.75	321.92	163.11	1.35	-41.56	-17.42
24.89%	156.87	78.55	235.42	315.64	158.06	0.00	-43.37	-18.92

Figure 4 demonstrates how for an Atmospheric Window with a 25% solar energy loss, the lit hemisphere average air temperature declines to below zero Celsius. This scenario, in which the lit hemisphere is too cold to melt ice, can comprise one component in the formation of Snowball Earth [14].

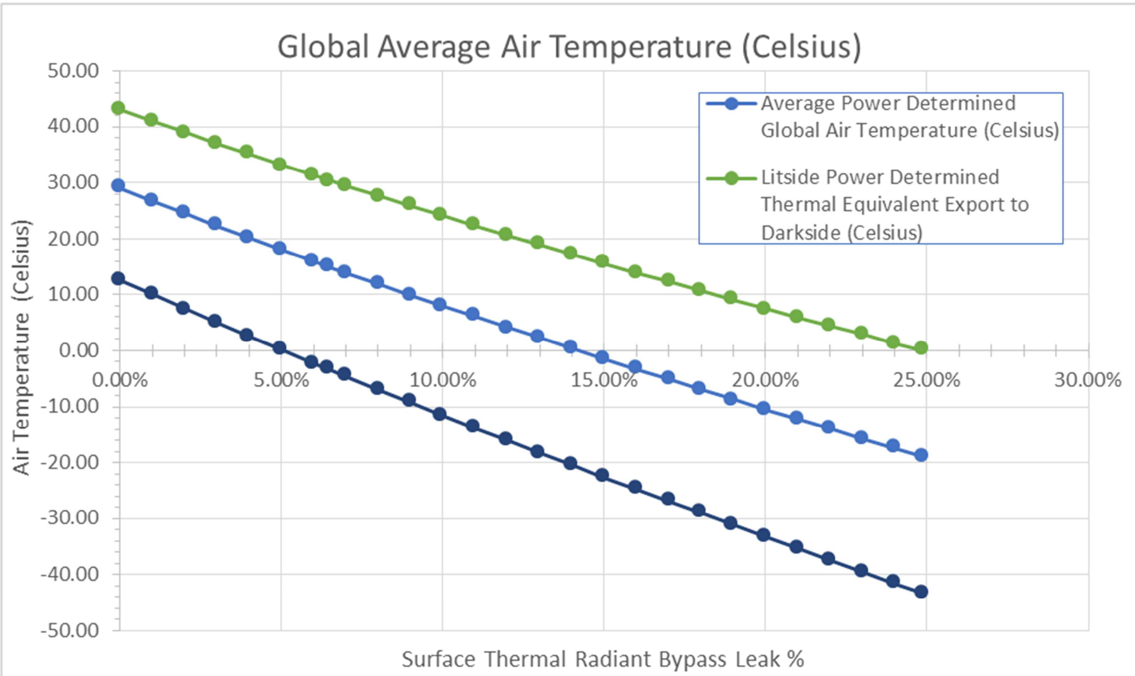

Figure 4. *Lossy Surface Atmospheric Window Sensitivity Study.*

5.2. Habitable Zone Insolation Strength Sensitivity Tests.

A sensitivity study of the impact on global average air temperature of a variation in the size of the Earth's Insolation Strength was conducted. In this analysis it is assumed that both the size of the Atmospheric Window and the planetary Bond albedo are held constant at their present measured values. The purpose of this test is to explore the boundaries of the habitable zone [15] for the Earth within the Solar System. In determining the boundaries of the habitable zone using the Adiabatic DAET Lossy Surface Model, it is assumed that the inner limit for a Hot Earth is the point where the night time surface of the DAET model exceeds 100°C. This concept envisions an orbital radius where the delivery of power to the dark night surface by the meteorological processes of the Hot Earth's atmosphere causes the oceans to boil planetwide (Table 14).

Table 14. *Hot Earth Adiabatic DAET Lossy Surface Model.*

Cycle Number	Incoming Lit Hemisphere Intercepted Radiation W/m^2	Powering the Lit side W/m^2	Lit Surface Bypass Reduction W/m^2	Lit side Radiant Topside Loss to Space W/m^2	Lit side Thermal Export to Darkside W/m^2	Dark Surface Bypass Reduction W/m^2	Darkside Radiant Topside Loss to Space W/m^2	Darkside Thermal Return to Lit side W/m^2	Total Radiant Energy Exiting to Space W/m^2
	Solar Irradiance Target: Darkside Air Temperature 373.1 Kelvin (100°C)		6.4890%	33.3333%	66.6667%	6.4890%	33.3333%	66.6667%	
0	1729.315							0	
1	1729.315	1729.315	1617.099	539.033	1078.066	1008.110	336.037	672.074	1057.241
2	1729.315	2401.388	2245.562	748.521	1497.041	1399.898	466.633	933.265	1468.123
3	1729.315	2662.580	2489.805	829.935	1659.870	1552.161	517.387	1034.774	1627.806
2997	1729.315	2828.616	2645.067	881.689	1763.378	1648.952	549.651	1099.301	1729.315
2998	1729.315	2828.616	2645.067	881.689	1763.378	1648.952	549.651	1099.301	1729.315
2999	1729.315	2828.616	2645.067	881.689	1763.378	1648.952	549.651	1099.301	1729.315
3000	1729.315	2828.616	2645.067	881.689	1763.378	1648.952	549.651	1099.301	1729.315
Infinity	1729.31	2828.62	2645.07	881.69	1763.38	1648.95	549.65	1099.30	1729.31
Stefan-Boltzmann σ	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08
Kelvin	417.9	472.6	464.7	353.1	419.9	413.0	313.8	**373.1**	417.9
Celsius	144.8	199.5	191.6	80.0	146.8	139.8	40.6	**100.0**	144.8
Statistic	Available Energy Temp	Mean Air Temp	Mean Exit Temp						
Energy Flux W/m^2	2296.00	1431.34	715.67	Lit-side Power W/m^2	Lit Surface Bypass Power Loss W/m^2	Dark-side Power W/m^2	Dark Surface Bypass Power Loss W/m^2	Total System Power W/m^2	Average Global Area Power Loss to Space W/m^2
Stefan-Boltzmann σ	5.67E-08	5.67E-08	5.67E-08						
Kelvin	448.59	398.60	335.18	2828.62	183.55	1763.38	114.43	4591.99	864.66
Celsius	175.44	125.45	62.03						
	Atmospheric Response		Thermal Enhancement (Celsius)	Lapse rate K/Km	Tropopause Height (km) Delta K	Km			
	Lit Hemisphere		54.7	6.5	119.5	18.4			
	Dark Hemisphere			6.5	106.2	16.3			

The pre-albedo insolation that generates this planetary boiling ocean crisis is 5,034 W m^{-2} (Table 15) and for the current power output of the Sun this orbital radius is 0.52 AU. This distance is closer to the Sun than the current 0.72 AU orbit of the planet Venus (Table 15).

Table 15. *Establishing the Inner Limit of the Solar System Habitable Zone for Planet Earth with its Current Lossy Surface Atmospheric Window and Bond Albedo.*

Symbol	Parameter	Value	Metric	Source Commentary
σ	Stefan-Boltzmann Constant σ	5.67037E-08	$W.m^{-2}.K^{-4}$	Stefan–Boltzmann constant - Wikipedia
T_s	Temperature of the Sun	5,772	K	Reverse Engineered from NASA Irradiance data
R_S	Radius of Sun	695,700	Km	Sun Fact Sheet (nasa.gov) [16]
$4\pi r^2$	Surface Area of Sun	6.0821E+12	Sq. km	Determined from Solar Radius R_S
E_S	Irradiance of the Sun	62,931,165	$W.m^{-2}$	Determined from Solar Temperature T_S
E_{HE}	Irradiance of the Hot Earth	5,034.4	$W.m^{-2}$	Using Present Earth Bond Albedo (0.306) [12]
r_{HE}	Orbital Distance of Hot Earth	77,782,384	Km	Closer in than Venus is.
r_{HE}	Orbital Distance of Hot Earth	0.52	AU	Astronomical Units
σ	Stefan-Boltzmann Constant σ	5.67037E-08	$W.m^{-2}.K^{-4}$	Stefan–Boltzmann constant - Wikipedia
T_s	Temperature of the Sun	5,772	K	Reverse Engineered from NASA Irradiance data
R_S	Radius of Sun	695,700	Km	Sun Fact Sheet (nasa.gov) [16]
$4\pi r^2$	Surface Area of Sun	6.0821E+12	Sq. km	Determined from Solar Radius R_S
E_S	Irradiance of the Sun	62,931,165	$W.m^{-2}$	Determined from Solar Temperature T_S
E_V	Irradiance of Venus	2,601.2	$W.m^{-2}$	Venus Fact Sheet (nasa.gov) [17]
r_V	Orbital Distance of Venus	108,210,000	Km	Venus Fact Sheet (nasa.gov) [17]
r_V	Orbital Distance of Venus	0.72	AU	Astronomical Units
σ	Stefan-Boltzmann Constant σ	5.67037E-08	$W.m^{-2}.K^{-4}$	Stefan–Boltzmann constant - Wikipedia
T_s	Temperature of the Sun	5,772	K	Reverse Engineered from NASA Irradiance data
R_S	Radius of Sun	695,700	Km	Sun Fact Sheet (nasa.gov) [16]
$4\pi r^2$	Surface Area of Sun	6.0821E+12	Sq. km	Determined from Solar Radius R_S

Symbol	Parameter	Value	Metric	Source Commentary
E_S	Irradiance of the Sun	62,931,165	$W.m^{-2}$	Determined from Solar Temperature T_S
E_E	Irradiance of the Earth	1,361.0	$W.m^{-2}$	Earth Fact Sheet (nasa.gov) [12]
r_E	Orbital Distance of Earth	149,598,000	Km	Earth Fact Sheet (nasa.gov) [12]
r_E	Orbital Distance of Earth	1.00	AU	Astronomical Units

To determine the outer boundary limit of the habitable zone using the Adiabatic DAET Lossy Surface Model it is assumed that this limit for a Frozen Earth is the point where the day-time surface of the DAET model never exceeds 0°C. This concept envisions an orbital radius where the pre-albedo insolation intercepted by the planet and delivered to the lit surface (post-albedo) is insufficient to melt water ice, thereby causing the oceans to freeze over planetwide (Table 16).

Table 16. *Frozen Earth Adiabatic DAET Lossy Surface Model.*

Cycle Number	Incoming Lit Hemisphere Intercepted Radiation W/m²	Powering the Lit side W/m²	Lit Surface Bypass Reduction W/m²	Lit side Radiant Topside Loss to Space W/m²	Lit side Thermal Export to Darkside W/m²	Dark Surface Bypass Reduction W/m²	Darkside Radiant Topside Loss to Space W/m²	Darkside Thermal Return to Lit side W/m²	Total Radiant Energy Exiting to Space W/m²
	Solar Irradiance Target: Lit side Air Temperature 273.1 Kelvin (0°C)		6.4890%	33.3333%	66.6667%	6.4890%	33.3333%	66.6667%	
0	192.969							0	
1	192.969	192.9692	180.4474	60.1491	120.2983	112.4921	37.4974	74.9948	117.9745
2	192.969	267.9640	250.5758	83.5253	167.0505	156.2106	52.0702	104.1404	163.8236
3	192.969	297.1096	277.8302	92.6101	185.2201	173.2012	57.7337	115.4674	181.6422
2997	192.969	315.6371	295.1554	98.3851	196.7703	184.0018	61.3339	122.6679	192.9692
2998	192.969	315.6371	295.1554	98.3851	196.7703	184.0018	61.3339	122.6679	192.9692
2999	192.969	315.6371	295.1554	98.3851	196.7703	184.0018	61.3339	122.6679	192.9692
3000	192.969	315.6371	295.1554	98.3851	196.7703	184.0018	61.3339	122.6679	192.9692
Infinity	192.97	315.64	295.16	98.39	196.77	184.00	61.33	122.67	96.48
Stefan-Boltzmann σ	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08	5.67E-08
Kelvin	241.5	273.2	268.6	204.1	242.7	238.7	181.4	215.7	203.1
Celsius	-31.6	0.0	-4.5	-69.1	-30.4	-34.5	-91.8	-57.5	-70.0
Statistic	Available Energy Temp	Mean Air Temp	Mean Exit Temp	Lit-side Power W/m²	Lit Surface Bypass Power Loss W/m²	Dark-side Power W/m²	Dark Surface Bypass Power Loss W/m²	Total System Power W/m²	Total Power Loss to Space W/m²
Energy Flux W/m²	256.20	159.72	79.86						
Stefan-Boltzmann σ	5.67E-08	5.67E-08	5.67E-08						
Kelvin	259.27	230.38	193.73	315.64	20.48	196.77	12.77	512.41	192.97
Celsius	-13.88	-42.77	-79.42						
	Atmospheric Response		Thermal Enhancement (Celsius)	Lapse rate K/Km	Tropopause Height (km) Delta K	Km			
	Lit Hemisphere		31.6	8.0	69.1	8.6			
	Dark Hemisphere			9.8	61.4	6.3			

The pre-albedo insolation that generates this planetary frozen ocean crisis is 193 W m^{-2} (Table 16) and for the current power output of the Sun this orbital radius is 1.57 AU. This distance is farther from the Sun than the current 1.52 AU orbit of the planet Mars (Table 17).

Table 17. *Establishing the Outer Limit of the Solar System Habitable Zone for Planet Earth with its Current Lossy Surface Atmospheric Window and Bond Albedo.*

Symbol	Parameter	Value	Metric	Source Commentary
σ	Stefan-Boltzmann Constant σ	5.67037E-08	$W.m^{-2}.K^{-4}$	Stefan–Boltzmann constant - Wikipedia
T_s	Temperature of the Sun	5,772	K	Reverse Engineered from NASA Irradiance data
R_S	Radius of Sun	695,700	Km	Sun Fact Sheet (nasa.gov) [16]
$4\pi r^2$	Surface Area of Sun	6.0821E+12	Sq. km	Determined from Solar Radius R_S
E_S	Irradiance of the Sun	62,931,165	$W.m^{-2}$	Determined from Solar Temperature T_S
E_E	Irradiance of the Earth	1,361.0	$W.m^{-2}$	Earth Fact Sheet (nasa.gov) [12]
r_E	Orbital Distance of Earth	149,598,000	Km	Earth Fact Sheet (nasa.gov) [12]
r_E	Orbital Distance of Earth	1.00	AU	Astronomical Units
σ	Stefan-Boltzmann Constant σ	5.67037E-08	$W.m^{-2}.K^{-4}$	Stefan–Boltzmann constant - Wikipedia
T_s	Temperature of the Sun	5,772	K	Reverse Engineered from NASA Irradiance data
R_S	Radius of Sun	695,700	Km	Sun Fact Sheet (nasa.gov) [16]

Symbol	Parameter	Value	Metric	Source Commentary
$4\pi r^2$	Surface Area of Sun	6.0821E+12	Sq. km	Determined from Solar Radius R_S
E_S	Irradiance of the Sun	62,931,165	$W.m^{-2}$	Determined from Solar Temperature T_S
E_M	Irradiance of Mars	586.1	$W.m^{-2}$	Mars Fact Sheet (nasa.gov) [18]
r_M	Orbital Distance of Mars	227,956,000	Km	Mars Fact Sheet (nasa.gov) [18]
r_M	Orbital Distance of Mars	1.52	AU	Astronomical Units
σ	Stefan-Boltzmann Constant σ	5.67037E-08	$W.m^{-2}.K^{-4}$	Stefan–Boltzmann constant - Wikipedia
T_s	Temperature of the Sun	5,772	K	Reverse Engineered from NASA Irradiance data
R_S	Radius of Sun	695,700	Km	Sun Fact Sheet (nasa.gov) [16]
$4\pi r^2$	Surface Area of Sun	6.0821E+12	Sq. km	Determined from Solar Radius R_S
E_S	Irradiance of the Sun	62,931,165	$W.m^{-2}$	Determined from Solar Temperature T_S
E_{FE}	Irradiance of the Frozen Earth	556.1	$W.m^{-2}$	Using Present Earth Bond Albedo (0.306) [12]
r_{FE}	Orbital Distance of Frozen Earth	234,032,183	Km	Farther out than Mars is.
r_{FE}	Orbital Distance of Frozen Earth	1.57	AU	Astronomical Units

The current model of the Solar System Habitable Zone based on radiative physics is 0.95-1.67 AU [15]. The results presented here are for a Solar System habitable zone of 0.52-1.57 AU. These limits are closer to the Sun than the current model, however they still include the planet Mars located at 1.52 AU (Table 17) and crucially they are now extended sunward to include the planet Venus located at 0.72 AU (Table 15).

An albedo sensitivity test has not been conducted here, but noting that the Bond Albedo of the planet Venus is 0.77 [17] it is concluded that a planet with this high reflective albedo, and with an Earth style surface atmospheric pressure of 1 bar, would also be habitable at an orbital distance from the Sun of 0.72 AU. In the study of the atmospheric pressure profile of Venus [19] calculations were made that the air temperature at an elevation of 47.67 km in the upper troposphere, where the air pressure is 1 Bar, has a value of 322 Kelvin (59°C).

6. Conclusions

This work identifies and corrects a conceptual modelling error previously made [4],[6] that now results in a complete computational agreement between the standard Vacuum Planet equation derived from astronomy and radiative physics [3], and the DAET model concept based on meteorological studies of physical air mass-motion in the presence of a planetary gravity field [5].

The Lossy Surface Adiabatic DAET Opacity Model has three main controlling parameters that feature in its design. These are:

1) Insolation Strength, which is a direct function of the average orbital distance of a planet from the Sun.
2) Planetary Bond Albedo, which is a short-wave reflective property of the lit hemisphere that is governed by a combination of surface character (desert land, vegetated land, liquid water, and solid ice) and the presence of a condensed volatile in the atmosphere (water clouds and ice clouds).
3) The Atmospheric Window, which is a lossy by-pass route by which surface thermal radiant energy can escape directly to Space without being absorbed *en-route* by any atmospheric gasses, condensed liquid droplets (clouds), and solid particles (ice and dust).

Water vapour is the Earth's primary condensing volatile. The freezing of water vapour at elevation in the troposphere generates a process of albedo creation that fundamentally depends on surface temperature and planetary lapse rate. The study of the atmosphere of Venus [19], where a comparative process of top of the atmosphere freezing of concentrated sulphuric acid cloud droplets occurs, suggests that planetary atmospheric albedo is controlled by the atmospheric elevation at which a given planet's condensing volatile liquid droplets freeze and become ice crystals.

It is observed that the current 80 W m^{-2} size of the Earth's Atmospheric window as identified by Kiehl and Trenberth [1] balances in Figure 3 with a surface to space nighttime window leak of 31 W m^{-2} that is directly sourced from daytime surface illumination. This is appropriate, because the Earth has a rapid diurnal rotation and their data is derived from real world observation. The conceptual DAET model is predicated on the assumption that the translation of all energy contained within the climate system is mediated by convection.

The diurnal rotation of the solid Earth is a zonal process and therefore it is impossible for surplus energy collected in the Tropics to be delivered to the Poles by solid surface rotation. This energy delivery to the polar regions of energy deficit requires a meridional transport process. For the Earth this process is undertaken by the movement of the mobile fluids, the water in the oceans and the air of the atmosphere. It is this meridional transport process of oceanography and meteorology that dominates the Earth's climate and so the conceptual DAET model is designed to maximise the application of this mobile fluid energy delivery process.

It is here demonstrated that the Greenhouse Effect results from the summation of two separate physical atmospheric processes, both of which are mathematically equivalent and which together create an energy reservoir within the Earth's troposphere. These processes are the thermal radiant opacity blocking of radiative physics [1] and the process of adiabatic convection and conserved energy delivery to distance of mass-motion physics [11]. Both these processes involve the infinite summation of halves-of-halves of energy flux and are saturated at a surface atmospheric pressure of 1 bar.

It has been shown by example how the two fundamental controls on terrestrial planetary climate of a given solar system orbit are the downwelling high frequency energy reflection filter of planetary Bond Albedo and the upwelling low frequency energy bypass to space filter of the Atmospheric Window.

The full balance of the logic in the present work is that:

On one side of the scales of reason there is the Vacuum Planet Equation of Astronomy based on Opacity derived from Radiative Physics.

On the other side of the scales of reason there is the DAET model of Meteorology based on Adiabatic Convection derived from Mass-Motion Physics.

The essence of the discovery made here is that the geometric infinite summation of Halves of Halves, which lies at the heart of the process of thermal radiant opacity blocking of the standard model, occurs twice. This mathematical procedure also occurs as an identical process of infinite geometric summation of Halves of Halves at the heart of the mechanism of thermal energy retention by adiabatic convection, within the gravity mediated atmospheric circulation of the Hadley cell.

The Adiabatic DAET opacity model presented here is based on meteorological principles that incorporates both thermal radiant opacity and the presence of an Atmospheric Window energy leak, and can be adapted to the study of the atmosphere of terrestrial exo-planets. It is recommended that the DAET model concept, which is capable of further development, be explored by experts in this new field of astronomy.

To summarise:

Both the radiative theory and the DAET process can explain the greenhouse effect on their own, but to maintain long term stability both need to be acting in opposition to each other to neutralise imbalances arising within either.

Previously the authors thought that a choice had to be made between radiation physics or mass-motion physics, but what this analysis demonstrates here is that both processes are needed and that both are invariably present.

It appears that both physical processes are present and running in parallel on every planet and within each body in space that contains mobile fluids of any density, even within plastic mobile solids such as the Earth's mantle.

This principle applies to planets with atmospheres based on hard surfaces, gas planets, stars, galaxies, clusters of galaxies, and perhaps even the universe itself.

References

[1] Kiehl, J. T and Trenberth, K. E., 1997. Earth's Annual Global Mean Energy Budget. Bulletin of the American Meteorological Society, Vol. 78 (2). pp. 197-208.

[2] Sagan, C. and Chyba, C., 1997. The Early Faint Sun Paradox: Organic Shielding of Ultraviolet-Labile Greenhouse Gases. Science, 276 (5316), pp 1217–1221.

[3] Wilde, S. P. R. and Mulholland, P., 2020. An Analysis of the Earth's Energy Budget. International Journal of Atmospheric and Oceanic Sciences, 4 (2), pp. 54-64.

[4] Mulholland, P. and Wilde, S. P. R, 2020. Inverse Climate Modelling Study of the Planet Venus, International Journal of Atmospheric and Oceanic Sciences. Volume 4, Issue 1, June 2020, pp. 20-35. doi: 10.11648/j.ijaos.20200401.13

[5] Wilde, S. P. R. 2015 Neutralising Radiative Imbalances Within Convecting Atmospheres. New Climate Model. https://www.newclimatemodel.com/neutralising-radiative-imbalances-within-convecting-atmospheres/

[6] Wilde, S. P. R. and Mulholland, P., 2020. Return to Earth: A New Mathematical Model of the Earth's Climate. International Journal of Atmospheric and Oceanic Sciences, 4 (2), pp. 36-53.

[7] Simpson, G. C., 1928. Some Studies in Terrestrial Radiation. Royal Meteorological Society (London) Memoir, Vol II. No. 16, pp. 69-95.

[8] Dima, I. M. and Wallace, J. M., 2003. On the seasonality of the Hadley cell. Journal of the atmospheric sciences, 60 (12), pp. 1522-1527.

[9] Miskolczi, F. M., 2007. Greenhouse effect in semi-transparent planetary atmospheres. Quarterly Journal of the Hungarian Meteorological Service, 111 (1), pp. 1-40.

[10] Miskolczi, F. M., 2010. The stable stationary value of the earth's global average atmospheric Planck-weighted greenhouse-gas optical thickness. Energy & Environment, 21 (4), pp. 243-262.

[11] Huang, H. P. 2010 MAE578 Environmental Fluid Dynamics Slides (Fall 2010) mae578_lecture_06.pdf (asu.edu) School for Engineering of Matter, Transport, and Energy, Arizona State University.

[12] Williams, D. R. 2021. NASA Earth Fact Sheet Earth Fact Sheet NSSDCA, Mail Code 690.1, NASA Goddard Space Flight Center, Greenbelt, MD 20771.

[13] Golovneva, L. B., 2000. The Maastrichtian (Late Cretaceous) climate in the northern hemisphere. Geological Society, London, Special Publications, 181 (1), pp. 43-54.

[14] Hoffman, P. F. and Schrag, D. P., 1999. The Snowball Earth. Scientific American, 9, p. 38.

[15] Kopparapu, R. K., Ramirez, R., Kasting, J. F., Eymet, V., Robinson, T. D., Mahadevan, S., Terrien, R. C., Domagal-Goldman, S., Meadows, V. and Deshpande, R., 2013. Habitable zones around main-sequence stars: new estimates. The Astrophysical Journal, 765 (2), p. 131.

[16] Williams, D. R. 2018. Sun Fact Sheet Sun/Earth Comparison Fact Sheet NSSDCA, Mail Code 690.1, NASA Goddard Space Flight Center, Greenbelt, MD 20771.

[17] Williams, D. R. 2021. Venus Fact Sheet Venus/Earth Comparison Fact Sheet NSSDCA, Mail Code 690.1, NASA Goddard Space Flight Center, Greenbelt, MD 20771.

[18] Williams, D. R. 2022. Mars Fact Sheet Mars/Earth Comparison Fact Sheet NSSDCA, Mail Code 690.1, NASA Goddard Space Flight Center, Greenbelt, MD 20771.

[19] Mulholland, P. and Wilde, S. P. R, 2021. The Venusian Insolation Atmospheric Topside Thermal Heating Pool. Conference: Institute of Physics. Planetary Atmospheres: from Earth and beyond. 09 June 2021. DOI: 10.13140/RG.2.2.22043.59687