On the Saturation and Thermalization of Carbon Dioxide

by
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On the saturation and thermalization of Carbon Dioxide

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Introduction

In earlier papers the author has studied the hindering of the evacuation of heat from the terrestrial surface to outer space by a mechanism of a stack of fine gauze's, simulating the infra-red-active trace gasses.
A finite element method (FEM) has been used.
Not in the classical way of solving differential equations, but rather using FEM strategies to model the phenomenon, and dealing with a great number of simultaneous algebraic equations using matrix notations.
In [1] is given a more detailed description of the FEM based stack model.

The stack model for the evacuation of heat from the planet.

We consider a stack of fine grids, with absorption coefficients $f<<1$, being the ratio of the cross-section of the wires divided by the total surface. We consider two layers of black grids with coefficient f_i and f_j, respectively.
The grids have absolute temperatures (Kelvin) T_i and T_j,.respectively.
According to the classical Stefan-Boltzmann relation with $\sigma = 5.67e\ {-8}$,
the heat flux by radiation between the two grids can be written as :

$$\varphi\ (i \rightarrow j) = f_i f_j\ \sigma(T_i^{\,4}-T_j^{\,4}) \qquad \text{and} \qquad \varphi(j \rightarrow i) = 0 \qquad \text{for } T_i > T_j \qquad (1)$$

With $\vartheta = \sigma\ T^4$ and $fe = f_i f_j$ relation (1) can be written as:

$$\varphi(i \rightarrow j) = fe\ (\vartheta_i-\vartheta_j) \qquad \text{and} \qquad \varphi(j \rightarrow i) = 0 \qquad \text{for } \vartheta_i > \vartheta_j \qquad (1a)$$

In **Figure 1** a radiation finite element with nodal parameters is depicted.

Figure 1 Radiation finite element .

$q_j \longrightarrow$ - - - - - - - - - - - - - - - - f_j , ϑ_j

$\uparrow$ $fe*(\vartheta_i-\vartheta_j)$

$q_i \longrightarrow$ - - - - - - - - - - - - - - - - f_i , ϑ_i

Nodal parameters of grids : f absorption coefficients of grids
ϑ nodal variables representing σT^4 Watt/m²
q external heat loads into Watt/m²
Constitutive relation : fe element radiation coefficient

By means of a Galerkin-type of variation, the element heat balance can be written as:

$$\begin{vmatrix} q_i \\ q_j \end{vmatrix} = \begin{vmatrix} fe & -fe \\ -fe & fe \end{vmatrix} \begin{vmatrix} \vartheta i \\ \vartheta j \end{vmatrix} \qquad \textbf{(2)}$$

Equations (2) describe for given ϑ_i and ϑ_j the flow of heat by LW radiation between the grids i and j and the necessary external heat sources q_i and q_j for a balance.
For an element with grids in adjacent levels i and j the equivalent transfer coefficient is indeed fe = f_i f_j. Elements of the type of figure 1 can be overlapped with each other, and in case that between grid i and grid j of one element other grids of other elements are present, the transfer of heat by radiation between grid i and grid j will be hindered and fe becomes :

$$fe = f(i)*viewfactor(i\ ,\ j)*f(j) \qquad \textbf{(2a)}$$

In **(2a)** the viewfactor(i, j) takes into account the fact that other grids k are present between grid i and grid j of an element (i, j).
The viewfactor(i, j) of the element (i, j) can then be written as :

$$viewfactor(i\ ,\ j) = 1 - \sum f(k) \qquad \textbf{(2b)}$$

When the viewfactor(i , j) becomes negative it is put to zero.

The element matrices for the different pairs of grids are assembled in the system matrix. For a stack with 41 grids there are 40*40/2=800 pairs of grids with a 2x2 radiation balance (2) to be assembled in a system matrix of order 41x41, denominated by a bold character **K.**
Nodal parameters ϑ(i) and nodal heat loads q(i) are assembled in vectors of order 41, denominated with bold characters **ϑ** and **q**, respectively.
The characteristic equations of the atmospheric LW radiation become :

$$\mathbf{q} = \mathbf{K} * \boldsymbol{\vartheta} \qquad \textbf{(3)}$$

For a model with N levels :

ϑ : vector of N variables $| \vartheta_1 , \vartheta_2, \vartheta_3 \ldots\ldots\ldots \vartheta_N |$ with $\vartheta_i = \sigma T_i^4$

q : vector of N heat loads $| q_1 ,q_2, q_3. \ldots\ldots\ldots q_N |$

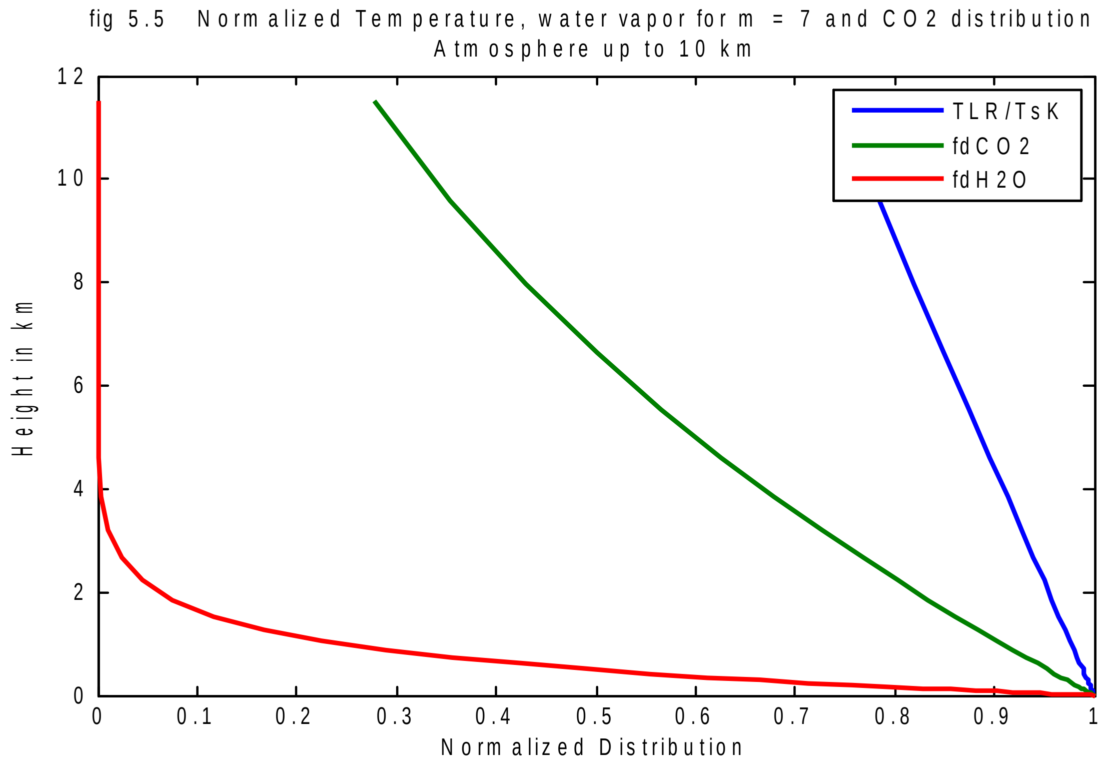
K : matrix of order NxN, containing the element parameters: fe.

Water vapor and CO2: infra-red-active gasses in the atmosphere
From the infra-red-active trace gasses in the atmosphere, those consisting of molecules with three or more atoms, such as H2O and CO2, are the most important to keep the temperature of the planet convenient for mankind.
The stack model can be used to analyze the effect of those infra-red-active gasses which are hindering the LW radiation of heat to outer space and as a consequence the surface temperature augments.
In order to apply the matrix relation, **q = K*ϑ** we need to determine the components of the system matrix **K** as well as the components of the vector **ϑ** related to temperatures in a column above the surface.
In figure 2 the temperature distribution, defined by the measured ELR **(**environmental lapse rate) has been depicted. It is the basis of the analysis to study the heat evacuation from the planet. The temperature distribution is converted to the variables ϑ_i assembled in the vector **ϑ.**
With the surface temperature TsK and ELR = dT/dz = - 6.5 K/km :

$$TLR(i)=TsK + ELR*z(i) \quad \text{and} \quad \vartheta(i) = \sigma*(TsK +ELR*z(i))^4 \qquad \textbf{(4)}$$

Where z(i) is the vertical coordinate of the grid in km.

Figure 2



In figure 2 are also depicted the normalized distribution of H2O vapor and of CO2 : fdH2O and fdCO2, respectively.

The normalized H2O distribution is defined heuristically by an exponential drop :

$$f(z)=\exp(-m*z/height)$$

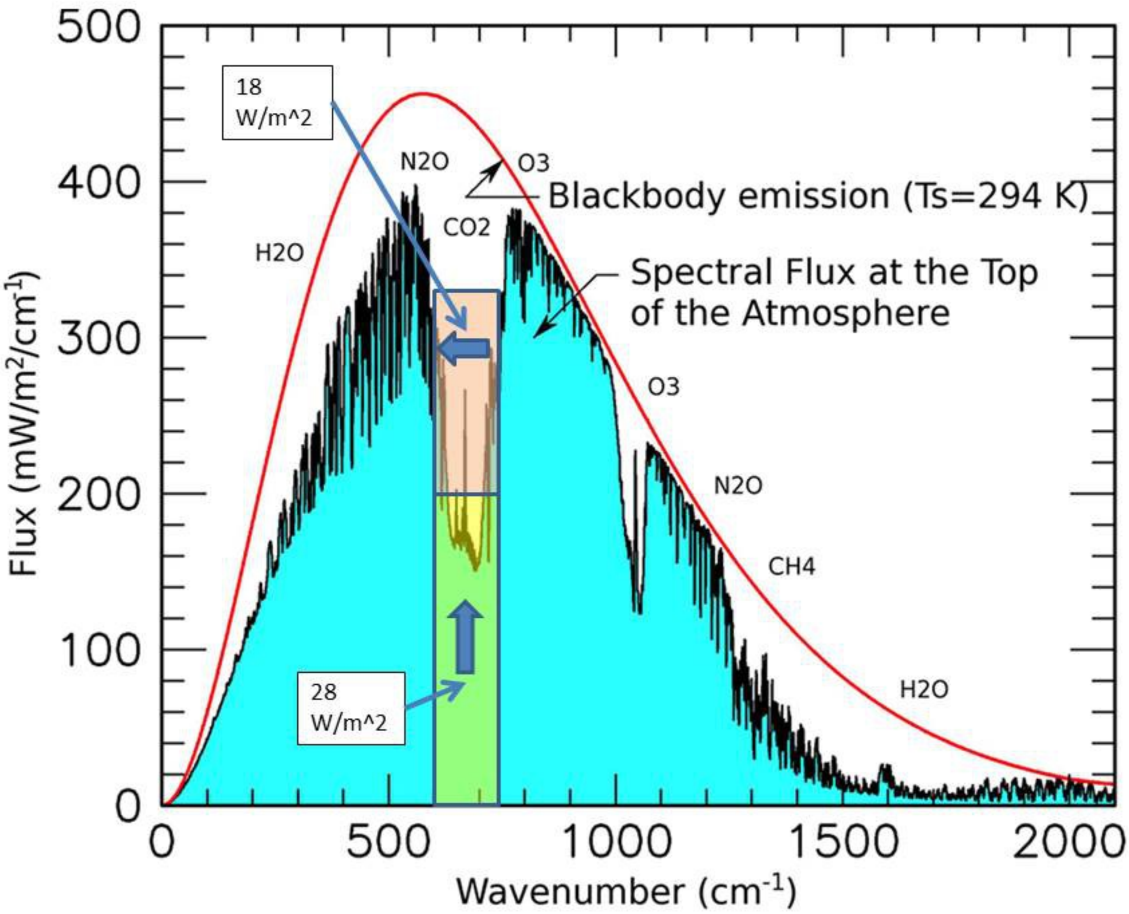
The coefficient m = 7, for a reference height of 5 km, is obtained by comparing the results with the mainstream papers on the subject.

The CO2 distribution is taken proportional to the density variation in the atmosphere, assuming the volumetric concentration is constant over the height. More details are given in [1].

In figure 2 are hidden the arguments that CO2 integrated over the height with a concentration 420 ppm can not be neglected as compared the often mentioned figure of 10 000 ppm at the surface for water vapor.

Indeed, figure 2 indicates that the total amount of 420 ppm CO2 over a height of 25 km is not negligible as compared to a 10 000 ppm of water vapor integrated over an effective height of not even 5 km.

Figure 3 From Climatechangedrivers , Pangburn blog [2]



Thermal radiation from below assessed from top-of-atmosphere. Lower wave number photons are lower energy. (original graph is from NASA)

In figure 3 we see that the fraction of CO2 in the spectrum is about 28 Watt/m² of the total Prevost flux $\sigma TsK^4 = 423.61$ Watt/m² for TsK=294:

fractionCO2 = 0.0661 and fractionH2O= 1-fractionCO2 =0.9339

We see indeed that the influence of CO2 is not big but it needs to be studied in more detail, apart from the fact that CO2 thermalyzes which makes it indeed harmless.

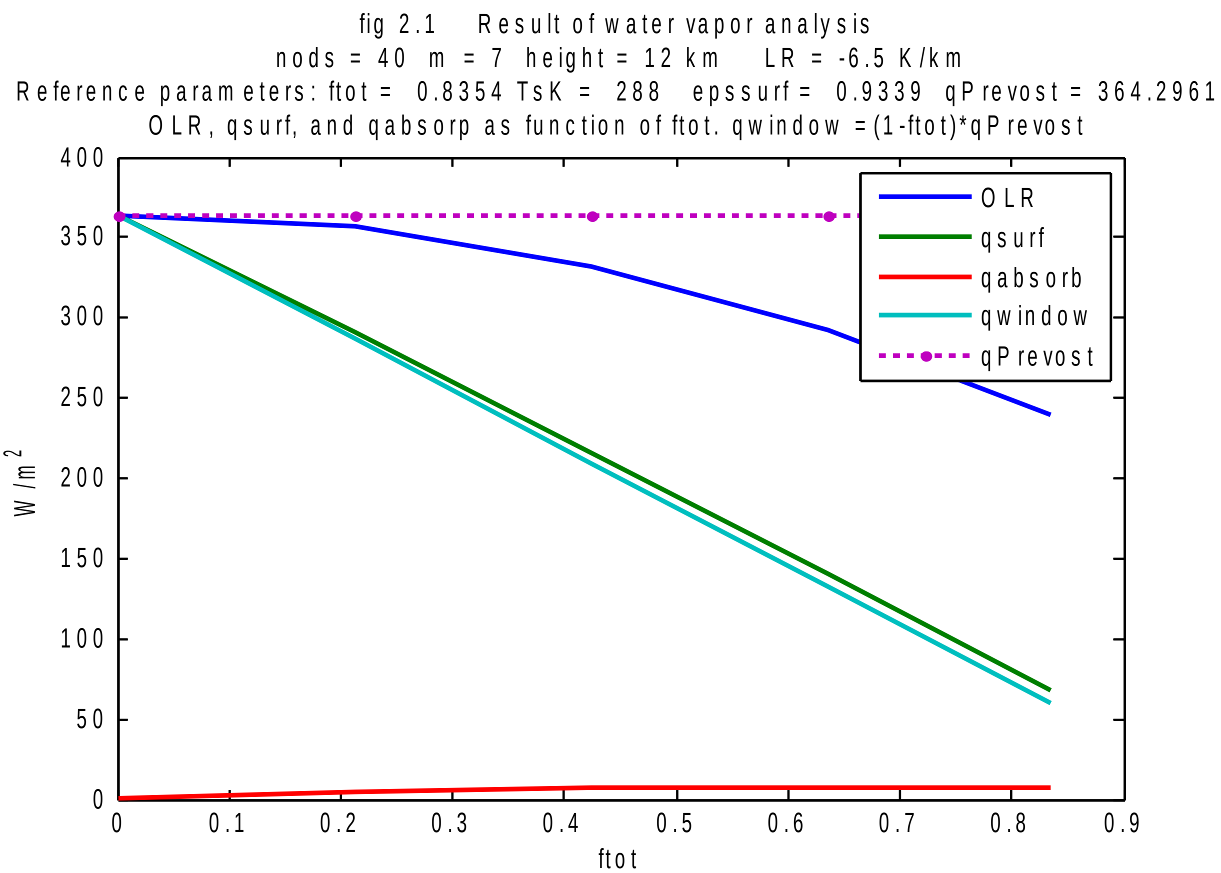
Fort the annual global mean heat budget the global mean average surface temperature: TsK = 288.

The CO2 Prevost flux for zero CO2 becomes 25.8 Watt/m² for TsK=288.

Results of stack model for water vapor.

From figure 2 we can see that the necessary height for the evacuation of heat through an atmosphere with only water vapor , a model with a height of 12 km is sufficient.
A Matlab program includes a mesh generator with element sizes based on geometric series with ratio 1.2: for a model with 40 nodes of order of 2 meter at the surface of the planet and 2 km at 12 km height.
We can build from the water vapor distribution the system matrix **K** and from the temperature distribution the vector **ϑ.** See [1] for more details.
Figure 4 gives the graphical display of the stack equation **q = K*ϑ.**
It might be useful to repeat in words what the relation **q= K*ϑ** means:
for a measured temperature distribution given in 40 nodes by a vector **ϑ** *of order 40 and with a multiplication by a radiation matrix* ***K*** *of order 40x40, one obtains a vector* ***q*** *of order 40.*
We see in figure 4 a certain number of the components of the vector **q** as function of ftot, being the sum of the coefficients f_i from the surface to the top of atmosphere: ftot =sum(f_i).

Figure 4



What is the physical interpretation of the components of the vector **q** ?
They represent:

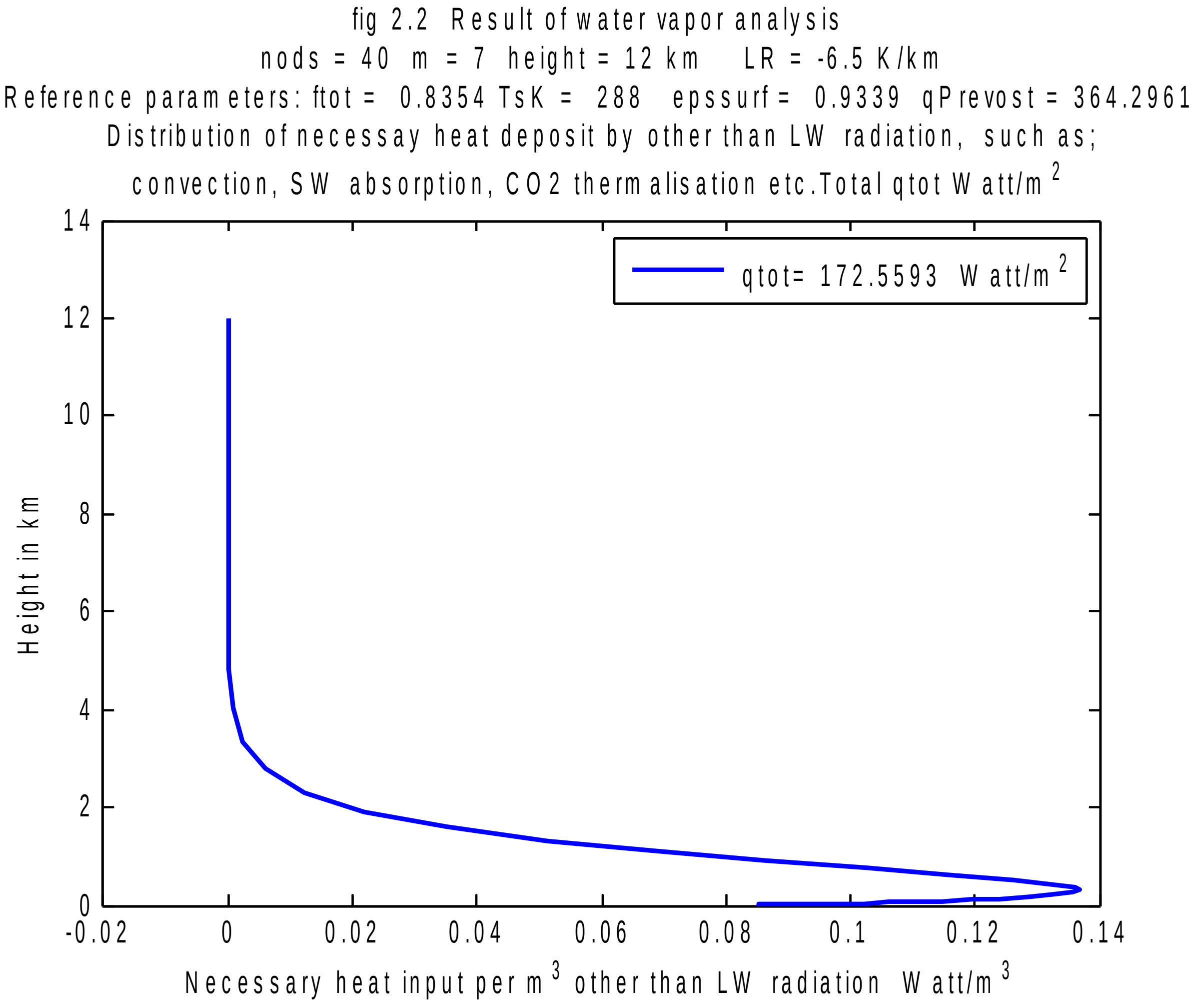
q(1) = qsurf = LW surface flux
-q(nods) = OLR = outgoing LW radiation

The components of **q** are not given by the user, they follow:

- from the radiation matrix **K** which depends on the water vapor distribution given in figure 2
- from the given surface temperature TsK = 288, and
- from the measured environmental lapse rate ELR = - 6.5 K/km!

The values of outgoing LW radiation in figure 4 correspond with those of main stream authors on the subject: OLR=240 Watt/m²
The calculated values of the other components of **q** are given in Figure 5

Figure 5



We see for the planet that the stack on the basis of the radiation matrix **K** and the measured temperature distribution assembled in the vector **ϑ ,** the atmosphere needs an input of 172.6 Watt/m² from *other* sources:

- *absorption of incoming SW radiation by aerosols*
- *convection from the surface of sensible and latent heat,* and
- ***thermalization of CO2 i.e. absorbance of LW radiation from the surface but not re-emitted***

The thermalization contribution seem to be ignored by the main-stream papers on the subject. We come back on the phenomenon further on, in fact it is the main purpose of the present paper.

For studies related to the dependence on the ambient temperature of the evacuation of heat from the planet by LW radiation, we need the dependence of OLR for water vapor on the surface temperature TsK. We don't need to make runs for different TsK around 288 degrees K, we can differentiate analytically the relation **q=K*ϑ .**
For that purpose we differentiate relation (4) with respect to TsK:

$$TLR(i)=TsK + ELR*z(i) \quad \text{and} \quad \vartheta(i) = \sigma*TLR(i)^4 \qquad \textbf{(4)}$$

$$d\,TLR(i)/dTsK = 1 \quad \text{and} \quad d\,\vartheta(i)/dTsk = 4*\vartheta(i)/TLR(i) \qquad \textbf{(4a)}$$

The derivative of the components of the vector **ϑ (**or **theta)** with respect to TsK are assembled in a vector **dthetadTsK.**
By differentiating the stack equation **q=K*theta** we find , for constant **K:**

$$\mathbf{dqdTsK = K*dthetadTsK} \quad \rightarrow \quad dOLR/dTsK = -\,dqdTsK(nods)$$

The result is: $dOLR/dTsK = 3.3875 = (dOLR/dTsK)_{H2O}$

It serves to calculate the temperature increase deltaTsK of the planet for the increase $deltaOLR_{CO2}$ due to increasing CO2 concentrations:

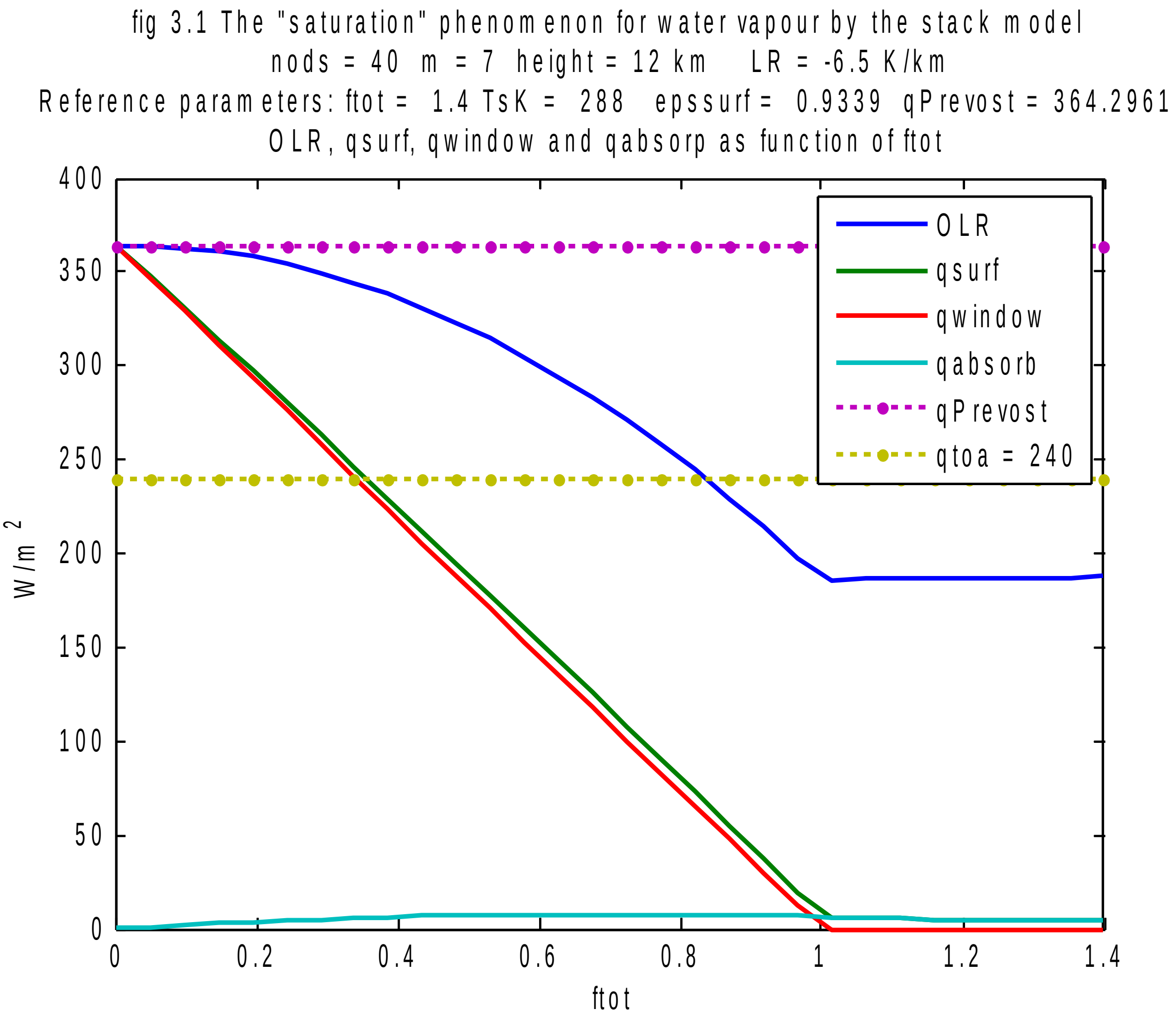
$$deltaTsK_{planet} = deltaOLR_{CO2} / (dOLR/dTsK)_{H2O} \qquad \textbf{(5)}$$

Before going to the section for the analyses of the influence of CO2 we show the phenomenon of saturation of infra-red-active gasses.
For that reason we give in figure 6 the analyses for different water vapor concentrations including ftot>1.
The stack model has been validated for water vapor: it is now shown that the phenomenon of saturation can also be analyzed by the stack model.
The phenomenon is explained by equation (2b) , repeated here:

$$\text{viewfactor}(i\ ,\ j) = 1 - \sum f(k) \qquad (2b)$$

For $\sum f(k) > 1$ the viewfactor(i,j) becomes negative and it is put to zero.

Figure 6



Above results for water vapor of figure 4 and figure 5 have been published before , and validated with results from mainstream authors on the subject.
The stack model is a mono-chromatic model of the evacuation of heat from the planet, but it turns out it is accurate enough when compared to the results of mainstream authors on the subject.
The validated stack model can also be used to analyze the behavior of CO2, *at-least if we assume that the CO2 reaction to LW radiation is the same as for water vapor i.e. to ignore the phenomenon of thermalization of the infra-red-active gas molecule CO2.*

Results of the stack model for CO2

The stack model is used to establish the relation **q =K*ϑ** for CO2 gas
The preparation of the **K** matrix for the CO2 gas is similar to the water vapor case.
As can be seen from figure 2 which gives the CO2 distriution in the atmosphere , the CO2 model should go up to 25 km.
The mesh can be more homogeneous since the CO2 concentration is not that pronounced at the surface of the planet, we obtain mesh size 1 m at the surface and 4 km at an height of 25km.
Figures 7 and 8 for CO2 are equivalent to figures 4 and 5 for water vapor, representing the relation **q =K*ϑ.**
What is the physical interpretation of the components of the vector **q** ?
They represent:

q(1) = qsurf = LW surface flux
-q(nods) = OLR = outgoing LW radiation

The other components of **q,** given in figure 8**,** are not given by the user, they follow:

- from the radiation matrix **K** which depends on the CO2 distribution given in figure 2
- from the given surface temperature TsK = 288, and
- from the measured environmental lapse rate ELR = - 6.5 K/km!

Figure 4 has been validated with the results of the main-stream authors on the subject. Figure 7 for CO2 can not be compared, nobody has published them to the author's knowledge.

Figure 7

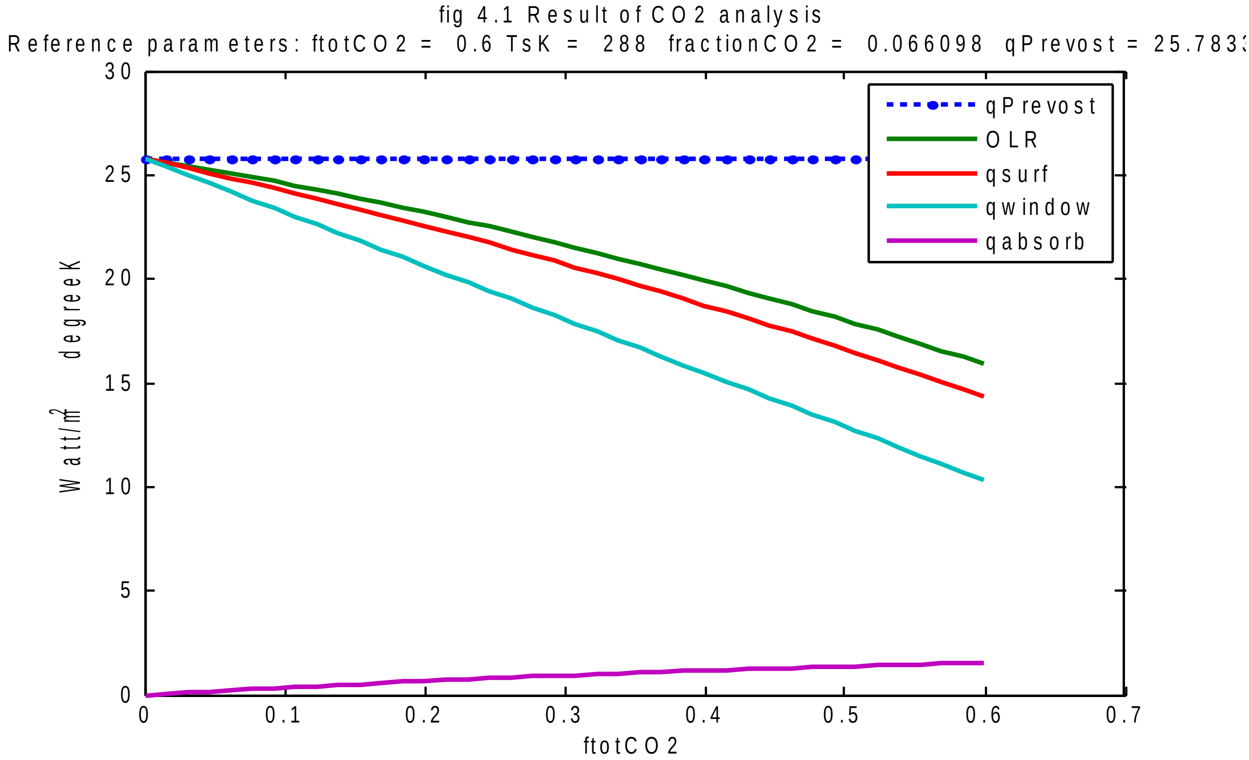
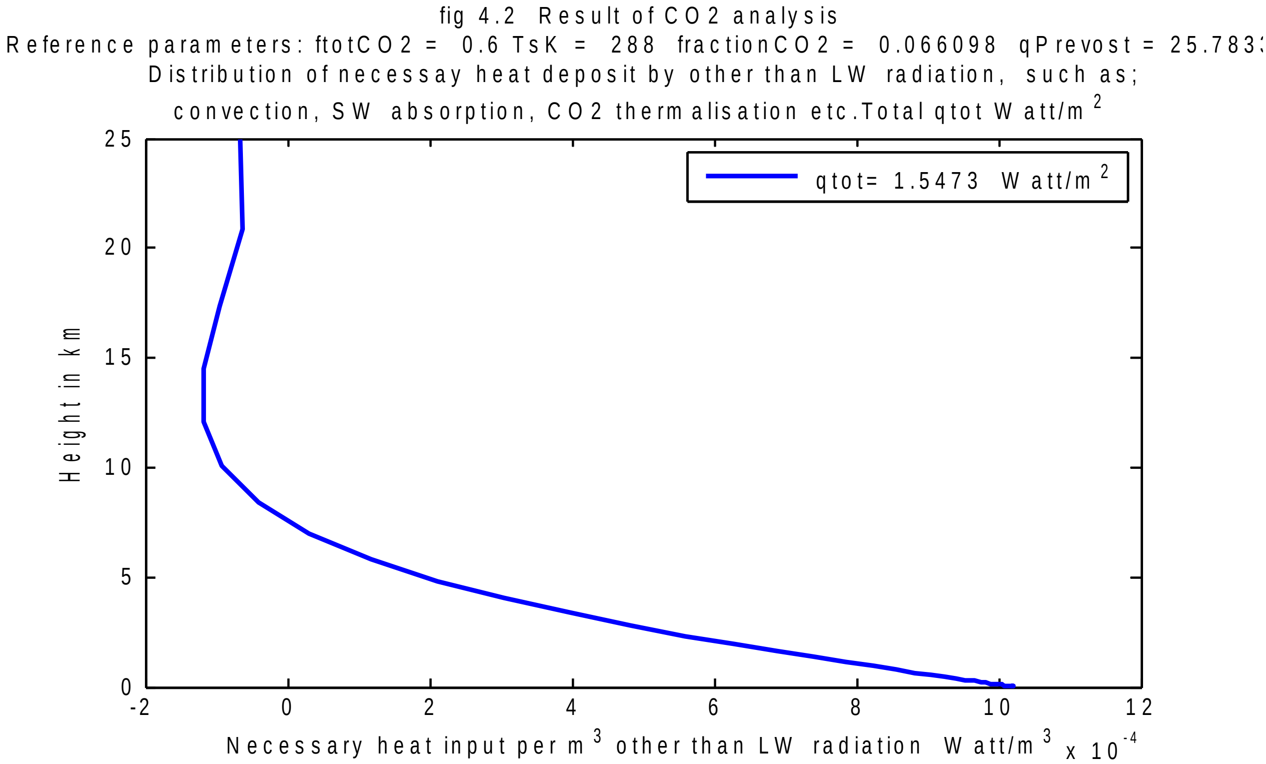


Figure8



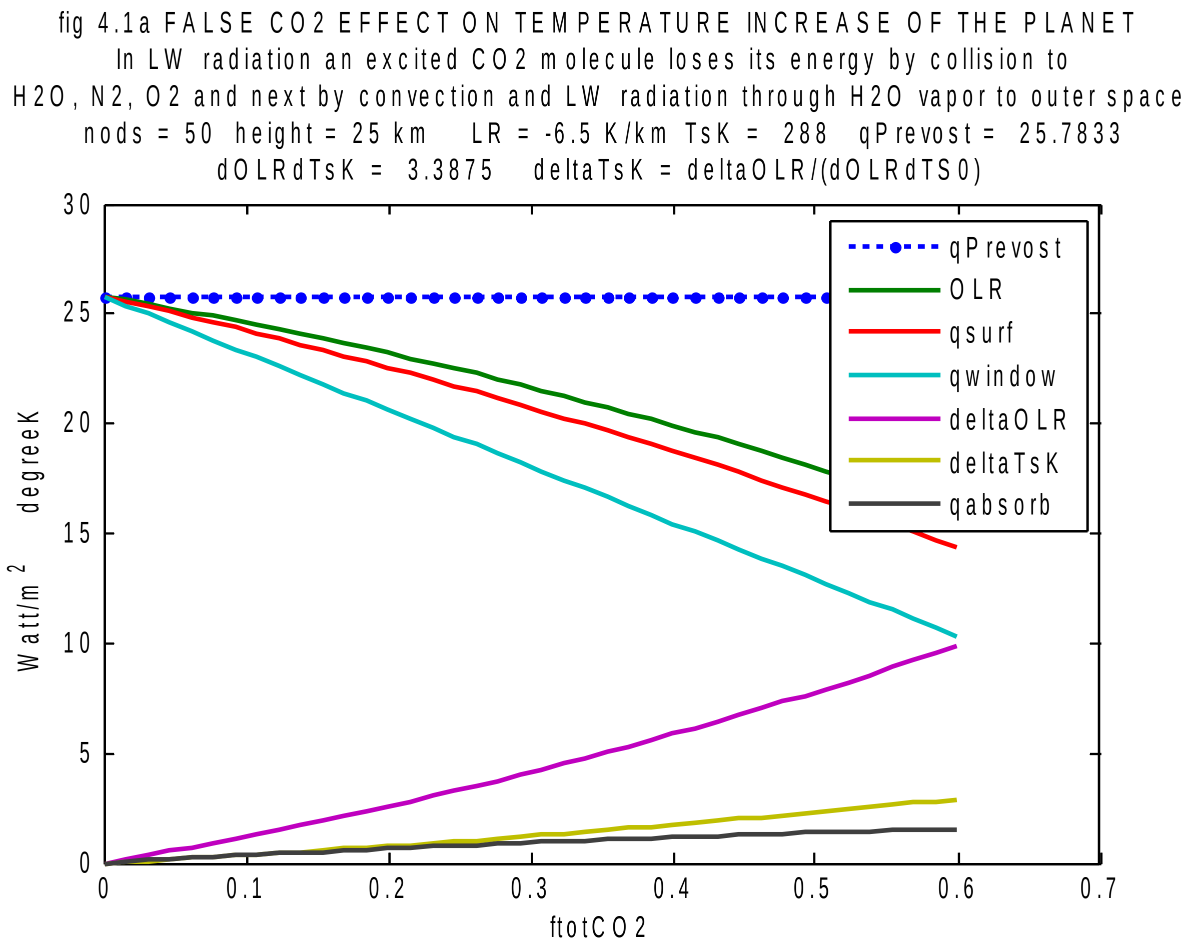
IPPC authors use the results of figure 7 in an implicit way.
The reasoning is that to find the influence of CO_2 on the surface temperature, the OLR of CO_2 has to be added to the OLR of water vapor.
In figure 7 is given the qPrevost flux i.e the OLR in the case that ftotCO2 =0 : the surface flux of the CO_2 band (25.8 Watt/m²) goes straight through the CO_2 window to outer space. Water vapor allows to evacuate the necessary OLR=240 at TsK=288.
For values of ftotCO2 >0 the amount of energy (qPrevost - OLR) would be the increase of the total OLR due to CO_2, plotted in figure 9:

$$\text{deltaOLR} = \text{qPrevost} - \text{OLR}$$

We repeat equation (5) to show how deltaTsK due to CO_2 is obtained:

$$\text{deltaTsK}_{\text{planet}} = \text{deltaOLR}_{CO_2} / (\text{dOLR/dTsK})_{H_2O} \qquad (5)$$

Figure 9



In figure 9 the IPPC reasoning is depicted, the reader might be aware that the deltaOLR quantity is called the “ *forcing of CO2*” by IPPC authors.
It is false simply because figure 7 and 8 are not correct, CO2 does not react in the same way as water vapor. The stack model assumes that the molecules of the infra-red-active trace gasses re-emit immediately after having been excited by a photon.
The CO2 molecule does not, CO2 thermalizes. See Pangburn [2}.
We add in figure 10 the false IPPC reasoning for values of ftotCO2 far into the saturation region.

Figure 10

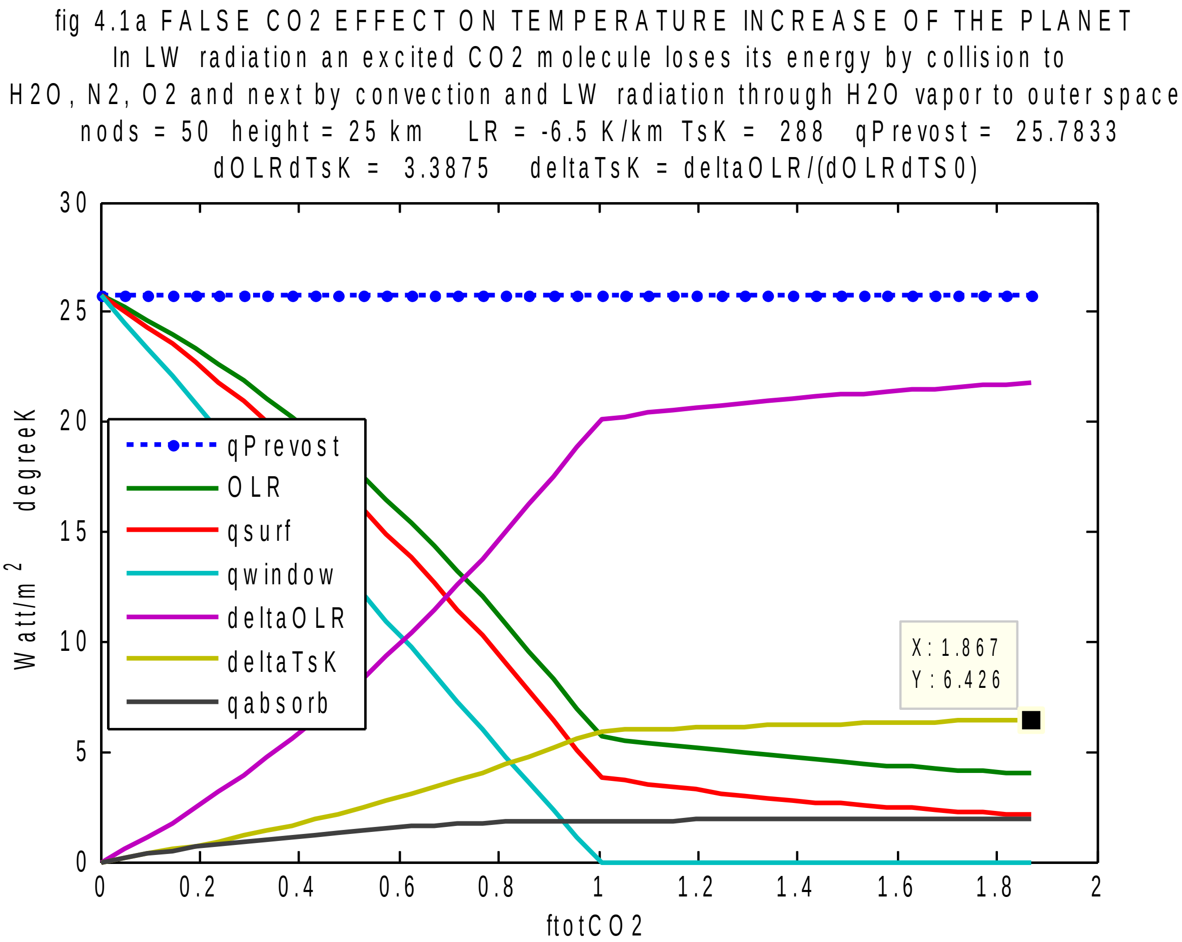


Figure 10 shows the reason of the alarming messages of IPPC, based on the increase of the planet surface temperature deltaTsK as function of the CO2 concentration expressed as ftotCO2, for the coming decades.
We see two regions: one from ftotCO2 =0 to 1, and another region for ftotCO2>1.

We do not try to find a logarithmic expression for the first region.
And the second region of saturation is not mentioned by the mainstream papers on the subject.

But the CO2 results of figure 10, similar to those of IPPC for the first region , are false because the thermalization of CO2 has not been taken into account.

From the historical point of view:

- Bouguer, and later (Beer and Lambert) suggested a first order decay law with varying coefficients, around 1700.
- The famous astronomer Schwarzschild indicated a solution with a coordinate transformation, introducing optical depth, in 1916.
- Another famous astronomer Carl Sagan , under contract with NASA, suggested IPPC to use the Schwarzschild solution, around 1980.
- NASA's James Hanssen testifies to congress that the planet was heating up, 23 Juin 1988.

But all four were not aware that CO_2 molecules behave differently from what was assumed: they thermalize.
In [2] Pangburn gives a detailed description of the phenomenon.

The 25.8 Watt/m² surface flux in the frequency band where the CO_2 molecule is active, the CO_2 molecule is excited but does not not re-emit in time: the excited CO_2 molecule collides with other molecules H_2O, N_2, O_2, etc and the surplus energy is converted to heat, and added to the category of the 172.6 Watt/m^2 of figure 5 of the water vapor results,

That amount of energy is not only due to incoming SW absorption and convection from sensitive and latent heat from the surface:
it includes the 25.8 Watt/m² of the thermalization of CO_2.
It follows the H_2O path of LW radiation to outer space.
(figures represent the case that CO_2 concentration would be at the point of saturation: ftotCO2 =1, and no CO_2 window, see “Global and annual mean heat budget “ in Appendix 1).

Conclusions

The chicken-wire stack model of infra-red-active trace gasses , already validated for the analysis of LW radiation through the atmosphere with water vapor has now been applied to the analysis of CO_2 gas in the atmosphere.
The issue of saturation has been dealt with, which would have given a limited increase of the surface temperature, from a situation with no CO_2 at all (0 ppm!) towards the saturation point of CO_2 for ftotCO2=1, and higher ftotCO2 values.
The thermalization of CO_2 as reported by Pangburn [2] and by le Pair [3] makes indeed the saturation of CO_2 a non-issue:

increase of the CO2 concentration has no effect on the surface temperature.

It is the other way around, the temperature of the planet varies due to variations of the Sun activity: for an increasing ocean water temperature, absorbed CO_2 dissolves from the ocean water back into the atmosphere.
The declarations of the 2021 Glasgow IPCC meeting of Participating states are alarming, but they are simply false.
The thermalization of CO_2 gas has been ignored.
The classical global and annual mean heat budget has been extended and has now two windows, one for water vapor and one for CO_2.

Acknowledgment
The author expresses his gratitude to John O'Sullivan for hosting this paper on Principia Scientific.

References
[1]https://principia-scientific.com/publications/Reynen-Finite.pdf

[2]Pangburn blog
https://www.researchgate.net/publication/316885439_Climate_Change_Drivers

[3]Private communication 10/11/2021 from C. le Pair, The Netherlands.

Appendix 1

Global and annual mean heat budget in W/m^2

It is obvious that the classical heat budget of the planet has to incorporate the fact that not only water vapor has its contribution but also the CO2 analysis have to be taken into account :
fractionCO2 = 0.0661, fractionH2O = 0.9339, TsK=288, ELR = -6.5 K/km
And in particular the thermalization of the CO2 molecule.
The diagram has two windows : one for H2O and one for CO2.
For smaller values of ftotCO2 the window gives an open way to outer space for nearly all the surface flux from the CO2 band.
For ftotCO2 =1, the saturation point, there is no CO2 window anymore.
Figure A1