Greenhouse Gas Theories and Observed Infrared Absorption Properties of the Earth's Atmosphere

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ABSTRACT

In the last decade fundamental theoretical equations were developed for describing and understanding the global average radiative equilibrium state of the Earth-atmosphere system. We show that the key climate parameters of the planet can be deduced theoretically from purely astronomical considerations and some plausible assumptions on the material composition of the planetary surface and structure of the atmosphere. We also show that the Earth-atmosphere system is in radiative equilibrium with a theoretical solar constant, and all global mean flux density components satisfy the theoretical expectations. The greenhouse effect predicted by the Arrhenius greenhouse theory is inconsistent with the existence of this radiative equilibrium. Hence, the CO_2 greenhouse effect as used in the current global warming hypothesis is impossible. The greenhouse effect itself and the CO_2 greenhouse effect based global warming hypothesis is a politically motivated dangerous artifact without any theoretical or empirical footing.

KEYWORDS

Climate change, global warming, greenhouse effect, radiative equilibrium

Introduction

All planets in our solar system are isolated celestial objects orbiting around the Sun. Isolated objects can only exchange energy with other objects and the surrounding environment by mains of radiation. The exchange of radiant energy happens through the **active planetary surface (APS)**.

By definition the APS is the sum of the (solid or liquid) surface areas which contributes to the exchange of radiant energy with the Sun and the surrounding (space) environment.

The APS may receive inward radiation from the full 4π solid angle, and also emits and reflects (or scatters) radiation into the full 4π solid angle. Planets with condensing greenhouse gas (GHG) atmospheres usually have complex multi-layer adaptive APS which control the planetary radiative equilibrium. Further on, we shall use the concept of a 'passive' planet.

By definition a passive planet has negligible internal source of thermal energy propagating through the APS and the atmosphere above and contribute to the top of the atmosphere (TOA) net radiation. The global average geothermal flux is of the order of 0.086 Wm^{-2}, which is indeed negligible compared to the terrestrial outgoing long wave radiation (OLR^A), or, if necessary, can be quantified as a small contribution to the surface net long wave (LW) radiation (Kandel & Viollier, 2005).

On a properly chosen time scale a passive planet is said to be in steady state radiative equilibrium (RE) if the total available (or intercepted) solar shortwave (SW) radiation is equal to the sum of the total LW radiation and reflected SW radiation leaving the APS, and the absorbed available SW radiation (ASR) is equal to OLR^A leaving at the top of the atmosphere. Such a planet will obey the energy and momentum conservation principles of the radiation field in its simplest form where all planetary LW flux density components scale with the solar luminosity.

These are the top-level constraints imposed on the radiation field of the Sun-planet system and actually assures that a passive planet cannot change the local solar constant. Obviously, such a planet is an abstraction, but it is not an unrealistic one. It is quite reasonable to assume that after the formation and during the billions of years of planetary evolution planets have ample time to reach the steady state RE.

On the other hand, any power dissipation in the system which is unrelated to the incoming solar radiation will just add an extra (small) energy term to the OLR and move the planetary flux emissivity a little above unity. Planets or Moons without atmosphere have limited capabilities to regulate their radiative budget and their equilibrium state are not discussed here.

Climate change will be regarded as deviations from the long-term average state due to possible internal (natural random) fluctuations or external perturbations of the total energy input to the system. Internal fluctuations are due to the chaotic nature of the dissipative dynamic climate system, and they do not alter the long-term radiative balance. Regarding the large variety of time scales of the possible internal fluctuations and external perturbations that may occur one has to be careful with selecting the length of a characteristic averaging time interval where the radiative equilibrium is established.

Planets with large amount of latent heat storage (in geological reservoirs) may moderate the internal and external fluctuations by phase pinning (Maxwell rule). In the Earth's atmosphere the water vapor is the only condensing GHG therefore the triple point (we call it phase temperature) of the H_2O at $t_P = 273.16$ K has a unique role in the climate system. Although the relationship between the thermal history of the Earth and the composition of the atmosphere on evolutionary time scale is an interesting subject, the man-made CO_2 greenhouse problem is only relevant to the last century.

The purpose of this paper is to answer two greenhouse effect related fundamental questions:

1. Do greenhouse gas theories contradict energy balance equations?
2. Is the proposed greenhouse effect due to anthropogenic carbon dioxide emissions supported by observed atmospheric thermal and humidity structures and global scale simulations of the infrared absorption properties of the Earth's atmosphere?

In 2017, the Supreme Court of British Columbia raised these two questions in the cases of Michael Mann vs. Timothy Ball and Andrew Waver vs. Timothy Ball.

This paper follows the testimony presented to the Court in the above cases (Court, 2016). Further on, we will address some problems of recent global radiative budget schemes and present a realistic planetary radiative budget based on a new theoretical approach to the greenhouse effect.

We will show the theoretical expectations are fully consistent with the observations. Other planets or moons in the solar system have entirely different physical environments therefore we shall not discuss the relevance of our theoretical considerations here.

We will introduce some definitions and present observed empirical facts on the radiative structure of the Earth-atmosphere system (section 1); discuss the methodology of the greenhouse effect validations (section 2); present relevant new radiative transfer background information (3); summarize the new results (4); and state the conclusions (5).

1. Greenhouse gas theories and radiative balance equations

1.1. Definitions of basic greenhouse parameters

The planetary GE is an observed global radiative phenomenon and, so far, a structured theoretical foundation of the planetary GHG greenhouse effect (GE) does not exist. In climate science GE is defined as the difference between the surface radiative temperature t_S and the planetary shortwave effective absorption temperature

$$t_A : \Delta t_A = t_S - t_A \text{ K,}$$

where

$$t_A = (F_A / \sigma)^{1/4} \text{ ,}$$

F_A is the effective available ASR, and

$$\sigma = 5.6699833 \times 10^{-8} \text{ W m}^{-2}\text{ K}^{-4}$$

is the Stefan-Boltzmann (SB) constant. Unless specified otherwise, all physical constants are from the National Institute of Standards and Technology, (Mohr et al., 2007).

The thermodynamic ground surface temperature is $t_G = t_S / \varepsilon_b^{1/4}$ where ε_b is the LW surface (lower boundary) flux emissivity. Perfectly black surfaces will have

$$\varepsilon_b \equiv 1,\ t_G = t_S, \text{ and } S_U = \sigma t_S^4 = S_G = \sigma t_G^4,$$

where $S_G = \sigma t_G^4$ is the upward blackbody radiation from the ground surface.

GE may also be expressed by the all-sky greenhouse factor (GF) which is the difference of the respective flux densities (computed via the SB law):

$$G_A = \sigma t_S^4 - \sigma t_A^4 = S_U - F_A.$$

The ASR depends on the long term mean of the local solar constant F_0, and the Bond albedo

$$\alpha_B : F_A = F_0(1 - \alpha_B) / 4,$$

where,

$$\alpha_B = F_R / F_E.$$

Here $F_E = F_0 / 4$ is the global mean available shortwave flux density over a unit area at the TOA, F_R is the reflected part of F_E, and obviously,

$$t_A = ((1-\alpha_B)F_0/(4\sigma))^{1/4}.$$

Similar to t_A one may define the $t_E = (F_E/(4\sigma))^{1/4}$ effective planetary temperature, and the $t_R = (F_R/(4\sigma))^{1/4}$ effective reflection temperature of the planet.

In astrophysics, GE is defined via the total SW energy interacting with the planet:

$$G_E = \sigma t_S^4 - \sigma t_E^4$$

$$\Delta t_E = t_S - t_E. \; t_A$$

$$G_A$$

are constrained by the energy conservation principle:

$$t_A = (t_E^4 - t_R^4)^{1/4},$$

and

$$G_A = G_E + F_R.$$

To determine the Δt_E and Δt_A one needs to know the global mean surface temperature, the solar constant, the Bond albedo, and the OLR at the TOA for all-sky condition.

The conventional textbook data of these quantities are:

$$t_S = t_G = 288 \text{ K}$$

$$F_0 = 1368 \text{ W m}^{-2},$$

$$\alpha_B = 0.3$$

and

$$OLR^A = 239 \text{ Wm}^{-2}$$

(Schmidt, et al. 2010).

Slightly different numbers giving the same Δt_A may be found in Lacis et al. (2010). Based on these numerical data the greenhouse temperature rise and the corresponding flux density difference are:

$$\Delta t_A = t_S - (F_A / \sigma)^{1/4} = 33 \text{ K},$$

and

$$G_A = S_U - OLR^A = 151 \text{ Wm}^{-2}.$$

The often used normalized (dimensionless) GF is:

$$g_A = (S_U - F_A) / S_U = 0.387$$

The astrophysical Δt_E GE definition results in significantly lower value:

$$\Delta t_E = 288 - (1368 / 4 / \sigma)^{1/4} = 9.31 \text{ K}.$$

Without internal planetary heat sources (entering into the system at the lower boundary) isolated planets in steady state RE obey the conservation principle of radiant energy. The long-term global mean absorbed part of F_E should satisfy the $OLR^A = F_A$ equation.

In the example above, the planetary RE condition is closely satisfied, the imbalance (rounded to the nearest integer) is zero:

$$OLR^A - F_A = 0 \text{ Wm}^{-2}.$$

In **Figure 1** the spectral aspects of the greenhouse effect are presented. Notice that in the wavenumber domain the areas under each curve are proportional with the spectrally integrated flux densities. Remember also, that the 288 K surface temperature is not an empirically measured quantity but based on an international agreement. There is no unique definition of a standard (empirically verified) global mean surface temperature.

1.2. Radiative balance and cloud cover

The GHG GE hypothesis assumes that the radiative balance requirement is in the form of

$$OLR^A(\overline{\tau}_A, S_U) = F_A(F_0, \alpha_B)$$

where $\overline{\tau}_A$ is the IR flux optical depth of an air column, and S_U is the surface upward flux density. $\overline{\tau}_A$ can only be accessed by extremely complex RT computations.

Keeping the right side at a constant F_A (meaning that F_0, and α_B are constants), then the increased GHG content must be compensated by the LW absorption and emission processes of the surface-atmosphere system. For example in a global average clear atmosphere CO_2 doubling will increase $\overline{\tau}_A$ by about 0.0242 (Miskolczi and Mlynczak, 2004).

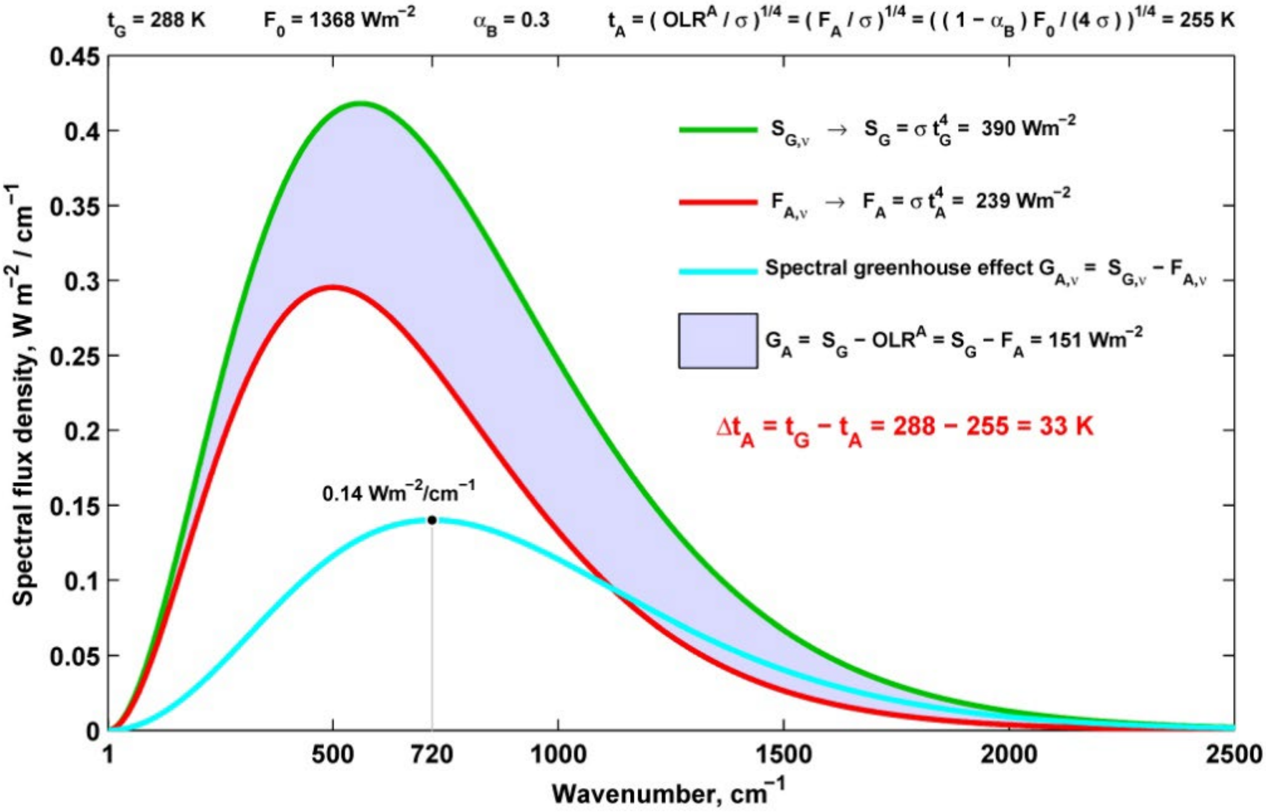

Figure 1. Textbook definition of the atmospheric greenhouse effect. The curves are the Planck spectral flux density distributions belonging to the equivalent effective temperatures. The greenhouse warming in steady state radiative equilibrium $F_A = OLR^A$ is the $\Delta t_A = 33$ K difference between the surface thermodynamic temperature t_G and the planetary effective absorption temperature t_A. The greenhouse factor $G_A = 151$ Wm^{-2} is the difference in the respective flux densities (blue shaded area). In this view the planetary ground surface (lower boundary) is assumed to be perfectly black and t_G is equal to the surface radiative temperature $t_S = t_G = 288$ K, and $S_U = \sigma t_S^4 = \sigma t_G^4 = S_G = 390$ Wm^{-2}, where S_U is the surface upward infrared flux density. The maximum of the $G_{A,\nu}$ function is at the center of a strong CO_2 absorption band.

It was shown with sufficient mathematical rigor that the clear-sky OLR and the surface upward radiation in radiative equilibrium are related by the

$$OLR = S_U f(\overline{\tau}_A)$$

where,

$$f(\overline{\tau}_A) = 2(1 + \overline{\tau}_A + \exp(-\overline{\tau}_A))^{-1}$$

is the transfer function (Miskolczi, 2007).

Locally, in the stochastic dissipative climate system the radiative equilibrium is not a constraint. $\overline{\tau}_A$, and S_U can take any value. However, on global scale the radiative equilibrium is a strict constraint and the

$$OLR^A(\overline{\tau}_A, S_U) = F_A$$

assumption violates the energy conservation principle. That is, the reduced OLR (due to increased $\overline{\tau}_A$) cannot be restored without adding thermal or radiative energy to the system.

The correct relationship must have the form of

$$OLR^A(\overline{\tau}_A, S_U, \beta, S_U^C) = F_A(F_0, \alpha_B)$$

where,

β is the cloud cover,

$S_U^C = S_U^C(h^C)$ is the upward flux density from the cloud top,

h^C is the average or equilibrium cloud top altitude.

Evidently α_B will also depend on the cloud cover and cloud altitude:

$$\alpha_B = \alpha_B(\beta, h^C)$$

The practical derivation of the equilibrium cloud cover is given in Miskolczi (2014). Note that ignoring the

$$OLR^A(\overline{\tau}_A, S_U, \beta, S_U^C) = F_A(F_0, \alpha_B)$$

strict energy balance requirement discussion on the GE and the related global climate change do not have much merit.

Without any theoretical or experimental proofs Δt_A and G_A are simply attributed to the absorption and re-emission of the surface upward radiation by the infrared (IR) active atmospheric gases. So far, no structured GHG GE theories exist that can predict a-priori the observed equilibrium Δt_A and G_A. Since the definition completely ignores the radiative effect of the cloud cover, the missing GHG GE theory is not surprising.

The principle of the conservation of the radiant energy dictates that the real world planetary all-sky OLR^A must be the weighted sum of the clear-sky and cloudy sky OLRs:

$$OLR^A = (1-\beta)\, OLR + \beta\, OLR^C .$$

Here OLR and OLR^C are the clear-sky and cloudy sky components of the OLR, and β is the cloud fraction. In a two-level radiating system (cloud-free surface and cloud top) the Δt_A or G_A alone can never be directly associated with the GHG content of the atmosphere.

In 1896, Svante Arrhenius put forward the question:

> "Is the mean temperature of the ground in any way influenced by the presence of heat-absorbing gases in the atmosphere?"

He tried to quantify the effect of the CO_2 and associate it with the ice-ages in the planetary climate history (Arrhenius, 1896).

The CO_2 greenhouse effect hypothesis in its simplest form states that increasing CO_2 content of the atmosphere will increase the absorbed upwelling LW radiation from the surface, will reduce the outgoing LW radiation, and will increase the downward LW radiation received by the surface. As a result, the surface will warm up until the top of the atmosphere radiative balance is restored, (Pierrehumbert, 2011; Lindzen, 2007; Nurse and Cicerone, 2014; Smith, 2008).

Of course, this is not a greenhouse theory but an unproven hypothesis which poses deliberate constraint on the atmospheric response to increased greenhouse gas content.

The key missing information is the expected response of the global mean flux optical depth and the long time RE state of the atmosphere.

Climate modelers generally assume a hypothetical positive feedback process that amplifies the initial warming: higher surface and atmospheric temperatures increase the water vapor content of the atmosphere, and the increased water vapor absorption further increases the warming effect.

This unphysical assumption stems from the Schwarzschild solution of the RE situation in stellar atmospheres (Schwarzschild, 1906). Since the magnitude and quantitative constraint of this effect is unknown, climate models are stabilized with different kinds of ad-hoc H_2O feedback parameterizations.

We will discuss the unresolved theoretical problems of the origin and mechanism of the atmospheric GE in section 3.

We will show the GE effect is a global scale RE process with a definite equilibrium state of the global mean radiative climate parameters. Related to the GE, the most important radiative transfer parameter is the global mean flux optical thickness $\overline{\tau}_A$.

2. Quantitative validation of the greenhouse effect

2.1. The global mean picture

Properly attributing the hypothetical CO_2 greenhouse-effect anthropogenic global warming (AGW) theory to the greenhouse phenomenon needs empirical validation.

To answer the important question,

> "Is the proposed greenhouse effect due to anthropogenic carbon dioxide emissions supported by observed atmospheric thermal and humidity structures and global scale simulations of the infrared absorption properties of the Earth's atmosphere?"

we must rely on relevant empirical facts.

The practical approach to this validation effort is to collect long-term, geographically diverse, global radiosonde data sets that contain information about the state of the surface and the atmosphere. Then we must perform high-quality radiative transfer computations to obtain the true long-time global average radiative structure of the system. Once the reliable global mean flux density components of the system are known, then we can compare the global mean observed greenhouse effect to the predicted one by the GE hypothesis.

The first obvious requirement to conduct such studies are the availability of global scale primary radiosonde observations. Readily available sources of the vertical temperature, water vapor and ozone structures are the world climate data centers and the national meteorological data archives.

In our validation efforts, we frequently used the following radiosonde data sets:

1. One full year of high-resolution soundings from the former NOAA testing facility in Sterling VA;
2. Two archives of global radiosonde observations between 1976 and 1989 (known as TIGR2, and TIGR2000);

3. 61 annual global mean sounding data from the NOAA-R1 archive for years 1948-2008.
4. Several simulations were also performed for the different versions of the US Standard Atmosphere 1976 (USST76, 1976).

Figure 2 compares the thermal and water vapor structures of the global mean TIGR2 and the USST76 atmospheres. Compared to the USST76 atmosphere, the significant differences in the vertical temperature and H_2O structures are obvious. Notice the USST76 tropospheric lapse rate is much higher, the isothermal stratosphere does not exist, and the H_2O column amount is about half of the global average. Unfortunately, global climatological data sets are also subject to deliberate data manipulations therefore extreme care is needed to identify a suitable archive.

The second obvious requirement is an adequate high quality RT software. The accuracy of a research RT code should not be restricted by speed requirements, vertical resolution, or absorption band structures common in radiative transfer modules in climate models.

Our choice was the High-resolution Atmospheric Radiative Transfer Code (HARTCODE) which was developed for extreme numerical accuracy (Miskolczi, 1989; Rizzi et al., 2002). Test computations shows HARTCODE adequately responds to the extremely small changes of the most important input parameters (Miskolczi, 2010). Comparisons of different RT codes – involving HARTCODE – and their validations are found in Kratz et al. (2005) and in Saunders et al. (2007).

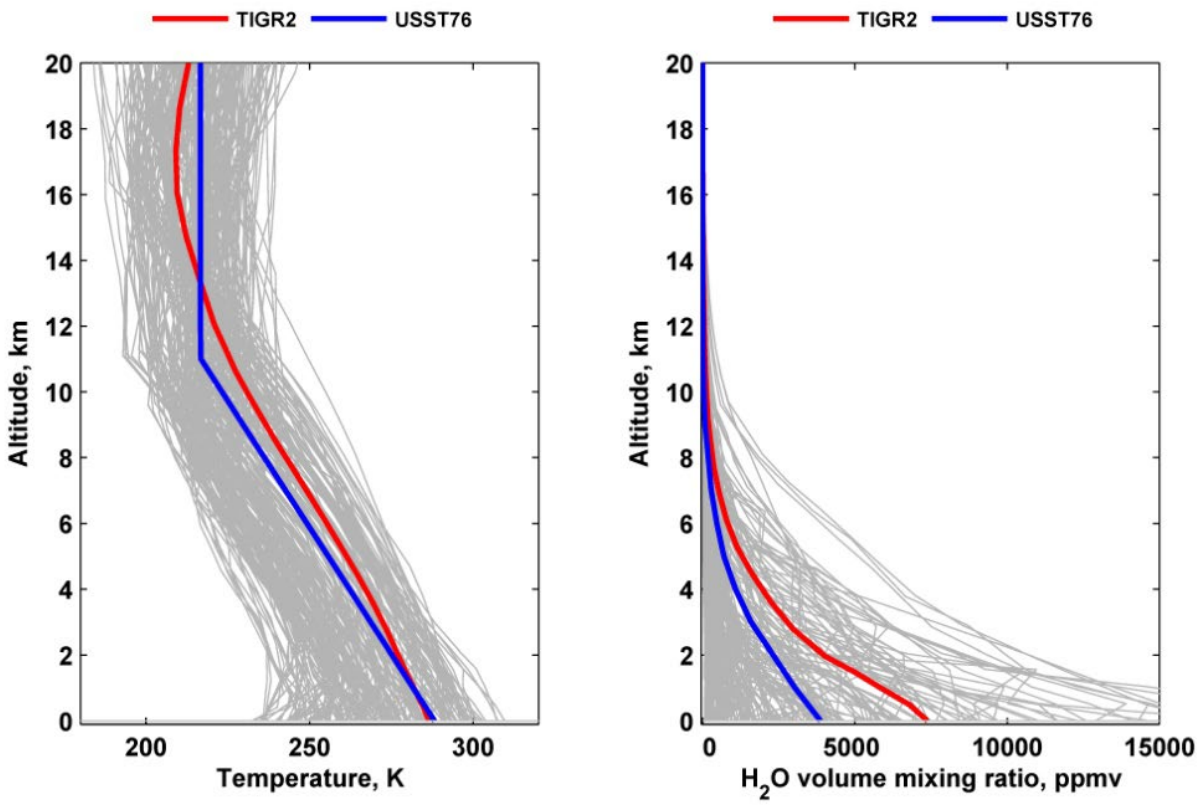

Figure 2. Comparisons of the vertical thermal and humidity profiles of the global average TIGR2 (GAT) and theUSST76 atmospheres. Thin gray lines are the individual radiosonde data as it was observed by the TIGR2 global radiosonde archive. One has to notice the significant differences between the averages in both the thermal and humidity profiles (blue and red lines). Such differences adversely affect the flux density simulations.

Further unique features of HARTCODE are the strict preservation of the monochromatic Beer-Lambert law, the Helmholtz reciprocity principle, and the spherical refractive computation of the directional transmittances through every optical path segments.

The spectroscopic details of the infrared flux transmittance and optical depth computations are presented in Miskolczi (2011, 2014).

Figure 3 shows the Helmholtz reciprocity principle for vertical and horizontal viewing geometries.

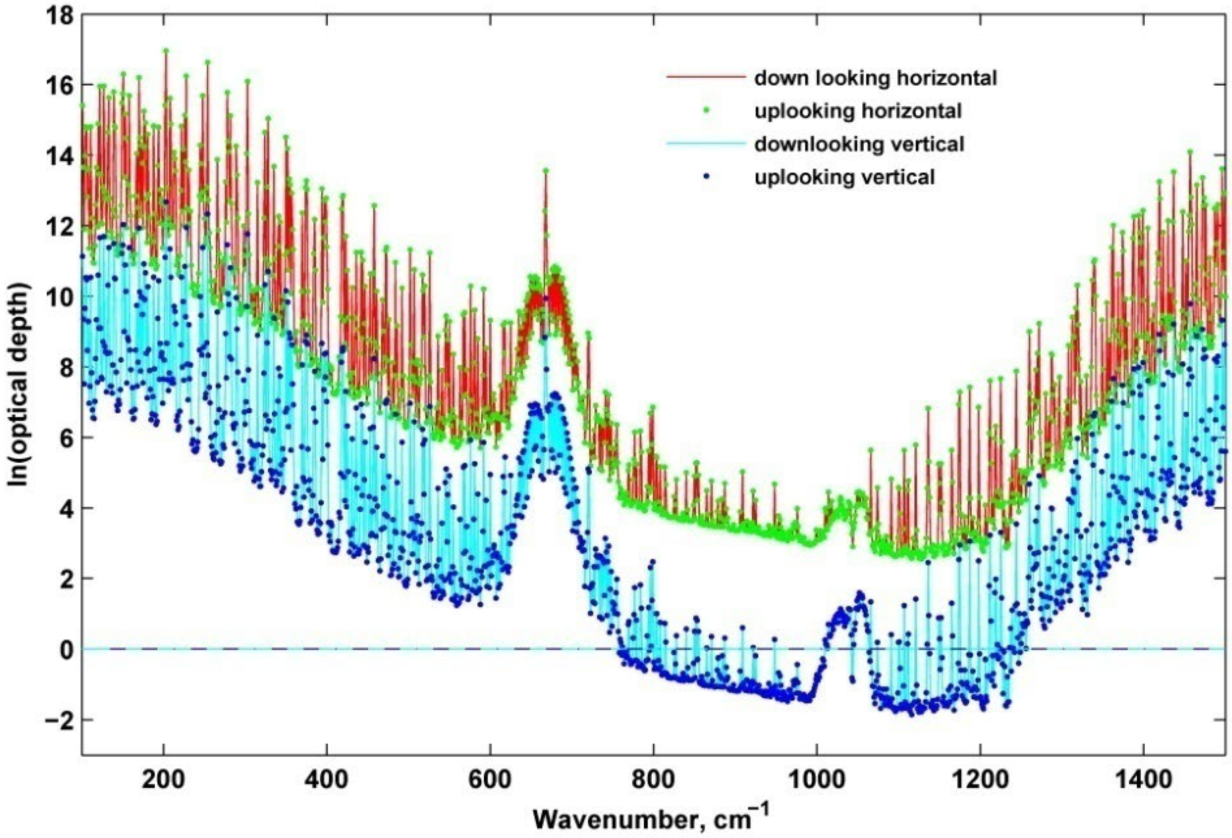

Figure 3. Helmholtz reciprocity principle requires the equal line of sight optical depth (and path transmittance) for every slanted atmospheric optical paths. This test considered vertical and horizontal viewing. High-resolution HARTCODE spectral optical depth computations perfectly reproduce the Helmholtz reciprocity principle. Note that the Helmholtz principle is not valid for spherically integrated (hemispheric) flux optical depths.

2.2 Flux density components

The average planetary climate – as a set of scalar climate parameters – assumes an extensive global average cloud cover with a characteristic global average cloud altitude. The global average cloud cover breaks up the IR planetary radiation field into three major regions.

Figure 4 shows **t**he three regions (red, blue, and green shaded areas), and the definitions of the flux density components of interest.

From computational point of view – for obtaining accurate flux density components at the external and internal boundaries of the planet – a spherical refractive line-by-line (LBL) flux code should operate over three spherical shell sectors with sufficient vertical, angular, and wavenumber resolution and for about a thousand atmospheric structures from global radiosonde locations. Such complexity of computations is far beyond the capability of any publicly available LBL code, and any climate radiative transfer module built into general circulation models (GCMs).

Figure 4 shows the transmitted, absorbed, upward, and downward emitted and lower boundary fluxes in the three regions: S_T, A_A, E_U, E_D, and S_U (clear-sky, red shading), S_T^C, A_A^C, E_U^C, E_D^C, and S_U^C (above cloud, blue shading), S_T^{Cu}, A_A^{Cu}, and E_U^{Cu}, and S_U (below cloud upward, green area), S_T^{Cd}, A_A^{Cd}, E_D^{Cd}, and S_D^C (below cloud downward, green area). The reference altitude is at $z_0 = 0.0$ km, the TOA altitude is at $z_{top} = 70.0$ km and the top of the equilibrium global average cloud cover is at $h^C = 1.916$ km.

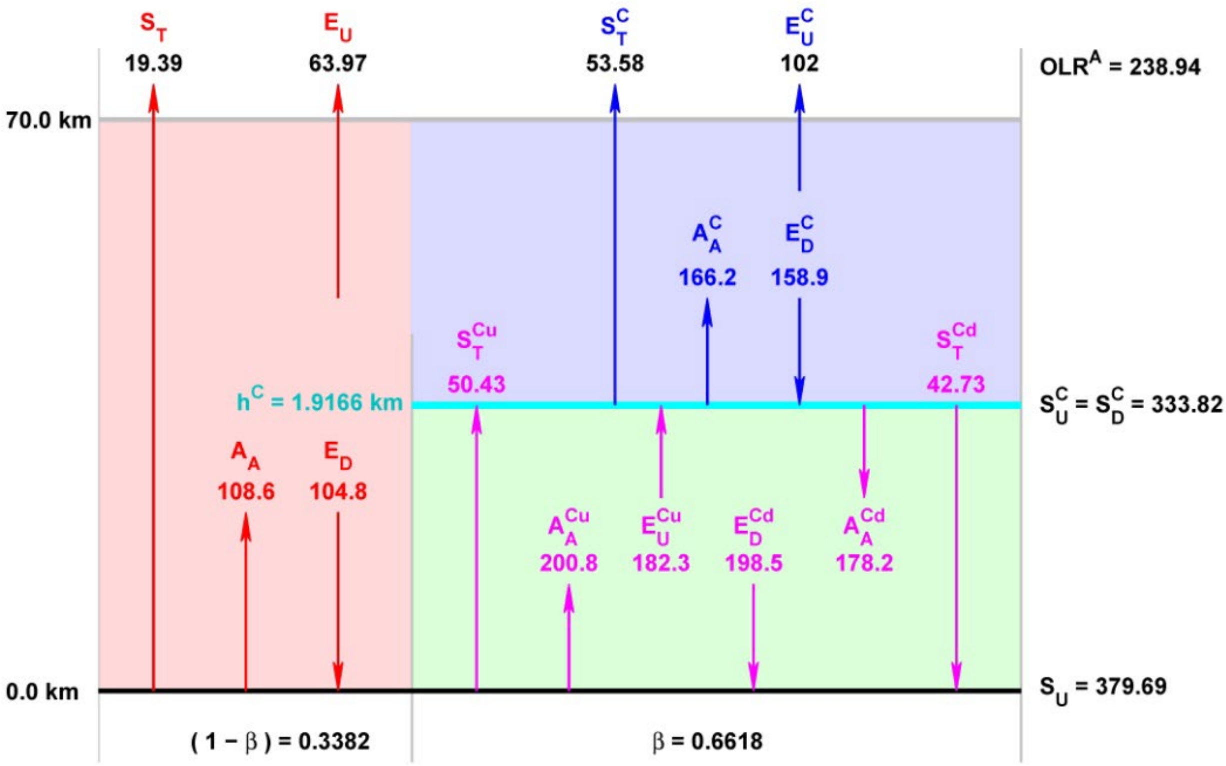

Figure 4. All-sky IR radiative flux components (Wm^{-2}). The red, blue and green regions represent the sum of the clear, above cloud, and below cloud portions (spherical shell sectors) of the atmosphere. This view is not a simplified

model; the flux density arrows are the real global mean fluxes of a spherical refractive atmosphere as derived from the TIGR2 global radiosonde archive. TOA fluxes are referenced to 70 km altitude; all other fluxes are referenced to the ground surface. The numerical accuracy of the flux density components are five significant digits.

The downward upper boundary fluxes at the clear and above cloud regions are zero. Surface fluxes may be referenced to the TOA by applying an s_C spherical correction: $s_C \approx R_E^2 / (R_E + z_{top})^2 = 0.97838$ where $R_E = 6371000$ m is the volumetric radius of the Earth. Due to refraction (and the related vertical layering) the accurate computation of s_C is far more complex and results in an $s_C = 0.978918$ (0.0547 % larger) value, which corresponds to an effective altitude of $z_{top}^e = 68.236$ km.

In cloud free areas, the ground surface (having a global average thermodynamic temperature t_G) and the semi-transparent atmosphere above (with an average GHG and thermal structure) can directly and freely cool to space. The same is true above an average planetary cloud cover, but with different lower boundary condition. The combined lower boundaries of these two regions constitute the active planetary surface of the Earth. In the third region (below the cloud cover) the IR radiation cannot escape to space and cannot contribute directly to the planetary RE. Among the flux density components, the

$$OLR = S_T + E_U$$

$$OLR^C = S_T^C + E_U^C$$

$$OLR^{Cu} = S_T^{Cu} + E_U^{Cu}$$

$$OLR^{Cd} = S_T^{Cd} + E_D^{Cd}$$

relationships must hold where,

OLR is the clear sky OLR,

OLR^C is the cloudy sky OLR,

OLR^{Cu} and OLR^{Cd} are the upward and downward LW radiation below the cloud layer, respectively.

According to the long-term steady-state requirement there cannot be any accumulation of direct radiant energy in any of the three regions. However, unlimited transfers of radiant energy to-and-from the global latent heat reservoirs are permitted (as it happens in the real environment through the phase boundaries).

The most important conclusion of our computations is the solid empirical proof of the existence of the assumed steady state planetary RE. The key planetary IR fluxes from the active planetary surface are:

$$OLR^A = (1-\beta)(S_T + E_U) + \beta(S_T^C + E_U^C) = 238.94 \text{ Wm}^{-2}$$

$$S_U^A = S_U(1-\beta) + S_U^C\beta = 341.98 \text{ Wm}^{-2}.$$

The astrophysical textbook value of the effective planetary surface radiative temperature is

$$t_G = (16\pi\sigma d_E^2 / L_0^T)^{-1/4} = 278.683 \text{ K}$$

which is in perfect agreement with the mean all-sky surface temperature of the APS from radiosonde observations:

$$t_S = (S_U^A / \sigma)^{1/4} = 278.68 \text{ K}.$$

Here,

$L_0^T = (2/5)\pi^{4/3}\sigma^{-1/3}d_E^{8/3}r_0^{-2/3}$ is our theoretical solar luminosity,

d_E is the semi-major axis of the Earth's orbit, and

r_0 is the solar radius (both are in meters).

From the observed fluxes, the Bond albedo and the cloud cover may also be easily deduced:

$$\beta = (S_U^A / sc - S_U) / (S_U^C - S_U) = 0.6615$$

and

$$\alpha_B = 1 - OLR^A / S_U^A = 0.3013 .$$

From about thirteen years (1976-1989) of radiosonde observations, the indirectly derived solar constant is

$$F_0^{obs} = 4S_U^A = 4OLR^A / (1 - \alpha_B) = 1367.93 \text{ Wm}^{-2}.$$

Later we shall see that F_0^{obs} is also in perfect agreement with the F_0^T theoretical solar constant of

$$F_0^T = 1367.9514 \text{ Wm}^{-2}.$$

2.3. RT functions and the global mean flux optical thickness

From large scale simulations (involving the TIGR2, TIGR2000, NOAA-R1 and NOAA-S radiosonde archives) we gained enough confidence to conclude the Earth's long time global mean flux optical thickness $\overline{\tau}_A$ is equal to a theoretically predictable universal constant τ^T :

$$\overline{\tau}_A = \tau^T = 1.86756$$

Figure 5 shows the fundamental radiative transfer functions and the normalized upward atmospheric emissions for about a thousand weather balloon observations. Radiosonde observations show the $E = E_U / S_U$ ratios and the optical depth τ_A are theoretically constrained by the radiative transfer functions.

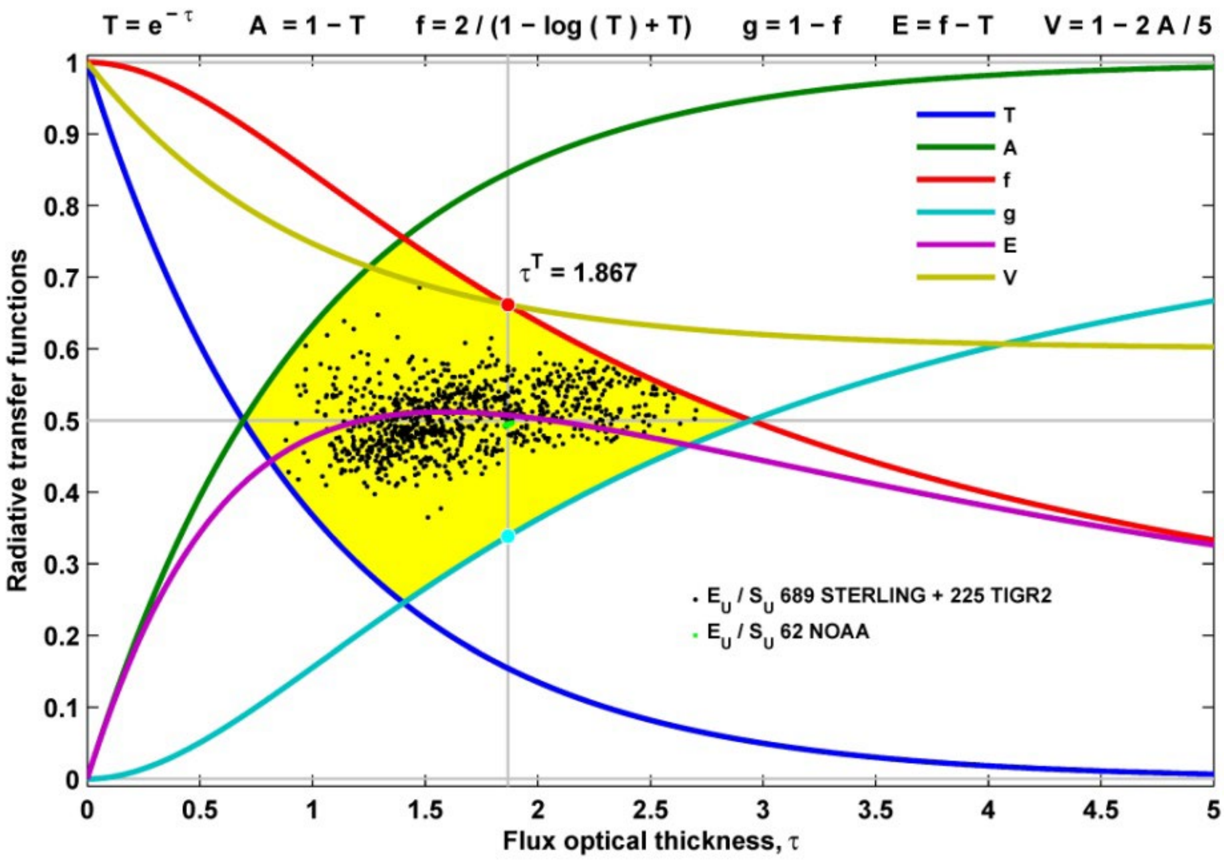

Figure 5. Radiative transfer functions. Here T, A, f, g, E, and V are the transmission, absorption, transfer, greenhouse, emission and virial functions respectively.

The theoretical τ^T may be computed from

$$f(\tau_A) = V(\tau_A)$$ (red dot)

or from

$$g(\tau_A) = 2A(\tau_A)/5$$ (light blue dot)

The definition of the $V(\tau_A)$ virial function is:

$$V(\tau_A) = 1 - 2A/5$$

The theoretical equilibrium optical depth is the natural constraint on the equilibrium mass of the condensing GHG (water vapor) in the atmosphere.

The average τ_A of the NOAA-R1 annual global means (green dots) and τ_A of the GAT atmosphere are equal to τ^T .

Figure 6 shows how the constancy of the IR flux optical depth is maintained in each and every randomly selected subsets of different length from a 61 year long NOAA-R1 time series.

The increase of the atmospheric carbon dioxide in the studied NOAA-R1 time series is apparently coupled with the decrease of the atmospheric water vapor column amount.

Figure 6 plots the CO_2 and H_2O normalized column amounts for the 1948-2008-time interval.

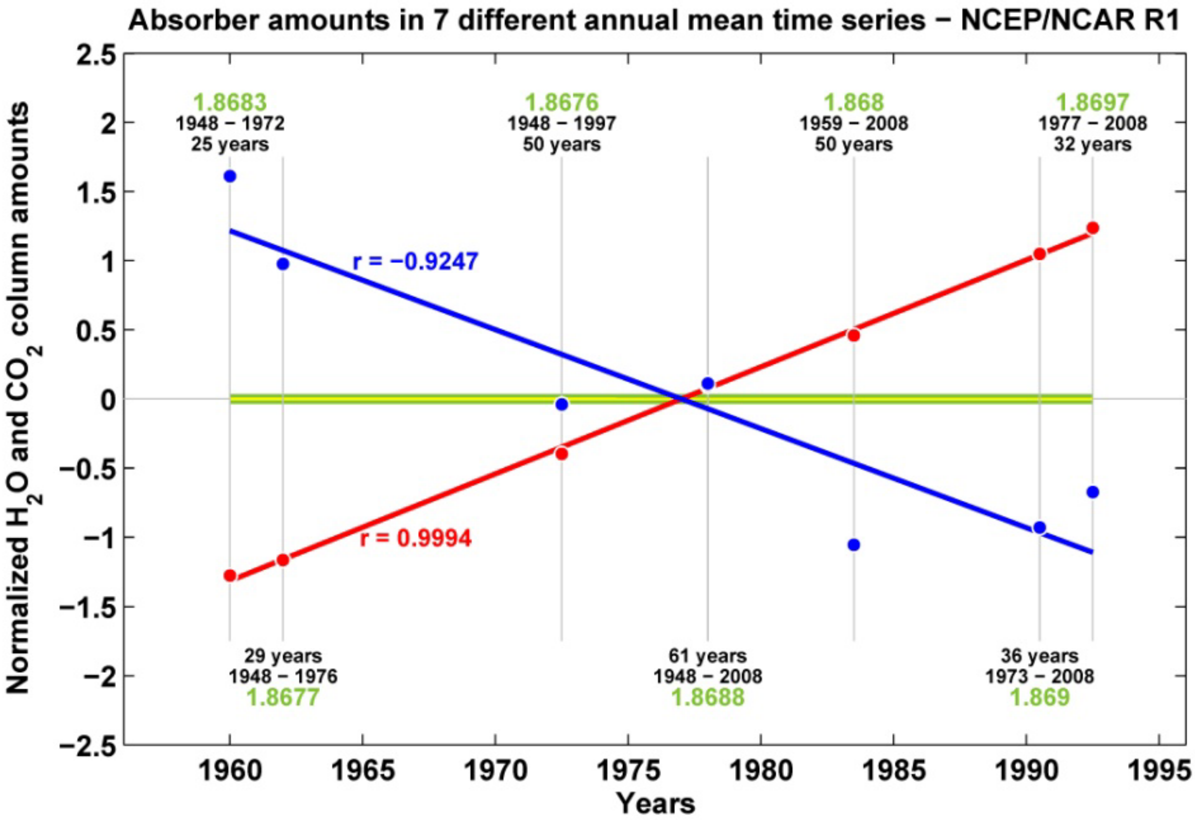

Figure 6. Changes of H_2O (blue) and CO_2 (red) column amounts in 7 different time series. Data are from the NOAA-R1 radiosonde archive.

Figure 7 …..

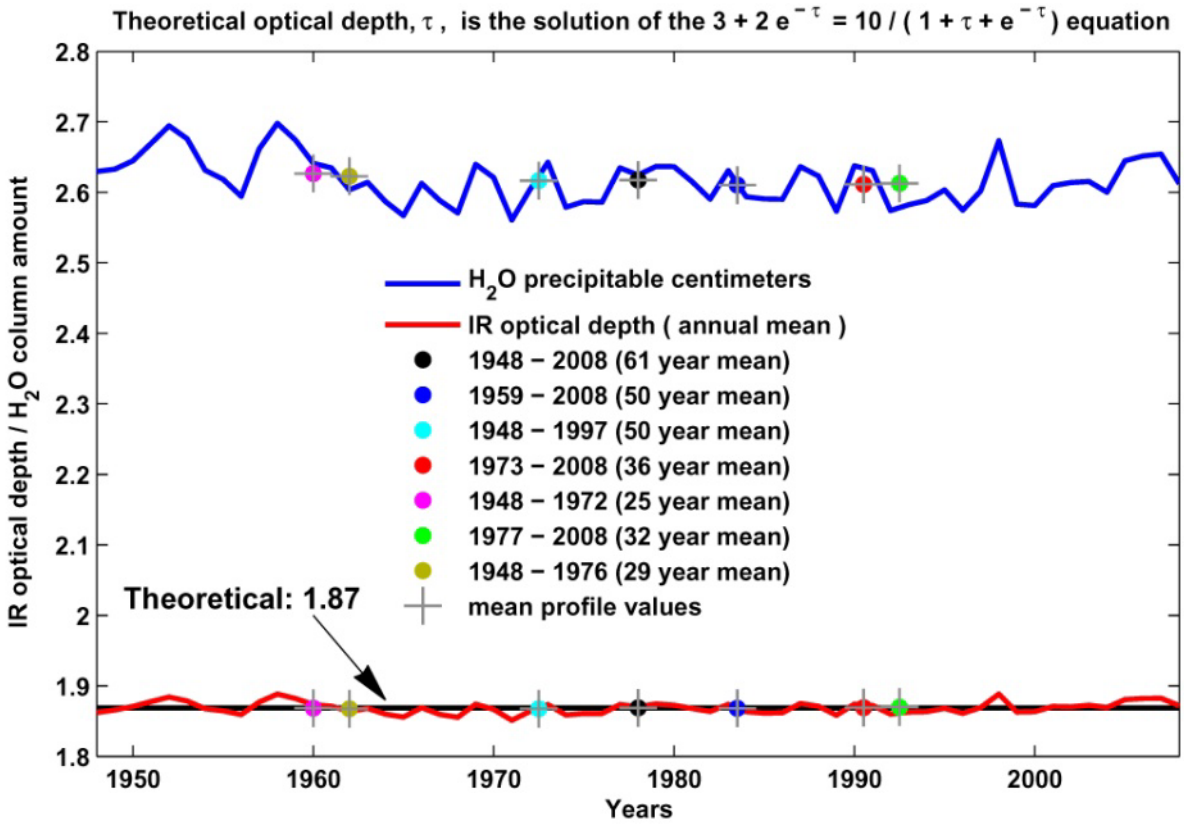

Figure 7. The constancy of the annual mean flux optical depth in seven time series of different length (NOAA-R1 radiosonde archive). The H_2O column amounts are in prcm.

Figure 7 shows the constancy of the flux optical depth and the H_2O column amount. The random fluctuation in the IR optical depths (red line) correlate well with the H_2O column amounts (blue line). The constancy of the flux optical depth is coupled with the constancy of the water vapor content of the air column. The sample means (colored dots) are practically equal to the mean profile values (+ symbols) which is an indication that a single column average atmospheric structure can safely be used instead of the global average fluxes from a large data set.

Table 1 shows the IR flux optical depth has no correlation with time and a strong signal of increasing atmospheric CO_2 content in any time series is not present in the IR flux optical depth data. Consequently, the atmospheric CO_2 increase cannot be the cause of global warming.

Table 1. Trend line correlation summary of seven NOAA-R1 time series. The last five columns on the right are linear regression coefficients for the top altitude of the air column, surface temperature, water vapor and carbon dioxide column amounts, and the flux optical depth.

Time period	Centre	Years	Altitude	Temperature	H_2O	CO_2	Tau
1948–2008	1978	61	0.7931	0.8183	−0.2841	0.9839	0.06488
1959–2008	1983.5	50	0.8059	0.8349	0.04499	0.9937	0.2976
1948–1997	1972.5	50	0.6621	0.6625	−0.4843	0.9827	−0.2284
1973–2008	1990.5	36	0.6947	0.7987	0.1148	0.9974	0.3491
1948–1972	1960	25	−0.005748	0.1731	−0.5907	0.983	−0.4184
1977–2008	1992.5	32	0.58	0.7424	0.03992	0.9973	0.267
1948–1976	1962	29	0.001769	0.0584	−0.6048	0.9804	−0.4396

Table 1 shows the detailed numerical data of the regression analysis of the key variables – altitude, temperature, H_2O, CO_2, and flux optical depth. According to **Figures 5**, **6**, and **7**, the long-term global mean OLR and S_U cannot change independently.

The sign of the H_2O regression coefficient in **Figure 7** (blue color) indicates the climate stabilizing role of H_2O. The green and yellow trend lines (deviations from the sample mean and deviations from the $\tau^T = 1.867$ theoretical value show no tendency.

Based on the NOAA-R1 soundings and simulations **Figure 8** shows the no-feedback response and the true observed changes of the OLR in the 200-1500 cm^{-1} spectral range. In **Figure 9** the chaotic structure of the upper tropospheric humidity field is presented, (McIDAS, 2008). Evidently, to find the solution of the global mean radiation climate (or the GHG GE) is not an appropriate task for GCMs.

More details are presented in **Figure 10** where the no-feedback responses of some other GHGs are also displayed. There is no such thing that the OLR remains constant and the surface warms up due to some incorrect GHG GE hypothesis, or because of the outcomes of CO_2 doubling experiments conducted with never validated GCMs. The Intergovernmental Panel on Climate Change (IPCC) ignores the fact that the clear-sky OLR is governed by the unpredictable stochastic nature of the upper tropospheric humidity field (and the global cloudiness) which cannot be modeled by any (deterministic) global climate model.

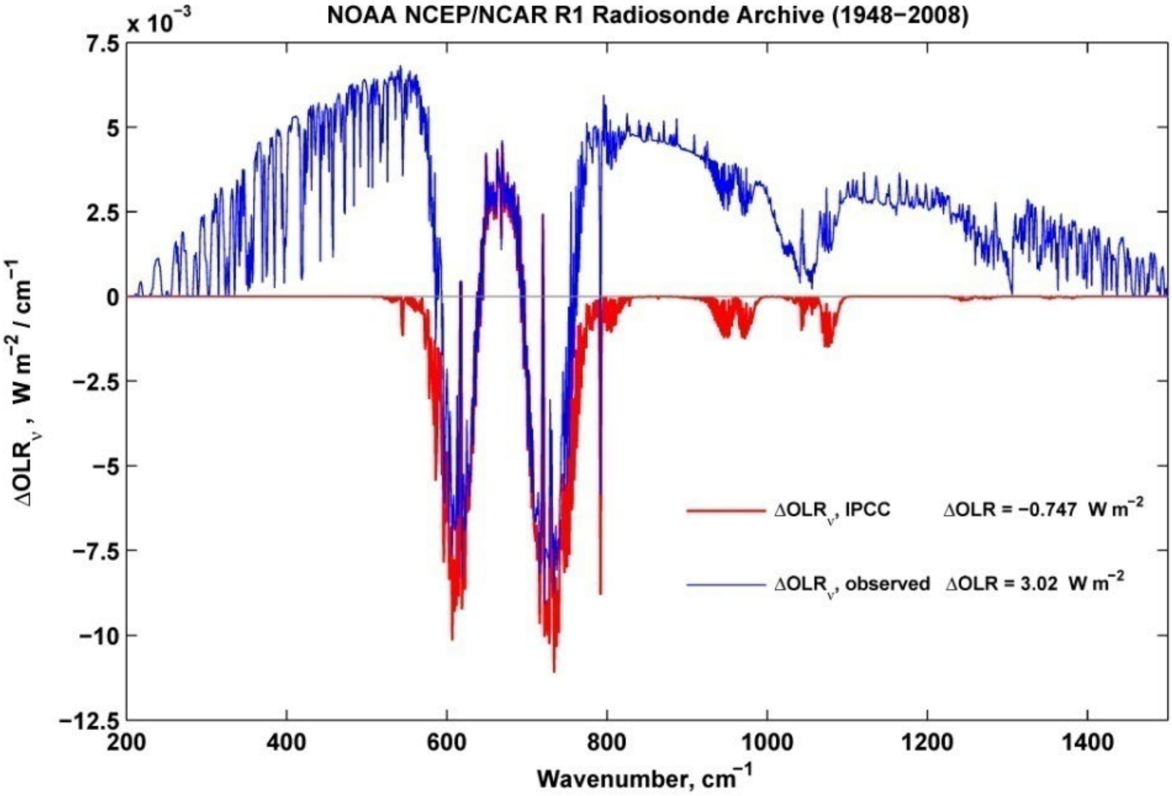

Figure 8. Comparison of the observed and expected changes in the clear-sky spectral OLR. The IPCC type no-feedback response to 23.56% increase in carbon dioxide is negative. The real atmosphere does not follow the GHG GE hypothesis of the IPCC. The observed true change in the OLR is positive and the atmosphere and the whole system does not resume the initial state. The fictitious no-feedback response is unrelated to climate change.

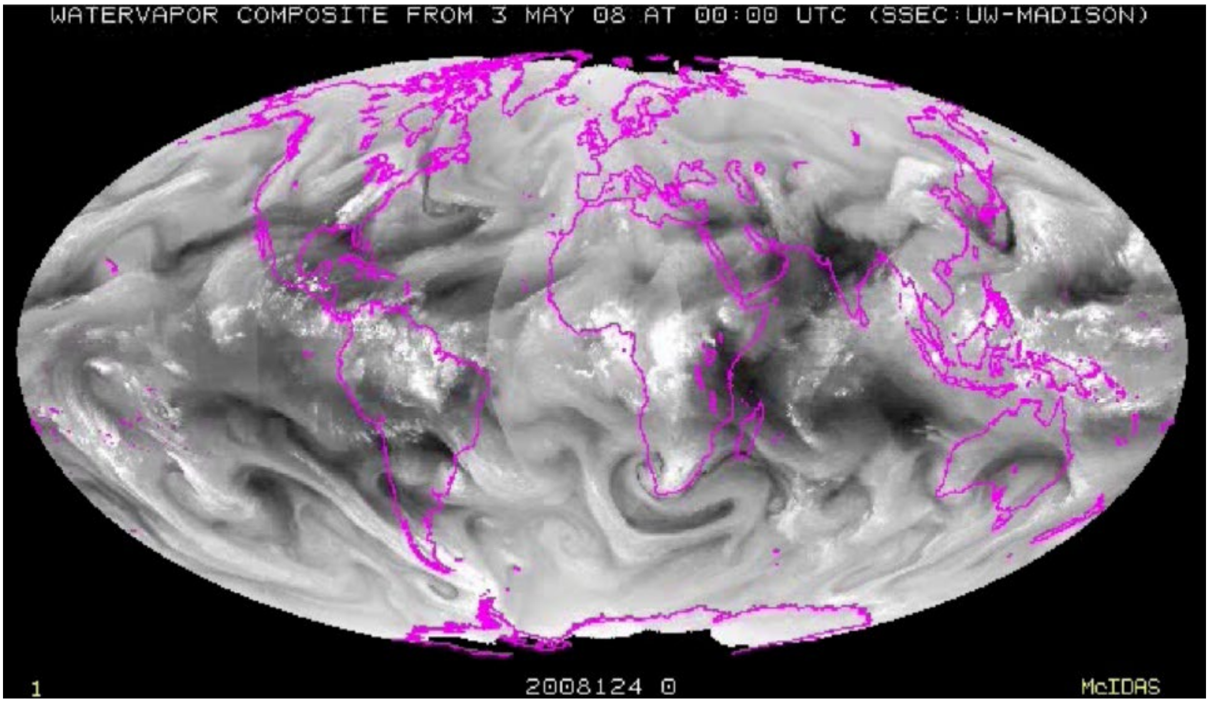

Figure 9. Satellite view of the changes in the upper tropospheric humidity field.

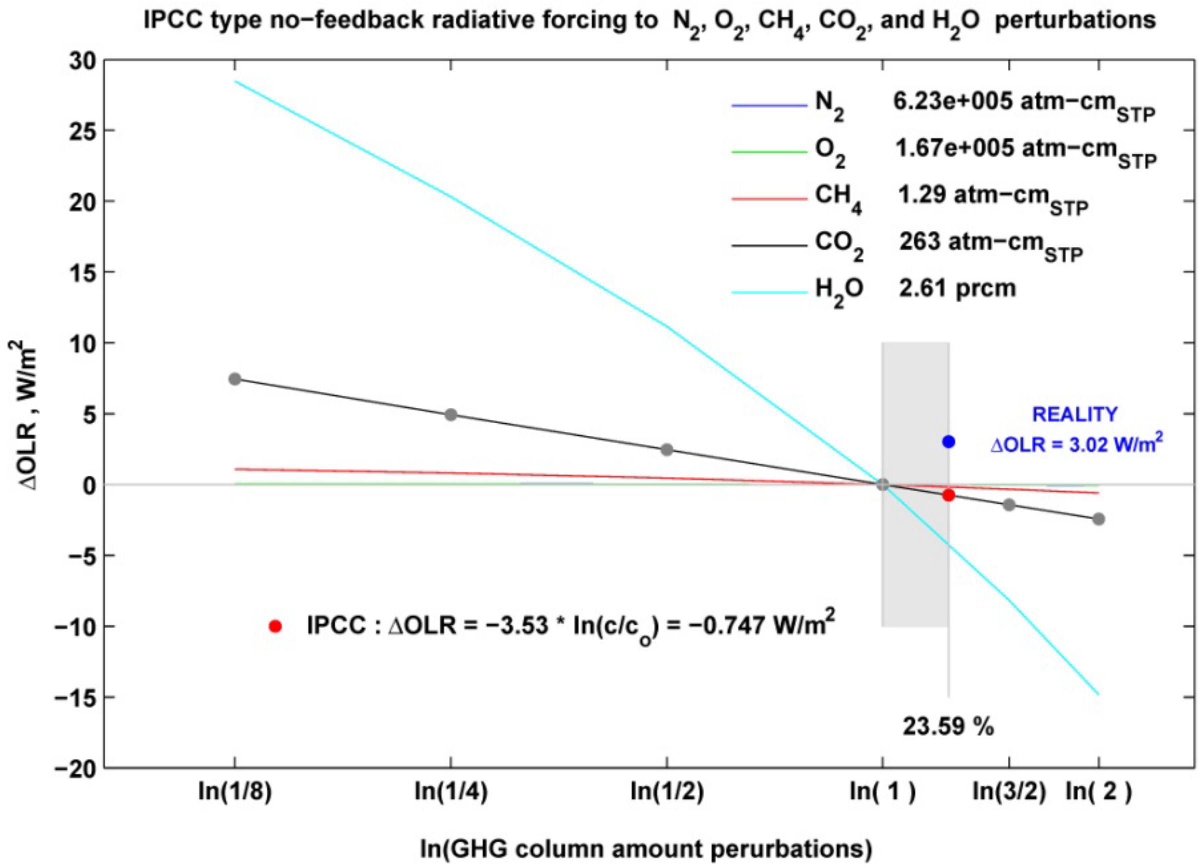

Figure 10. HARTCODE GHG perturbation study shows that at the TOA the no-feedback response of increased atmospheric CO_2 is negative. The observed 23.6 % increase in CO_2 column amount causes -0.75 Wm^{-2} radiative imbalance (red dot). In the same time period, based on the NOAA-R1 archive the real change is 3.02 Wm^{-2} (blue dot). The changes of OLR due to the pressure induced continuum absorption of N_2 and O_2 are negligible.

The global mean atmospheric IR emission to space is controlled by the chaotic changes of the humidity field. GCMs are unable to model the stochastic nature of the radiation climate. The theoretical constraints governing the global mean radiation flux components are also not part of the GCMs.

3. The scientific background

3.1. The Sun

It should be recognized that the Sun is a very complex object, and the solar constant has its own natural fluctuations. Depending on the state of the Sun F_0 may vary (on different time scales) between $F_0^{\min} = 1359.7$ and $F_0^{\max} = 1376.2$ Wm^{-2} introducing 1.2% (quasi-periodic) changes in the short term averages, (Berk et al. 2008).

From $F_0^{\min}$ and $F_0^{\max}$ the arithmetic average is $F_0^{av} = 1367.95$ Wm^{-2}, which is very close to the established long term average of 1368 Wm^{-2} from ground based observations. It is not very wise to declare an official solar constant and continuously upgrade it according to the relatively short-term satellite observations. Even NASA warns that their data in the (NASA 2016) are approximations and they are not appropriate for scientific use. The data are usually given in three or four significant digits and they cannot be consistent with the known physical laws of nature where the key astronomical information and the most fundamental constants of the theoretical physics are given with 10-50 ppm relative accuracy.

Sun is the source of the observable radiative and not directly observable entropy flux densities and their specific intensity, radiance or brightness counterparts. We have found that the theoretical solar constant may be derived from the next theoretical equation:

$$F(d) = (\pi / \sigma)^{1/3} d_E^{8/3} r_0^{-2/3} d^{-2} / 10$$

where,

$F(d)$ is the flux density in Wm^{-2}

d is the distance from the center of the Sun in meters.

In this universal function d may vary from inside the Sun to anywhere in the solar system. This equation stems from the temperature-flux density duality principle which rests on an intrinsic mathematical property of the Planck distribution (Miskolczi, & Héjjas, 2021).

The theoretical solar luminosity, solar surface emission, solar constant and the available SW flux density may easily be computed from $F(d)$:

$$L_0^T = 4\pi^{4/3}\sigma^{-1/3}d_E^{8/3}r_0^{-2/3}/10$$

$$E_0^T = (\pi/\sigma)^{1/3}(d_E/r_0)^{8/3}/10$$

$$F_0^T = (\pi/\sigma)^{1/3}(d_E/r_0)^{2/3}/10$$

$$F_E^T = F_0^T/4$$

The theoretical solar constant and the available SW radiation over a unit area at the TOA are:

$$F_0^T = 1367.95145 \text{ Wm}^{-2}$$

$$F_E^T = 341.98785 \text{ Wm}^{-2}.$$

The diluted theoretical solar entropy flux density

$$(4/3)\sigma T_{SUN}^3(r_0/d_E)^2 = (4/3)(\pi\times 10^{-3})^{1/4} = 0.31566483 \text{ Wm}^{-2}\text{K}^{-1}$$

which is a mathematical constant. The theoretical solar surface temperature equals

$$T_{SUN} = (E_0^T/\sigma)^{1/4} = 5778.0754 \text{ K}$$

The very important point here is the fact that the $F(d)$ theoretical function depends only on geometrical factors (the solar radius and the semi-major axis of the orbit of the Earth) and of course, independent of any short term or long-term satellite or ground based radiation measurements. Consequently, debate on the theoretical F_0^T solar constant should be restricted to the debate on the accuracy of r_0, and d_E.

Of course, the barycenter of the solar system and the steady state center of the Sun (as a fixed geometrical point) does not exist. Sun is not a fixed perfect sphere but a rotating and pulsating gas globe that is subject to gravitational perturbations from other members of the solar system. This physical reality reflected in the singularity of the $F(d)$ function at $d \equiv 0$ where $F(0) = \infty$.

The reference solar constant F_0^T is mathematically consistent with the radiation laws and the known accuracies of the Planck and Boltzmann constants from NIST. It is also consistent with the most accurate values of r_0, and d_E, and with the spectral solar constant of Chance and Kurucz (2010).

The existence of the theoretical solar constant does not support the idea of introducing a new standard solar constant (and the backward correction of previous standards) based on purely the newest satellite observations. The accuracy of flux density or radiance measurements will never conquer the accuracy of the measurements of distance, linear size or time.

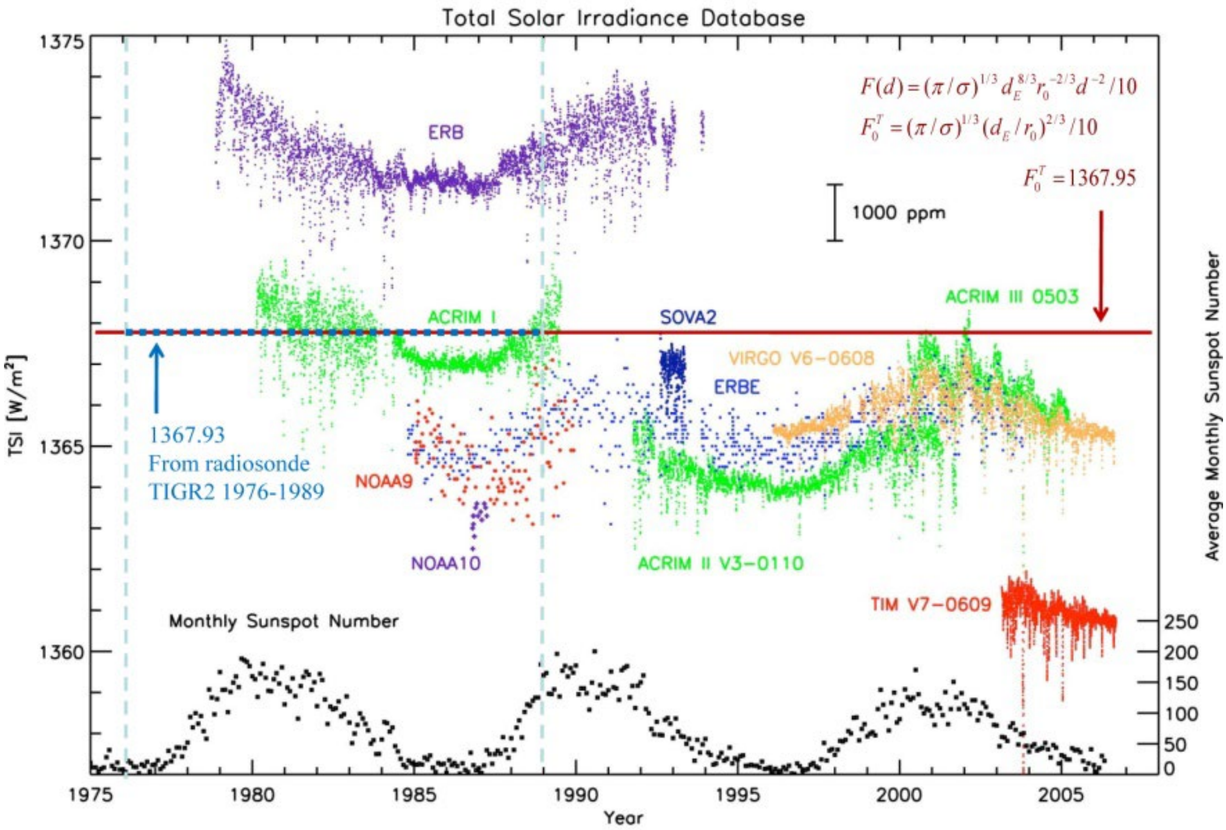

Figure 11. Comparisons of the theoretical solar constant with direct satellite observations, and with LW flux density simulations from the TIGR2 archive. The blue dotted line is at $F_0^{obs}=4S_U^A$, and S_U^A is the all-sky global mean surface upward flux density from the active planetary surface. The $F_0^{obs}=F_0^T=F_0^{av}$ is the indication of strict planetary radiative equilibrium. Total solar irradiance, TSI and the other fluxes are in Wm^{-2}.)

The extreme stability of the climate over millions of years is obviously based on the existence of the F_0^T theoretical solar constant. In **Figure 11** F_0^T is compared to the observed F_0^{obs} (quoted under paragraph **2.3**), and the newest satellite observations from Kopp and Lean, 2011. The $F_0^T=F_0^{obs}=F_0^{av}$ equality means that the planet is in strict radiative equilibrium with the theoretical solar constant.

3.2. Greenhouse gas greenhouse effect

Recently there is a serious problem with the use of the classic definition of the GHG GE. The ambiguity arises from the fact that some scientists recognized that the classic GHG greenhouse effect cannot be discussed without the presence of the global cloud cover and started to use the greenhouse effect terminology in a generalized way, including the cloud effect, see Lacis, et al., 2010, Schmidt, et al., 2010. This confusion should be avoided, CO_2 is a greenhouse gas and not a solid or liquid substance.

There is another serious problem with the classic definition, namely the use of the ground surface thermodynamic temperature and assume a perfectly black surface. In reality the ground surface is not black, and what we need to put into the SB law is the true t_S radiative temperature. If there is no cloud cover present in an air column one has to talk about the clear-sky greenhouse effect, and in fact that is what we are interested in.

Radiosonde observations show that $t_S = 286.06$ K and the physically meaningful GHG Δt and G at the ground are: $\Delta t = 27.9$ K, and $G = 127.9$ Wm^{-2}. In **Figure 12** the vertical contribution to the clear-sky G factor is demonstrated. In the figure on the right side the slightly larger cumulative G values (ΔG ~0.6 Wm^{-2}) originate from rounding errors in the vertical resolution of the layering routines in the RT software.

Here the different computations of the G factor gives consistent results. However, G_R from Raval & Ramanathan, 1989 or Ramanathan & Inamdar, 2006 shows large discrepancy (about 20 Wm^{-2} overestimate). The cause is the incorrect mathematical representation of GF, (see for example equations 1 & 2 in Raval & Ramanathan, 1989 Nature article).

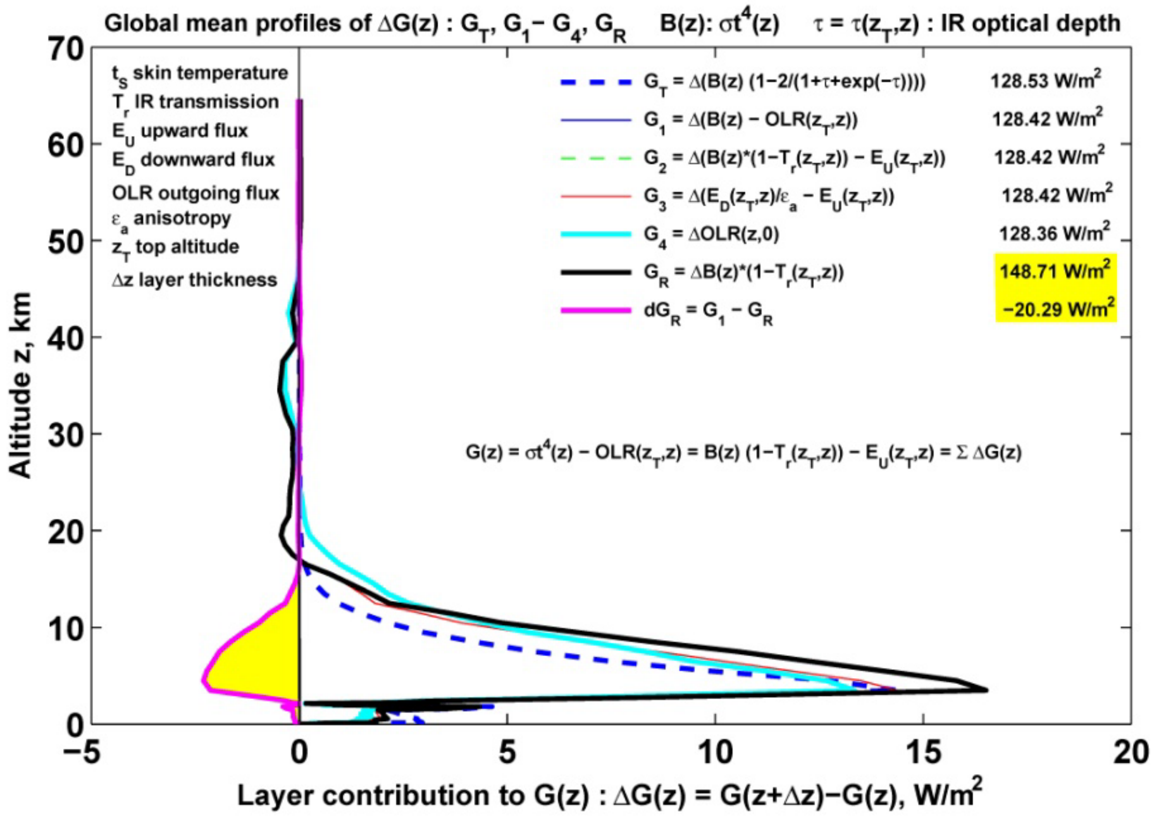

Figure 12. Layer contributions to the greenhouse factor. Except G_R the different greenhouse factors are in good agreement.

3.3. Cloud effect

Theoretically steady state RE of non-condensing GHG atmosphere of a passive planet cannot exist, since the ground surface of such planet would cool down freely to the astronomical limiting temperature dependent partly on the local solar constant and Bond albedo, and partly on the outward diffusion of thermal energy from the planetary interior. In the special case of Earth, the astronomical limiting temperature is practically equal to the temperature of the triple point of H_2O. In other word, at some (sufficiently low) temperature any gas will become a condensing GHG, therefore, without the presence of condensing GHGs in the system there is no atmosphere at all.

The above concept is fully consistent with observations of atmospheres of comets and planets in the solar system. A comet starts to build up atmosphere when getting closer to the Sun and the surface materials start to evaporate. On the reverse trajectory when getting farther from the Sun the atmosphere condenses back to the surface and disappears.

Atmospheres with condensing GHGs might have several internal boundaries (cloud layers) at different altitudes which instantly disrupt the propagation of the electromagnetic radiation, consequently, the global mean cloud cover is the major factor in establishing and maintaining the planetary radiative balance. Note that in gas phase the spectral gas absorption is restricted to certain spectral ranges characteristic of the molecular structure of a particular GHG.

In the interesting case of the thin Martian CO_2 atmosphere – due to the lack of cloud cover – we can only speak of clear-sky GE. The Martian atmosphere contains 33.3 times more CO_2 but the GE is only about ~3 K, indicating that the amount of CO_2 is not a major factor in creating the Martian GE. Compared to the ~2.61 prcm of water vapor in the Earth's atmosphere, the Martian atmosphere contains a negligible amount of water vapor, approximately 0.00155 prcm, which is insufficient to form extensive cloud cover and significantly increase GE and GF. In the Martian carbon dioxide atmosphere, the planetary RE is maintained by the diurnal changes of the mass of the GHG atmosphere and the heat (released or received) at the lower boundary by the phase changes of the CO_2. One has to conclude that the Earth's clear-sky GE cannot be explained by the CO_2 content of the atmosphere. GE are closely related to the amount of condensing greenhouse gases and their physical state.

In the hot and thick atmosphere of the Venus the complex, fully closed multi-layer cloud structure completely de-couples the IR radiation field of the ground surface from the OLR. Below the closed cloud layers, the IR radiation field is a type of cavity radiation in RE. The planetary RE is maintained solely by the radiation from the cloud top (at an effective cloud top altitude) and the atmosphere above.

The formation and functioning of the greenhouse effect is quite different on the three planets, due to the dramatically different roles of the atmospheric composition, clouds and surface. In **Figure 13** the GE of the Martian atmosphere is compared to the GE in the Earth's atmosphere.

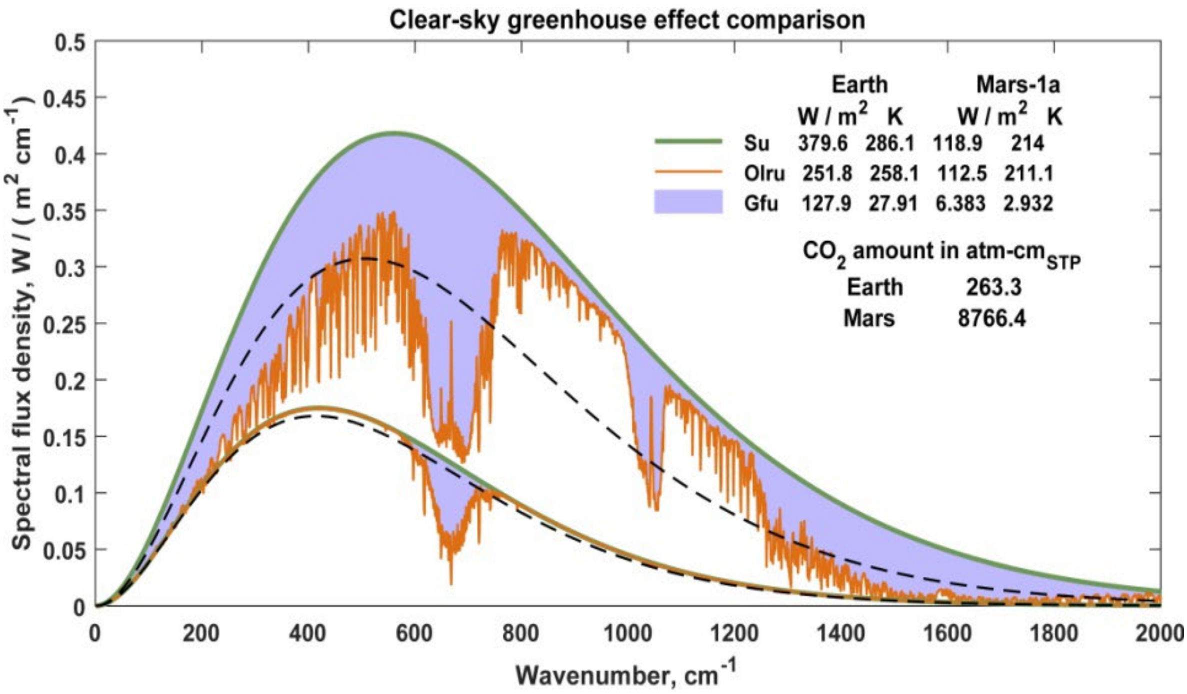

Figure 13. Greenhouse effect on Earth and Mars. The clear sky GH, $(S_U/\sigma)^{1/4}-(OLR_U/\sigma)^{1/4}$ and GF , S_U-OLR_U are not controlled by the CO_2 content of the atmosphere.

$$F_A = (1-\beta^A)\,OLR + \beta^A\,OLR^C$$

$$F_E = (1-\beta^E)\,S_U + \beta^E S_U^C$$

$$\beta^A(F_A, h^C) = (F_A - OLR)\,/\,(OLR^C(h^C) - OLR)$$

$$\beta^E(F_E, h^C) = (F_E - S_U)\,/\,(S_U^C(h^C) - S_U)$$

$$F_A = (1-\alpha_B)F_E$$

$$\min(\,\|\,\beta^A(h^C,\alpha_B) - \beta^E(h^C,\alpha_B)\,\|^2\,)$$

Figure 14. Radiative equilibrium cloud cover constraints. At the TOA LW fluxes from the APS must be equal to F_E , the all-sky outgoing LW radiation must be equal to F_A , and the cloud covers from the two constraints must be equal.

In section **1.2.** it was shown that the planetary radiative equilibrium cannot be established without involving the cloud cover into the greenhouse problem. The concept of the numerical evaluation of the equilibrium cloud cover is presented in **Figure 14**. Here we define the $\beta^{A}(F_{A},h^{C})$ and $\beta^{E}(F_{E},h^{C})$ global mean cloud covers relevant to the TOA and APS radiative balance requirements. From a set of β^{A} and β^{E} (computed for large number of different α_{B} and h^{C}) and using a multi-parameter optimization algorithm the global average α_{B} and h^{C} can be calculated. In the two-dimensional optimization problem, only one global average cloud layer is assumed, and the norm of $\| \beta^{A}-\beta^{E} \|$ is to be minimized, see **Figure 15**.

From a 20-year long time series data of ISCCP–D2 in Van Andel (2010) a global mean of 66.38 +/− 1.48 % was reported. In **Figure 16** satellite cloud climatology data are in excellent agreement with our theoretical cloud cover of $\beta = 0.6618$. As a computational detail, the accuracy of our global average cloud cover largely depends on the vertical resolution of the LBL code used. In our case around 2 km altitude the layer thickness was set to 40 m.

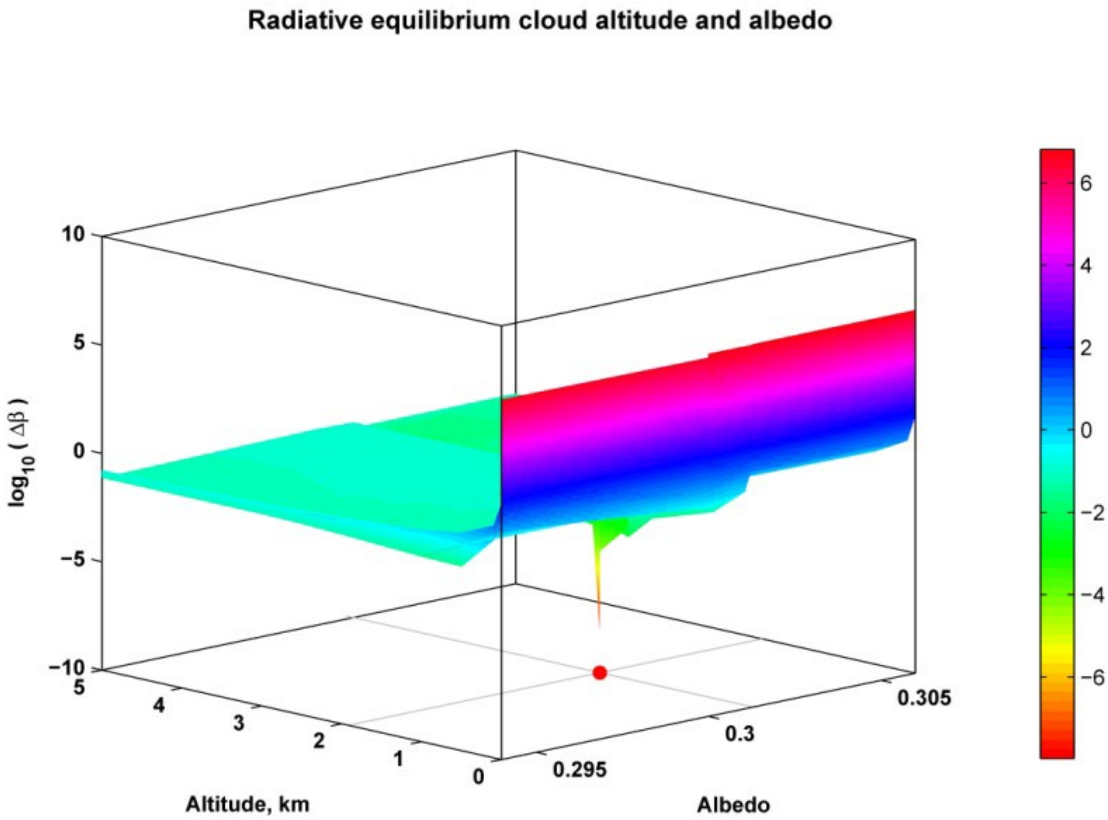

Figure 15. The multi-parameter optimization algorithm. Sharp minimum of the $\| \beta^A - \beta^E \|$ found at $\alpha_B = 0.3013$ and $h^C = 1.9166$ km.

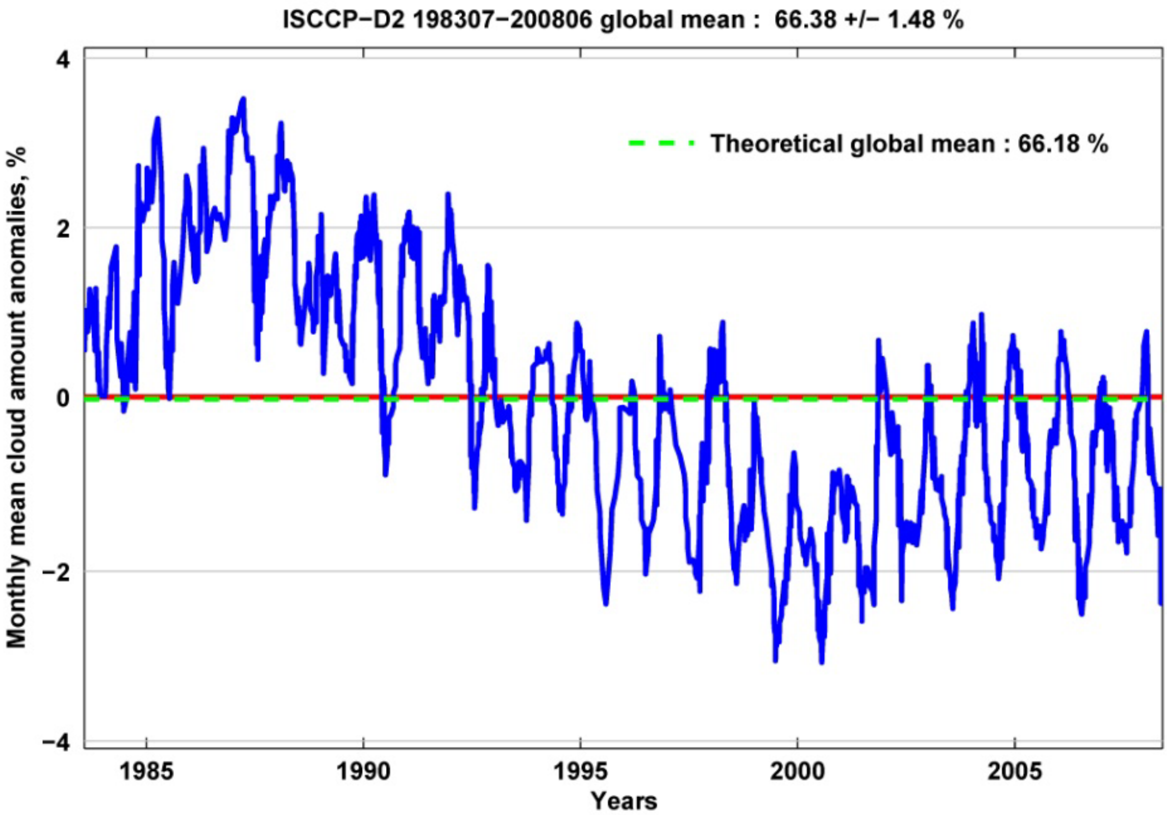

Figure 16. The theoretical cloud cover (green dashed line) is compared with satellite observations in the 1983-2008-time interval (red line). The agreement is well within the uncertainty of the satellite observations. The theoretical equilibrium cloud cover is practically equal to the theoretical transfer function: $\beta = 2(1+\tau^T + \exp(-\tau^T))^{-1}$, where $\tau^T = 1.8676$ is the theoretical equilibrium flux optical depth.

3.4. Water vapor

Compared to Mars and Venus on the Earth the planetary RE situation is far more complex. Since the phase changes of the H_2O may happen at any time and anywhere in the system the Earth has an extremely variable cloud, surface ice and snow cover. The combined surfaces where the water vapor is in direct contact with liquid water, snow, and ice will be termed as the phase boundary.

Through this hypothetical complex surface the total amount of water vapor in the atmosphere will change by the release or buildup of the latent heat by evaporation, condensation or sublimation. In steady state the net condensation and evaporation associated with rain droplets (within the atmosphere) must be zero and the mass balance of the atmosphere is maintained by the evaporation or sublimation from the ground surface and precipitation or deposition to the ground surface. These processes will result in decrease or increase of the flux optical thickness which is coupled with the mass exchange trough the lower boundary.

The total mass (or the potential energy) of the atmosphere and the flux optical thickness is controlled by the virial theorem, (Miskolczi, 2014). The mass conservation in the hydrological cycle expresses indirectly the conservation of the flux optical thickness.

The observed and theoretically predicted constant flux optical thickness (Miskolczi, 2010) is a plain proof of the climate control by the water cycle. In other words, increasing or decreasing the energy input to the system will result in the release or store of the required amount of radiant or thermal energy through the phase boundary to assure the radiative equilibrium while keeping the temperature of the phase boundary unchanged.

The water vapor feedback problem was already mentioned in **1.2.** From the NOAA-S archive 689 high quality all-sky radiosonde observations were processed to show the relationship between the local mean layer temperature and water vapor column density. During 1992-1993 from the high resolution (6 second) data 654130 individual layer mean temperature and water vapor column density pairs were collected.

In **Figure 17** the primary measured relative humidity and the computed H_2O column density profiles are plotted showing no significant correlation. In **Figure 18** the linear correlation coefficient between the temperature and natural logarithms of the column density is 0.99, which – considering the relevant quantitative theoretical relationships – is not a surprise. In view of the known analytical dependence of the ambient temperature on the water vapor content of an individual air parcel the whole positive H_2O feedback hypothesis seems to be a nonsense.

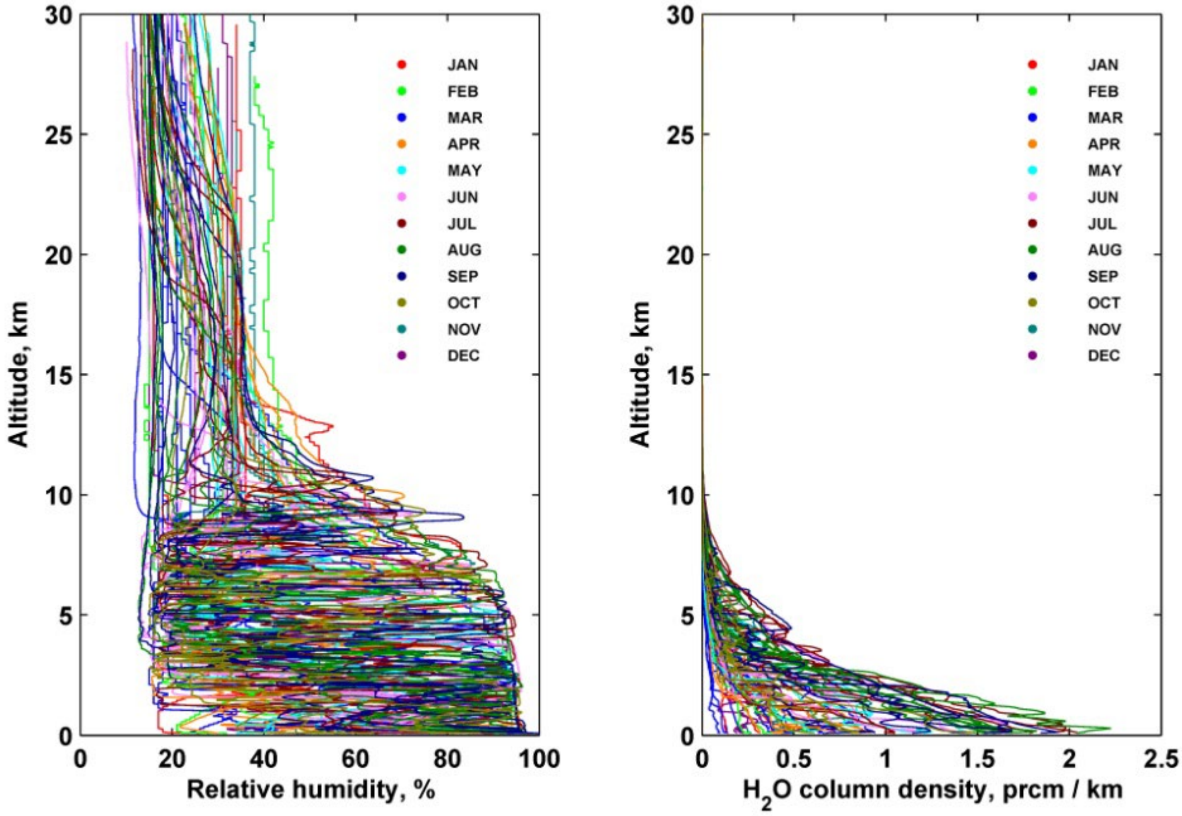

Figure 17. High resolution radiosonde observations from NOAA Sterling, Virginia. The H_2O column density directly enters to the LBL computation of the layer flux transmittance and optical thickness. The left panel shows, that the tropospheric relative humidity is a true stochastic component of the climate system.

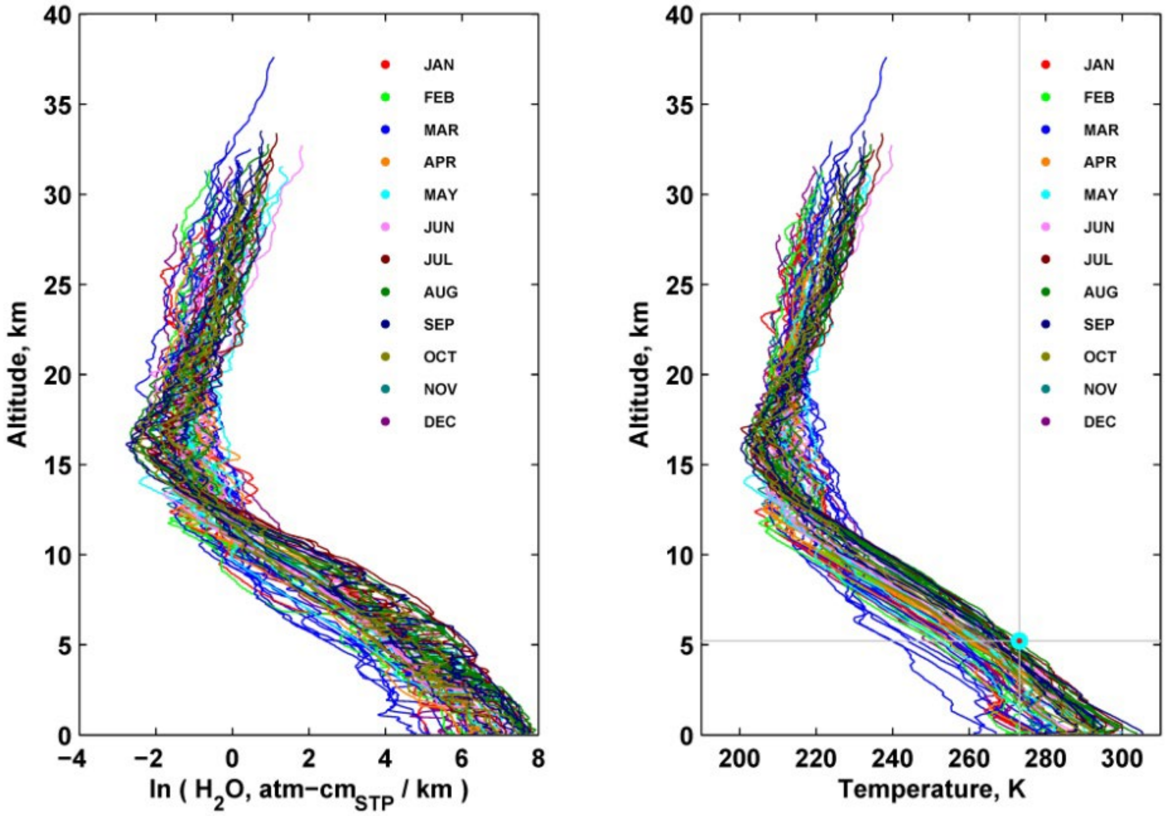

Figure 18. High resolution radiosonde observations from NOAA Sterling, Virginia. The temperatures and H_2O column density are highly correlated, and they follow the relevant theoretical relationships. Many climatologists mistakenly call this relationship as positive feedback. The light blue dot around 5 km (in the right plot) is the observed maximum altitude of the H_2O condensation temperature at Sterling.

It must be clear that locally the temperature and water vapor content of the air parcels are alternative variables and they are not connected by some ad-hoc positive or negative feedback parameter. According to thermodynamics phase transitions are controlled by the changes in the molar free energy and entropy.

3.5. Energy budget cartoons

The usual way to support the idea of the classic greenhouse effect is to present planetary energy budget schemes where the global radiative flux density components as well as the sensible and latent heat fluxes in the system are estimated either from direct measurements or from radiative transfer computations.

The most well-known is the Kiehl & Trenberth, 1997 (KT97) energy budget. In Miskolczi, 2014, based on 13 years of radiosonde observations, it was first shown with high degree of accuracy that the Earth-atmosphere system is in the state of radiative equilibrium. The radiative imbalances at the upper and lower boundaries of the atmosphere that appear in recent radiative budget cartoons of Trenberth et al., 2009, Stephens et al., 2012, Wild et al., 2012, and NASA, 2010 do not exist.

The radiative equilibrium stems from energy conservation and energy minimum principles and it is the natural state of the Earth-atmosphere system. So far none of the published planetary energy budgets give any bearing to the origin and physics of the atmospheric greenhouse effect and unfortunately, almost all of them suffer from serious errors in the methodology and evaluation. Some of them are listed below.

1. Quantitative discussion of the greenhouse effect should be based on the strict, detailed, clear, and physically meaningful definition of the phenomenon. For example, in Schmidt et al. 2010 and Lacis et al. 2010, we see published totally misleading quantitative results about how the share of the present-day global GE is distributed between GHGs and the cloud cover: 50 % from H_2O, 20 % from CO_2, 25 % from clouds, and 5 % contribution from minor GHGs. In common understanding these data means that the CO_2 absorption in the 15μm band is half of the absorption of the H_2O in the whole IR, which is sheer nonsense.

2. Due to the heavily overlapping nature of the terrestrial spectral radiation field it is mathematically impossible to decompose the flux optical depth into the contributions of the individual molecular species, (see Miskolczi, 2007, Appendix A). The LBL computational technique was developed to remove the uncertainties due to the spectral overlaps of the absorption coefficients of different GHGs. Clouds (or any kind of solid or liquid particles in the atmosphere) radiate continuous IR spectra and have nothing to do with the IR spectral absorption of the greenhouse gases. The cloud forcing approach to the greenhouse problem does not help to clarify and quantify the planetary radiative budget. The $F_E = S^A$ and $OLR^A = F_A$ equalities show clearly that the global average atmosphere is in radiative equilibrium.

3. From the confirmed $G^A = S_U^A - OLR^A = F_R$ and $S_U^A = F_E$ equalities follow the conservation of radiant energy, radiative equilibrium, and they give solid empirical support to the theoretically introduced equivalent blackbody temperature. Because of the two layer structure of the global average atmosphere the ground surface referenced GE cannot contain any dependences on the albedo, cloud cover, radiative temperature, LW absorption, or flux optical thickness, rendering the GE to observations of t_G, and OLR^A, and leaving the greenhouse problem entirely to the mercy of the GCMs and their unphysical assumptions and countless ad-hoc tuning parameters.

4. No quantitative constraints on the shortwave system albedo, cloud cover and cloud altitude are established. These are key climate parameters, and some kind of theoretical expectation must be referenced or developed. The steady state planetary radiative balance is abandoned in favor of a hypothetical man-made greenhouse warming. In science the quantitative estimate of 0.6 ± 17 Wm^{-2} missing heat in Stephens, 2012 means that climatologists have no idea why and how the hidden (thermal and radiant) energy is distributed among the different latent heat reservoirs.

5. In the budgets the global mean thermal and GHG structure of the atmosphere is not specified. Generally, the LW fluxes relevant only to the USST76 are used as the global average. The most recent NASA, 2010 budget (presented in **Figure 19**) adopted the flux density components from the KT97 radiative budget which is obviously wrong. Transmitted flux densities from the surface (40 Wm^{-2}) in KT97 were computed for the USST76 atmosphere and its 390 Wm^{-2} surface upward flux. About 15 years later, in the NASA picture the corresponding fluxes are 40.1 and 398.2 Wm^{-2} which is nonsense. About ~10 Wm^{-2} increase in surface upward flux and practically unchanged surface transmitted flux density deserves some explanations.

Apparently – due to the fatal mistake of using the USST76 atmospheric model – not even one flux density component from NASA budget is close to the ones from GAT structure. And of course – as is shown by the true global average fluxes – the atmospheric Kirchhoff's law is closely satisfied without applying any 'fudge factor' and the planet is in radiative equilibrium without any 'missing heat'.

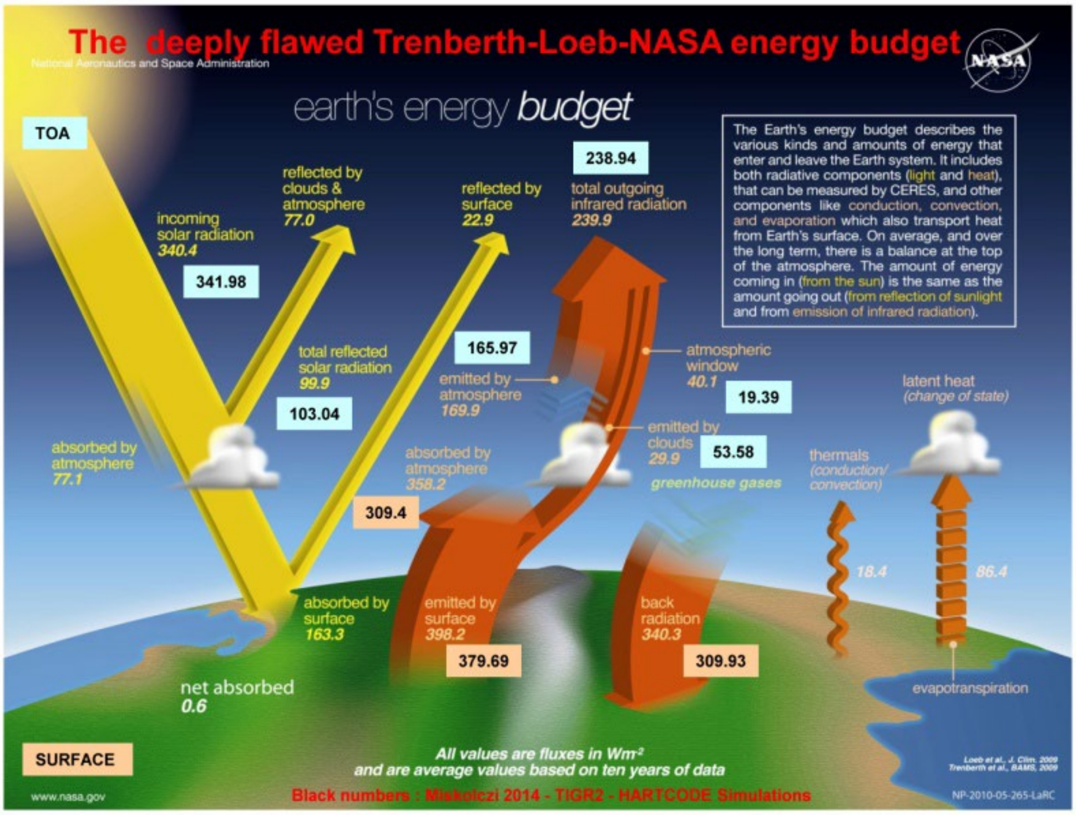

Figure 19. All-sky energy budget of the Earth-atmosphere system, adopted from NASA, 2010.

Because of the use of the USST76 Atmosphere the IR flux density components (light red numbers) are incorrect. The 0.6 Wm^{-2} fictitious missing heat (white number) is meaningless and violates energy conservation principles (atmospheric Kirchhoff law). For reference the flux density terms from **Figure 4** are inserted into the original plot (black numbers). They were computed for the GAT atmosphere using HARTCODE. The blue and red squares are the top of the atmosphere and surface referenced components subsequently.

3.6. Complexity is not an excuse to violate physics

The most serious problem with the cartoons are the ignorance of a long line of well-known fundamental concepts and principles of theoretical physics. Some of them are energy and momentum conservation principles of the radiation field, Wien's law, virial theorem, energy minimum principle, Maxwell rule, Kirchhoff law, Helmholtz reciprocity principle, Vogt-Russel theorem, LeChatelier-Brown principle.

Apart from the ignorance of the newest laws of atmospheric radiation transfer, one must observe that the complexity of the climate system is not a free ticket for violating the first principles of physics.

Further on, it is not clear that climatologists have access to an accurate RT software for the calculation of correct atmospheric flux densities. Note, that remote sensing applications use high accuracy inter-calibrated LBL radiance codes developed for special applications. However, there is a long way to go to arrive at a correct LBL flux density software from simple directional LBL radiance-transmittance codes.

3.7. Radiative equilibrium at the bottom of the atmosphere

To establish the radiative equilibrium at the ground surface the spherical emissivity (or the anisotropy) of the inhomogeneous IR radiation field of the atmosphere has to be considered. The anisotropy of the downward LW radiation is the $\varepsilon_A = E_D / E_D^i$ ratio, where E_D is the radiation from the real atmosphere, and E_D^i is the radiation from an isotropic atmosphere of temperature t_S (t_S is the ground surface radiative temperature).

Because of the $E_D^i \equiv S_U(1-\exp(-\overline{\tau}_A))$ mathematical identity, the equilibrium ground surface temperature is $t_G = (S_U/(\sigma\,\varepsilon_\mathrm{A}))^{1/4}$.

From the GAT profile $\varepsilon_A = E_D / E_D^i$=0.96515341, and the ground surface equilibrium temperature is $t_G = 288.61$ K.

According to the

$$\overline{\tau}_A = \ln [\, S_U^2 \,/\, (S_U^2 - \sigma t_G^4 E_D) \,] = 1.86912 \approx \tau^T = 1.86756$$

relationship these results are fully consistent with the observed constant flux optical thickness.

The surface phase temperature

t_P is $t_P = (\sigma^{-1/3} + \varepsilon_A^{1/4} t_G)/2 = 273.18$ K.

Summarizing our quantitative results in **Figures 20**, **21**, and **22** the spectral distributions of the most important flux density components are presented. The spectrally integrated fluxes are accurate up to 4-5 significant digits.

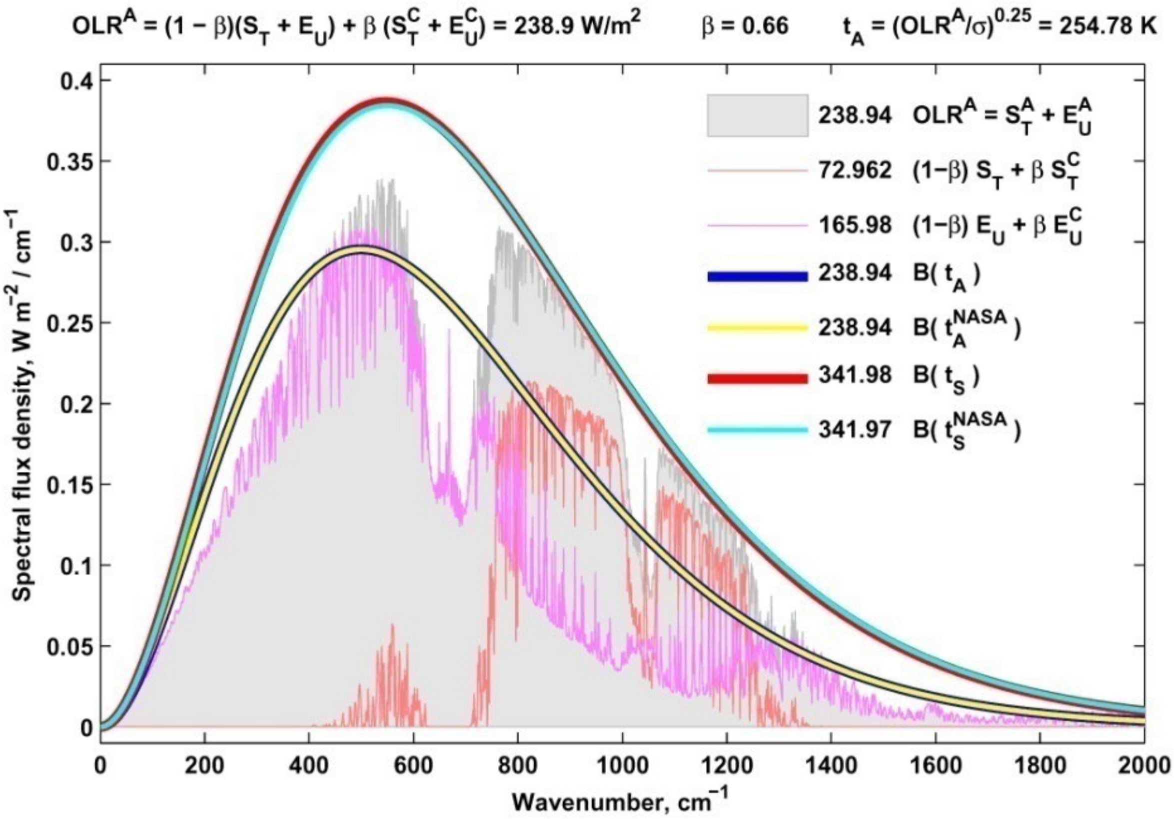

Figure 20. Flux density spectra of the all-sky GAT atmosphere. The equivalent blackbody spectra $B(t_A)$, and $B(t_S)$ are equal to the equivalent spectra

from $B(t_A^{NASA})$, and $B(t_S^{NASA})$. This is an indication that the GAT atmosphere is close to the real global average atmospheric structure.

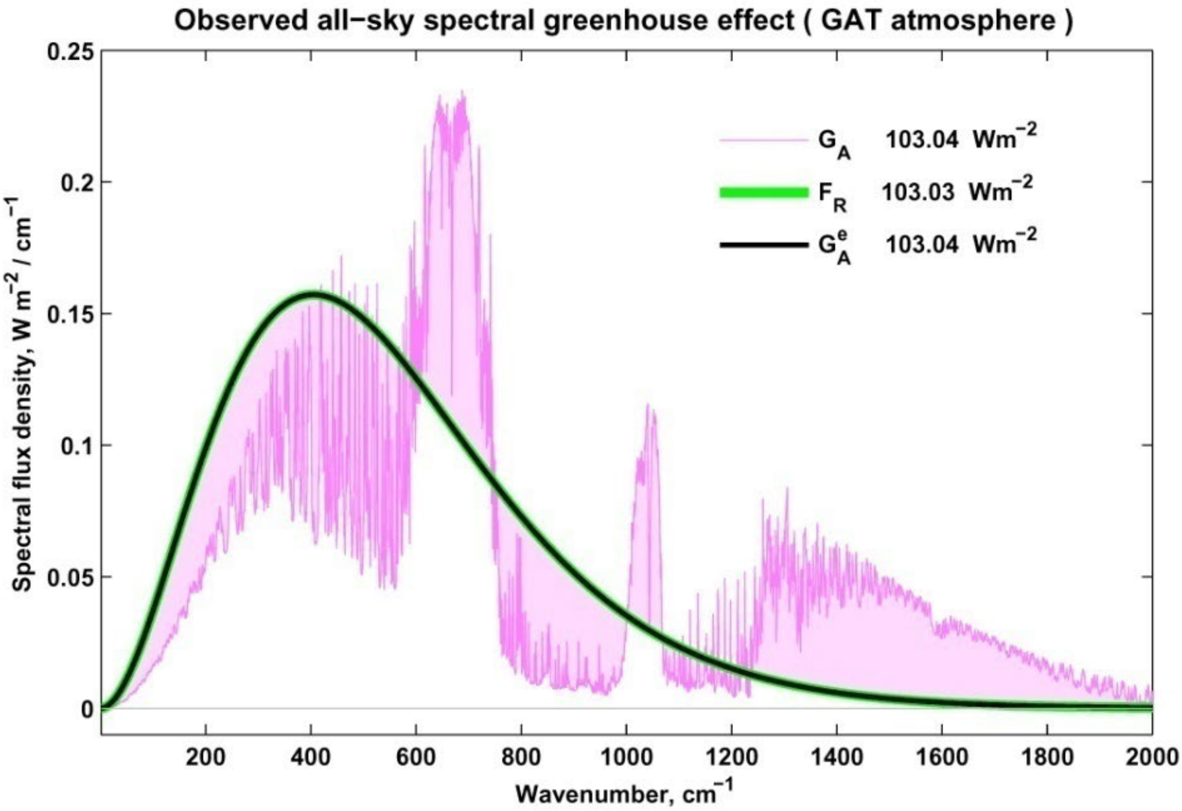

Figure 21. Spectral all-sky greenhouse effect referenced to the APS. The integrated flux densities from the G_A^e and F_R curves agree reasonably well. While the surface referenced clear sky greenhouse effect ($\sigma t_G^4 - OLR^A = 154.5$ Wm-2) has no clear physical meaning while the APS referenced GF can easily be associated with the deposited momentum by the reflected radiation.

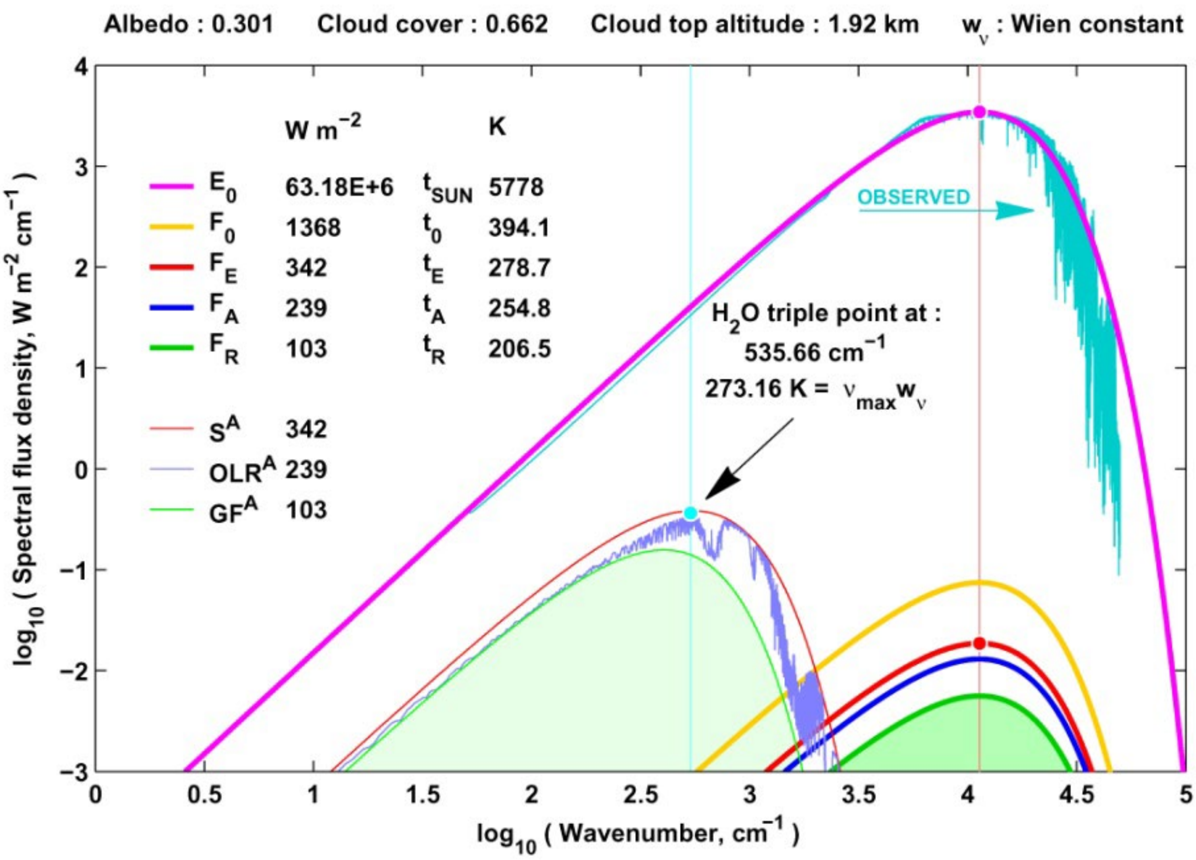

Figure 22. Solar and terrestrial equilibrium blackbody spectra. The observed solar reference spectrum (dark cyan line) is from Chance and Kurucz, 2010. The light blue line is the observed TOA OLR^A from the TIGR2 radiosonde archive. The light cyan dot at the maximum of the OLR^A shows that the Earth has a special orbit where the Wien temperature is equal to the t_P phase temperature of the H_2O. Obviously OLR^A has the maximum entropy flux density.

3.6. Deliberate data manipulation of climatological data

We have discovered that vital climatological data sets were deliberately manipulated. The verification of the planetary energy budget and radiative balance require high quality primary information from global scale radiosonde observations. If the radiosonde observations are wrong then no one will trust in the satellite retrievals of the temperature, humidity or ozone structures. Satellite products depend on the calibration and tuning (of the instruments and retrieval algorithms) based on the ground truth information, (see Miskolczi, 2005).

The common mistake of the climatologists is to assume that the satellite information is correct, no matter what. This is not true; satellite information cannot ever be more accurate than the ground truth. It should be kept in mind that most of the vital flux density components cannot theoretically be measured by any instruments. For example, the so-called windows radiation (usually defined in the 721-1260 cm^{-1} spectral range) is not a good representation of the true S_T surface transmitted flux density.

Scientist must also be aware that government research institutions may deliberately manipulate their databases to reflect their wild imagination on how the GE works. A good example is the NOAA-R1 archive which was used in our trend analysis study in Miskolczi, 2010. This global archive shows consistently that between 1948 and 2008 the flux optical depths from the profiles are equal to the theoretical τ^T of 1.867 (see **Figure 7**).

However, the true equilibrium optical depths of the NOAA-R1 time series is $\tau^e = 1.937$ and it is far off from τ^T which is an indication that none of the annual mean profiles are close to the radiative equilibrium. The $\tau^e - \tau^T = 0.06$ optical depth difference corresponds to about 250 % increase in CO_2 concentration.

This is of course impossible; the Earth cannot be out of radiative balance (by about 4 Wm^{-2} at the TOA) for 61 years. Such situation can only happen by altering the thermal structure (especially the close to surface temperature field). Much more serious is the problem with the USST76 atmosphere and the KT97 budget, where due to the unrealistic temperature and humidity structure the imbalance in the OLR at the TOA is about 29.38 Wm^{-2}. The NOAA-R1 archive may be used for trend analysis, but – because it violates the energy conservation principle – it is useless for global energy budget research.

Other examples are the TIGR2 and the updated TIGR2000 archives. A closer look at the TIGR2000 revealed that more than half (915 out of 1761) of the profiles are coincidental, and they are included in both archives.

The humidity and ozone structures in those coincidental profiles were poorly modified in an obvious way that the original thermal structures were preserved. The authors of the database should have known that the H_2O, O_3, and the thermal structures in the real atmospheres are highly correlated, which property is widely used in water vapor and ozone statistical retrievals from satellite spectral measurements.

In **Figure 23** we present one sample (out of the 915 manipulated profiles) where the increased H_2O and ozone content resulted in increased flux optical depth (to a value corresponding to a CO_2 doubling). The left plot shows the unchanged temperature profile, the right two plots show the manipulated H_2O and O_3 profiles respectively.

As a result of the data manipulation the TIGR2000 archive now contains 915 unrealistic atmospheric structures (mostly with increased upper tropospheric humidity and ozone amounts) which makes the database useless for both remote sensing and radiative budget applications. Creating fake radiosonde observations to support the belief in CO_2 GE based global warming is not a scientific approach.

The upper tropospheric humidity problem (if there is any) will not be resolved by artificial increase of the humidity data in the raw radiosonde observations. Unfortunately, there are evidences of extended data manipulations in other climate data sets which renders the whole climate science to a hiding game, and largely reduces the chances to obtain scientifically sound answers to the role of the GHGs in the global warming.

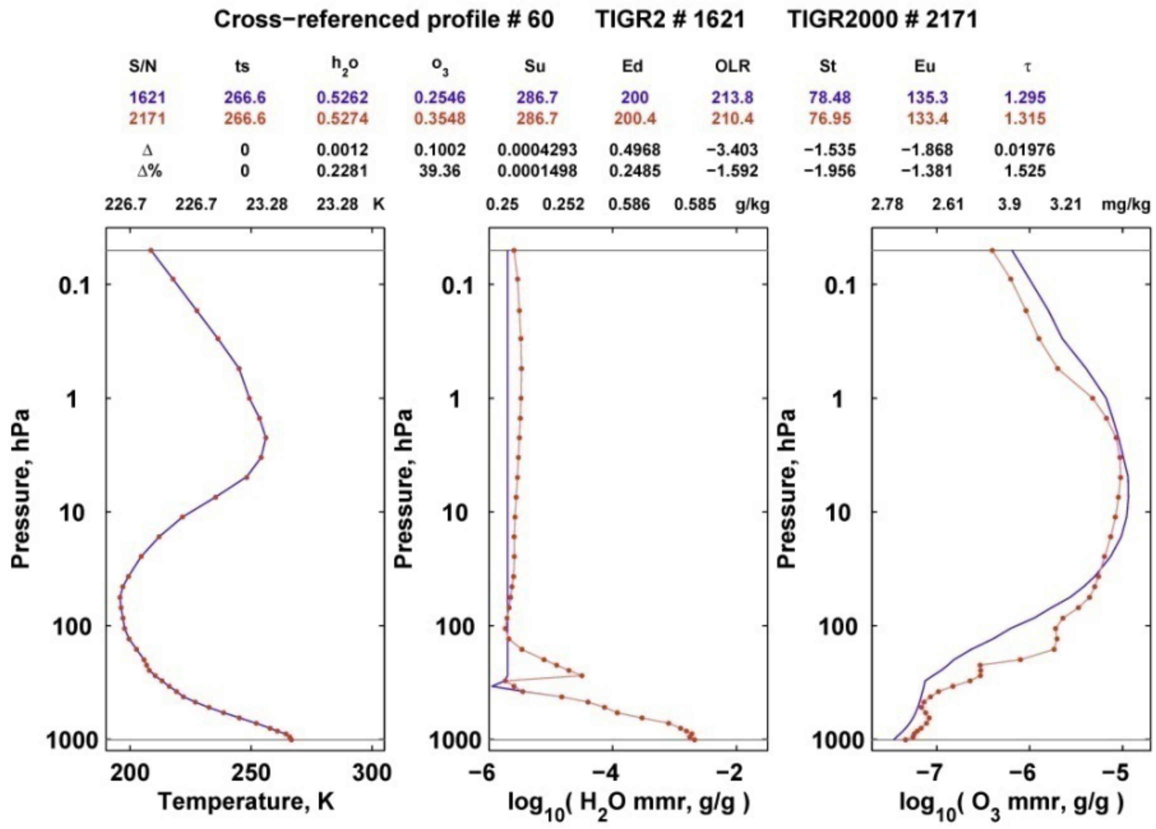

Figure 23. Evidence of large-scale data manipulation in radiosonde observations. Comparing the two versions of the TIGR database shows that in more than 50 % of the humidity profiles the upper tropospheric H_2O and O_3 mass mixing ratio were increased. In this example the changes resulted in 3.4 Wm^{-2} decrease in OLR and significant increase in the flux optical depth.

3.8. Comments on the new view of greenhouse effect

Almost all attempt to publish the results presented in this paper failed. Articles were routinely rejected by the mainstream scientific journals – Science, Astrophysical Journal, Tellus, Journal of Quantitative Spectroscopy and Radiative Transfer, Journal of Geophysical Researches etc. – mostly without sending for review. For example, the Hungarian Science magazine (Magyar Tudomány) rejected the publication of the above results saying that it should be published first in some elite journals. Probably this is the reason why it is hard to find any critical comments on the quantitative results in the peer reviewed literature.

However, the blogosphere is flooded with academically illiterate comments from self-declared experts. As an example, it worth to read the ridiculous comments of A. Lacis (moderated by J. Curry at her Climate Etc. blog) on the Miskolczi, 2014paper. The whole comment is just an ad hominem attack, probably motivated by the lack of his knowledge of basic radiative transfer concepts. Let us quote J Curry's own brave comment:

> "The only potentially interesting point is whether the clear sky atmospheric optical depth has remained the same in the face of rising CO2, implying a decrease in water vapor. In any event, his analysis (theoretical and empirical) doesn’t seem up to the task of sorting this out."

It is a mystery why is she so sure without reading the article and trying to reproduce the numerical results. To not risk making a quantitative statement, J. Curry suggests people to read the related critiques at the faceless *Science of Doom* blog, the *Real Climate* blog or at Roy Spencer's website. *Science of Doom* devotes number of posts and comments to discredit my quantitative results unfortunately only by his belief and not by his theoretical or computational skills.

The same is true for the comments of G. Schmidt in the *Real Climate* web site. His attitude is clear in the next quote in his blog where somebody asked him if it is possible for a physicist to explain Ferenc Miskolczi’s theories and disprove them in a peer reviewed journal. His response:

> "They are nonsense and so it is unlikely that anyone will take the time. See Roy Spencer's discussion for probably the best rebuttal yet. Further discussion on this is out of topic ".

This does not sound like a scientific comment from a radiative transfer giant.

The 'best' rebuttal was from Spencer, 2010, who wrote an 'executive summary' on my E&E article (Miskolczi, 2010) where he simply ignored the important fact that in the whole article I dealt with clear sky condition.

Since the clear and all sky fluxes are not directly (and quantitatively) comparable, Spenser's numerical comparisons with the KT97 radiative budget is meaningless. He confuses a series of radiative transfer details. He is unable to comprehend anisotropy and how to compute it (he called the spherical emissivity a 'fudge factor'). He does not understand the flux density form of the Kirchhoff-Planck relationship, the Virial theorem and how to apply it, and the directional and flux optical depth.

If the blog comments above – without correct quantitative references to my well documented computational results – represent the matured opinion of the global warming community on the greenhouse science, then certainly an open scientific discussion is impossible on this topic.

One should remember that real science cannot ever be settled. Planetary climate science is not an exception. It will eventually make progress with or without the consensus of the corrupt IPCC. It will prevail over privileged climate scientists or ambitious politicians looking for more control over the people using false scientific reasoning. Hopefully, sooner or later, the question will be raised on the responsibility of the wasted millions of dollars of tax-payers' money on fighting a hypothetical catastrophic AGW.

4. Summary

The classic GH effect hypothesis is not a theory, and it is unable to establish the required quantitative relationship between the GHG content of the atmosphere and the planetary surface temperature. In climate science the arbitrary definition of the GE is not suitable to associate the heat absorption properties of the atmosphere with the amount of GHGs present in the atmosphere.

The reason is the two-level radiative structure of the atmosphere and the unlimited supply of the water vapor in its three phases. In addition to this the strongly stochastic nature of the humidity field makes tracking the phase changes of the H_2O impossible. Therefore, the quantitative knowledge on the changes of the optical depth (that is related to the phase transitions of the H_2O) is unknown.

The large number of new physical relationships – and new universal constants of radiation physics – converge to form a coherent picture of the planetary IR radiative processes which ultimately establishes the correct radiative budget of the Earth-atmosphere system.

Compared to surface and satellite flux density observations, the rigorous numerical testing of the new equations has not produced any contradictory results. The new equations and constants were presented in a series of published papers, open conference presentations, and in NASA science team meetings. So far, neither the equations nor the numerical results were openly solved by radiative transfer experts or challenged by the wider climate science community.

The theoretically constant equilibrium flux absorption coefficient of the Earth's atmosphere negates the existence of the Arrhenius type greenhouse gas greenhouse effect. If there are no changes in the greenhouse effect, then there is no climate sensitivity to manmade increase of the atmospheric CO_2. The excess optical depth from increased CO_2 will condense into water droplets and will eventually rain out from the atmosphere. Alternatively, structural variations in the global wind and humidity field or cloud cover may easily restore the equilibrium flux optical depth.

Science is not a talk-show. All arguments and critiques against the new view of the greenhouse effect must be quantitative. Eventually, the system of new equations will be upgraded to the only greenhouse theory that explains the observed facts and obeys the fundamental principles of physics. Evaluating the global average flux density components from ground truth observations makes it evident that the Earth-atmosphere system is in RE with a theoretical solar constant.

Some simple empirical manifestations of this equilibrium include:

1. equivalence of the APS's greenhouse factor and reflected solar flux: $G^A = F_R = 103.04$ Wm^{-2};
2. equality of the Bond albedo and the empirical normalized all-sky greenhouse factor referenced to the APS $g^A = G^A / S_U^A = \alpha_B = 0.3013$;

3. equality of the sum of the radiative fluxes from the cloud top and cloud base and the total infrared radiation absorbed in the atmosphere: $S_U^C + S_D^C = A_A + A_A^C + A_A^{Cu} + A_A^{Cd} = 653.8$ Wm^{-2};
4. constancy of the global average atmospheric equilibrium infrared flux optical thickness: $\tau^T = \overline{\tau}_A = 1.86756$;
5. constancy of the radiative equilibrium water vapor column amount: $u = 1/(1 - 4\exp(-\overline{\tau}_A)) = 2.612$, prcm;
6. theoretical and empirical equivalence of the cloud cover, transfer, and virial functions: $\beta = f = V = f^T = 0.661$;
7. equivalence of the theoretical intercepted absorbed available solar flux density from astronomical parameters and the empirical all sky planetary TOA IR fluxes from the APS: $F_A = OLR^A = 238.95$ Wm^{-2};
8. equality of blackbody temperature of the intercepted available solar radiation over a unit area and the temperature of the APS: $(F_E/\sigma)^{1/4} = (S_U^A/\sigma)^{1/4} = 278.68$ K;
9. equality of the theoretical solar constant , empirical solar constant, and the long term observed average solar constant: $F_0^T = F_0^{OBS} = F_0^{\mathrm{av}} = 1367.95$ Wm^{-2};
10. Equality of the above cloud downward flux and the above cloud OLR: $E_D^C = OLR^C = 155.58$ Wm^{-2};
11. equality of the phase temperature from the IR fluxes and the H_2O triple point temperature: $t_P = (\sigma^{-1/3} + \varepsilon_A^{1/4} t_G)/2 = 273.18$ K.;

The easily verifiable numerical facts mentioned above are only a fraction of the infinite number of possible quantitative relationships that all ensure the stability of the Earth's climate.

Scientific facts are stubborn things. They cannot be changed by fraud, misinformation, falsification of climate data, censorship or democratic voting. Unfortunately, understanding the greenhouse effect phenomenon requires detailed knowledge of radiation physics, which can only be expressed in complex mathematical relationships, equations and formulae that are not expected to be known by the general public, nor by climatologists, environmentalists and politicians who boldly make statements on the subject but are not familiar with radiation physics.

A good example is the most recent public announcement of the politician Orsolya Ferencz (in Ferencz, 2022). She declared that the Miskolczi Greenhouse Theory (MGT) officially invalid. Obviously, her scientific background on atmospheric radiative transfer is somewhere at the level of Greta Thunberg, and unfortunately, she has no idea about the falsification protocol of a scientific theory.

Someone should remember that in the Middle Ages there was an official, government-approved view of the structure of solar system and how the inquisition worked to suppress new ideas. I hope climate science will proceed in a better way.

5. Conclusions

In this article all the arguments focused on the theoretical and observational issues of the greenhouse effect and not on the question whether the global surface temperature is changing or not. So long as the greenhouse effect terminology of climatologists refers only to the steady state temperature difference between t_S and t_A I have no objection.

The $\Delta t_A \approx 28$ K, and the related $G_A \approx 128$ Wm^{-2} clear sky temperature and flux density differences are real, they can be measured, computed, and theoretically predicted. However, these numbers are constants, they cannot violate the planetary radiative equilibrium and energy conservation principles.

Any perturbations to the flux optical depth by non-condensing GHGs will force the hydrological cycle to restore the theoretical equilibrium optical depth. The greenhouse effect predicted by the Arrhenius greenhouse theory is inconsistent with the existence of this RE. Hence, the CO_2 greenhouse effect as used in the current global warming hypothesis is impossible.

The overall conclusion is the Arrhenius type greenhouse effect of the CO_2 and other non-condensing GHGs is an incorrect hypothesis and the CO_2 greenhouse effect based global warming hypothesis is an artifact without any theoretical or empirical footing.

Acknowledgements

I am indebted to István Héjjas, László Szarka and Szabolcs Barcza for their substantive professional discussions. Also, thanks are due to K. Sifrin, K. Vinnikov, I. Wilson, A. Harvey, J. Pompe, A. Rörsch, R. Tscheuschner, D. Hagen, S. Welcenbach, N. VanAndel, C. Wiese, G. Fulks, D. Brooks, W. Guang, Y. Shao-min, R. Tattersall, Z. Kolláth, S. Kenyeres, E. Függerth, and all those who have followed my many years of research and contributed with their useful advice to clarify the numerous theoretical problems that have arisen in the course of my work. I am very grateful to J. Ginsberg and E. Murányi for their help in editing and technical preparation of the manuscript.

References

Arrhenius S. (1896). On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground. Philosophical Magazine and Journal of Science Series 5, Volume 41, April 1896, pages 237-276.

Berk A., Anderson G. P., Acharya P. K., Shettle E. P. (2008). MODTRAN5.2.0.0 User's Manual.
ftp://ftp.pmodwrc.ch/pub/Claus/Vorlesung2009/ModtranDaten_etc/MODTRAN(R) 5.2.0.0.pdf

Chance K., and Kurucz R. L., 2010: An improved high-resolution solar reference spectrum for earth's atmosphere measurements in the ultraviolet, visible, and near infrared. Journal of Quantitative Spectroscopy & Radiative Transfer 111 (2010) 1289 1295

Court (2016).https://climatecite.com/ferenc-miskolczi-testimony-in-mann-vs-ball-libel-case/

Ferencz O. (2022). HÍRTV; ferencz-orsolya-eldontott-kerdes-hogy-a-miskolczi-elmelet-nem-helyes-2540247.html

Kopp, G., and Lean, J., L. (2011). A new, lower value of total solar irradiance: Evidence and climate significance. Geophysical Research Letters, Vol. 38, L01706, DOI: 10.1029/2010GL045777

Kandel R., and Viollier M. (2005). Planetary radiation budgets Space Science Reviews (2005) 120: 1-26 DOI: 10.1007/s11214-005-6482-6, pp. 4

Kiehl J. T., and Trenberth K. E., 1997: Earth's Annual Global Mean Energy Budget. AMS, BAMS, VOL. 78, No. 2, 1997, pp.199

Kratz, P. D., Mlynczak, G. M., Mertens, J. C., Brindley H., Gordley, L. L., Martin-Torres, J., Ferenc M. Miskolczi, M. F., Turner, D. D. (2005). An inter-comparison of far-infrared line-by-line radiative transfer models, Journal of Quantitative Spectroscopy & Radiative Transfer 90 (2005) 323-341

Lacis, A., Schmidt G. A., Rind D., Ruedy R. A. (2010). Atmospheric CO_2: Principal Control Knob Governing Earth's Temperature. Science 330 (2010) 356-359

Lindzen R. S. (2007): Taking Greenhouse Warming Seriously, E&E, Vol. 18, No. 7+8, 2007 pp. 937-950

Miskolczi, F. (1989). High resolution atmospheric radiative transfer code (HARTCODE).
https://www.researchgate.net/publication/287994595DOI:
10.13140/RG.2.1.2319.6240

Miskolczi, F., & Mlynczak M. (2004). The greenhouse effect and the spectral decomposition of the clear-sky terrestrial radiation. Időjárás, 108, 4, 209-251

Miskolczi F. M., & Mlynczak M. G. (2005). AIRS – CERES Window Radiance Comparison, AIRS-to-CERES Radiance Conversion. NASA, CERES Science Team Meeting, November 2005, https://ceres.larc.nasa.gov/documents/STM/2005-11/miskolczi_airs.pdf

Miskolczi F. M. (2007). Greenhouse effect in semi-transparent planetary atmospheres. IDŐJÁRÁS, Quarterly Journal of the Hungarian Meteorological Service, Vol. 111, No. 1, January-March 2007, pp. 1-40

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

Miskolczi F. M. (2011). The stable steady-state value of the Earth's global average atmospheric infrared optical thickness, European Geophysical Union, EGU 2011, Vienna, 13662, 1-20, http://presentations.copernicus.org/ EGU2011-13622_presentation.pdf

Miskolczi, F., M. (2014). The Greenhouse Effect and the Infrared Radiative Structure of the Earth's Atmosphere Development in Earth Science Volume 2, 2014 http://www.seipub.org/des

Miskolczi, F. & Héjjas, I. (2021). The self-regulation of climate. Ferenc Miskolczi's climate theory with comments by István Héjjas (in Hungarian). Az Éghajlat Önszabályozása. Miskolczi Ferenc klímaelmélete (Püski 2021) [ISBN 978-963-302-328-0]

McIDAS Water Vapor Composite_2008: http://www.ssec.wisc.edu/data/composites.html

Mohr P. J., Taylor B. N., & Newell D. B. (2007). CODATA Recommended Values of the Fundamental Physical Constants: 2006, National Institute of Standards and Technology, Gaithersburg, Maryland 20899-8420, USA

NASA, (2010). Earth's energy budget. http://www.nasa.gov, Document: NP-2010-05-265-Larc, http://science-edu.larc.nasa.gov/energy_budget

NASA, (2016). Notes on the Fact Sheets. NASA Official: Ed Grayzeck, edwin.j.grayzeck@nasa.gov, Updated: 29 February 2016, DRW

Nurse P., & Cicerone R. J. (2014). Climate Change, Evidence & Causes. An overview from the Royal Society and the US National Academy of Sciences, RS & NAS Feb. 27th 2014

Pierrehumbert R. T. (2011). Principles of Planetary Climate, Cambridge University Press, ISBN 9780521865562, pp. 414

Raval, A., and Ramanathan, V. (1989). Observational determination of the greenhouse effect. Nature 342 (1989) 758-761

Ramanathan V., and Inamdar A. K. (2006). The radiative forcing due to clouds and water vapor. In Frontiers of Climate Modeling, Eds. J.T. Kiehl and V. Ramanathan; Cambridge University Press, 2006.

Rizzi R., Matricardi M., and Miskolczi F. (2002). Simulation of up looking and down looking high-resolution radiance spectra with two different radiative transfer models. APPLIED OPTICS, Vol. 41, No. 6, 20 February 2002

Saunders R., Rayer P., Brunel P., von Engeln A., Bormann N., Strow L., Hannon S., Heilliette S., Liu Xu, Miskolczi F., Han Y., Masiello G., Moncet J. L., Uymin G., Sherlock V., and Turner D. S. (2007). A comparison of radiative transfer models for simulating Atmospheric Infrared Sounder (AIRS) radiances. http://onlinelibrary.wiley.com/doi/10.1029/2006JD007088/epdf JGR-Atmosphere, Vol. 112, D01S90, 2007, 1-17

Schmidt, G. A., Ruedy R. A., Ron L. , Miller R. L., Lacis A. A. (2010). Attribution of the present-day total greenhouse effect, JGR, VOL. 115, D20106, DOI: 10.1029/2010JD014287, 2010, pp. 3

Schwarzschild K. (1906). On the equilibrium of the Sun's atmosphere. Nachr. v. d. Königliche Ges. d. Wissenscaften zu Göttingen. Math-Phys. Class, Vol. **195,** pp. 41-53.

Smith, A., P., 2008: Proof of the Atmospheric Greenhouse Effect, American Physical Society, 1 Research Road, Ridge NY, 11961, PACS numbers: 92.60. Vb, 05, 90. +m, (2008) http://arxiv.org/abs/0802.4324v1

Spencer R. W. (2010). Comments on Miskolczi's (2010) Controversial Greenhouse Theory. August 5th, 2010, http://www.drroyspencer.com/2010/08/

Stephens G. L., et al. (2012). An update on Earth's energy balance in light of the latest global observations. Nature. Geo-science. 5 (2012) 691–696, DOI: 10.1038/ngeo1580

Trenberth K. E., Fasullo J. T., and Kiehl J. (2009). Earth's global energy budget. AMS, BAMS, March 2009 pp. 311-323

US Standard Atmosphere, (1976). NOAA, NASA, USAF, Washington, D.C. October 1976, NOAA-S/T 76-1562

VanAndel, N., (2010). Note on the Miskolczi Theory. E&E, Vol. 21, No. 4, 2010, pp.281

Wild M., Folini D., Schar C., Loeb N., Dutton E. G., Konig-Langlo G. (2013). The global energy balance from a surface perspective. Climate Dynamics (2013) 40:3107–3134, DOI 10.1007/s00382-012-1569-8