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The Greenhouse Effect Calculations by an Iteration Method and the Issue of Stratospheric Cooling

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The anthropogenic global warming theory is based on the greenhouse effect (GH), which is due to the longwave (LW) absorption by GH gases and clouds according to the IPCC. This LW radiation downward is the imminent cause for the GH effect increasing the surface temperature by 33°C. It has been shown that latent and sensible heating are essential parts of downward LW radiation and the total GH effect. In this study, an iteration method utilizing this basic GH effect mechanism has been applied to simulate the warming impacts of enhanced GH effect changes. The results are compatible with the Transient Climate Response (TCR) of 0.6°C. The issue of stratospheric cooling due to increased CO_2 concentration has been calculated and analyzed. The stratospheric cooling effect is real but its impact on the Effective Radiative Forcing (ERF) has been shown to be negative and not positive as generally implied. The reason is that the decreased absorption of LW radiation in the atmosphere always decreases the GH effect. This result challenges the new concept of the ERF that is the sum of Instantaneous RF (IRF) and rapid adjustments as applied in General Climate Models (GCMs). If the stratospheric adjustment has the opposite effect, then the IRF values would be also wrongly calculated in these models. Two independent validation methods were applied to test the temperature impacts of CO_2 concentration increases.

Keywords: Greenhouse effect; climate change; stratospheric cooling; climate model.

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1. INTRODUCTION

1.1 The Greenhouse Effect

The greenhouse (GH) effect is the basic paradigm of the IPCC in global warming. The definition of the GH effect according to AR5 [1] is: *"The longwave radiation (LWR, also referred to as infrared radiation) emitted from the Earth's surface is largely absorbed by certain atmospheric constituents - (greenhouse gases and clouds) - which themselves emit LWR into all directions. The downward directed component of this LWR adds heat to the lower layers of the atmosphere and to the Earth's surface (greenhouse effect)."*

Ollila [2] has analyzed the Earth's energy balance and the energy fluxes connected to the GH effect. His conclusion is that the IPCC's definition violates the physical laws because the downward LW radiation to the surface is much greater than the LW absorption by GH gases and clouds: in all-sky conditions 345.6 Wm^{-2} versus 155.6 Wm^{-2}. This means that also latent and sensible heating is part of the GH effect and these three factors are together 155.6 + 90.8 + 24.2 = 270.6 Wm^{-2}. The difference of the total downward flux 345.6 Wm^{-2} and the total GH effect 270.6 Wm^{-2} is 75 Wm^{-2} and it is the same as the shortwave absorption by the atmosphere. In Fig. 1 the energy balance of the Earth has been depicted including the fluxes essential for the GH effect. The numerical values are rounded without showing decimals.

Ollila has defined the GH effect in this way [2]: *"The Earth's surface emits LW radiation (infrared radiation) and it transfers heat energy in the form of latent and sensible heating into the atmosphere. Most of the emitted infrared radiation is absorbed by trace gases and clouds in the atmosphere. All three energy fluxes increase the temperature of the atmosphere. The part of the infrared radiation due to these three energy sources emitted downward from the atmosphere adds to the warming of Earth's surface by sunlight and it is called the greenhouse effect."*

The IPCC has also used the term enhanced greenhouse effect [1], which means that an increase in the concentration of greenhouse gases increases the magnitude of the GH effect. One of the objectives of this study is to calculate the warming impacts of various enhanced GH effects applying the energy balance fluxes and the GH effect definition.

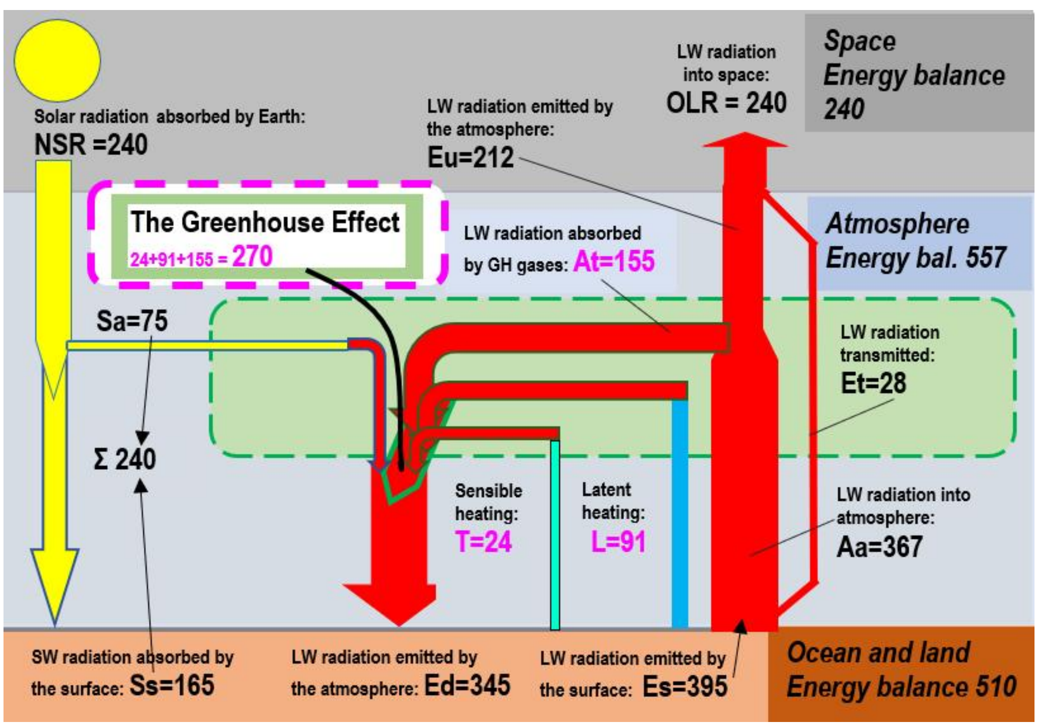

Fig. 1. Energy fluxes contributing to the greenhouse effect in all-sky conditions (Wm^{-2})

1.2 Instantaneous Forcing and Rapid Adjustments

The warming effect of enhanced GH effect is based on the mechanism where GH drivers increase LW absorption in the atmosphere and this causes unbalance to the Earth's energy balance by decreasing the LW radiation into space. Since the cooling rate of the surface has decreased, the surface's temperature starts to increase, which causes an increase in the emitted LW radiation. Finally, the LW radiation at the TOA (top of the atmosphere) will reach its original value before a perturbation.

It should be noticed that the Earth energy balance reacts on the LW radiation changes and not for example on temperature changes in different parts of the atmosphere. The energy balance can be achieved with different temperature profiles in the atmosphere if the energy balance can be satisfied.

The IPCC has used the Radiative Forcing (RF) equation of Myhre et al. [3] (henceforth MHSS98) for CO_2 in the three latest Assessment Reports TAR [4], AR4 [5] and AR5 [1] for calculating RF at the top of atmosphere (TOA). The RF equation of Ollila [6] (henceforth Ollila14) has the same form

$$RF = k * \ln(C/208) \quad (1)$$

where k is 5.35 [3] or 3.12 [6] and C is the concentration of CO_2 (ppm). MHSS98 has used the term "Instantaneous Radiative Forcing" (IRF) meaning the RF value calculated by the means of Line-By-Line (LBL) spectral analysis method or by a narrow or a broadband method at the tropopause. MHSS98 introduced two adjustment terms for the IRF and they were negative shortwave RF in the stratosphere -0.11 Wm^{-2} and positive stratospheric cooling +0.05 Wm^{-2} for the CO_2 concentration change from 280 ppm to 363 ppm.

IPCC [1] has defined that RF is the change in the net, downward minus upward, radiative flux (expressed in Wm^{-2}) at the tropopause or the TOA due to a change in an external driver of climate change. Since RF values can be calculated at two different places of the atmosphere a new term has been introduced. The IPCC has used the term Effective Radiative Forcing (ERF) to mean the final RF after adjustments to IRF and the ERF happens always at the TOA.

In the case of MHSS98 the ERF of CO_2 concentration 560 ppm (henceforth $2*CO_2$) is the sum of these three entities (instantaneous forcing, shortwave forcing, and stratospheric cooling) ERF = 3.86 – 0.29 + 0.13 = 3.71 Wm^{-2}. The adjustment terms have been estimated from the reported values for CO_2 the concentration of 363 ppm versus 560 ppm. Shortwave absorption by GH gases has no net warming or cooling effect on the surface temperature. If there is for example an increase in shortwave absorption, the direct solar insolation forcing to the surface will be reduced with the same amount. It is a zero-sum game.

Etminan et al. [7] (henceforth EMHS16) has updated the original calculations using the latest HITRAN databases and atmospheric data and the calculated value 3.82 Wm^{-2} for $2*CO_2$ is remarkably close to the value of MHSS98.

Researchers [8,9] have introduced more adjustments in addition to the stratospheric cooling. The most comprehensive presentation comes from Chung & Soden [10] with six different adjustments

$$ERF = IRF + A_T + A_S + A_{TS} + A_W + A_a + A_c + E \quad (2)$$

where A_x is a rapid adjustment due to tropospheric temperature (T), stratospheric temperature (S), surface temperature (TS), water vapor (W), surface albedo (A), clouds (C), and E is a residual that accounts for nonlinearities. According to the analyses of Smith et al. [11] (henceforth S&al18) the critical adjustment in equation (2) is the stratospheric temperature adjustment because the sum of other adjustments is practically zero. ERF value of $2*CO_2$ is thus ERF = IRF + A_S = 2.6 + 1.1 = 3.7 Wm^2 (estimated from a graphical presentation).

In Fig. 2 has been depicted the instantaneous RF values, stratospheric adjustments, and ERF values according to various studies for $2*CO_2$. The ERF value of Ollila14 for $2*CO_2$ is 2.16 Wm^{-2}.

The ERF values of MSHH98, EMHS16 and S&al18 are close to each other. There is a big difference between the value IRF value of 2.6 Wm^{-2} of S&al18 and 3.86 Wm^{-2} of MHSS98. There are essential differences in calculation methods. The IRF of MHSS98 is based on the spectral calculations at the tropopause, the ERF of EMHS16 is based on the spectral calculations at the TOA, and S&al18 values are based on the average IRF values of 11 Global Climate Models (GCM). The researchers of S&al18 have carried out simulations with these models applying 2*CO_2 concentration of 280 ppm and 560 ppm. They call simulation runs "experiments" as if they had been carried out in the real climate conditions.

There is a straightforward method for calculating ERF values. The ERF values of Ollila14 and EMHS16 has been calculated by spectral analysis from the surface to the TOA. The spectral analysis applications have no theoretical or practical problems to include the atmosphere above the tropopause. The ERF value of EMHS16 is practically the same as S&al18.

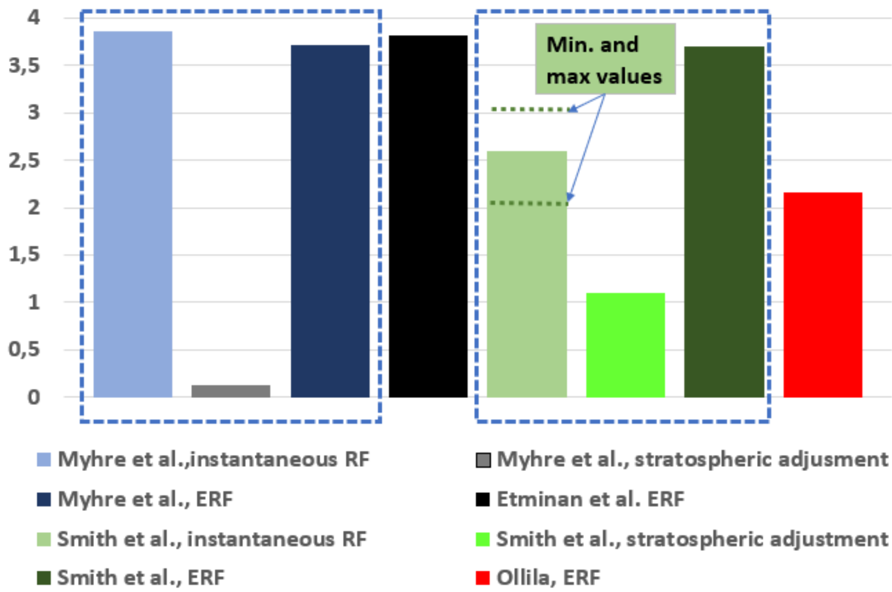

Fig. 2. The instantaneous RF, stratospheric adjustments, and ERF values according to different studies for CO_2 is 560 ppm (2*CO_2). The RF values are in Wm^{-2}

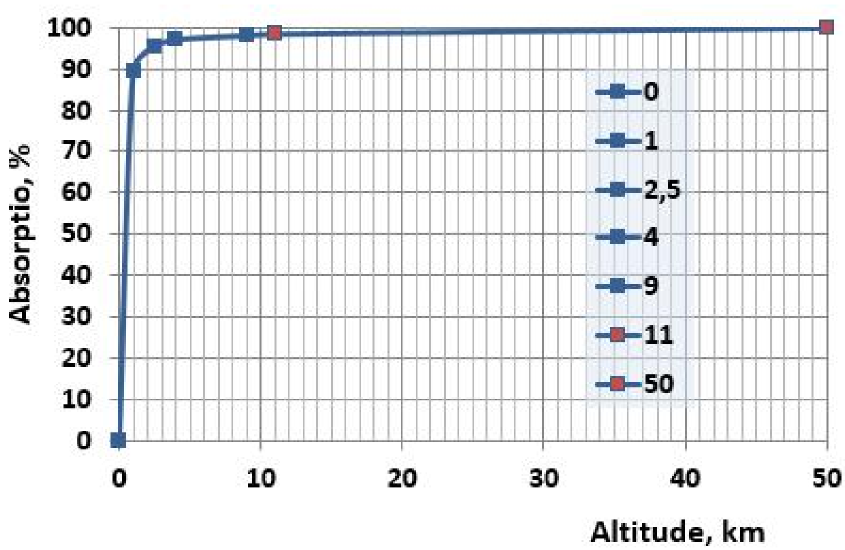

Fig. 3. Total absorption in the atmosphere in clear sky conditions for average atmosphere in year 2015

In Fig. 3 the absorption in the atmosphere has been depicted as a function of altitude. At the tropopause already more than 98% of the total absorption has happened. The enhanced GH effect is based on the absorption impact. It is very contradictory to think that something happening in the stratosphere would have a contribution of about 30% in the total ERF.

The magnitude of stratospheric cooling for $2*CO_2$ is 0.13 Wm^{-2} by MHSS98 and the same by S&al18 is 1.1 Wm^{-2}. There are no comments about these striking differences in the latter paper of S&al18. Therefore, a separate analysis is needed about stratospheric cooling and it is one of the objectives of this study.

1.3 Temperature Response for Radiative Forcing

The surface temperature values can be calculated by a simple equation as defined by the IPCC [4] (p. 664)

$$dTs = \lambda * RF \tag{3}$$

where dTs the global mean surface temperature, and λ is the climate sensitivity parameter. Since the IPCC [4,5] applies the positive water feedback, the λ value is 0.5 $K/(Wm^{-2})$ for TCR = 1.85°C. The λ value of 0.8 $K/(Wm^{-2})$ is applicable for Equilibrium Climate Sensitivity (ECS = 3.0°C). On page 1112 of [5] the IPCC states that *"TCR is a more informative indicator of future climate than ECS"* and this is especially true during the 21st century."

Ollila [6] has calculated with three independent methods the value of λ: The Earth' energy balance 0.268 ($K/(Wm^{-2}$), spectral calculations by Spectral Calculator [12] application 0.259 ($K/(Wm^{-2}$), and by MODTRAN application [13] 0.319 ($K/(Wm^{-2}$). The value calculated by the energy balance shows that there is no positive water feedback mechanism in the atmosphere and the author has used the λ value of 0.27 $K/(Wm^{-2})$ thereafter. The direct humidity and temperature measurements from 1980 onward show no positive water feedback either [14].

2. ITERATIVE WARMING CALCULATIONS OF DIFFERENT RADIATIVE FORCINGS

2.1 Warming Based on the Greenhouse Effect and Radiative Forcing

The calculation method of temperature change by GH drivers in this study is based on the definition of GH effect and the physical connection of energy fluxes and temperatures of the Earth's energy balance. The IPCC writes in the glossary of Assessment Report 5 (AR5) [1] that *"the change in a greenhouse gas concentration contributes to an instantaneous radiative forcing (RF). RF is the change in the net, downward minus upward, the radiative flux at the tropopause, or top of the atmosphere. Surface temperature and troposphere warm in response to this RF gradually restoring the radiative balance at the top of the atmosphere."*

This chain of steps has been depicted in Fig. 4.

On the second row of boxes in Fig. 2 has been shown that the surface emitted flux Es will increase due to the increased surface temperature. This increase has a further effect on the increase of the absorption flux At. This increase is much smaller than the initial step

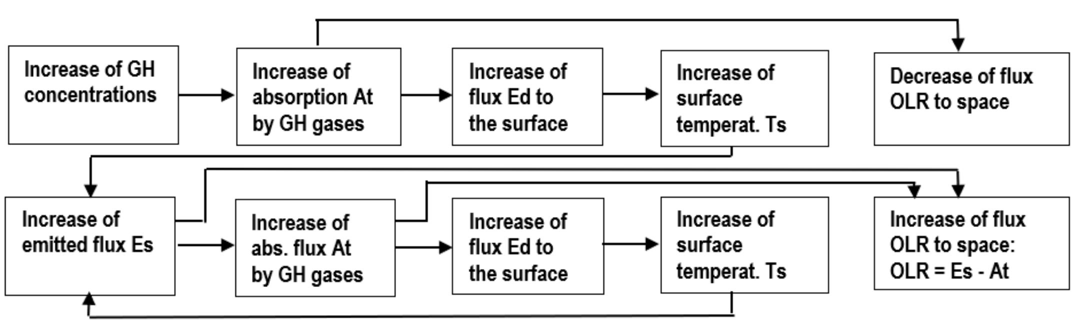

Fig. 4. A flow diagram of the stepwise increase effects of the GH gas concentrations happening through gradual changes in fluxes and temperatures

caused by GH gases. The emitted flux OLR (outgoing longwave radiation) to space starts to increase because now the change of Es flux is greater than the absorption flux At. If this would not be true, the OLR flux to space would not gradually increase to the original value of the OLR. It should be noticed that the net energy flux absorbed by the Earth has been assumed to be constant 240 Wm^{-2}.The second row in Fig. 2 shows that the mechanism of the flux effect and temperature effect can be repeated until the outgoing Et flux has reached its original value.

2.2 Dependency of Emitted and Absorbed Fluxes

The emitted flux according to Planck's equation looks very nonlinear but around the average surface temperature it is practically linear. This fact has been illustrated in Fig. 5 of [15] showing the temperature effects of radiative forcing applying spectral calculations and a constant climate sensitivity parameter λ. The differences are insignificant in these curves.

According to Planck's radiation law the emitted flux of the material at the temperature of 15°C is 390.93 Wm^{-2}, and the same at the temperature of 17.2°C is 403.10 Wm^{-2} assuming the emissivity 1.0. A linear equation has been applied based on these two points for calculation the surface temperature Ts (°C) based on the emitted flux Es.

$$Ts = -55.6684 + 0.18077 * Es \tag{4}$$

The calculation methods of flux changes are based on simple linear relationships. The magnitude of the total radiation SRF to the surface is the sum of SW radiation and LW radiation by the atmosphere SRF = Ss + Ed. The relationships of the energy balance values of Fig. 1 have been applied to calculate the changing flux values as the iteration proceeds. The relationships values are collected in Table 1.

Magnitude differences of fluxes have been illustrated in Fig. 5 by normalizing the changes to be zero at 15°C.

The emitted flux Es value 395.6 Wm^{-2} corresponds to the temperature of 15.84°C assuming the emissivity to be 1.0. Generally, the surface temperature has been assumed to be 15°C which is not the same as the measurement-based Es values of the Earth. Prather and Hsu [16] have found that the Earth receives 1.5 Wm^{-2} more insolation energy than in the climate models. This is since the Earth is a spherical object, but the climate models are based on the flat Earth model. This discrepancy is not an essential issue in the calculations of this study, but it is an indication that climate model variables do not equate completely with the reality.

There is no univocal basis for selecting the temperature starting point for iteration calculations. In this study the starting point is 15.24°C being 0.6°C lower than the temperature based on the energy balance value of 15.84°C. Because the dependencies are essentially linear in the iteration changes, the temperature effects are not depending on the starting point selection.

By using the starting point temperature and flux values, the value of reradiation flux Ed from the atmosphere must be 341.199 Wm^{-2} to give the OLR flux value 240.0 Wm^{-2}. The OLR flux is the same as in the energy balance of the present-day meaning that the solar insolation changes have not been included.

The flux Ed is the sum of shortwave absorption flux Sa, the latent heating L, the sensible heating T, and the LW absorption flux At [2]

$$Ed = Sa + L + T + At \tag{5}$$

Table 1. Coefficients for calculating the flux in iteration process based on the energy balance values of the present day

Flux	Coefficient	Value
LW radiation emitted to the atmosphere, Aa	Aa/SRF	0.719
LW radiation transmitted from surface to space, Et	Et/SRF	0.0558
Total absorption by GH gases, At	At/Aa	0.4182
Total LW radiation emitted by the surface, Es		Es = Aa + Et
Total LW radiation to space, ORL		OLR = Es-At

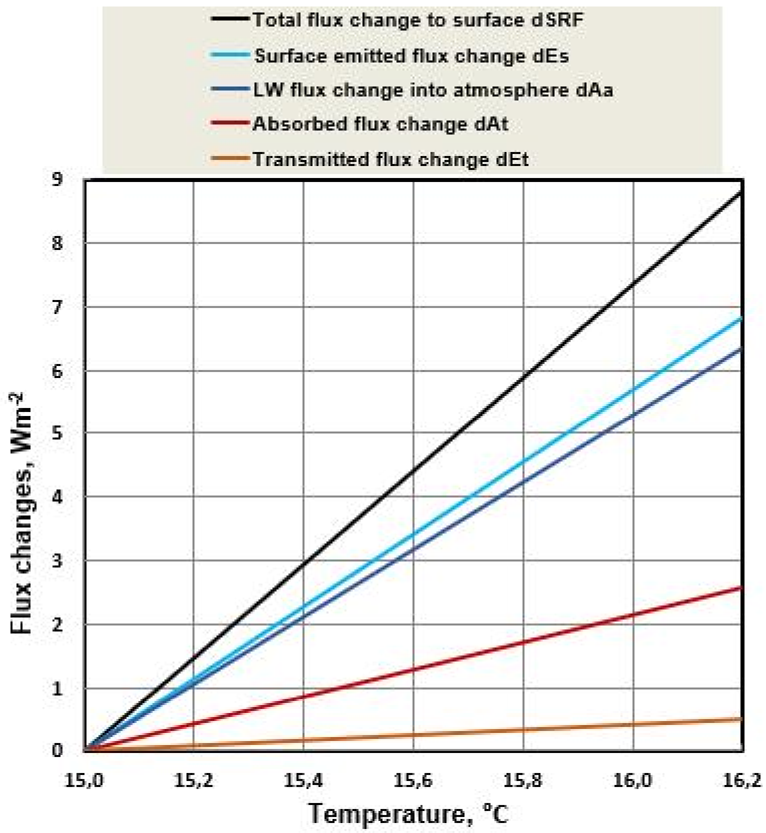

Fig. 5. Linear dependencies of flux changes

Ollila [6,14] has shown above that there is no positive water feedback in the atmosphere. It means the same constant value of 90.8 Wm^{-2} can be used for latent heating in iterations. The sensible heating must be 23.008 Wm^{-2} to give 341.199 Wm^{-2} at the temperature of 15.24°C by applying equation (5). Using these two points (15.24°C / 23.008 Wm^{-2}, and 15.84°C / 24.2 Wm^{-2}) a linear relationship can be formulated for sensible heating flux Ts

$$T = -7.277 + 1.9867 * Ts \qquad (6)$$

If this linear equation would be valid for a broader temperature range, then the sensible heating flux would be about zero at the temperature of 4°C, which seems to be reasonable.

2.3 Iteration Results

Applying the calculation principles as described above, four different simulations were carried out. The first simulation is for RF value of 2.16 Wm^{-2} which is the RF value of Ollila14 for climate sensitivity (CS) 2*CO_2. The results are depicted in Table 2 showing a warming value of 0.61°C. This is remarkably close to the value of 0.58°C calculated by equation (3) using λ value is 0.27 K/(Wm^{-2}) per Ollila14.

It should be noticed that the RF value of 2.16 Wm^{-2} has been added to At value in the first iteration step, and this constant RF value change remains the same during the iterations. Otherwise the At will be calculated using its relationship to the LW radiation emitted to the atmosphere, Aa.

The 2*CO_2 value by iterations for the IPCC's RF value of 3.7 Wm^{-2} is 1.12°C. The warming caused by the anthropogenic factors since 1750 is also possible to simulate using this iteration method. The total RF value for the year 2011 is 2.29 Wm^{-2} according to the IPCC [1] and this RF gives the warming of 0.66°C. The same RF value according to Ollila [6] is 1.344 Wm^{-2} and this forcing gives the value of 0.35°C. These iterations are tabulated in Appendix 1. The summary of the results is depicted in Fig. 6.

Table 2. The simulation results of radiative forcing of 2.16 Wm^{-2}

Step	Ts	Ss	Ed	SRF	Aa	T	Et	Es	At	dAt	OLR
Start	15.24	165.00	341.20	506.20	363.94	23.01	28.25	392.19	152.19		240.00
1	15.20	165.00	341.00	506.00	363.79	23.01	28.24	392.04	154.29	2.10	237.74
2	15.49	165.00	343.10	508.10	365.30	22.92	28.36	393.66	154.92	2.73	238.74
3	15.57	165.00	343.64	508.64	365.69	23.50	28.39	394.08	155.09	2.89	239.00
4	15.67	165.00	344.39	509.39	366.23	23.66	28.43	394.66	155.31	3.12	239.35
5	15.73	165.00	344.77	509.77	366.50	23.86	28.45	394.95	155.42	3.23	239.53
6	15.77	165.00	345.09	510.09	366.73	23.97	28.47	395.20	155.52	3.33	239.68
7	15.80	165.00	345.29	510.29	366.88	24.06	28.48	395.36	155.58	3.39	239.78
8	15.82	165.00	345.44	510.44	366.98	24.11	28.49	395.47	155.63	3.43	239.85
9	15.84	165.00	345.54	510.54	367.06	24.16	28.50	395.55	155.66	3.46	239.90
10	15.85	165.00	345.61	510.61	367.11	24.18	28.50	395.61	155.68	3.49	239.93
11	15.85	165.00	345.66	510.66	367.14	24.20	28.50	395.65	155.69	3.50	239.96
12	15.86	165.00	345.70	510.70	367.17	24.22	28.51	395.67	155.70	3.51	239.97

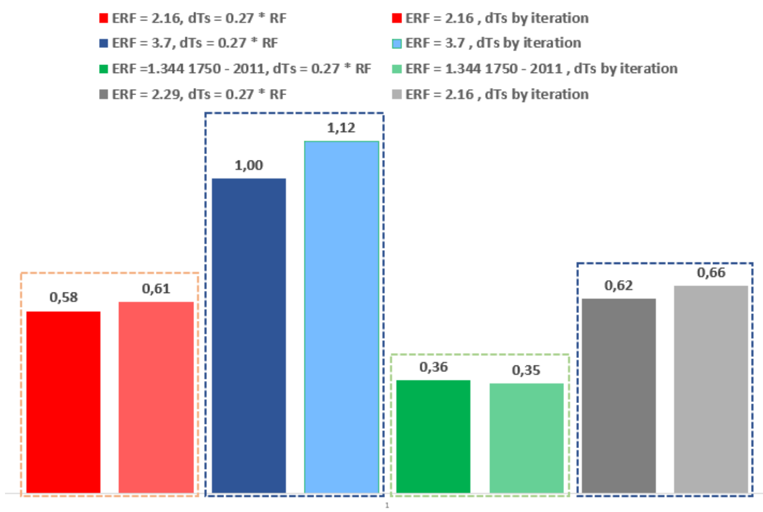

Fig. 6. RF values calculate by iteration method and by a climate sensitivity parameter λ

3. STRATOSPHERIC COOLING

Stratospheric cooling has been challenged in some studies. In a study of [17] the objective was to analyze if there is any stratospheric cooling effect and the result was that it is insignificant. Goessling and Bathiany [18] carried out a thorough analysis of stratospheric cooling because they had not found this kind of analysis anywhere. Their analysis was based on the absorption of GH gases according to wavelengths and partially also in the different parts of the atmosphere. The researchers have used a quite simple window-grey atmospheric model composed of an opaque wavelength zone and a completely transparent region from 8 to 12 μm. Their conclusion was that it is real, and it has a positive impact on RF.

The absorption areas of GH gases have been depicted in Fig. 7 according to wavelengths and it is useful information for understanding the stratospheric cooling phenomenon. At the troposphere, about 98% of the total absorption has been achieved. According to the spectral analysis calculations of this study, in the stratosphere ozone absorbs 66%, water 32.5%, and methane & nitrogen oxide 1.5% in the present-day climate. The absorption of ozone happens in the so-called “atmospheric window” wave zone from 9 to 10 μm. In Fig. 7 it can be noticed that the ozone absorption peak is much greater in the stratosphere than in the troposphere. The reason is that water is the only GH gas capable to absorb in the absorption zone of ozone, but its concentration is extremely low in the stratosphere. CO_2 is so strong absorber is its wavelength zone from 12 to 19 μm that its absorption does not increase after 1 km altitude. Strong absorption of O_3 in the stratosphere and non-existing absorption of CO_2 are decisive features in stratospheric cooling.

When CO_2 absorption increases, the lower part of atmosphere warms, less upwelling radiation in the non-window part reaches the higher altitudes and therefore these altitudes cool. The stratosphere is warmer than the troposphere and it is caused mainly by shortwave absorption of O_3 and partially by LW radiation absorption of O_3 in the region from 9 μm to 10 μm and these absorptions remain practically the same regardless of CO_2 concentration changes. When the absorption by CO_2 increases in the troposphere, it reduces the absorption of water (the main competitor with the CO_2 absorption) also in the stratosphere in the wavelength zone from 12 to 14 μm, Table 3.

The results summarized in Table 3A show that the stratospheric absorption decreases when the CO_2 concentration increases from 280 ppm to 560 ppm. Table 3B shows that the IRF value 3.196 Wm^{-2} is 0.507 Wm^{-2} greater than the ERF value of 2.689 Wm^{-2}. It means that the stratospheric cooling decreases the final ERF value. This result is univocal, and it contradicts the results of Chung & Soden [8] and S&al18. This result is in line with Fig. 3 showing that at the tropopause the absorption value is already about 98% of the total absorption in the atmosphere indicating that the stratospheric cooling has an insignificant role in the ERF value anyway.

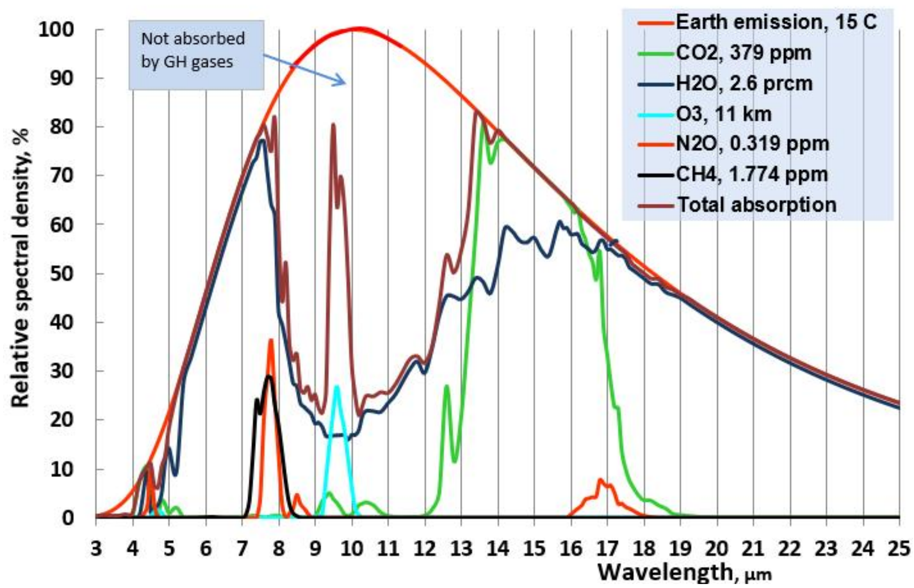

Fig. 7. Absorption bands and areas of GH gases being alone in the atmosphere. The total absorption curve (a purple line) illustrates the average global climate conditions

Table 3. A. The absorptions (Wm^{-2}) by GH gases in the stratosphere for CO_2 concentrations of 280 ppm and 560 ppm applying the atmospheric GH gas profiles of the year 2015. B. LW radiation upward (LWup) values and changes at the tropopause and at the TOA (70 km). Both calculations have been carried out in clear sky conditions

A. Absorption changes	**Absorption CO_2 280 ppm**	**Absorption CO_2 560 ppm**	**Absorption Change, Wm^{-2}**
Ozone	5.04	4.92	-0.12
Water	2.91	2.11	-0.79
Methane & nitrogen oxide	0.13	0.10	-0.03
Total change	8.08	7.13	-0.95
B. LWup changes	**CO_2 280 ppm**	**CO_2 560 ppm**	**ΔLWup, Wm^{-2}**
LWup at the tropopause	272.295	269.100	IRF = 3.196
LWup at the TOA (70 km)	265.365	262.676	ERF = 2.689
ΔLWup in the stratosphere	7.015	6.434	-0.581

The conclusion about the stratospheric cooling is that it is a real phenomenon, but its impact does not increase RF but decreases it. In this respect, the stratosphere does not differ from the troposphere. The earth's energy balance reacts on LW radiation changes at the TOA and it does not matter if the absorption changes happen in the troposphere or in the stratosphere.

There is an analogy to shortwave absorption in the atmosphere. About 30% of this absorption happens in the stratosphere mainly by ozone. The Earth's energy balance at the TOA would not be in balance if this 30% would not be included.

The iterations show that the changes in the calculated values are insignificant after 10 steps. It is essential to notice that the OLR value really closes the original starting value of 240 Wm^{-2}. The difference between the simulated OLR value and the original value 240 Wm^{-2} varies between 0.006% and 0.06%. It means that the climate reacts to GH gas concentration changes as defined in the GH effect definitions [1,2].

In the first simulation for RF = 2.16 Wm^{-2}, the LW absorption flux At increases from value 152.19 Wm^{-2} to the value 155.70 Wm^{-2}. This increase is 3.51 Wm^{-2} which is 62.5% greater than the initial RF value increase of 2.16 Wm^{-2}. The reason is the increased LW radiation emitted to the atmosphere (Aa). The repetitive calculations simulate in correct way what will happen in the atmosphere when there is a change in radiative forcing by GH gases.

The TCR value for the RF forcing of 2.16 Wm^{-2} is 0.61°C and it is remarkably close to 0.58°C calculated by Equation (3). The IPCC has reported that the average TCR value for the initiative forcing of 3.7 Wm^{-2} is 1.85°C. This value has been calculated applying equation (3) and the λ value of 0.5 $K/(Wm^{-2})$ meaning positive water feedback. The IPCC [1] has reported the TCR value without feedback effects to be 1.2°C. This simulation method gives the value of 1.12°C, and according to equation (3) it is 1.00°C.

Applying equation (3) with λ values of 0.27 $K/(Wm^{-2})$ and the RF value of 1.344 Wm^{-2} for GH gases, the warming value is 0.36°C from 1750 to 2011 This simulation method by iterations gives almost the same warming of 0.35°C. For the same period, the IPCC [1] has reported the RF value of 2.29 Wm^{-2}. By using Equation (3) and λ value of 0.5 $K/(Wm^{-2})$, the temperature increase would be 1.15°C and by λ values of 0.27 $K/(Wm^{-2})$ the temperature change would be 0.62°C. This iteration method gives the warming value of 0.66°C for 2.29 Wm^{-2} forcing.

4. VALIDATION

This study shows that if the calculations have been carried out according to the definition of the GH effect by iterations, there is no positive water feedback. It should be noticed that positive water feedback has not been mentioned in the original GH effect definition of the IPCC [1].

The warming values of different climate sensitivity presentations can be tested by using the result that the contribution of the CO_2 400.6 ppm is 2.5°C applying the correct GH effect definition [2]. In Fig. 8 two warming graphs are depicted.

The green curve is the Ollila14 model based on equations (1) and (2). The red IPCC model curve is based on same equations which give TCR values of 1.0°C if no water feedback has been applied (λ = 0.27 $K/(Wm^{-2})$). IPCC has reported [5] that the TCR value is 1.2°C if there are no feedbacks included. The IPCC has not reported in which way they have calculated this value, and there is a small discrepancy between the values of 1.0°C and 1.2°C. The warming change from CO_2 concentration 0 ppm to 280 ppm (dashed curves) is based on the absorption decrease by spectral calculations [15] as depicted in Fig. 9.

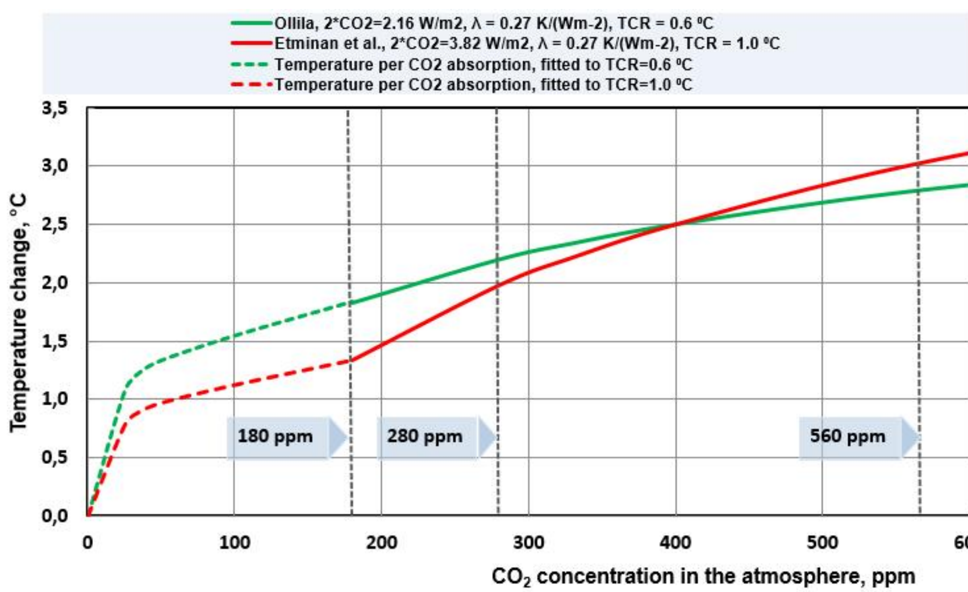

Fig. 8. Warming effects of CO_2 normalized to the greenhouse effect of CO_2 being 2.5°C in 2014 (400.9 ppm). CO_2 warming effects from 280 ppm onward are per a green curve, TCR = 0.6°C, and per IPCC (2013), a red curve, TCR = 1.0°C

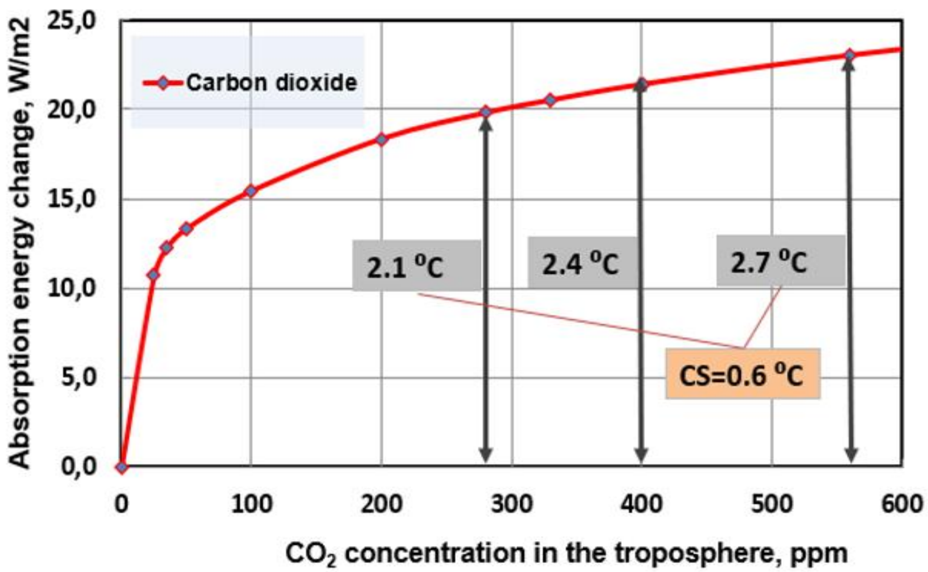

Fig. 9. The total absorption by CO_2 in the troposphere using the average global atmosphere

It should be noticed that the total absorption by CO_2 does not increase after the altitude of 1 km and therefore the absorption calculations in the troposphere are applicable.

The general feature of absorption is that the absorption rate change, i.e. the angle coefficient of the absorption curve, diminishes with increasing GH gas concentration. The absorption due to a GH gas also follows another general rule of absorption, which is that increasing concentration change from zero upward has the strongest effect in the beginning. The starting phase approximately follows the Beer-Lambert law, which states that absorbance depends linearly on the concentration and path length. When the concentration increases, this relationship is no longer valid. There is a very nonlinear dependency from 20 to 100 ppm for CO_2, and thereafter the relationship is slightly nonlinear after 180 ppm, which can be approximated by a logarithmic relationship very well.

The curve of the model (TCS = 0.6°C) according to Eq. (3) of this study shows a smooth feature of a warming rate without a transition point at the 180 ppm. The curve of the IPCC model (TCS = 1.0°C) has a transition point at 180 ppm because the angle coefficient starts to increase after 180 ppm when it should steadily diminish. This curve fitting shows that the IPCC model cannot be fitted into this new GH effect magnitude.

There is a semi-empirical way to calculate the warming impact of the CO_2 concentration of 400.83 ppm. Ollila [12] has calculated the total absorption values of five climate zones (°C / (Wm^{-2})) at the tropopause: polar winter -16 / 163.329, polar summer 15 / 294.701, mid-latitude winter -1 / 217.534, mid-latitude summer 21 / 335.221, and tropics 26.5 / 380.064. A fitted curve can be calculated between the climate zone temperature (T) and the total absorbed energy (E)

$$T = -274.3249 - 50.7580 * \ln(E) \qquad (7)$$

The coefficient of determination is 0.999, and the standard error of the estimate is 0.62°C. Utilizing the weighting factor based on the geographical areas for these climate zones, the global absorption value is 307.533 Wm^{-2}. It is only 0.5% higher than 305.978 Wm^{-2} calculated applying the one profile approach for the average global atmosphere. Without CO_2 the absorption is 291.31 Wm^{-2}. Applying equation (7) the temperature change is 2.49°C for this absorption change. The same value calculated by the GH effect analysis [2] is 2.5°C and thus the difference is insignificant. This validation result is important because equation (7) is related to the real climate conditions.

The climate zone temperatures are related to two radiative fluxes absorbed by the surface namely solar insolation 165 Wm^{-2}, and infrared radiation from the atmosphere 345 Wm^{-2}. The latter is a combination of solar absorption 75 Wm^{-2} and the GH effect 270 Wm^{-2}. Therefore, equation (7) is applicable for radiation flux changes of solar insolation or total absorption changes caused by GH gas concentration perturbations.

In this study the spectral analyses are carried out utilizing the Spectral Calculator application [12] and the average global atmospheric temperature and GH gas concentration profiles. The synthesis analysis by Stephens et al. [19] shows an average value of 314.2 Wm^{-2} in 13 independent observation-based studies for the downward LW flux on the surface in the clear sky conditions. The value of the same flux of this study model is 310.9 Wm^{-2}, meaning a difference of 1.0%. The LW radiation flux at TOA in the clear sky conditions according to spectral calculations of this study is 265.3 Wm^{-2}. The same flux value based on the NASA CERES satellite observations [20] from 2000–2010 is 266.4 Wm^{-2}. The difference is 0.4%. These uncertainties are much smaller than the uncertainties of the observed flux values. These values mean that the atmospheric model of this study used in the spectral calculations, describes very accurately the radiation fluxes of the real atmosphere.

5. DISCUSSION

The climate sensitivity parameter λ can be calculated from temperature increases and the corresponding RF values of this study. The λ varies from 0.26 $K/(Wm^{-2})$ to 0.30 $K/(Wm^{-2})$ and the average value is 0.28 $K/(Wm^{-2})$. This value is remarkably close to the value of 0.27 $K/(Wm^{-2})$. Ollila [6] has calculated this latter value with two different methods: 1) The energy balance equation and 2) using spectral analysis calculations. The third method of this study gives almost the same result.

This study's scope covers partially the calculations of ERF value of 2*CO_2 because a new iteration method has been applied. There is a great difference between the ERF values (Wm^{-2}): Ollila14 2.16, MHSS98 3.71, EMHS16 3.82. The real reconstruction of two latter values is impossible because atmospheric data has not been properly referred in these studies. The IPCC [5] and EMHS16 refer to the study of Shi [21] indicating that its simplified expression gives almost identical ERF value with their studies. It looks like researchers have not noticed that Shi's calculations have been carried out in the fixed relative humidity conditions, which duplicates the CO_2 forcing [5].

An interesting point is, why the stratospheric cooling effect of 1.1 Wm^{-2} per S&al18 is 750% greater than the value of 0.13 Wm^{-2} by MHSS98. The researchers of EMHS16 do not comment on this huge difference at all. A hint can be found in S&al18 that the IRF values of many models are not known. The radiative kernel method applied in the GCMs has rapid adjustments in key roles [8]. Since the IRF value of many GCMs was not available, it means that the IRF values have been calculated backward, i.e. from an ERF value that has been subtracted the sum of rapid adjustments. A fact is that the IRF applied in GCMs cannot be calculated by the LBL method and therefore there must be a discrepancy in the term "IRF". The IRF should be greater than the ERF value because the stratospheric cooling effect decreases the IRF value and not increase as calculated by S&al18.

The following criticism can be suggested concerning shortwave absorption changes by CO_2 which MHSS98 have integrated into the ERF value. The net solar energy absorbed by the Earth is the sum of the absorption by the atmosphere and by the surface. If the absorption by the atmosphere increases, it will decrease by the same amount the absorption by the surface, which means literally zero-sum game thinking the warming effect of shortwave absorption. Therefore, the shortwave part of MHSS98 is not justified to be a climate driver.

The expression that stratospheric cooling causes surface warming is misleading. According to the GH effect definition [1] the increased absorption by GH gases decrease the outgoing LW radiation causing an RF effect at the TOA: *Surface temperature and troposphere warm in response to this RF gradually restoring the radiative balance at the top of the atmosphere.* Firstly, according to physical laws, the outgoing LW radiation does not react to the temperature profile of the stratosphere but only to the radiative balance of the Earth. Secondly, the total LW absorption by the GH gases has reached about 98 % of its final value already at the tropopause. Therefore, the LW flux changes in the stratosphere are insignificant as also calculated by MHSS98. This study shows that the small RF effect in the stratosphere has a negative impact on surface warming. The correlations between temperatures and radiations have been illustrated in Fig. 10.

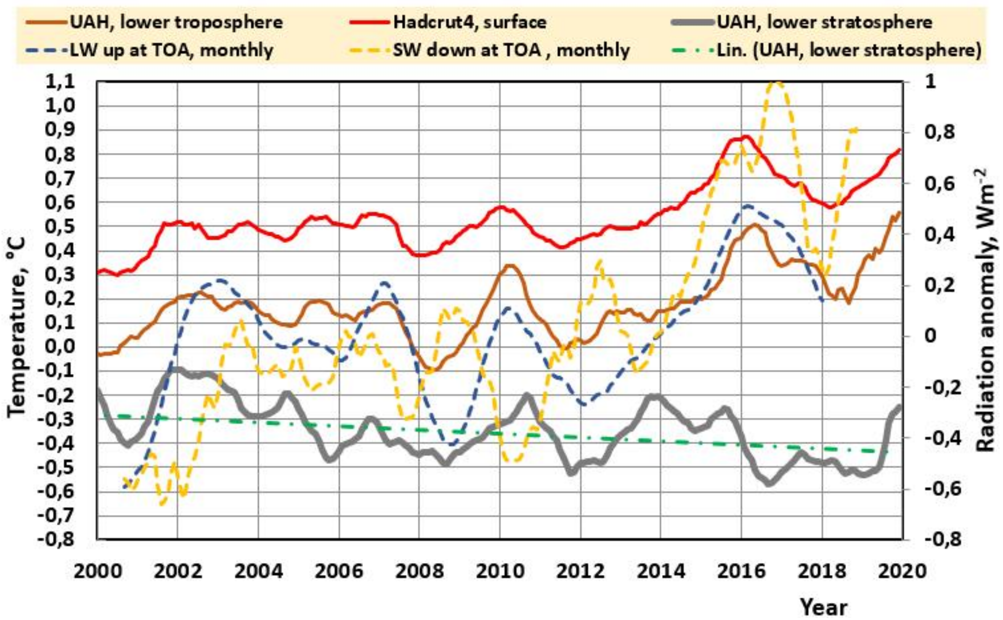

Fig. 10. Temperature trends of the surface, lower troposphere, lower stratosphere, SW radiation anomalies, and LW radiation anomalies at the TOA. The temperature values are 13 months running averages and the radiation anomaly values are 12 months running anomalies

The correlation between the lower stratospheric temperature and the surface temperature is -0.0021 and the same between the LW radiation anomaly and the lower stratospheric temperature is 0.058. These nonexistent correlations show that the stratospheric temperature has not a measurable effect on the surface temperature or the outgoing OLR. On the other hand, the SW radiation anomalies during the 2000s have had strong effects on the surface temperatures of 2015-16 – even stronger than the El Nino effect itself [22]. It has been shown that the SW anomaly during the ENSO (El Nino southern oscillation) 2015-18 is due to low-level cloudiness changes [23].

The IPCC has evaluateg the confidence level of the RF value of CO_2 in the AR5 [1] to be *very high* being the highest ranking among all the atmospheric drivers. This means that the final CO_2 forcing cannot be changed radically without losing confidence in these assessments. Anyway, well-known climate scientists have now introduced a radically new concept for the elements of the CO_2 forcing without creating any comments in the climate science society.

A paradigm means a theory being generally accepted and preferred by the authorities of the science in question - in this case the IPCC and most of the climate science community. The main paradigm of climate change science has been the GH effect and the present warming caused by enhanced GH effect due to increased GH gas concentrations.

The studies of Chung et Soden [8], EMHS16, and S&al18 do not encompass the word "greenhouse effect". These studies may be signs about the common paradigm change of climate change science. The main role in global warming is nowadays RF with different rapid adjustments and the IRF value of many GCMs is not known. The GCMs have been used to carry out "experiments" but they are simulation runs. It is almost impossible to know in which way these GCMs have been composed. It looks like the basic theory of the GH effect is not needed at all; It is only a question of instantaneous radiative forcings, rapid adjustments, and feedbacks.

An explanation could be that the IPCC seems to be aware of the scientific problem of its GH effect definition as well as the problem with positive water feedback. The new Assessment Report AR6 is under review. It will be interesting to see in which way the IPCC will address these issues. The history shows that the IPCC tries to ignore these kinds of problems by not addressing them at all or changing the terminology.

6. CONCLUSION

This study has shown that the atmosphere really works in the way defined by the IPCC: "*Surface temperature and troposphere warm in response to this RF gradually restoring the radiative balance at the top of the atmosphere.*". The author has shown by repetitive iterations that the original outgoing LW radiation OLR returns to its original value after an RF perturbation.

A conclusion of this study is that the calculations carried out by the way as defined by the IPCC do not indicate any positive water feedback mechanism in the atmosphere. There are now together three independent calculation methods resulting in the same conclusion and the humidity versus temperature observations show the same. In practical calculations, amazingly simple equations can be applied in calculating the temperature impacts of RF by using the λ value of 0.27 Wm^{-2}.

This study also shows that the magnitude of the GH effect is the sum of three energy fluxes emitted by the surface namely LW absorbed by GH gases and cloud, latent heating, and sensible heating (270 Wm^{-2}) . The atmosphere reradiates these fluxes to the surface together with SW absorption by the atmosphere. The GH effect flux 270 Wm^{-2} recycle between the surface and the atmosphere and it is the driving force of the GH effect and not only the LW absorption by the GH gases and clouds 155 Wm^{-2}.

Stratospheric cooling can be deducted by the general knowledge of radiation behavior in the stratosphere and the numerical calculations confirm these analyses. The results of this study show that stratospheric cooling happens when CO_2 concentration increases but its effect on radiative forcing is negative and not positive as reported in many studies. It means that the concept of ERF being the sum of instantaneous radiative forcing (IRF) plus rapid adjustments can be challenged to have serious flaws. If the stratospheric cooling has a negative effect of RF, then also the IRF magnitude has been wrongly calculated in GCMs.

Two independent validation calculations show that the TRC value of 0.6 of Ollila16 based on $2*CO_2$ value of 2.6 Wm^{-2} pass the tests but the TRC value of 1.8°C of the IPCC based on the $2*CO_2$ value of 3.71 Wm^{-2} or 3.82 Wm^{-2} cannot pass two independent tests.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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APPENDIX 1

Table A1. The simulation of IPCC's CS value using RFvalue ofd 3.7 Wm^{-2}

Step	Ts	Ss	Ed	SRF	Aa	T	Et	Es	At	dAt	OLR
Start	15.24	165.00	341.20	506.20	363.94	23.01	28.25	392.19	152.19	0.00	240.00
1	15.20	165.00	341.00	506.00	363.79	23.01	28.24	392.04	155.83	3.64	236.20
2	15.71	165.00	344.64	509.64	366.41	22.92	28.45	394.86	156.92	4.73	237.93
3	15.85	165.00	345.65	510.65	367.13	23.93	28.50	395.64	157.23	5.04	238.41
4	16.03	165.00	346.96	511.96	368.08	24.21	28.58	396.65	157.62	5.43	239.03
5	16.13	165.00	347.64	512.64	368.56	24.58	28.61	397.18	157.83	5.64	239.35
6	16.21	165.00	348.21	513.21	368.97	24.77	28.65	397.62	158.00	5.81	239.62
7	16.26	165.00	348.56	513.56	369.23	24.93	28.67	397.90	158.11	5.91	239.79
8	16.30	165.00	348.83	513.83	369.42	25.03	28.68	398.10	158.19	5.99	239.92
9	16.32	165.00	349.01	514.01	369.55	25.10	28.69	398.24	158.24	6.05	240.00
10	16.34	165.00	349.14	514.14	369.64	25.15	28.70	398.34	158.28	6.09	240.06
11	16.35	165.00	349.23	514.23	369.71	25.19	28.70	398.41	158.31	6.11	240.11
12	16.36	165.00	349.29	514.29	369.75	25.21	28.71	398.46	158.32	6.11	240.14

Table A2. The simulation of warming for 1750-2011 using RF value ofd 1.344 Wm^{-2}

Step	Ts	Ss	Ed	SRF	Aa	T	Et	Es	At	dAt	OLR
Start	15.24	165.00	341.20	506.20	363.94	23.01	28.25	392.19	152.19	0.00	240.00
1	15.20	165.00	341.00	506.00	363.79	23.01	28.24	392.04	153.47	1.28	238.56
2	15.38	165.00	342.28	507.28	364.72	22.92	28.31	393.03	153.86	1.67	239.17
3	15.42	165.00	342.58	507.58	364.93	23.28	28.33	393.26	153.95	1.76	239.31
4	15.48	165.00	343.03	508.03	365.25	23.36	28.36	393.61	154.08	1.89	239.52
5	15.51	165.00	343.25	508.25	365.41	23.49	28.37	393.78	154.15	1.96	239.63
6	15.54	165.00	343.43	508.43	365.54	23.55	28.38	393.92	154.21	2.02	239.72
7	15.56	165.00	343.55	508.55	365.63	23.60	28.39	394.01	154.24	2.05	239.77
8	15.57	165.00	343.64	508.64	365.69	23.63	28.39	394.08	154.27	2.08	239.81
9	15.58	165.00	343.70	508.70	365.73	23.66	28.39	394.13	154.29	2.10	239.84
10	15.58	165.00	343.74	508.74	365.76	23.67	28.40	394.16	154.30	2.11	239.86
11	15.59	165.00	343.77	508.77	365.79	23.68	28.40	394.18	154.31	2.12	239.88
12	15.59	165.00	343.79	508.79	365.80	23.69	28.40	394.20	154.31	2.12	239.89

Table A3. The simulation of warming for 1750-2011 using RF value ofd 2.29 Wm^{-2}

Step	Ts	Ss	Ed	SRF	Aa	T	Et	Es	At	dAt	OLR
Start	15.24	165.00	341.20	506.20	363.94	23.01	28.25	392.19	152.19	0.00	240.00
1	15.20	165.00	341.00	506.00	363.79	23.01	28.24	392.04	154.42	2.23	237.61
2	15.51	165.00	343.23	508.23	365.40	22.92	28.37	393.76	155.09	2.90	238.67
3	15.59	165.00	343.81	508.81	365.81	23.54	28.40	394.21	155.27	3.08	238.95
4	15.71	165.00	344.61	509.61	366.39	23.70	28.44	394.83	155.51	3.31	239.33
5	15.76	165.00	345.01	510.01	366.67	23.92	28.47	395.14	155.63	3.44	239.52
6	15.81	165.00	345.35	510.35	366.92	24.04	28.49	395.41	155.73	3.54	239.68
7	15.84	165.00	345.56	510.56	367.07	24.13	28.50	395.57	155.79	3.60	239.78
8	15.86	165.00	345.72	510.72	367.19	24.19	28.51	395.70	155.84	3.65	239.86
9	15.88	165.00	345.83	510.83	367.27	24.24	28.51	395.78	155.87	3.68	239.91
10	15.89	165.00	345.91	510.91	367.32	24.27	28.52	395.84	155.90	3.71	239.94
11	15.90	165.00	345.96	510.96	367.36	24.29	28.520	395.88	155.91	3.72	239.97
12	15.90	165.00	346.00	511.00	367.39	24.30	28.52	395.91	155.92	3.73	239.97

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