Original Research Article

Warming Effect Reanalysis of Greenhouse Gases and Clouds

ABSTRACT

The author has reanalysed the warming effects of greenhouse (GH) gases utilising the latest HITRAN 2012 database and improved water continuum calculations in the spectral analysis tool. The contributions of GH gases in the GH effect in the all-sky conditions are found to be: H_2O 81 %, CO_2 13 %, O_3 4 %, CH_4 & N_2O 1 %, and clouds 1 %. Because the total absorption is already 93 % from the maximum in the altitude of 1.6 km, which is the average global cloud base, the GH gas impacts are almost the same in the clear and all-sky conditions. The impacts of clouds are based on the normal cloudiness changes between the clear and cloudy skies. The positive impact of clouds is analysed and it is based on the warming impact of clouds during the night-time. The warming impact of CO_2 is very nonlinear and it means that in the present climate the strength of H_2O is 11.8 times stronger than CO_2, when in the total GH effect this relationship is 6.2:1. The atmospheric Total Precipitable Water (TPW) changes during ENSO events are the essential parts of the ENSO process and they are not actually separate feedback processes. The TPW changes during the ENSO events almost double the original ENSO effects. On the other hand, during Mt. Pinatubo eruption and during the three latest solar cycles, the long-term water feedback effect cannot be found despite of rapid warming from 1980 to 2000. This empirical result confirms that the assumption of no water feedback in calculating the climate sensitivity of 0.6 ºC is justified. Because there is no long-term positive feedback, it explains why the IPCC model calculated temperature 1.2 ºC in 2015 is 44 % greater than the average 0.85 ºC of the pause period since 2000.

Keywords: Global warming; greenhouse effect; greenhouse gases; climate sensitivity; cloud forcing; water feedback

1. INTRODUCTION

1.1 Objectives and Symbols

The physical properties of greenhouse (GH) gases in absorbing shortwave and longwave radiation have been well-known for decades. The latest updated knowledge has not been always available in some common spectral analysis tools. This has been also the case with the Spectral Calculator [1], the tool used by the author in earlier analyses. Now the latest HITRAN line data version 2012 is available [2]. The coefficients in water continuum model are also updated as to 2.5.2 MT_CK [3].

These updates created an objective to reanalyse the warming impacts of GH gases in the GH phenomenon itself and the real impacts in the present climate. The warming and cooling effects of clouds have been a continuous issue of different opinions and therefore it is another objective of this study. The third objective is to carry out a water feedback analysis, which has a major impact on the climate sensitivity (CS).

Table 1 includes all the symbols, abbreviations, acronyms, and definitions used repeatedly in this paper.

Table 1. List of symbols, abbreviations, and acronyms

Acronym	Definition
AGA	Average Global Atmosphere
CF	Cloud Forcing
CL	Cloudiness
CS	Climate Sensitivity
CSP	Climate Sensitivity Parameter (=λ)
ENSO	El Niño Southern Oscillation
GCM	General Circulation Model
LW	Longwave
MLS	Mid-latitude climate zone, summer
MLW	Mid-latitude climate zone, winter
OLR	Outgoing longwave radiation
prcm	precipitated water in centimetre
PS	Polar climate zone, summer
PW	Polar climate zone, winter
RF	Radiative Forcing change
SW	Shortwave
TCF	Temporary Climate Forcing
TOA	Top of the Atmosphere
TPW	Total Precipitable Water
TROP	Tropical climate zone
UAH	University of Alabama in Huntsville temperature data set

1.2 The Survey of Greenhouse Effect Studies

The difference between the average global mean surface temperature (15 °C) and the temperature (-19 °C) corresponding to the average outgoing longwave (LW) radiation (239 Wm^{-2}) at the top of the atmosphere (TOA) is a common measure of terrestrial GH effect thus being 34 °C. The GH gases and clouds absorb the LW radiation emitted by the Earth's surface and in this way, they prevent the cooling of the Earth making it a habitable planet.

The number of studies for calculating and analyzing the contributions of GH gases is surprisingly low. The most important results are summarized in Table 2.

Table 2. The contribution percentages of GH gases in the GH phenomenon after different studies.

GH gas	Michell	Kiehl & Trenberth	Schmidt et al.	Ollila
H_2O	65	60 (38)	50	82
CO_2	32	26	19	11
O_3	1	8	Others 7	5
CH_4 & N_2O	2	6		2
Clouds		(39)	25	

Michell [4], Kiehl & Trenberth [5], and Ollila [6] have carried out the calculations in the clear sky conditions and Schmidt et al (7) values are for all-sky. Kiehl & Trenberth have also two percentages for cloudy sky conditions. In addition to these comprehensive studies, there are some studies indicating percentages for individual GH gases: Clough et Iacono [8] water 63 %, Miskolczi & Mlynczak [9] CO_2 9 % and Pierrehumbert [10] CO_2 about 33 %.

The atmosphere composition applied in the calculations has a decisive role. Michell has not specified the atmosphere. Kiehl & Trenberth have used US Standard 76 atmosphere (USST 76) and they have reduced the water content by 12 %. It means that in their analysis, the water content is only 50 % about the average global atmosphere (AGA), which is 2.6 prcm (precipated water in centimeters). Ollila [11] has carried out these calculations also applying the USST 76 and the results are very close to Kiehl & Trenberth [5]. Even though some researchers [12] think that the use of USST 76 is an international and IPCC accepted standard for atmospheric calculations, its composition makes it not applicable for any global atmospheric calculations.

The calculation method is not similar in all studies. Kiehl & Trenberth [5], Miskolczi & Mlynczak [9] and Ollila [11] have calculated the contribution of each GH gas by removing it from the atmospheric model. Schmidt et al. [7] have used a more complicated method by calculating the minimum and maximum impact. The minimum impact comes from the removing process and the maximum by applying the GH gas in question alone in the atmosphere. In this case, the result concerning the major absorbers water, carbon dioxide and clouds is almost exactly the average value of minimum and maximum impacts.

Only Schmidt et al. [7] have proposed that clouds have a positive contribution in the GH phenomenon even though they admit that the net radiative impact including SW effects of clouds is one of cooling. This is one of the issues discussed and analyzed later in this study.

The spread of the results in the contributions of GH gas may have been a reason, why IPCC has not concluded what are the most reliable values.

1.3 Warming and Cooling Effects of Clouds

Clouds have remained a subject of various and even opposite opinions in climate change science. The term *cloud forcing* (CF) is commonly used. This effect is due to the difference between the clear sky and all-sky conditions. The all-sky is the normal overall condition of the global atmosphere, where the average cloudiness is about 66 % [13]. The CF is specified as the difference between incoming SW radiation flux and outgoing LW radiation flux between clear sky and all-sky at TOA. The difference of SW radiation in these conditions is 51.2 Wm^{-2}, and the difference in LW radiation is 21.2 Wm^{-2} using the values of the study of Ollila [14]. In this study the major source of radiation fluxes are from Zhang et al. [15]. This means the CF value of -30.0 Wm^{-2}, which is cooling. A survey of the CF studies [14] shows that CF varies normally between the -17 Wm^{2} and -28 Wm^{-2} giving the average value of -23.4 Wm^{-2}.

It should be noticed that this specification has a special nature. The SW radiation change happens immediately, if the cloudiness changes. The LW radiation fluxes react immediately for cloudiness changes but SW changes start to warm up the atmosphere, the surface of the ocean and the land and it takes a long time before a new balance could be reached. The time constant is for ocean is 56±11 days, 29±6 days for the land [16], and 2.7 days for the atmosphere [14]. This means that in about one year the surface temperature would be close to the value corresponding to a new cloudiness value.

In two studies the CF effect has been found to be -0.11ºC/CL-% [17] and -0.1 ºC/CL-% [14], which are based on different research methods (CL-% = Cloudiness-%). This result means that the long-term cloudiness changes can result in relatively great temperature changes. For example, the permanent cloudiness change of 8 % would cause the temperature increase of 0.8 ºC.

There is a special dynamic feature included in the CF phenomenon. It is not generally known or understood. It could be called *transient cloud forcing* (TCF). This phenomenon comes out in analyzing the radiative balance of the Earth's surface. This energy balance includes only two major incoming radiative fluxes: the SW flux from the Sun and the downward LW flux emitted by the atmosphere – sometimes called a reradiated LW flux. In calculating the final incoming SW flux on the surface, six different fluxes must be subtracted from the original insolation flux of the Sun.

Ollila has carried out the calculation of the energy balance for clear, cloudy, and all-sky conditions [14], [18]. The summary of the balance for the surface is in Table 3.

Table 3. The energy budget of the Earth's surface. Clear and cloudy sky values are for pseudo-balance conditions.

Radiation flux, Wm^{-2}	Clear	Cloudy	All-sky
SW radiation absorbed by surface	190.0	154.8	166.8
Downward radiation emitted by atmosphere	318.0	359.0	344.7
Surface balance	508.0	513.8	511.8

The balance values are very close to each other. The cloudy sky value is greater than the clear sky value. This seems to be incorrect, because the CF studies show that more clouds mean lower temperatures.

The explanation is in the measurement time and in the dynamics of the cloudiness change. The Earth will never be in the steady-state conditions for clear and cloudy skies. Locally cloudiness changes continuously. For example, a measurement value of a clear sky means that the sky has been clear during some hours or days and in some rare cases even weeks.

It has not had time enough to reach the new steady state value of the clear sky, which means that the surface is in the state of a dynamic change. Ollila [18] calls this state a pseudo-balance state.

There is no reliable information available, that could be the average periods of clear and cloudy skies locally in the global scale. A practical estimate could be 1 day for clear sky and 2 days for cloudy sky making the average cloudiness-% to be 100*2/3 = 67 %.

Why is the balance value of the cloudy sky greater than that of the clear sky? An analysis shows, what happens, when the clear sky turns to the cloudy sky. In two or ten days, the temperature of the surface ocean (70 % of the Earth's surface) does not decrease practically at all regardless of radiation changes. The land surface temperature and especially the temperature of the atmosphere start to change but they do not decrease but they increase. The decrease effect will come later. This is called an inverse response and it is rather rare in the process dynamics. The reason is in the diurnal radiation fluxes. The clouds trap more LW radiation than the cloudless atmosphere and because of this, the downward radiation increases from 318 Wm^{-2} to 359 Wm^{-2}, which is 5.8 Wm^{-2} more than the decrease of the SW radiation from 190 Wm^{-2} to 154.8 Wm^{-2}.

The measured radiation fluxes [14] reveal that the radiation flux emitted by the surface is in clear sky 394.1 Wm^{-2}, and in cloudy sky 396.3 Wm^{-2}. They correspond the black surface temperatures of 15.6 ºC and 16.0 ºC, which is in line with the surface balance values. These are the effects of the TCF phenomenon. Because the incoming SW radiation is the original energy source of the Earth, the surface temperature must follow the decreasing SW radiation flux eventually. The downward radiation flux depends on the incoming radiation flux directly (= SW radiation absorption by the atmosphere) and indirectly (= the GH gases absorb LW radiation emitted the surface) and it must decrease later according to the time constants of the ocean, land and the atmosphere.

What is the time, when the temperature reacts into "wrong" direction? In this example the temperature increases first 0.4 degrees and thereafter it stars gradually to decrease depending mainly on the time constant of the atmosphere, which is 2.7 days. The time needed to overcome this "wrong" direction change is from 2 to 10 days. TCF is a real phenomenon, which has been confirmed by the radiation flux measurements. Even though TCF reacts firstly in the "wrong" direction, it should not be confused with the temperature change of CF. CF and TCF phenomena have critical roles in calculating the contributions of clouds in the GH effect.

2. ABSORBTION BY GREENHOUSE GASES

2.1 Effects of HITRAN 2012 and Water Continuum

The first calculations were carried out to find out the impacts of HITRAN 2012 and water continuum updates in the absorption calculations. The author has used in earlier studies the atmospheric one profile model called average global atmosphere (AGA) [6], [11], [14], [18], [19], [20]. This model was based on the GH gas concentrations in 2005 and therefore it is called AGA05. The GH gas concentrations of AGA05 are modified from the GH gas profiles of the Polar Summer of Spectral Calculator to correspond the values reported by IPCC [21]. The water profile was adjusted in such a way that the total precipitable water (TPW) was 2.6 cm [22].

The total absorption in the troposphere applying the AGA05 condition and the HITRAN 2008 version was 302.709 Wm^{-2}. When the AGA05 was applied using the newest HITRAN 2012 version and the updated water continuum, the total absorption was 303.308 Wm^{-2}. It is only a 0.2 % greater value, which mean that these updates have a very small effect for absorption calculations.

In later calculations of this study, the GH gas concentrations are updated to correspond with the values in year 2015 [23] and therefore this climate model is called AGA15. The AGA15 profile gives the value of 305.978 Wm^{-2} as the total absorption. The difference is mainly due to the higher CO_2 concentration (400.83 ppm versus 379 ppm).

2.2 Simulation of Climate Zones

I have used one climate profile in calculations utilizing AGA15. Because the climate varies in the different climate zones, the question is, how well one profile represents the global conditions. This can be tested by calculating the absorption in the troposphere applying 5 climate zones: tropical (TROP), mid-latitude summer (MLS), mid-latitude winter (MLW), polar summer (PS) and polar winter (PW). The results of these calculations are (Wm^{-2}): PW 163.329, PS 294.701, MLW 217.534, MLS 335.221, and TROP 380.064. Utilizing the weighting factor based on the geographical areas for these climate zones [19], 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 AGA15. The difference is mainly due to the fact that the TPW value of climate zones is 2.7 cm and the one of AGA15 is 2.6 cm. The results of these calculations are depicted in Figure 1.

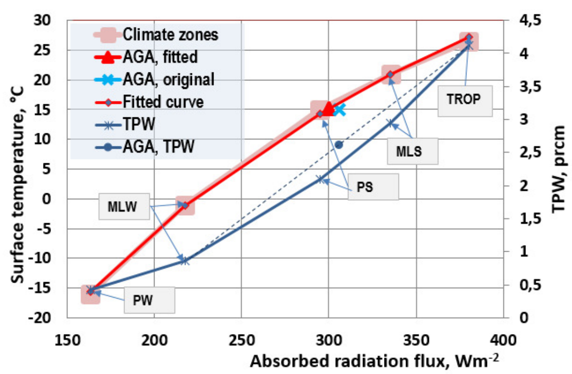

Figure 1. The relationship between the absorption fluxes, temperatures, and water contents of different climate zones. The climate zones of the curves starting from the left corner are PW, MLW, PS, MLS, TROP. The temperatures and TPW values are from the climate profiles of Spectral Calculator [1].

The relationship between the temperatures (T, ºC) and absorption energies (E, Wm^{-2}) is logarithmic:

$$T = -274.3249 + 50.7558 * \ln(E) \qquad (1)$$

The coefficient of determination r^2 is 0.999 and the standard error of the temperature estimate is 0.9 ºC. In Fig.1 is depicted also the AGA15 value, which is 15 ºC / 305.978 Wm^{-2}. This point is not exactly on the fitting curve, because the overall TPW value of climate zones is 2.7 cm and the one of AGA15 is 2.6 cm. The AGA15 point (a blue cross) is slightly modified to fit it (a red triangle) on the curve applying the values of 15.19 º C / 300 Wm^{-2}. The blue curve shows the increasing TPW values according to the warmer climate zones. The blue dot is the AGA15 value of 2.6 prcm.

2.3 Warming Impacts of Greenhouse Gases in the Clear Sky

Applying the AGA15 atmospheric profile, the absorption values of GH gases can be calculated by changing the concentration of each GH gas starting from zero level in clear sky condition. The warming effects can be then calculated by using equation (1). The results are depicted in Fig. 2.

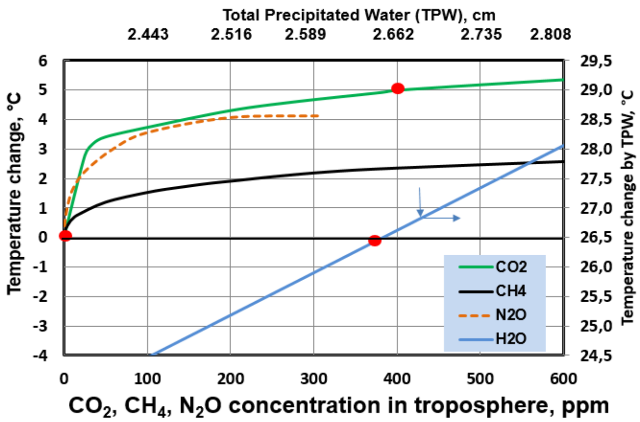

Fig. 2. The warming impacts of GH gases in the clear sky conditions. The red dots represent the concentrations and warming impacts of the year 2015.

The warming effect of CO_2 is highly nonlinear in the present atmosphere but the effect of H_2O is practically linear around the average TPW value of 2.6 cm. Also, the concentrations of CH_4 and N_2O are so low that they are still in the region of Beer-Lambert law, where the absorption is almost linearly dependent on the gas concentration. The warming impacts of CO_2 can be fitted with the logarithmic equation:

$$T = -1.01403 + 0.988487 * \ln (CO_2) \qquad (2)$$

where T is the temperature impact (ºC) and CO_2 is the concentration of CO_2 (ppm). The coefficient of determination r^2 is 0.999, the standard error is 0.02 ºC. This formula is valid in the concentration range from 200 ppm to 800 ppm. This formula gives the temperature change 0.6 ºC for the CO_2 concentration from 280 ppm to 560 ppm.

The reasons for the nonlinear effects can be illustrated by the absorption graphs of GH gases, when the relative spectral density is calculated as a function of wavelength. In Fig. 3 the absorption graphs are depicted from the 3 μm to 25 μm.

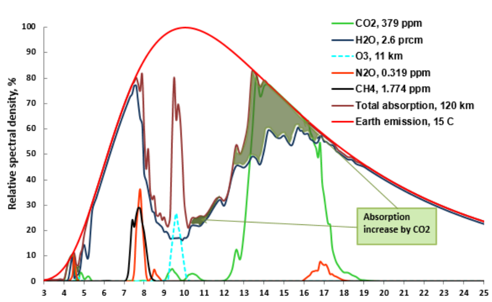

Figure 3. The absorption band Graphs of GH gases in the AGA05 atmosphere. The green shaded areas indicate a total warming impact of CO_2 of concentration of 379 ppm.

Water absorbs completely all the IR radiation emitted by the Earth's surface in the wavelength zone from 25 µm to 100 µm. The shaded green area gives a good image of the magnitude of CO_2. The absorption area changes due to the increased concentrations of CO_2, CH_4, and N_2O from 2005 to 2015 are so small that they could not be detected in the graphical presentation of Fig. 3.

The curve of each GH gas is calculated when it is the only GH gas in the atmosphere in the AGA05 conditions. The combined effect of all GH gases is not a summary of the band areas of single GH gases. The actual total absorption can be calculated only when all the GH gases are present at the same time. The total absorption is depicted by the purple line. The absorption areas of CH_4 and N_2O show that they are very small and inside the absorption areas of H_2O, which reduces their impacts further. Also, the CO_2 absorption area overlaps with water and the real impacts are possible to calculate only by the means of spectral analysis by varying the CO_2 concentration.

3. WATER FEEDBACK

3.1 Water Feedback in the Climate Zones

Water feedback is one of the most important issues in the climate change science. The results and opinion deviate completely from each other. IPCC and many research communities use the approach that water feedback exists and it is positive in nature by doubling the warming effects of other GH gases. The Table 9.5 in AR5 [24] summarizes 30 different GCMs (General Circulation Model), which have the Climate Sensitivity Parameter (CSP or λ) averaging 1.0 K/(Wm^{-2}). Because this CSP value is for Equilibrium Climate Sensitivity (ECS) value, it includes water feedback and other positive feedbacks. The CSP value of 0.5 K/(Wm^{-2}) includes only water feedback [24]. The opposite result is from Miskolczi [22] that the GH effect of the Earth's climate is constant, which means that the water feedback is negatively compensating for the warming effects of other GH gases.

One possible way to analyze the water feedback is to calculate the warming effect of water by hypothesizing that the Earth's climate follows the humidity features of the climate zones. From Fig. 1 it is easy to find out that the absolute water content increases as the climate is getting warmer.

The absorption flux of CO_2 concentration 280 ppm is 298.728 Wm^{-2} and the same of CO_2 concentration 560 ppm is 301.177 Wm^{-2}, which corresponds the temperature change of 0.48 ºC according to equation (1). If we assume that the absolute water content of the global atmosphere follows the climate zone behavior, the water content change would increase this absorption change like this: 280 ppm absorption 297.728 Wm^2 and 560 ppm absorption 301.592 Wm^{-2}. This change corresponds to the temperature change 0.66 ºC. Thus, the water feedback would positively increase the warming effects of GH gases by 35.4 %.

3.2 Water Feedback During the Last 25 Years

Rather reliable conclusions about the water feedback can be drawn from the behavior of the climate during the last 35 years. I have selected this period, because the encompassing satellite temperature measurements were introduced in 1979. Also, a new humidity semiconductor sensor technology Humicap® was introduced by the leading humidity measurement company Vaisala. This technology replaced rapidly the hygrometer technology, because it was more accurate and more reliable than the hygrometer technology.

I have started the analysis from the year 1979 by modifying temperature changes and all warming impacts to start from zero. The temperature is according to the UAH satellite data set [25] and absolute TPW values from NOAA [26] NCEP/NCAR Reanalysis dataset. The warming impacts of water are calculated based on the absorption calculations by increasing the water content of the AGA conditions (2.6 prcm / 305.978 Wm^{-2}) to the TPW value of 2.856 prcm giving the absorption value of 306.709 Wm^{-2}. By forcing the warming value (T) in Celcius degrees to be zero in 1979, equation (3) could be concluded:

$$T = -6.797 + 2.81 * TPW, \qquad (3)$$

where TPW is the absolute humidity in prcm. The warming impact of CO_2 is calculated by the equation introduced by Ollila [6]:

$$T = CSP * k * \ln(C/280), \qquad (4)$$

where CSP is 0.27 K/(Wm^{-2}, and k is 3.12 in the formula of radiative forcing of CO_2 (Wm^{-2}). The CO_2 concentration changes are from the data set of NOAA [23]. The results of these calculations are depicted in Fig. 4.

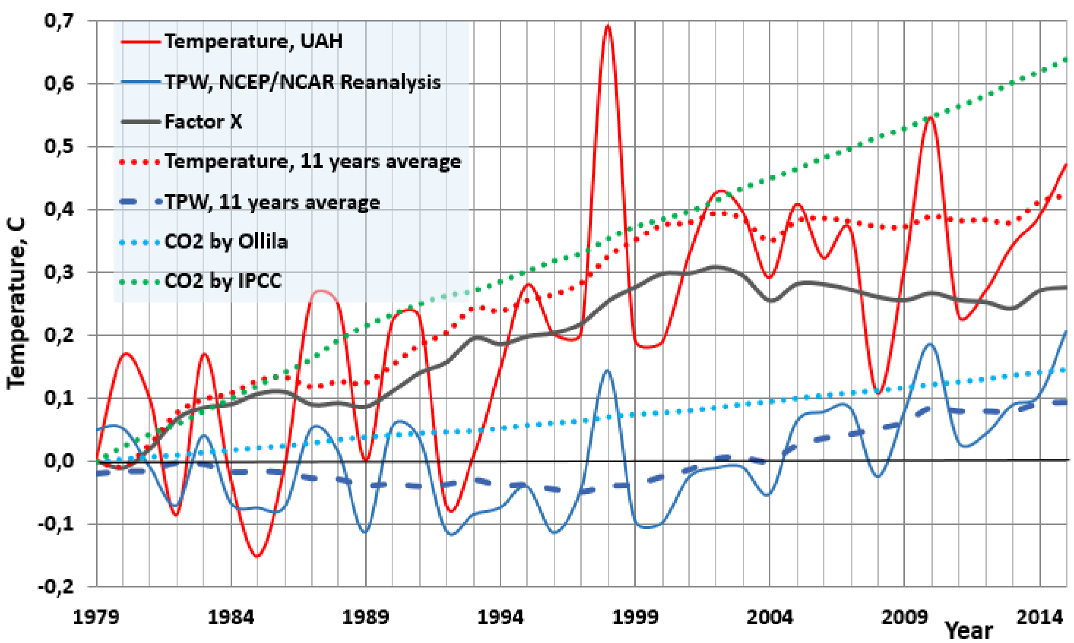

Figure 4. The temperature trend from according to UAH [25] and the major warming factors, which are absolute humidity and CO_2. The variable labelled "Factor" is the difference between the measured average temperature and the warming impacts of CO_2 by Ollila [6]. El Niño events are marked as to the strengths and they are followed by La Niña events which are not marked.

The variable labelled "Factor X" is also depicted in Fig. 4. It is the difference between the measured average 11 years temperature and the warming effect of CO_2 by Ollila [6]. This presentation makes it very clear that the warming impacts of water, CO_2, and ENSO events cannot explain the observed warming. It is easy to notice that the short-term temperature changes very closely correlated to the TPW changes. This relationship is even easier to notice from Fig. 5, where these two variables are detrended. All the short-term changes are ENSO events except Mt. Pinatubo eruption in 1991.

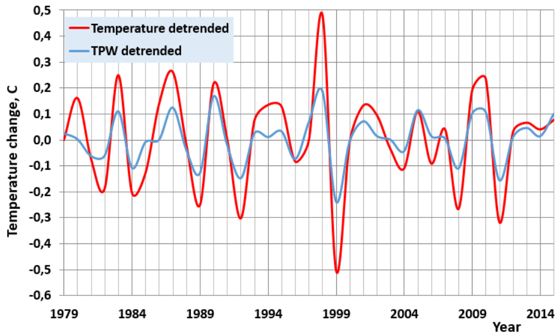

Figure 5. The detrended graphs of temperature and TPW values.

A hasty conclusion would be that the TPW variations have caused the temperature changes since 1979 until today. Looking at the shape of the monotonically rising temperature effect of CO_2 (IPCC or Ollila) and the sharp short-term changes of TPW, it is very clear that the relationship between these two variables is very poor.

The detrended analysis reveals that the short-term TPW changes could explain about 50 % of the short-term temperature changes. Concerning the El Niño / La Niña events, we already know that the cause is the regional changes in Pacific Ocean currents and winds. They initiate the temperature change and the strong change of TPW amplifies the change by a factor of about 100 percent. It is practically the same as the positive feedback used by IPCC, but can it be found in the long-term trends?

There is an essential feature in the long-term trends of temperature and TPW, which are calculated and depicted as 11 years running mean values. The long-term value of temperature has increased about 0.4 ºC since 1979 and it has now paused to this level. The long-term trend of TPW shows a minor decrease of 0.05 ºC during the temperature increasing period from 1979 to 2000 and thereafter only a small increase of 0.08 ºC during the present temperature pause period. It means that the absolute water amount of the atmosphere is practically constant reacting only very slightly to the long-term trends of temperature changes. Long-term changes, which last at least one solar cycle (from 10.5 to 13.5 years), are the shortest period to be analyzed in the climate change science. The assumption that the relative humidity is constant and it amplifies the GH gas changes by doubling the warming effects, finds no grounds based on the behavior of TWP trend.

It seems that there is a dilemma between the short-term behavior of TPW changes and the long-term (> 11 years) changes. It looks like that the global atmosphere does not behave in the same way as it does in the climate zones, where a higher temperature means always a higher TWP value. Because the analysis period is slightly more than three solar cycles, the conclusions for long-term behavior of TPW is rather reliable. This result supports the climate sensitivity (CS) calculations, where the absolute water amount has been assumed to be constant, and which gives the CS value of 0.6 ºC [6].

So, there is a “Factor X”, the unknown force or forces that change the Earth’s temperature. During the period from 1995 to 2005 these forces have caused a temperature increase of a 0.2-0.3 ºC and now these effects are decreasing, see the black curve in Fig. 4. These forces are outside of the scope of this study but they could be the cosmic forces such as the Sun and other forces acting in our solar system. There are studies proposing the possible reasons [27], [28] and the synthesis analysis combining these reasons together with the GH gases [29] showing very high correlations starting from year 1880.

In Fig. 4 is also depicted the warming impact of GH gases according to the IPCC. This graph is calculated using the CSP value of 0.5 K/(Wm^{-2}) and the radiative forcing (RF) values of GH gases. The temperature change, according to this method, is about 0.2 ºC higher than the measured temperature at the end of the period. The error becomes even greater, if the calculation would be started from the year 1750. The RF of GH gases in 2011 was 2.29 Wm^{-2} [24] and the increase from 2011 to 2015 has been 0.149 Wm^{-2} [30]. This means that the temperature increase caused by GH gases would be 0.5 (K/(Wm^{2})) * 2.44 Wm^{-2} = 1.22 ºC since 1750. It is 44 % higher than 0.85 ºC which is the average temperature of the pause period since 2000.

During the period from 1979 to 2000 the IPCC-model follows very accurately the long-term trend of temperature. Even during this period there is a serious problem in the model that it is based on the positive feedback of water. During this period the real TWP content has a slight downward trend, and therefore it cannot double the warming impacts of GH gases. When the real causes of warming do not increase anymore after 2000, the IPCC model still shows a strong increasing trend.

4. CONTRIBUTIONS OF GREENHOUSE GASES IN GLOBAL WARMING

4.1 The Contributions of Greenhouse Gases in the Greenhouse Effect

As summarized in section 1.2, the results of GH gases in the GH effects deviate a lot in the published research results. Because the lowest values for CO_2 warming effects are calculated for clear sky conditions, I have carried out a new analysis for calculating the results for all-sky conditions. The all-sky radiation fluxes and temperatures can be calculated as a combination of clear and cloudy sky values [31] utilizing the following equation

$$(1-k) * F_b + k * F_o = F_a \quad (5)$$

where F_b is the radiation flux of the clear sky, F_o is the radiation flux of the cloudy sky, F_a is the radiation flux of the all-sky, and k is the all-sky cloud cover factor [18]. In this study the value of k is 0.66, which means a cloudiness-% of 66 %.

The published values of average global cloud base and cloud top vary a lot. The results based on the radiosonde stations are 0.6 km for the base and 9.0 km for the top in 1995 [32]. The same values based on the weather satellite measurements over 20 years' dataset show the values of 1.6 km and 4.0 km [33]. The result of applying a semi-analytical cloud top height retrieval algorithm based on an asymptotic solution of the radiative transfer equation in the oxygen A-band gives the cloud top value of 6 km [34]. This analysis is valid for thick clouds only.

In this study the cloud base and top values of 1.6 km and 4.0 km have been used. The absorption calculations have been carried out by applying the AGA15 climate profile for the altitude of 120 km. In this connection, the absorption according to the altitude was calculated, and a technical problem in the Spectral Calculator was noticed. Namely the absolute absorption change in 1 km altitude without CO_2 was 20.092 Wm^{-2}, and in the altitude of 11 km, it was 16.515 Wm^{2}. There are two probable reasons for this, which occur at the same time.

In the atmospheric paths, the Spectral Calculator [1] divides the path into concentric spherical shells. The number of shells depends on the path and altitude range. For example, a path to 120 km altitude is split into 19 shells. The lowest shell is 250 meters thick and the highest is 10 km thick. In these shells, Spectral Calculator uses mass weighted values of temperature, pressure, and concentrations. This means that the calculation is more accurate for low altitude range of 1 km (the minimum for atmospheric paths) than the one of 11km range. This seems to create an accuracy problem for CO_2, which is a very strong GH gas in its absorption range from 12 µm to 19 µm. In the range from 14 µm to 16 µm CO_2 alone could easily absorb all the available infrared radiation emitted by the Earth's surface. In other words, in the presence of water, the CO_2 effect does not grow after the altitude of 1 km even though its concentration is practically the same up to the altitude of 80 km. After finding out this problem, the author has used the value of 20.092 Wm^{-2} for the total contribution of CO_2 from the concentration 0 ppm to 400.83 ppm. The author checked that this problem does not exist for CH_4 and N_2O, which are much weaker absorbers in the present-day atmosphere.

A very decisive selection is the calculation method. I have calculated the contribution of each GH gas by removing it from the atmospheric model. One of the most essential features of our planet is the ocean covers 70 % of our planet's area. They provide humidity into the atmosphere, which has the key role in the GH phenomenon. Therefore, it is a justified assumption that there is water all the time in the atmosphere.

The contributions are calculated for the clear sky and they are depicted in Table 4.

Table 4. The warming effects of GH gases in the clear sky conditions.

GH gas	Absorption	Absorption change	Percentage
Total	310.69		
CO_2	294.25	20.1	14.9
O_3	303.50	7.2	5.3
CH_4 & N_2O	308.65	2.1	1.5
H_2O		105.7	78.3
Total		135.1	100.0

The total absorption of the clear sky 135.1 Wm^{-2} is the difference of the surface emitted radiation flux 394.10 Wm^{-2} and the OLR at the TOA 259 Wm^{-2} [15]. These results show higher contribution for CO_2 (14.9 % versus 11.0 %) than those of the earlier study [6]. The contribution-% 14.9 is close to the one reported by Schmidt et al. [7] for a single factor removal process (14.0 %).

The results for the cloudy sky are summarized in Table 5.

Table 5. The warming effects of GH gases in the cloudy sky conditions.

	Below clouds 0-1.6 km			**Altitude 0-4.0 km**		**4-120 km**	**Cloudy sky, total**	
GH gas	Absor.	Absor. change	%	Absor.	Absor. change	Absor. change	Absor. change	%
Total	289.03	21.66		301.75	22.36	8.94		
CO_2	257.77	20.09	17.7	287.60	20.09	0.0	20.09	11.9
O_3	277.64	0.33	0.3	301.02	0.73	6.46	6.79	4.0
CH_4 & N_2O	276.73	1.32	1.1	300.21	1.54	0.51	1.74	1.0
H_2O		91.78	80.9		103.80	1.97	93.75	55.3
Clouds		0 .0	0.0		0.0	0.0	47.02	27.8
Total		113.44	100		126.2		169.4	100

The total absorption 169.4 Wm^{-2} of the cloudy sky is the difference of the surface emitted radiation flux 396.20 Wm^{-2} and the OLR at the TOA 222.8 Wm^{-2} [15]. The absorption fluxes for the altitudes from the surface to 1.6 km and to 4.0 km, are calculated in the clear sky conditions. The absorption values for the altitude from 4 km to 120 km are calculated by subtracting the altitude 0-4 km values from the total absorption 0-120 km. The total GH gas absorption values can be calculated by summarizing the values of altitudes 0-1.6 km and 4-120 km. The difference of the total absorption 169.4 Wm^{-2} and the GH gases is 47.02 Wm^{-2} and it represents the absorption of clouds. It means that the contribution of clouds would be 27.8 %, which is close to 25 % which was reported by Schmidt et al. [7].

The absorptions and contributions of GH gases in all-sky conditions are summarized in Table 6.

Table 6. The warming effects of GH gases in the all-sky conditions.

	All-sky, gross		**All-sky, net**		
GH gas	Absorp. change	%	Absorp. change	%	ºC
CO_2	20.1	12.7	20.1	12.7	4.3
O_3	6.9	4.4	6.9	4.4	1.5
CH_4 & N_2O	1.8	1.2	1.8	1.2	0.4
H_2O	97.8	62.0	127.3	80.7	27.4
Clouds	31.0	19.7	1.6	1.0	0.3
Total	157.7	100	157.7	100	34.0

The absorption flux values of the all-sky conditions are calculated using equation (5) and the values of clear and cloudy skies in Tables 4 and 5. The total absorption by GH gases and clouds in all-sky is 157.7 Wm⁻2. The flux values representing the maximum effects of clouds, have been called *gross values*. Clouds decrease the incoming SW solar radiation but in this calculation basis it has not been considered. We can demonstrate this situation by the greenhouse having glass walls and roofs, and which locates in the polar zone in April. During day-time the incoming solar insolation decreases considerably the need for heating the greenhouse by gas or oil. At night-time, the solar insolation effect deceases and much more heating is needed and it may override the energy-savings at the day-time. If we would calculate the energy savings only during the day-time, we would draw a wrong conclusion that more glass in the walls and in the roof, means more energy savings.

That is the case of gross effect of clouds in Table 6. Therefore, there is also the *net effect* of clouds included in Table 6. The net effect of clouds is the combination of increased absorption by clouds and therefore increased LW flux downwards and the decreased SW radiation. The most reliable measure of this TCF effect is the observed surface temperature increase of 0.3 ºC between clear sky and all-sky [15]. The increased absorption value of 1.6 Wm^{-2} is a theoretical absorption increase, which could create this temperature change. The net absorption percentages of GH gases and clouds are calculated from the total absorption of 157.7 Wm^{-2}. This calculation basis is not univocal for H_2O, because it is calculated by subtracting the total absorption of other GH gases from the total absorption. Anyway, if the contribution-% of H_2O in the clear sky is 78.3 %, and the one of the all-sky is 80.7 %, the conclusion is that this small increase is in the right direction, because the humidity of the all-sky is higher than that of the clear sky. These results are depicted in Fig. 6.

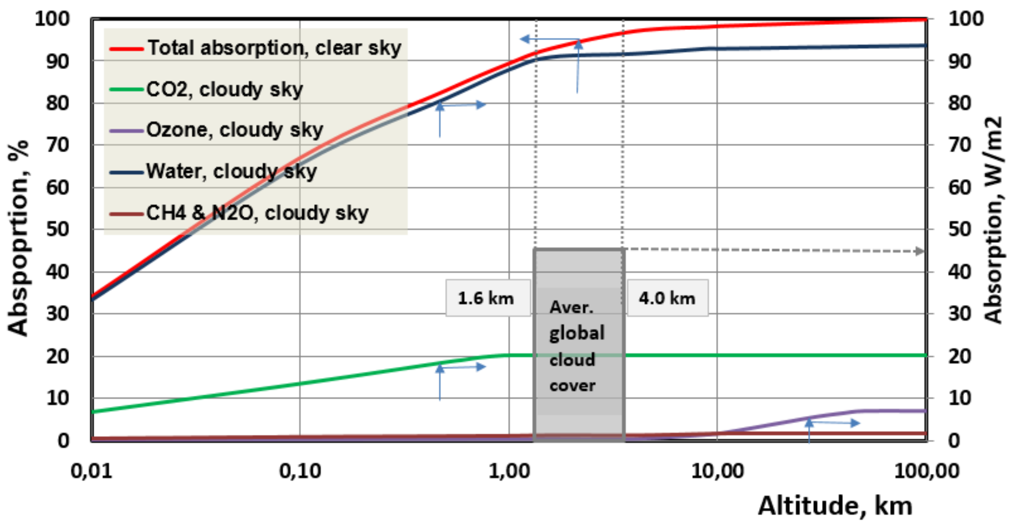

Figure 6. The absorption effects of GH gases in the clear and cloudy sky conditions.

The graphs in Fig.6 show that the total absorption in 1.6 km is already 93 % of that of 120 km. That is why the GH impacts of all-sky are very close to the values of the clear sky. The absorption effects of O_3 happens mainly in the stratosphere.

4.2 The Relative Strengths

The analysis of the contributions of GH gases in the GH effect is not applicable for the present-day atmosphere. The reason is that the warming impacts are too nonlinear. A separate analysis was carried out to find out the relative strengths by increasing the concentrations by 10 % and calculating the absorption for the altitude of 120 km.

Also in calculating the increased absorption caused by 10 % concentration increase, the CO_2 calculation was carried for the altitude of 1 km only. The other calculations were carried in the altitude of 120 km. The results are shown in Table 7.

Table 7. The increased absorption caused by the 10 % increase of concentration in AGA15 atmosphere. The reference value of the AGA15 absorption is 310.69 Wm^{-2}. The CO_2 change* is based in the altitude of 1 km.

GH gas	Total absorption	Absorption change	Relative strength
H2O	315.129	4.439	11.765
CO2	(310.996)	0.394*	1
O3	310.998	0.308	0.782
N2O	310.745	0.055	0.140
CH4	310.733	0.043	0.109

In the earlier study the relationship between H_2O:CO_2 was 15.2:1 and now it is 11.8:1. The main reason is in the more accurate calculation method for CO_2 absorption.

4. CONCLUSION

The new updates of Spectral Calculator with HITRAN 2012 and water continuum increases the absorption results of GH gases in the atmosphere only by 0.2 % in comparison to the older versions. This means that the results using the older versions are still applicable.

The analysis of the absorptions by climate zones approve that the absorption using the single average global atmosphere (AGA) profile has only 0.5 % difference to the sum of five different climate zones of the Earth. This means that the simulation using only one AGA profile is justified. The water content of a climate zone increases as the temperature becomes warmer. If the Earth would follow this humidity behavior, the water feedback would be positive and it would increase the warming impacts of other GH gases by 35 %.

The analysis of the period from 1979 to 2015 shows that the effects of water and other GH gases cannot explain the temperature trend. The warming impacts of GH gases (water feedback doubles the impacts of other GH gases) according to the IPCC model [24] are 44 % higher than the observed temperature in 2015 when compared to the average temperature from 2000 to 2015. The same impacts calculated by Ollila's formula [6] for the radiative forcing of CO_2, shows that the difference varies from 0 to 0.45 ºC during this period. The trend analysis shows that there is no water feedback during the three latest solar cycles. The conclusion is that the absolute water content can be kept constant in the long-term climate change analyses.

The detrended analysis shows very clearly that the short-term (1-2 years) CO_2 changes do not change the short-term absolute humidity values at all - there is no correlation. The culprit for the short-term changes is the ENSO event (El Niño and La Niña), which creates strong changes in the absolute water content. Usually this phenomenon is called positive water feedback but this term can be questioned in the ENSO events. When the temperature of the surface ocean increases, it increases evaporation and it gives rise to the water content in the atmosphere. The atmospheric TPW changes during ENSO events are the essential parts of the whole process and not actually separate feedback processes. The strong short-term global level changes of water amounts explain, why the El Niño and La Niña changes are so strong and why these regional phenomena have global effects after a 2-3 months' delay.

During the period from 1979 to 2015 there is only one short-term temperature change, which is not due to the ENSO. That is the eruption of Mt. Pinatubo in 1991 leading to the sudden global temperature drop of 0.5 ºC, which gradually vanished by 1995. It is interesting to analyze which kind of water feedback can be found if any. Soden et al. [35] reported that there was a water positive feedback applying -0.75 mm TPW peak reduction as to the NVAP-M trend [36] during the eruption. Ollila [37] found that it was impossible to draw any conclusions based on the trend TWP values, because the two datasets had opposite trends [26], [36]. The TPW trend in Fig. 4 is after NCEP/NCAR Reanalysis dataset and there is no trend from 1991 to 1995 meaning no water feedback. Therefore, the conclusion of the constant water content during the long-term temperature changes seems to be justified, because TPW changes happen only during ENSO events. This result supports the climate sensitivity (CS) calculations, where the absolute water amount has been assumed to be constant, and which gives the CS value of 0.6 ºC [6].

At the same time, there is an unknown force or forces, which create long-term temperature changes like the strong warming from 1985 to 2000. These unexplained warming effects vary between from 0 to 0.45 ºC as noticed before. They could be cosmic forces. The absolute water amount does not react to the long-term temperature changes (> 11 years).

The analyses of the GH gas impacts show that the impact of CO_2 is very nonlinear. The effects of GH gases for the all-sky are: H_2O 79 %, CO_2 13 %, O_3 5 %, CH_4 & N_2O 1 % and cloud 2 %. The cloud effort considers only the temporary (in average from 1 to 10 days) cloudiness changes of the Earth. The long-term cloudiness change increases still have the negative impact on the surface temperature (-0.1 ºC / cloudiness-%). These results mean that the all-sky values are close to clear sky values. The main reason is that the absorption in the altitude of 1.6 km is already 93 % of the total absorption in the altitude of 120 km. In these analyses the cloud base value has been 1.6 km and the cloud top value 4.0 km.

The effects of GH gases show that the warming effect of CO_2 is very nonlinear: in the GH phenomenon waters strength to CO_2 is 6.2:1, and in the present climate it is 11.8:1. The total absorption without CO_2 is 285.684 Wm^{-2}, which is very close to the absorption flux, if there is only water in the atmosphere: 286.704 Wm^{-2}. This latter water absorption is possible only, if the atmosphere can maintain the constant water amount 2.6 prcm of the present atmosphere. The empirical data shows that this is the case of the relatively small long-term changes of 0.5 ºC. Whether this would happen in the case of the average temperature drop of 4.3 ºC, we have no physical evidence. Anyway, the climate system seems to prefer maintaining the constant absolute water amount in the atmosphere rather than the constant relative water amount (positive feedback) or negative feedback, which would mean the constant greenhouse conditions.

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