GLOBAL WARMING AND THE ACCUMULATION OF CARBON DIOXIDE IN THE ATMOSPHERE

A Critical Consideration of the Evidence

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ABSTRACT
This paper provides a literature study of the observations on temperature changes and the accumulation of carbon dioxide in the atmosphere. It investigates the cause-effect relationship between these parameters, and makes an alternative interpretation to that given by the UN Intergovernmental Panel on Climate Change (IPCC).

The IPCC assumes increased used of fossil fuels is the major cause of the increasing concentration of carbon dioxide in the atmosphere. And the increasing carbon dioxide leads to global warming because of infrared absorption by this gas.

The following observations are not in agreement with the assumed direct correlation.

1. There is a very gradual increase to the annual human production of carbon dioxide, but the accumulation of carbon dioxide in the atmosphere is not proportional to the human emission. The annual uptake of carbon dioxide in the atmosphere is highly variable.
2. The measured average global temperature is also very variable and it is not proportional to the observed *concentration* of carbon dioxide in the atmosphere.

The variable amount of carbon dioxide added to the atmosphere each year, follows reasonably well the specific average value of the temperature in that year. This leads to the suggestion that the temperature causes the accumulation of carbon dioxide in the atmosphere (i.e. the opposite of the IPCC's assumption): *the annual average temperature varies under various influences, and this causes variable additions of carbon dioxide to the atmosphere. These influences can be external (cosmic) or internal (due to inherent instability of the climate system).*

The human emission of carbon dioxide may be contributing to the accumulation of this gas in the atmosphere – although we do not know to what extent – but this does not necessarily contribute to an extra temperature rise through infrared absorption. The temperature of the atmosphere is not exclusively determined by the radiation balance, but also by the high circulation rate of water. Evaporation from the Earth's surface absorbs heat and transports it to the higher air layers where condensation releases the heat so cool water returns to the surface as precipitation. This contributes to the pleasant climate on Earth.

The alarming message about a global temperature rise originates from measurements made at weather stations almost all in land areas. Weather balloons did not register this. The temperature of the troposphere has been measured world-wide since 1979. These observations – that include the oceans – do not as yet indicate a significant rise.

Taking into consideration the rapid passage of water through the atmosphere, which is expected to provide for an effective natural and self-regulating thermostat, provides explanation of several observations which are still puzzling in the current IPCC conception.

Climate change is a natural phenomenon that has always happened. It is generally assumed that since ~1870 there has been a trend of slight temperature increase over land. But this trend shows no direct annual relationship with the carbon dioxide concentration in the atmosphere.

1. INTRODUCTION

The UN Intergovernmental Panel on Climate Change (IPCC) warns that burning of fossil fuels may increase the concentration of carbon dioxide (CO_2) in the atmosphere to a level that will affect the climate by global warming.[1] The IPCC is a cooperation of the United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO). The increase of anthropogenic CO_2 emission between the years 1960 and 2000 and the accumulation of CO_2 in the air are well documented (see Figure 1), and their coherence is very suggestive.

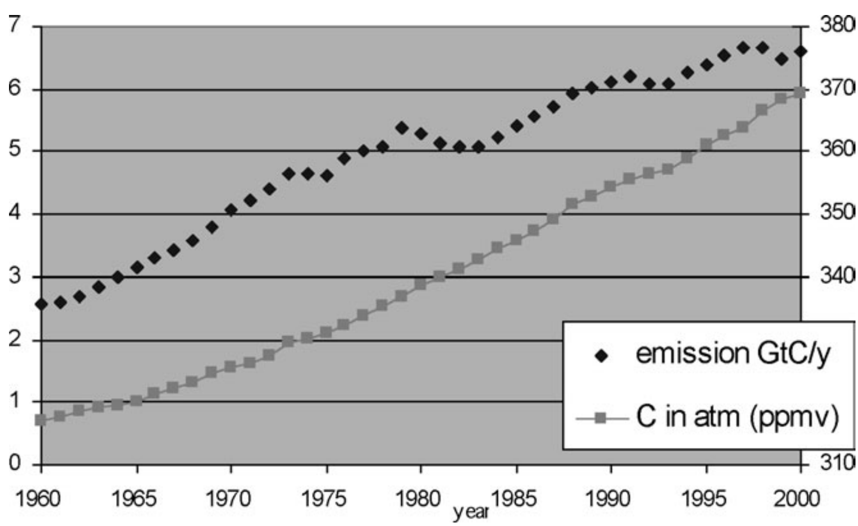

Figure 1. Anthropogenic emission and the accumulation of carbon dioxide in the atmosphere

1 The Kyoto Protocol, 1997. An international, recently ratified treaty, that requires developed nations to reduce emissions of infrared-absorbing gasses.

Left Y axis: Emission in GtC/y. Right Y axis: Concentration of carbon dioxide in the atmosphere in ppmv.

Sources: G. Marland and T. Boden. Carbon Dioxide Information Analysis Center Oak Ridge National Laboratory Oak Ridge, Tennessee (cdiac.ornl)
R.J. Andres,University of North Dakota,Grand Forks, North Dakota
C.D. Keeling and T.P. Whorf. "On line trends", cdiac.ornl.

An increase in surface temperature over the same period was also recorded by ground meteorological stations (see Figure 2).

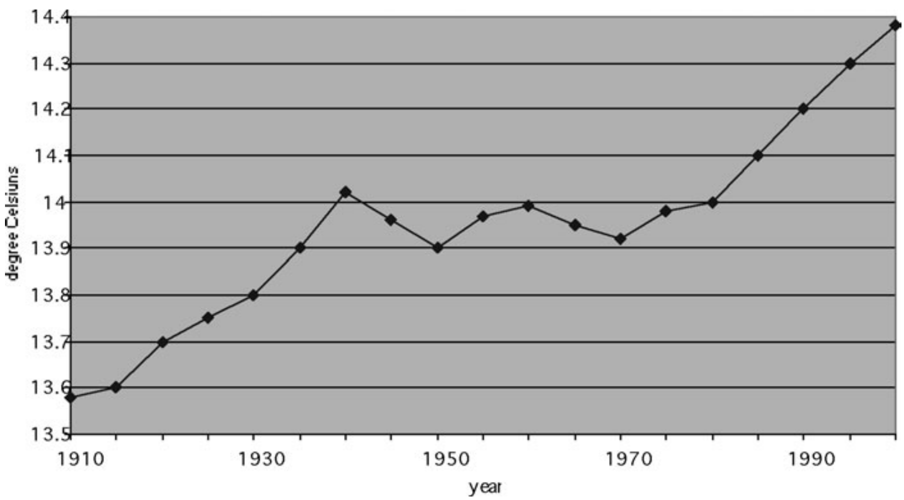

Figure 2. Moving nine year average of average temperature at the Earth's surface

Source: Redesigned from B. Lomborg[2]
Original reference: Jones *et al*. (2001, 2002), In "Trends", cdiac.ornl

However, measurements made using satellites and weather balloons provide serious doubt as to whether the average temperature of the lower troposphere increased significantly (see Figure 3).

Though the trends of both curves are different in Figure 3, the yearly fluctuations are surprisingly similar. This confirms the accuracy of both measurement series, but also emphasizes the significance of random variations between successive years, that are so far unexplained They may be caused by cosmic factors or by the inherent instability of the climate system (probably both).

Governmental policymakers proposed a protocol[1] to reduce the anthropogenic emissions, but many doubts have been raised as to whether they have jumped to

2 Therefore in Dutch the lower atmosphere is named the vapor sphere (dampkring).

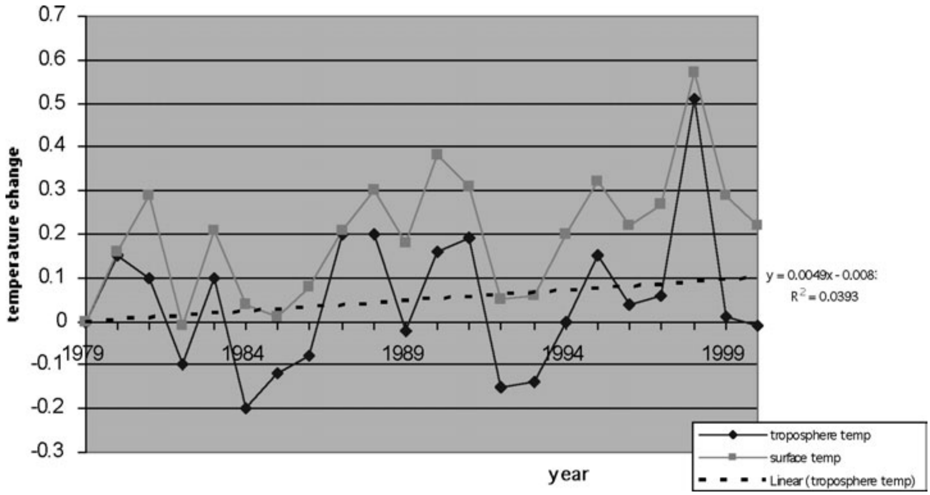

Figure 3. The annual fluctuation of the surface and the troposphere temperature

Source: B. Lomborg[2]
Original sources: J.K. Angell (1999) in "Trends" cdiac.ornl.[15] and J.R. Christy *et al*. (2000, 2001)[14] cdiac.ornl.

conclusions with their predictions for future global warming (for examples of reviews see reference 3). Herewith the climate debate went beyond the scientific dispute. Throughout this heated debate a major argument has been that such predictions cannot be made because the Earth's climate system is so complex.

Temperature, humidity, rain, sunshine, clouds, wind direction and strength are changing daily, during seasons, and over years and nowhere on earth in the same way. These variables can be measured every minute as representing a certain state that is the weather. The data set of the integral of all these variables over 30 years is usually considered to be the climate at a specific spot.

Each variable mentioned above represents a force that influences the other forces. Behind these interacting forces there is one independent major driving force; that is, the relative position of a site on earth to the sun. In the daily and annual cycles the temperature at a specific site on earth depends in the first place on its position relative to the sun. This changes periodically, so we can see the temperature as the major leading variable. The other variables are apparently strongly dependent on temperature, which indicates its central role, but the other variables also strongly influence each other. Therefore it is understandable that a possible change of climate

3 The volume of the atmosphere is estimated at $4.431*10^{18}$ m^3. At 360 ppmv (1995) the atmosphere contains $360*10^{-6} * 4.431*10^{18} = 1.60*10^{15}$ m^3 CO_2. Converted to GtC by a factor 12/24 this leads to 8.10^{14} kg C = 800 GtC. This corresponds to 360 ppmv, so 1 ppmv of CO_2 corresponds to 2.2 GtC. (The factor 12/24 is found as follows: At atmospheric conditions, 1 kmol gas has a volume ff 24 m^3, so 1 m^3 gas equals 1/24 kmol and 1 m^3 of CO_2 has a weight of 44/24 kg. This corresponds to 12/44 x 44/24 = 12/24 kg carbon.)

at a specific place is attributed to a change of temperature over a considerable period. But this is not necessarily so if the other variables react to neutralize a temporary temperature change over a certain time period.

Whether one can speak of an average global temperature is also questionable. Temperature indicates a *condition* and not an amount of anything. Theoretically an 'average temperature' makes little sense. This can be illustrated by the following example: a certain amount of thermal energy (heat) can be used to heat a body and raise its temperature, or it can be used to evaporate a quantity of water (or to melt a quantity of ice) at constant temperature.

Furthermore, average temperature indicates little about the planet's state. A planet with uniform temperature of 50ºC over its surface would have a mean surface temperature of 50ºC. But a planet with one hemisphere at 0ºC and its other hemisphere at 100ºC would also have a mean surface temperature of 50ºC. And if the regions of different temperature were moving across the planet then the mean surface temperature would not change.

This train of thought has mentioned only a limited number of variables as examples. The oceans (70 percent of the Earth's surface) are an important component of the Earth's climate system. Water has a high heat capacity. Since the emission received from the sun is strongest in the tropics at the equator, the water is heated there most and transported by flows to north and south to other climate areas. A considerable part of the solar energy that reaches the water surface is directly used for evaporation. The humid heated air rises (thermics) and transfers the heat to the cooler upper parts of the atmosphere, and it leads to complicated air flows all over the globe. Clouds are formed which reflect part of the sun's radiation energy. By these complex processes, temperature equilibrium is established in the lower troposphere as a result of incoming heat from the sun and outgoing heat from the Earth which is absorbed by certain components in the atmosphere.

Absorption of radiation in the air has been named the 'greenhouse effect' which is, however, a misnomer. Heat from the sun raises the air temperature inside a greenhouse, and this heated air is contained within the greenhouse. But the atmospheric 'greenhouse effect' does not contain warmed air near the surface. Warmed air can – and does – rise in the atmosphere because of convection. Backward radiation from the surface is partially absorbed by clouds and by gases (such as water vapour and CO_2) in the atmosphere, which causes heating of the atmosphere, and this is called the "greenhouse effect".

As indicated above, the heat absorbed by the Earth's surface and its atmosphere is intensively redistributed by air and water flows in vertical and horizontal directions. Nevertheless the atmosphere is like a skin which reflects radiation energy from the outside and contains partly radiation energy and heat from the 'body' in a dynamic equilibrium. The atmosphere (clouds and gases) loses energy by thermal radiation into space.

The major 'heat' radiation absorbing gases are water vapor and CO_2. The first occurs on the average in 1–2 volume percent in the atmosphere and is no doubt the most important one;[2] the atmospheric content of CO_2 is 370 parts per million volume (ppmv) or 0.037 volume percent. Like the human skin the planet's skin is not a static element, because the molecules of the heat-trapping gases are taking part in continuous cycles of emission and absorption on the earth surface.

Water evaporates continuously from the surface waters, condenses in clouds and returns as rain or snow. The flow through the atmosphere is extremely high. It is estimated that the flow[4] amounts to 496,000 km^3/y (liquid equivalent) and the total water in the atmosphere to 13,000 km^3 which corresponds to a recycle ratio of ~38 per year. Since evaporation and condensation heat is high, this water vapor flow is probably a major regulator of the lower troposphere's temperature.

CO_2 is continuously produced in the biosphere and again absorbed by green plants. The flow is usually expressed in gigaton carbon equivalents per year (GtC/y), and in this cycle it is estimated to amount to 60 GtC/y. There is, however, another cycle, because ocean waters liberate CO_2 when warming, and absorb it when cooling. This cycle is estimated at 90 GtC/y, thus the total circulation is 150 GtC/y.[5] The total content of the atmosphere is estimated at 800 GtC[3], and this corresponds to a recycle ration of 0.2 per year which is much lower than for water.

Despite these numbers, and the qualitative impression we have of the working of the atmospheric system as a whole, it is still impossible to describe its dynamics in more quantitative detail. One may wonder whether this will ever be possible because – in the complex system – we always have to consider the principle of predictable unpredictability. This was demonstrated in 1963 by the meteorologist Lorenz[6] who used simplified non-linear differential equations from fluid dynamics, and even with these simplified equations showed what he named 'deterministic nonperiodic flow' in the atmosphere. The study was useful exercise in complexity theory[4], but his model received little attention in meteorology, obviously for the reason that at present no more precise differential equations for the complicated interaction of variables can be stated.

We clearly see, however, the changes of a few variables coincide, per day, over seasons and over years (e.g., temperature with CO_2 concentration in the atmosphere) and this may give some more insight into the underlying processes, but it should be stressed that correlation does not prove a causal relationship: it may be coincidence. Mistaking coincidence for coherence happens very easily in a complex system with many interdependent variables. Such a mistake becomes very serious if a coincidence is used as a logical relationship in an attempt to predict.

Lastly it should be mentioned that climate change is a natural phenomenon that is observed to have occurred throughout recorded history and geological time. Its potential causes are also still the subject of investigation and speculation. It is postulated in the Kyoto hypothesis that today's climate is still changing naturally but

4 Complexity theory was formerly called catastrophe and chaos theory. Its principles were already developed in the 19th century. It dealt with nonlinear differential equations, which cannot be solved. The model study of complex systems was accelerated when the computers became sufficiently rapid to simulate the solution of differential equations. For an introduction see R.C. Hilborn, 'Chaos and Nonlinear Dynamics. An introduction for scientists and engineers', Oxford University Press, 1994.

5 These satellite observations are in agreement with those of weather balloons.

6 The disturbance may be a jump added to one of the flows through the system, or a change in the form of a sinusoidal function. The latter approach is named the sinusoidal response method.

now also under the influence of a major contribution from increasing fossil fuel burning. In the next Section we shall first consider this hypothesis, the observations on which it is based and the objections that have been raised by skeptical scientists. We shall see that very much at the bottom of the controversies are the questions; what is coincidence and what is correlation, and what is cause and what is effect?

2. CHALLENGES TO THE KYOTO HYPOTHESIS

In the IPCC reports and in most reports based on these, it is assumed that there must be a logical relationship between the three variables: increased human emission, CO_2 increase in the atmosphere, and temperature rise: and in this order of cause and effect. All further studies – including computer modeling leading to future projections of the climate – were based on these assumptions. And these projections finally lead to the "Kyoto Protocol". Therefore we introduce the term "Kyoto Hypothesis" to indicate this set of assumptions.

The simultaneous rise of two variables in a complex system cannot be assumed to be a correlation unless additional information or argument suggests such a correlation. However, at first sight, the simultaneous rise of CO_2 with human emission does imply a correlation (see Figure 1). Of course, one could expect that additional CO_2 emitted by human action would raise the CO_2 content of the atmosphere. However, there are natural CO_2 emission and absorption flows that are many times

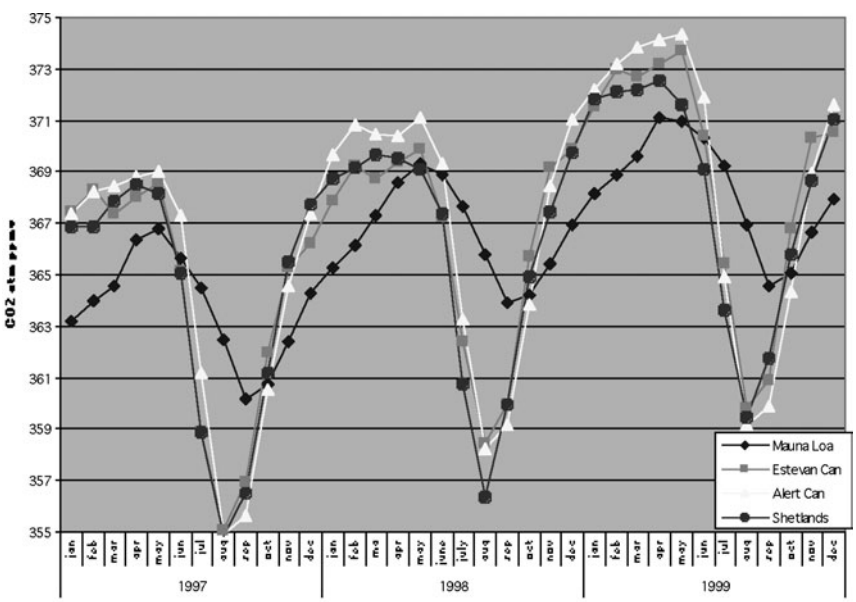

Figure 4. Rise and fall of carbon dioxide concentration in the atmosphere at four sites, Mauna Loa Hawaii, Estevan Canada, Alert Canada, Shetland Islands. Here three years are selected from the long term graph 1991–2000, C.D. Keeling and T.P. Whorf. "On line trends", cdiac.ornl

higher, and they are certainly not constant. For example, in the summer season the CO_2 content of the atmosphere decreases sharply, despite human emissions (see Figure 4).

More questionable is the assumed relationship between average global temperature rise and CO_2 in the atmosphere. Between 1910 and 1940 the temperature rose 0.4°C and the CO_2 concentration 10 ppmv. Between 1940 and 1970 the temperature decreased 0.1°C whereas the CO_2 rose 20 ppmv. Between 1970 and 2000 the temperature rose again 0.4°C, but then the CO_2 concentration rose 40 ppmv. So in these subsequent periods we see a temperature rise of +0.04°C/ppmv, followed by –0.005°C/ppmv, then followed by +0.01°C/ppmv. Next to that, the observed temperature rises are not evenly distributed over the Earth's surface. The current warm period occurs especially in central Europe. Relatively cool were the East of the Mediterranean, the North of the Atlantic, and Greenland.[7] The continental USA is of especial interest because it has exceptionally good and continuous coverage of measurement sites, and it shows a rise of 0.07°C from1880 to 1940 followed by a fall of 0.05°C until 2000 (i.e. a net rise of 0.02°C between 1880 and 2000).[7]

The assumption that increased CO_2 in the air raises temperature cannot explain the remarkable decline in mean global temperature from 1940 to 1970. But one effect may mask another. Fossil fuel burning increased throughout that time and may have released sulphur dioxide with resulting increase to sulphate aerosols in the air. These aerosols were assumed to have *cooled* the atmosphere by scattering solar radiation. Therefore, the temperature fall between 1940 and 1970 was assumed to have been caused by the aerosols cooling the air more than the increasing CO_2 warmed it. Cleaner emissions from power stations after 1970 were assumed to have reduced the aerosol emissions and, therefore, their cooling effect. However, the effect of soot particles – that retain thermal radiation – was not taken into account. The soot (i.e. carbonaceous material from combustion) combines with sulphate aerosol in the air and the combination provides strong greenhouse *warming*.[8] So, the aerosol should have *increased* the observed warming, not reduced it. The globally averaged warming (i.e. radiative forcing potential) from the soot/aerosol is calculated to be powerful (0.55 Wm^{-2}) and is between the potentials of CO_2 (1.56 Wm^{-2}) and methane (0.47 Wm^{-2}) that IPCC had claimed to be the two major trace greenhouse gases.[1]

This, of course, leaves hanging the question of why the temperature fell between 1940 and 1970. The IPCC's Third Assessment[1] used model studies to conclude that the fall was induced by changed solar activity. We agree, but – in common with the remainder of this report – we base our conclusion on empirical evidence: the mean length of the solar cycle correlates to the mean global temperature throughout the twentieth century until at least 1990.[9]

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7 Note the low regression factor of 0.05. If the exceptional 'hot' summer of 1998 is neglected, then the factor is down to 0.001. If the surface temperature is plotted against carbon dioxide concentration the regressing factor is 0.29 and with the summer 1998 neglected 0.22.

8 In a subsequent paper ('The interaction of climate change and the carbon dioxide cycle') we discuss in more detail the aspects of the flow of carbon dioxide as an important signal for climate change, but in the light of the proposed paradigm shift not as a major cause of the greenhouse effect.

The idea that increased concentration of CO_2 might increase the temperature stems from a theory by Arrhenius in the 19th century,[10] and from observations on a geological time scale of four subsequent glacials and interglacials. Many challenges to this theory of Arrhenius were presented soon after its publication (see Reference 11 for a review of these challenges). But the general idea of "radiative forcing" was accepted widely in more recent times. The hypothesis is that carbon dioxide (CO_2) and water (H_2O) absorb part of the infrared spectrum, and this leads to an understanding that there must be a direct relationship between the temperature of the atmosphere and the atmosphere's content of these "greenhouse gases".

Another important concept is the radiation balance of the planet. The incoming solar energy radiation (short waved) must be balanced by an outgoing heat radiation (long waved) from the surface of the earth. When the atmosphere absorbs part of the latter, the surface temperature of the earth must go up, whatever the distribution of energy within the atmosphere. It was also assumed that water vapour multiplies the effect of CO_2. Water and CO_2 both increase radiative forcing. A rise in the atmosphere's CO_2 content must create a certain temperature rise, which would cause more evaporation and consequently raise the water vapour concentration, thus further increasing the temperature rise

It is a fact that CO_2 makes some contribution to the containment of heat in the Earth's atmosphere. However, it is not at all sure that increasing CO_2 concentration would raise the temperature in the complex system in the long run. Other factors may overcome the temperature rise from increased CO_2 in the air. Indeed, until the warming effect of soot was discovered, supporters of the Kyoto Hypothesis made this argument to explain the fall in temperature between 1940 and 1970.

And this is illustrated by the 'geological' argument. During subsequent glacials and interglacials the temperature changed over a range of 10°C and the CO_2 over a range of 100 ppmv,12 that is 0.1°C / ppmv. During the last century the CO_2 increased from 280 to 370 ppmv, and if the ratio of rising CO_2 to temperature rise had been 0.1°C / ppmv then this would have raised the temperature 9°C. But only 0.8°C rise was observed.

Moreover, for a long time geologists have been in doubt about how temperature and CO_2 concentration could be related. More recently research on ice cores in Antarctica indicates that change in CO_2 follows change in temperature with a delay of several 100 years.[13] This suggests the temperature is changed by another outside influence of possibly cosmic origin. Consequently the CO_2 cycle was influenced, leading to a change of level in the atmospheric buffer.

Over the last 25 years satellites have been employed for measuring the temperature of the troposphere. These measurements show a rather high variability of plus or minus 0.2 to 0.3 °C in subsequent years[5] (just as the surface measurements did), but with no linear relationship to the concurrent level of CO_2. Also, the measured average temperature increase over these 25 years is much less than the one measured by the ground stations and is probably not even significant (regression factor 0.04, see Figure 3).

In this context, doubts have been uttered about the reliability of the global mean temperatures determined from ground stations. These doubts are based on the fact that the distribution of ground stations over the Earth's surface is very unequal, which makes the determination of a world average less reliable. The satellites measure over the entire surface of the Earth. The satellite measurements of near surface temperature show insignificant warming[14] and this agrees with measurements of the lower atmosphere made using radiosondes mounted on weather balloons[15] (see Figure 3).

Proponents of the Kyoto hypothesis have repeatedly tried to find fault with the satellite data, so far without success. And they have given great credence to the estimates of mean global surface temperature mostly obtained from weather station data. But there is little reason to believe these estimates. This is demonstrated by the differences between them. For the most recent 30 years (i.e. 1972 to 2001), the Jones *et al.*[16] and the Global Historical Climate Network (GHCN)[17] data sets each indicates a rising surface temperature trend throughout the period. GHCN gives a linear regression trend of 0.273 °C/decade and Jones *et al.* give a linear regression trend of 0.192 °C/decade. This is a difference of 0.081 °C/decade (i.e. 42% of the Jones *et al.* rate and 30% of the GHCN rate).

These data sets are each compiled from the same source data so the differences between them must result from the data sampling and processing used to generate the global means. Hence, it is certain that the data sampling and processing can – in at least one case they do – generate spurious trends to apparent mean surface temperature over time.

For completeness, the recent trends of the balloon[(15)] and satellite[(14)] data should be mentioned.

The balloon data gives a linear regression trend of 0.085 °C/decade for 1972 to 2001, and a linear regression trend of –0.027 °C/decade for 1979 to 2001. The satellite data (that started to be measured in 1979) gives a linear regression trend of 0.054 °C/decade for 1979 to 2001.

There is a perhaps coincidental similarity between the balloon trend (0.085 °C/decade) and the difference between the GHCN and Jones et al. trends (0.081 °C/decade) for the period 1972 to 2001. The difference is significant as an indicator of the accuracy of the GHCN and Jones *et al.* data sets.

The "projections" of future climate developments reported by the IPCC are based on three things: the Kyoto hypothesis, the observation that the surface temperature of the Earth appears to be rising (which would support the hypothesis but is debatable), and the use of advanced computer models that describe the climate. We have challenged the significance of an average global temperature rise.

In the next section we will further elaborate on the controversial issues by a quantitative analysis of the available primary data on human emission rates, the accumulation of CO_2 in the atmosphere, and the global temperature.

3. REINVESTIGATION OF THE PRIMARY DATA

The challenges presented in the preceding section are common knowledge among climate researchers. And discussions on controversial issues often result in statements that the great complexity and variability of the natural system hinders reaching explicit conclusions. But here we show that the variability of the climate system provides an instrument to obtain information about the underlying processes.

In laboratory studies of a continuous process it is general practice to add a disturbance to a system and to consider its effect. This provides information on the *dynamics* of the undisturbed process.[6] Such an experimental approach is usually not applicable in nature. But we can consider the human addition of CO_2 to the natural cycle of CO_2 as being such a disturbance of the natural cycle. And this disturbance may be able to provide information on the undisturbed process. The study of CO_2 in the air deserves some priority from this practical perspective.

From Figure 1 is read a gradual increase of the CO_2 concentration in the atmosphere with the human emission rate. These units have different dimensions. The human emission (F_{em}) has a rate dimension (GtC/y) and the atmospheric concentration of CO_2 has the magnitude dimension (ppmv). But the curve in Figure 1 for the CO_2 concentration rise can be used to convert them to the same dimension. This achieved by calculating the annual amount of CO_2 taken up by the atmosphere

F_a=_C/y

Then _C can be converted from ppmv to GtC by use of the generally accepted conversion factor of 2.1 (Footnote 3 indicates a factor of 2.2 and the difference is a result of rounding errors.) The result is presented in Figure 5.

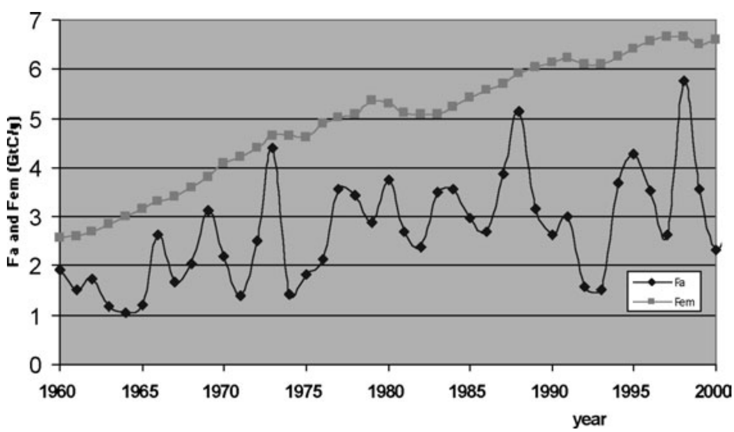


Figure 5. The annual anthropogenic emission (F_{em}) and uptake of carbon dioxide in the atmosphere (F_a)

It can be seen from Figure 5 that the annual accumulation of CO_2 in the atmosphere does not coincide with the annual emission of CO_2, and the annual accumulation shows a large variability which does not coincide with the annual emission.

This is also demonstrated when the annual flux into the atmosphere is plotted against the annual emission (see Figure 6). A wide spread is observed.

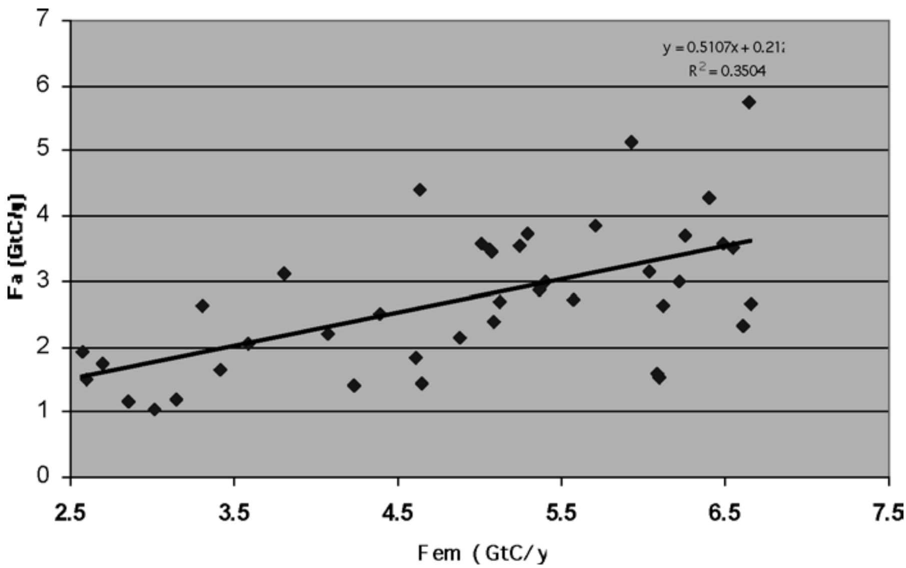


Figure 6. Flux into the atmosphere (F_a) as a function of anthropogenic emission (F_{em})

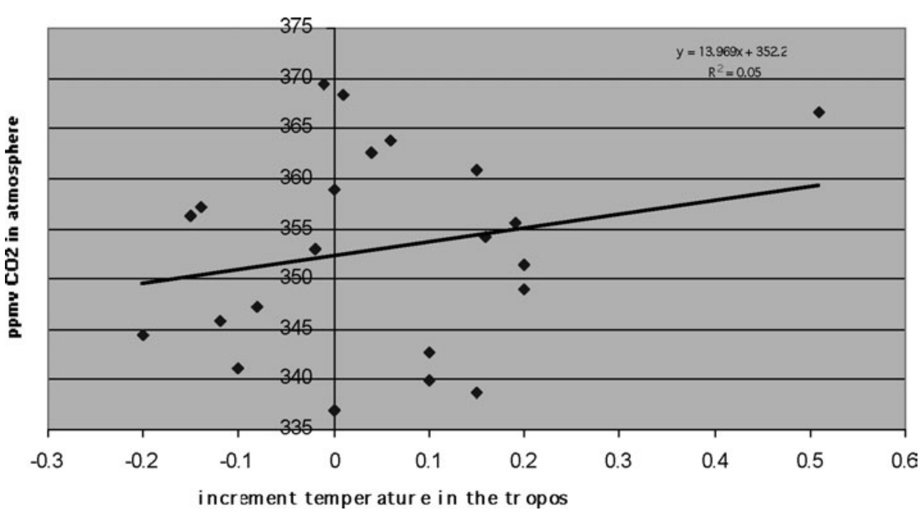


Figure 7. Carbon dioxide in the atmosphere as a function of *troposphere* temperature

Y axis: concentration of carbon dioxide in atmosphere derived from the data presented in Figure 1 for each year between 1979 and 2000.

X axis: Relative temperature change in the troposphere for the corresponding year derived from Figure 5. Zero corresponds to the average global temperature in the year 1979 (see figure 5, page 18)

Figure 2 indicated the nine year moving average of the surface temperature. It is well known that the (yearly) average of the temperature also fluctuates considerably.

Figure 3 indicated the surface temperature measurements and the satellite data[14] for measurements of the lower troposphere (the satellite data are available for since 1979). Their fluctuations coincide well. The values measured on the surface are, however, higher than those measured in the troposphere and the troposphere measurements show small and insignificant increase of 0.1 0C in the period 1979 to 2000.

Figure 7 shows the relationship between the concentration of CO_2 in the atmosphere in each year and the mean troposphere temperature. There is almost no coherence between the two.[7]

So, Figure 7 shows there is insignificant coincidence between the concentration of CO_2 in the atmosphere in each year and the mean troposphere temperature of the year. However, a remarkable coincidence is revealed when the annual fluctuation of the flux of CO_2 into the atmosphere (see Figure 5) and the annual fluctuation of the temperature (see Figure 3) are compared for each year. This coincidence is shown in Figure 8.

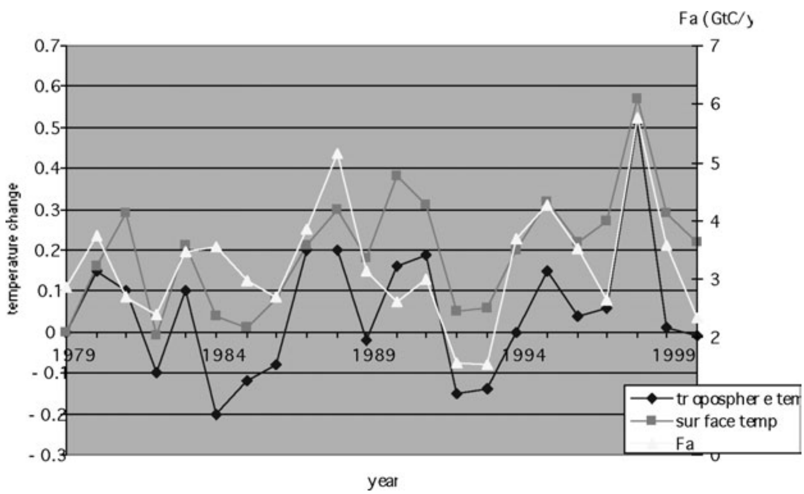


Figure 8. Annual change in temperature and the pulse of carbon dioxide into the atmosphere (F_a)

Left Y axis: temperature change over the years in troposphere and on the surface.
Right Y axis: Flux of carbon dioxide into the atmosphere
Source: B. Lomborg (see footnote 2, page 3).
Original sources: J.K. Angell (1999) in "Trends" cdiac.ornl. and
J.R. Christy et all (2000,2001, MSU temperature data P.D. Jones *et al*. (2000) cdiac.ornl.

Figure 8 clearly shows there is relatively high flow of CO_2 into the atmosphere in a relatively warm year and a relatively low flow of CO_2 into the atmosphere in a relatively cold year. This leads to the suggestion that *temperature determines (at least partly) the flow of CO_2 into the atmosphere*, and not the reverse as assumed in the 'Kyoto hypothesis'. The lack of a strong correlation between temperature and CO_2 concentration makes it unlikely that this concentration as such is the main cause of temperature change.

There is, however, a coherence between the temperature and the pulse F_a. In Figure 9, F_a is presented as function of troposphere temperature, and it has regression variance of 0.52.

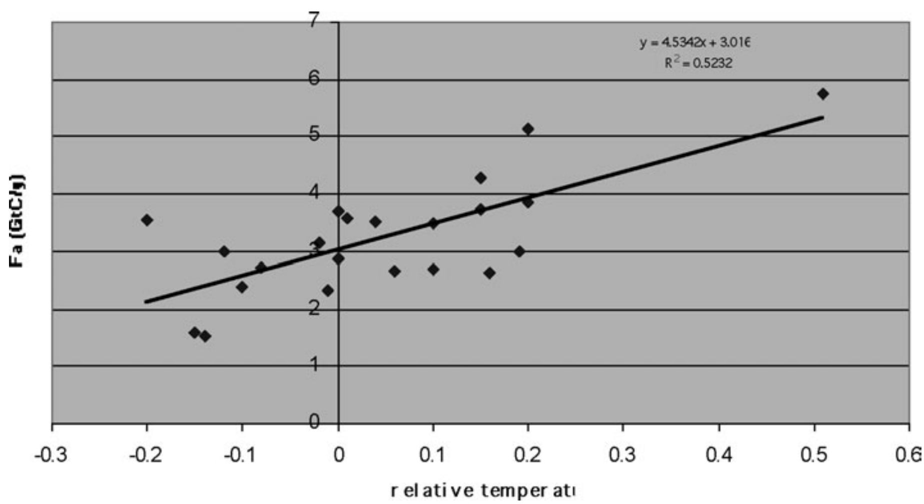


Figure 9. Pulse of carbon dioxide (F_a) into atmosphere as a function of troposphere temperature

X axis: Relative temperature taken from Figure 6.

Some relationship between this pulse in the atmosphere and the human emission pulse (F_{em}) can also be expected. This was presented in Figure 4, and its regression variance is 0.35. Consequently we may infer that both temperature rise and human emission contribute to the pulse of CO_2 into the atmosphere.

In summary, in addition to the challenges to the 'Kyoto hypothesis' in Section 2, further objections to the 'Kyoto hypothesis' are discovered by reinvestigation of the primary data to consider the annual dynamics of the system:

IPCC VIEW	CHALLENGES
Fossil fuel use	No quantitative annual relationship between CO_2 emission and accumulation of CO_2 in the atmosphere
→	
Accumulation of CO_2 in the atmosphere	
→	No quantitative relationship between temperature and CO_2 in the atmosphere in the periods
Temperature Rise from enhanced Greenhouse Effect	

4. THE WATER CYCLE REGULATOR HYPOTHESIS

There is an observed increase to the average temperature of the Earth's surface (as mostly measured at ground stations) over the 20th century and over the recent decades, but no significant increase is observed in the troposphere temperature (as measured using satellites) over recent decades. This is inconsistent with the Kyoto hypothesis and, therefore, suggests there should be some reconsideration of the hypothesis underlying the Kyoto Protocol: this hypothesis asserts that the human emissions of CO_2 increase the concentration of CO_2 in the atmosphere, and this increase induces a temperature rise at the Earth's surface.

The temperature recording at ground stations indicates that at certain sites – at least for some of the time – some heat, from what ever origin (human energy use, increased natural or anthropogenic CO_2 production, or solar radiation) has been retained near the surface and did not reach the troposphere for a considerable time (compare both temperature curves in Figure 3).

This leads to the assumption that the climate system provides for an efficient instrument to remove heat from the surface other than radiation. And, of course, conduction/convection and evaporation do remove heat from the surface.

The water cycle is the most likely candidate for efficient heat removal from the surface other than radiation. Heat at the surface evaporates water and the resulting damp, warm air near the surface rises to the upper troposphere. Adiabatic expansion reduces this air's temperature as it rises. The water condenses in the upper troposphere and part of the heat of condensation is transferred to the atmosphere and part is radiated into space. The water falls back to the surface as rain and snow. Lorenz identified this process to be a deterministic nonperiodic flow.[6]

The magnitudes of various components of the water cycle through the atmosphere are listed in Table 1.

Table 1. The water cycle

	Land	Oceans	Global	Units

Surface Area		148	361	509	10^6 km^2
Precipitation	P1	111	385	496	10^3 km^3/y
Evaporation	E1	71	425	496	10^3 km^3/y
Balance	**(P1-E1)**	**+40**	**–40**	**0**	**10^3 km^3/y**
Precipitation	P2	750	1.066	974	mm/y
Evaporation	E2	480	1.177	974	mm/y
Balance	**(P2-E2)**	**+270**	**–0.111**	**0**	**mm/y**
Heat flow	Eva	58.5	83.51	76.0	W/m^2
Total heat flow	Eva	8541	30147	38688	10^{12} W
Per cent heat flow		22	78		%
Surface percent		29	71		%

Note: There are two regulatory mechanisms; one over land, one over the oceans. The heat removed from the surface by evaporation of water is larger over oceans than over land, and even larger than one would expect from the surface distribution.

Table 1 shows the evaporation (and condensation) and precipitation flows are huge. As stated earlier, the water flow through the atmosphere amounts to 496,000 km^3/y (liquid equivalent), and the total water in the atmosphere to 13,000 km^3 which equates to a recycle ratio of ~38 per year. This flow of water vapour is probably a major regulator of the lower troposphere's temperature because water has high latent heat of evaporation and condensation.

The average evaporation and precipitation rates correspond to a little under 1,000 mm/year, and the average enthalpy flow is estimated to be between 75 and 85 W/m^2, which is about 50 times higher than the present radiative forcing by CO_2.

So, there is a mechanism that may efficiently remove additional heat from the surface if additional heat arrives at the surface (e.g. as a result of increased atmospheric CO_2 accumulation contributing to radiative forcing). And part of this heat removed from the surface is radiated into space from clouds.

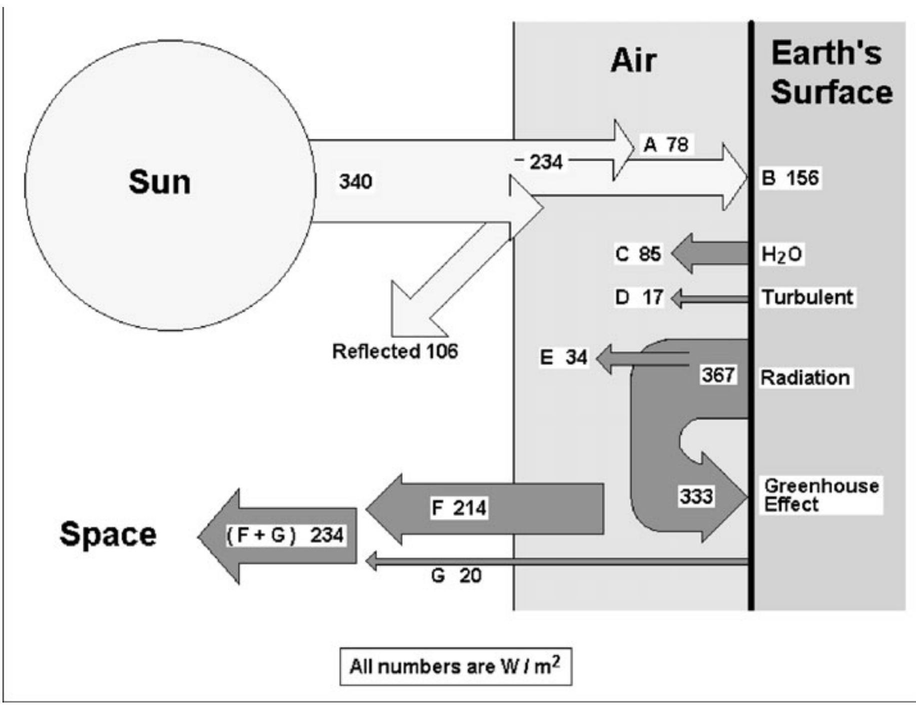
It should be added that the water cycle has another regulating effect. When the evaporation and condensation rates increase, the cloud cover will also increase although the quantitative relationship is not fully understood.[18] More clouds shield a larger fraction of the solar radiation from reaching the Earth's surface.

In addition, there is another interesting effect. Cloud condensation is enforced by nuclei and one substance that may be responsible for increased nuclei production, is dimethylsulfide (DMS)[19] produced by phytoplankton in the oceans. Consequently, superposed on the inorganic water regulator there may be a feed back regulatory mechanism of a biological origin: if an increase to CO_2 concentration in the atmosphere increased the near surface sea temperature, then increased plankton growth would increase DMS emission with resulting increase to cloud cover.

The order of magnitude of some of these effects can be estimated by using some simplifying assumptions. We make use of data from Paltridge and Platt[20] (1976) concerning the energy fluxes that take place in the atmosphere. These are summarized in Figure 10 where they are all expressed as annual averages, averaged over the surface of the Earth, in W/m^2. Of course, such averages have a limited physical reality, but they can be compared to the calculations of the "radiative forcing" by the additional greenhouse effect. For the present CO_2 concentrations, this effect is 1.5 W/m^2. For a doubling of the CO_2 concentration, the effect is estimated to be 3 W/m^2.

Figure 10. Thermal fluxes A to G in the climate System.

A flux of 340 W/m^2 from the sun reaches the Earth and 106 W/m^2 of this is reflected back to space from the atmosphere. Hence, a flux of 234 W/m^2 from the sun



enters the atmosphere. This is short wave radiation. From this, 78 W/m^2 (flux A) is absorbed by the atmosphere (both by clouds and by absorbing gases) and 156 W/m^2 (flux B) reaches the Earth's surface. From this flux, 85 W/m^2 (flux C) is used for the evaporation of water, and the remainder is transferred to the atmosphere, thus contributing to heating of the air. Flux D (17 W/m^2) is the turbulent heat transfer from the surface to the air, flux E (34 W/m^2) is radiation absorbed by the atmosphere (the "net" greenhouse effect) and flux G (only 20 W/m^2) is radiated directly into space (E and G are long wave radiation fluxes).

This diagram shows that large energy fluxes occur between the Earth's surface and the atmosphere. The flux of 333 W/m^2 can be considered a "gross" greenhouse effect. The flux of 234 W/m^2 entering the atmosphere (short wave) equals the sum of the long wave radiation flows F and G to space (from the atmosphere and the surface, respectively).

Importantly, from the above, it is clear that there are two pathways for heat to be transported from the Earth's surface to space: (a) 20 W/m^2 of radiation direct to space from the surface and (b) heat transported from the surface into the atmosphere and hence to space. The 136 W/m^2 of heat through the atmosphere pathway is:

85 W/m^2	water evaporation (flux C)	62.5 %
17 W/m^2	turbulent transfer (flux D)	12.5 %
34 W/m^2	greenhouse forcing net to space (flux E)	25.0%

Water evaporation is the major flux through the atmosphere pathway: it carries most of the heat. So, although more water in the atmosphere may cause additional radiative forcing, the evaporation of the water may control any resulting temperature rise.

Above, we indicated two regulatory mechanisms caused by the water cycle: the evaporation and condensation of water, and the shielding of the sun by extra cloud formation. Next we estimate their approximate magnitudes.

Let us assume an extra amount of heat of 1 W/m^2 accumulates at the surface. This will raise the total of flows C, D, E and G by 1 W/m^2. Let us assume that they are all increased proportionally, then the evaporation rate will increase with an energy flux of $85/(85+17+34+20) \times 1 = 0.54$ W/m^2. From this flux, a fraction will get lost to space due to heat radiation from the atmosphere. From the total fluxes entering the atmosphere about 45% is radiated back into space. So, one can assume that, from the extra condensation heat, $0.45 \times 0.54 = 0.24$ W/m^2 is lost to space from the air.

In addition, the cloud formation will increase. Let us assume that the horizontal cloud area increases with the increased evaporation and condensation rates to the power 2/3. Then an increase of the evaporation rate from 85 to 85.54 W/m^2 will raise the cloud deck area with a factor $(85.54/85)^{2/3} = 1.0078$. The flux of reflected sunlight will then be raised from 106 to 106.45, which means that an additional flux of 0.45 W/m^2 of solar energy will get reflected to space instead of entering the atmosphere.

This simplified reasoning suggests that for each W/m^2 of additional energy accumulation at the surface – such as from additional radiative forcing – approximately 0.7 W/m^2 will be lost to space. So according to this "water cycle regulator hypothesis", the radiative forcing would be reduced by a factor of 3, approximately. Naturally, this "calculation" is very coarse, but it indicates an order of magnitude of the regulatory effects. And it shows that these effects are probably significant.

Much additional research is required to obtain a more quantitative estimate of the "regulatory" flows, such as the water evaporation, the condensation, the cloud formation and all the radiative processes that affect – and are affected by – cloud cover. A vast global network for monitoring would be needed to conduct the necessary measurements throughout each day for several years. Only then would it be possible to describe the water cycle regulator on a global scale with defined precision. At present, a modification of a General Circulation Model (GCM) is required to assess the maximum potential for the water cycle to regulate global climate.

The existence of the seasons demonstrates that the 'water cycle regulator' cannot overcome effects of the natural seasonal large change of the radiation received from the sun. And the 'water cycle regulator' cannot overcome the temperature changes between day and night. If it did, then there would be no seasons and night and day temperatures would not differ. But it seems the 'water cycle regulator' can moderate climate changes over longer periods, within certain limits. Apparently because the water cycle is itself strongly influenced by temperature differences caused by variation of solar radiation. So, the 'water cycle regulator' does not operate like a thermostat with an ever fixed set-point. Its set point is regularly re-set by the Sun's and the Earth's behaviour. Its set-point changes over day and night and over the seasons. The 'regulator' uses two internal 'clocks', determined by the rotation of the earth around its own axis and by the rotation of the earth around the sun.

The existence of the 'water cycle regulator' system is supported by effects of land use changes. It is well documented that land use changes alter local climate mostly as a result of changed moisture transport between the air and surface (although the changed radiation absorption/reflection of the surface also contributes). And it is important to note that ~70% of the Earth's surface is covered by water.

Also, the action of the water cycle regulator provides an explanation for the difference between the 'surface' and troposphere measurements of changing global temperature (see Figure 3). Table 1 shows that there are two regulatory mechanisms; one over land, one over the oceans. The heat removed from the surface by evaporation of water is larger over oceans than over land, and even larger than one would expect from the surface distribution. Hence, it is not surprising that the regulator operates more rapidly to counteract temperature change over oceans than over land. And the surface measurements are made mostly over land but the troposphere measurements are made over the entire Earth.

Importantly, the water cycle regulator solves a major puzzle concerning the rise of surface temperatures in recent decades: most of the observed global surface warming has occurred mostly at night, and the night-time temperatures are rising three times faster than the daytime temperatures. The Kyoto hypothesis cannot explain this. In 1993 Thomas Karl said,[21] "Since 1950 all of the increase of temperature across the U.S.A. is due to an increase in the minimum temperature (about 0.75° C/ Century or 1.5° F/Century) with no change in the daily maximum temperature." Since then, it has been discovered that the night-time warming is global and it increases with latitude. This does not accord with the warming predicted by the Kyoto Hypothesis. In 1995, Hansen said,[22] Models show that daytime warming will be almost as great as night-time warming" [for greenhouse gas forcing]. In 1997 Watterton[23] pointed out that the observed rises in night-time temperatures "are not consistent with their being produced by the observed increase in greenhouse gases." In 2003 Stone and Weaver[24] used climate models to try to resolve this problem of the reducing diurnal temperature range (DTR) and found "the cause of the DTR trend is still poorly understood, as is its relation to anthropogenic forcing." They argued that increasing cloud cover and increasing soil moisture may be the cause of the observed DTR variations. But this disagrees with a study by Kaiser[25] that shows the cloud cover in China is decreasing along with the decrease in DTR. Thus neither the Kyoto hypothesis nor changing cloud cover can account for the rise of night-time temperatures in the surface observations. However, the water cycle regulator does explain it.

The water cycle regulator responds to increased surface heating (e.g. from increased greenhouse effect) by transporting additional heat from the surface, and this transport is greatest in the daytime when the surface heating is highest. The anticipated result is slightly higher night-time temperatures with little or no rise to daytime temperatures (as is observed).

The water cycle regulator hypothesis agrees with the different histories of recent temperature changes over land and sea areas. And its behaviour is supported by the moderation of local climate by the presence of large bodies of water. However, ENSO effects demonstrate that the oceans' high thermal capacity can overcome the 'water cycle regulator' for limited times in local ocean regions (just as the 'water cycle regulator' is overcome by the natural seasonal large change of the radiation received from the sun) with results over much larger areas.

Finally, the Sun is a g-type star so it has increased its thermal output ~30% in the ~2.5 billion years since the Earth has had an O_2-rich atmosphere. Liquid water has existed on the Earth throughout that time. If a direct relationship existed between radiative forcing and mean global temperature, then the oceans would have turned to steam long ago. The existence of the 'water cycle regulator' provides an explanation of why they have not.

5. DISCUSSION

The 'Kyoto hypothesis' is based on assumptions by Arrhenius to explain temperature changes on a geological time scale during subsequent glacials and interglacials by radiative forcing from changing CO_2 concentrations in the atmosphere. The 'water cycle regulator hypothesis' does not deny the existence of this radiative feedback but considers that extensive movement of moisture in the climate system diminishes the effect.

The Kyoto hypothesis considers the climate system to operate like a room (the Earth's atmosphere) heated by a single source (the Sun) and heat loss from the room is largely controlled by insulation (the greenhouse gases). It is essentially a static system that is sensitive to small disturbances. The radiative forcing is considered to have an inescapable forcing effect, which it would have on a dry planet.

The 'water cycle regulator hypothesis' also postulates that the climate system operates like a room (the Earth's atmosphere) heated by a single source (the Sun) with heat loss from the room only partly restricted by insulation (greenhouse gases) but largely assisted by air conditioning ('water cycle regulator') that aids heat transport through the insulation. It considers the earth plus atmosphere to be a dynamic system with several degrees of freedom. The huge exchanges of energy between the surface (land and sea) and the atmosphere are orders of magnitude higher than the "radiative forcing", and they make the system very robust (see Table 1). Evaporation and condensation may transfer large amounts of energy at unchanging temperature. And clouds contribute significantly to the radiative transport of heat to space.

As previously stated, observed effects of land use changes support the existence of the 'water cycle regulator', and the existence of the 'water cycle regulator' provides explanation of

(a) the difference between the ‘surface’ and troposphere measurements of changing global temperature,
(b) the recent reduction to diurnal temperature range, and
(c) why the oceans have remained as liquid water on a geological timescale while the Sun increased its thermal output ~30% (the ‘Kyoto hypothesis’ predicts this increased heating should have boiled the oceans to steam).

In our opinion, the water cycle regulator hypothesis must be favoured above the Kyoto hypothesis, based on the observations made both on a geological time scale and of recent decades. The major observations are (1) that since the satellite measurements have been available no significant increase of the troposphere temperature is observed and (2) that – thanks to the large annual variation of the temperature – it can be deduced that annual addition of CO_2 to the atmosphere follows the temperature and not the reverse.

The Kyoto hypothesis is supported by projections made using General Circulation Models (GCMs) of the climate system. But much of the climate system is not sufficiently understood for it to be modeled using mechanisms that are indicated by empirical evidence. Importantly, there is very little empirical knowledge of the behaviours of moisture in the atmosphere. Each modeling team makes algorithms to describe that team’s preferred assumptions of evaporation, convection, cloud formation and precipitation. And each GCM uses very different algorithms for these processes. There is only one Earth so – at most – only one GCM is emulating the mechanisms that, for example, form clouds in the real atmosphere. There are insufficient empirical data on the behaviours of atmospheric moisture to discern which algorithms are representing the mechanisms in the real atmosphere. Hence, the magnitudes of these mechanisms are adjusted in each model to make the model’s behaviour emulate the real climate as closely as possible (these adjustments are called ‘parametrisation’). For this reason, each model is a description of its modeling team’s understandings and opinions of climate behaviours. But all the modeling teams adhere to the Kyoto Hypothesis. The GCMs are parametrised such that atmospheric moisture is a positive ‘feedback’ on radiative forcing and not a compensation for changes to radiative forcing.

The water cycle regulator hypothesis warrants assessment by modeling using modifications of a GCM to include it. These modifications would need to be parametrised (as the Kyoto hypothesis is in each GCM). But the assessment would permit an estimate of the possible magnitude of the negative feedback on radiative forcing that the water cycle regulator may be providing. Until this assessment is done, it seems reasonable to suggest that projections of GCMs that all model the Kyoto hypothesis should be treated with caution.

Here we summarize our arguments, why the water cycle regulatory system should be considered as an alternative for the Kyoto hypothesis. It is an important paradigm shift with both scientific and socio-economic consequences.

If we consider the annual concentration of CO_2 in the atmosphere and the average global temperature, there is little coincidence. If, on the other hand, we consider the coherence between annual increment of CO_2 in the atmosphere and the annual average temperature the regression coefficient is two to ten times larger, depending on whether one considers the measured surface or the satellite troposphere temperature. This indicates: CO_2 concentration follows temperature and not the reverse[8].

We are of the opinion there is sufficient evidence that the water cycle provides for an adequate regulator effect, and we wonder why it has not received utmost attention from all who study climate change. It would explain why troposphere temperature is not rising when surface temperature (on land) is, and it would explain why the surface temperature rise is almost entirely at night. The weak point here is that the satellite measurements are not completely beyond doubt of interpretation. We must keep in mind the possibility that the satellites are underestimating temperature rise, but we don't think so. Anyway, even if the satellite measurements have to be corrected upwards – having taken note of all the arguments – the thesis that CO_2 is the cause of temperature rise is not sufficiently supported by the variations in CO_2 increments in the atmosphere and the dynamics of the annual relative variation in temperature measurements from satellites or from ground stations.

We note that opponents of the text of early manuscripts of this paper especially value the observation that over the last half century the CO_2 concentration in the atmosphere has increased by the suggestive high value of 33%. Many think the globe must be in distress by such a deviation from the 'natural' situation. On the other hand many references were brought to our attention that on a geological timescale such an increase is far from alarming. But much of this geological evidence can also be disputed.

Here we express the opinion that there is no doubt human activities have changed the face of the earth since agriculture began ~10,000 years ago, and that we now may be changing the atmosphere by our increasing energy output. But has this proven to been disastrous? We received no scientific evidence or arguments to support that it is or has been disastrous, but we received many emotional assertions that it is.

In a second paper, we will discuss various aspects of the carbon dioxide cycle.

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