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Science relies on evidence

Science checklist:
How scientific is it?

- [x] Focuses on the natural world
- [x] Aims to explain the natural world
- [x] Uses testable ideas
- [x] Relies on evidence
- [ ] Involves the scientific community
- [ ] Leads to ongoing research
- [ ] Benefits from scientific behavior

Ultimately, scientific ideas must not only be *testable*, but must actually be *tested* — preferably with many different lines of evidence by many different people. This characteristic is at the heart of all science. Scientists actively seek evidence to test their ideas — even if the test is difficult and means, for example, spending years working on a single experiment, traveling to Antarctica to measure carbon dioxide levels in an ice core, or collecting DNA samples from thousands of volunteers all over the world. Performing such tests is so important to science because in science, the acceptance or rejection of a scientific idea depends upon the evidence relevant to it — not upon dogma, popular opinion, or tradition. In science, ideas that are not supported by evidence are ultimately rejected. And ideas that are protected from testing or are only allowed to be tested by one group with a vested interest in the outcome are not a part of good science.

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SNAPSHOT

Scientists strive to test their ideas with evidence from the natural world.

TAKE A SIDETRIP

Just *how* does science test ideas with evidence? For more on how scientific ideas can be supported or refuted by evidence, visit our section on *The core of science: Relating evidence and ideas*.

TEACH THIS

- Learn strategies for building

The elusive proof of man-made warming

Richard Treadgold

March 2019

Evidence is everywhere, proof is elusive. Evidence for dangerous man-made global warming exists, but, like any evidence, becomes proof only after careful, impartial evaluation.

In law, evidence is presented, assessed as acceptable, circumstantial, irrelevant or inadmissible and ranked; witnesses are questioned and provide verbal evidence. Judge or jury evaluate it and arrive at a verdict, whereupon assessment ends.

A related process in science occurs in publication of a paper, which puts a hypothesis before a jury. Associated processes occur in peer review, when reviewers judge the merit of a paper, and at conferences, where evidence is presented for consideration by participants. Judging never ends and its resumption requires just a paper presenting new evidence.

In describing types of evidence in the AR5, the IPCC include data, mechanistic understanding, theory, models (not considered evidence until proven accurate) and expert judgement. Any of these may be more or less significant to a particular hypothesis.

Popper's principle of falsifiability means a good hypothesis allows for testing to prove it wrong. Where confirmation is impossible for difficult aspects of a hypothesis, the topic may be out of the reach of science.

The IPCC are not scientists, for they are the Inter-GOVERNMENTAL Panel on Climate Change—appointed by their governments and mostly bureaucrats. Their founding charter directs them to investigate global warming caused by man—that's how the charter defines it. So they claim mankind causes warming because that's what they are told to do.

Science has no forum to evaluate evidence, though scientists do little else. To base public policy on solid proof rather than ideology, emotion or hearsay, governments must establish forums and sponsor open, public debate, missing from 'climate change' for 30 years.

THE CONTRIBUTION OF GREENHOUSE GASES FROM AGRICULTURAL ORIGINS

Professor Emeritus Geoffrey G. DUFFY

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SUMMARY

Very low concentration greenhouse gases from agricultural sources are shown to make only a minute contribution to the absorption of solar radiant energy and longwave reradiation back from earth. Water vapour is more than 6,000 times higher in concentration than methane, and greater than 30,000 times that of nitrous oxide. Water vapour is able to absorb radiation over much more than 80% of the entire energy spectrum at high levels compared to the very small active range of the other greenhouse gases.

It is also shown that water vapour dominates all the greenhouse gases including carbon dioxide both in atmospheric concentration and superior efficacy in absorption of solar radiation and reradiation from earth. Water can also phase-change (liquify, evaporate and condense) and in clouds provides thermal radiation shielding in daylight hours. It is shown that there are other major factors in weather change apart from radiation.

INTRODUCTION

Atmospheric greenhouse gases (GHG) are those that can absorb and emit solar electromagnetic energy (UV, IR, visible light) as well as energy re-radiated from planet earth. Five of these are well known: water vapour, carbon dioxide, methane, nitrous oxide and ozone (1). The first four can be 'connected' to agricultural operations in some way (1).
Their effectiveness in influencing weather variations depends essentially on three factors:

1. Relative concentration in the atmosphere.
2. The fraction of the total radiant energy-band over which they are most strongly active.
3. The ability to be involved in weather in some way other than radiation.

The discussion about greenhouse gases is with reference to weather change and the resulting climate patterns developed long-term as an average of weather. Several other mechanisms apart from radiation must be considered simultaneously, namely, winds, clouds, precipitation, storms, ocean currents, etc., to name a few (2).

1. RELATIVE ATMOSPHERIC CONCENTRATION

The main atmospheric gases and their relevant concentrations are presented in Table 1. Water vapour is included because the real atmosphere always contains water. Trace pollutants such as man-made volatile chemicals, chemicals such as fluoro-hydrocarbons and dust are excluded here. The greenhouse gases are denoted by an asterisk in Table 1.

Table 1 Composition of the actual moist atmosphere (2) including water vapour taken at about 1% (Basis:1% at 20°C; 75% Relative Humidity). Volumetric concentration in parts per million by volume (ppmv).

GAS		Volume ppmv	Volume %		Comment
Nitrogen	N_2	780,840	77.17%		
Oxygen	O_2	209,460	20.70%		
Water Vapour *	H_2O	10,000	0.99%*		Basis: 1% at 20°C 75% Relative Humidity. Varies from about 0.01% to 4.5% (tropics) *10 - 45,000ppm*
Argon	Ar	9,340	0.923%		Most prevalent INERT gas: 23 times more than CO_2
Carbon Dioxide *	CO_2	404	0.0399%		Far less than 10% is man-made. Plankton and photosynthesis moderate the CO_2 level all the time
Neon	Ne	1,828	0.0018%		Inert gas
Helium	He	5.24	0.00052%		Inert gas
Methane *	CH_4	1.79	0.00018%		About 40% natural: <60% man-made.
Hydrogen	H_2	0.5	0.000049%		Trace reactive gas
Nitrous Oxide *	N_2O	0.3	0.00003%		About 60% natural: <40% man-made
Ozone	O_3	0.04	0.000004%		Very reactive gas

Nitrogen, oxygen, water vapour*, and argon are the top four gases making up 99.8% of the atmosphere on a moist-air basis, with the only GHG water vapour in that top group. The remaining gases of the entire moist atmosphere are at 'trace level': just over 0.2%. The literature mostly presents the atmospheric data on a dry-air basis, but this is never the case in real life. Even at -60°C water vapour is about 100ppm (3).

The five GHG denoted * in Table 1 can be examined separately and their relative amounts are presented in Table 2.

Table 2 Radiation-absorbing and emitting Greenhouse Gases: only 1.028% of the total atmosphere of which water vapour is 1% at 20°C and 75% Relative Humidity

GAS		Volume ppmv	GHG Volume %		Comment
1.Water Vapour	H_2O	10,000	96.1%		Almost 25 times greater than CO_2 at 20^{0}C (250 times greater than MAN-MADE CO_2). Can be over 100 times greater than CO_2 in the tropics (>1,000 x man-made CO_2)
2.Carbon Dioxide	CO_2	406	3.88%		About 225 times greater than methane. Total CO_2 is 406ppm; naturally produced CO_2 is about 20 times more than man-made CO_2 (man-made CO_2 is less than 30ppm)
3.Methane	CH_4	1.79	0.017%		About 40% naturally produced: wetlands, soil, ground natural gas, sediments wildfires, ocean floor, volcanoes. Less than 60% man-made: Industry, agriculture, waste processing, landfills
4.Nitrous Oxide	N_2O	0.3	0.0029%		60% naturally occurring: from Nitrogen cycle, fossil fuels, industry. Less than 40% from human activities: agriculture, wastewater treatment, combustion
5.Ozone	O_3	0.04	0.00038%		Vital in protecting UV-B from reaching the earth

1. Water Vapour (1,000 to 40,000 ppm): Table 2 shows the TOTAL GHG concentration including water vapour is only 1.028% of the atmosphere. Water vapour is 96.1% of that total GHG concentration. Because the oceans cover 70.9% of the earth's surface it is expected that the atmospheric water vapour concentration would be high. The humidity (water vapour in air) varies widely with location and elevation (3) due to the Thermal Lapse Rate being sizeable, reducing by 6.5°C per kilometre rise (4) in elevation. At the tropics the atmospheric water vapour can reach well over 40,000 ppm (over 4% of the atmosphere), which is over 100 times more than carbon dioxide (3). Water vapour in colder climates (or high elevations) can still be more than carbon dioxide; over 1,000 ppm at -20°C and 100% relative humidity. Unlike all other atmospheric gases, clouds form from condensing water which in turn can precipitate and cool the atmosphere (as rain, snow or hail). This additional significant change-of-phase contribution will be discussed further (see Point 3). Water vapour concentration is from 2 to over 100 times greater in concentration than carbon dioxide, more than 6,000 times higher in concentration than methane, and greater than 30,000 times that of nitrous oxide.

2. Carbon dioxide (406 ppm): At just over 400 ppm (0.04%), carbon dioxide is the second most abundant GHG. Man-made CO_2 is less than 0.004%. However, over 95% (360 ppm) of it is derived from natural causes: organic plant decomposition, vegetation, from the ocean (CO_2 is less soluble in warm water), from the land and from volcanoes (80% of all active volcanoes are under the sea). The remaining CO_2 (<6%) is man-made, mainly from the use of fossil fuels in industrial processes, power generation and motor vehicles. The growth rate of total CO_2 is small at just over 1ppm/year (man-made growth contribution about 0.1ppm/year). Probably the reasons why CO_2 has received so much attention is the misplaced emphasis on 'the radiation-only mechanism' as the cause of weather changes, as well as the pressure to blame fossil fuels rather than other natural causes. Other energy transfer mechanisms worldwide indeed play a big part in weather changes and must also be considered simultaneously, e.g., jet streams, storms, winds, atmospheric precipitation of rain and snow, etc.

3. Methane (1.79 ppm): The third largest GHG methane is at a very low concentration of less than 0.018% (CO_2 is 225 times higher in concentration, and water vapour about 6,000 times higher). On spray-irrigated farms or at higher atmospheric temperatures, the water vapour concentration is even higher. Natural production of methane is estimated to be about 40% of the total methane, coming from marshes and wetlands, forests and natural leakage from the ground. The man-made proportion is less than 60%, coming mainly from livestock, manure, landfill, industrial processes and, in particular, natural gas processing (1).

4. Nitrous Oxide (0.3 ppm): A small amount of nitrous oxide is naturally present as part of the nitrogen cycle (plants, animals and microorganism reactions). It increases during farming activity, industrial processing and wastewater treatment and is a product of fossil fuel combustion. Worldwide, less than 40% comes from man-made operations, including emissions from fertilisers, livestock excrement and urine. Nitrous oxide is generated in the manufacture of commercial fertilizers, nitric acid, some synthetic plastic products, some combustion processes, and certain fossil fuels.

5. Ozone (0.00038%): extremely rare in the atmosphere (1 molecule per ten-million air molecules). Most exists in the stratosphere (~10 km elevation upwards) and UV radiation is required to produce it from oxygen. It is a strong oxidising agent and reacts and breaks down biologically-damaging UV-B to minimise that reaching earth. In the lower troposphere

it can initiate photochemical smog and can be harmful to crops, forests and human health. Certain choro-fluorocarbons reduce its formation markedly, although there is a natural lowering of ozone for the winter periods when the poles are dark and the radiant energy virtually zero.

The relative concentrations of GHG is just one part of the overall picture as each gas is potentially active over only part of the electromagnetic spectrum.

2. ACTIVE RANGE OF GHG OVER THE TOTAL ELECTROMAGNETIC SPECTRUM

The second and most important factor is; ‘how much does each greenhouse gas actually absorb radiant energy?’ The ability of greenhouse gases to absorb and emit radiation has been investigated extensively. Figure 1 shows the radiation transmitted by the atmosphere as UV, visible light and infrared radiation (see the *yellow band* in the figure). The left-hand side of the figure shows the region of incoming solar radiation (0.2 to 3 micrometres wavelength span). The right-hand side denotes the re-radiation from earth as long-wave infrared energy covering the 3 to 70 micrometre span.

Each greenhouse gas is labelled in the lower part of the graph. The width and height of each absorption peak for each gas is also clearly shown. The height of the peak denotes the amount of radiant energy that each gas can possibly absorb at that specific wavelength range. The width of each graphical peak clearly shows the wavelength band over which that particular greenhouse gas is active to radiant energy.

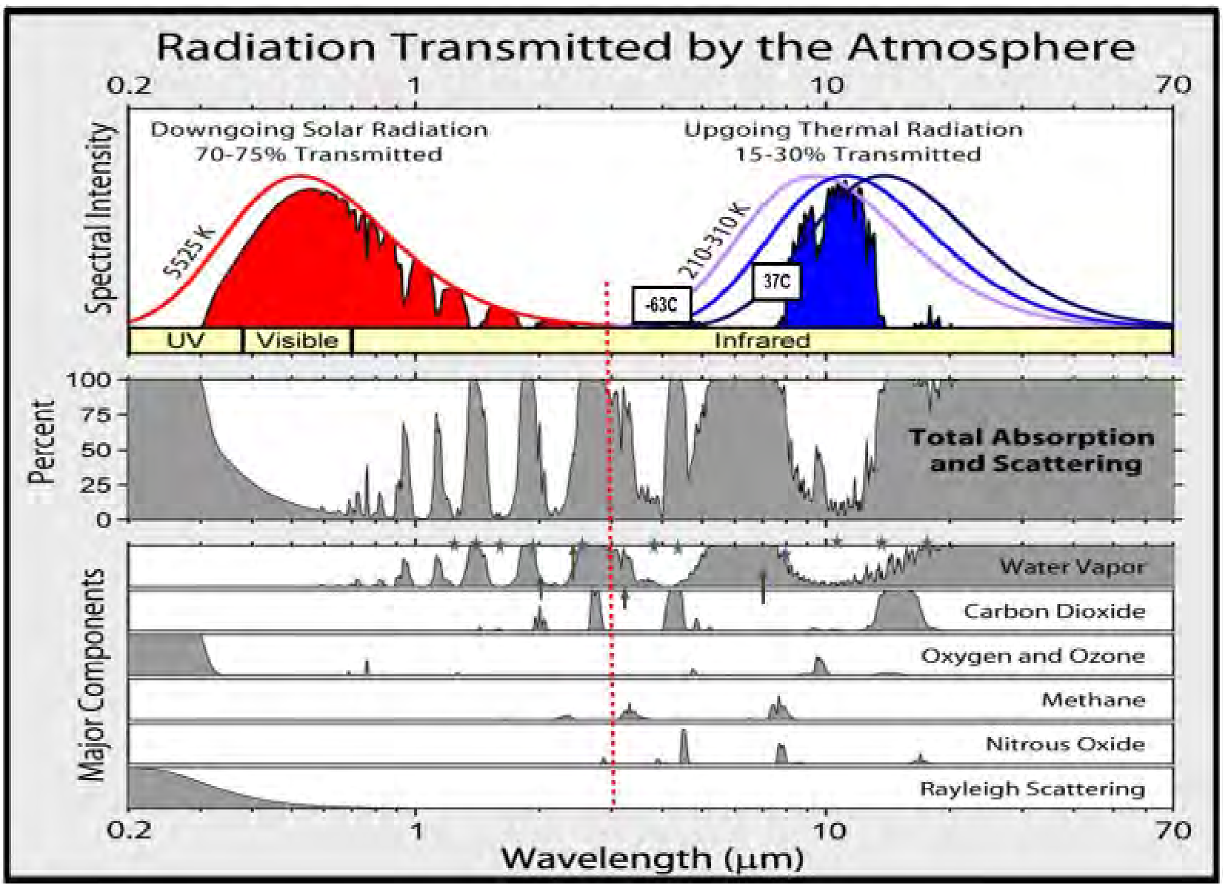

Figure 1 Total radiation transmitted by the Atmosphere (5)

An initial assessment indicates that methane, nitrous oxide and ozone have only a few narrow absorption bands, with none absorbing 100% at their active wavelength location within the spectrum. Even carbon dioxide only has 4 peaks over 50% at relatively narrow and specific wavelengths. Water vapour, in stark contrast, operates over a far wider wavelength range with many more peaks, several even absorbing up to 100% radiant energy at their location. Above 20 micrometres wavelength, the energy absorption of water vapour is 100%.

Incoming Solar (shortwave) Energy

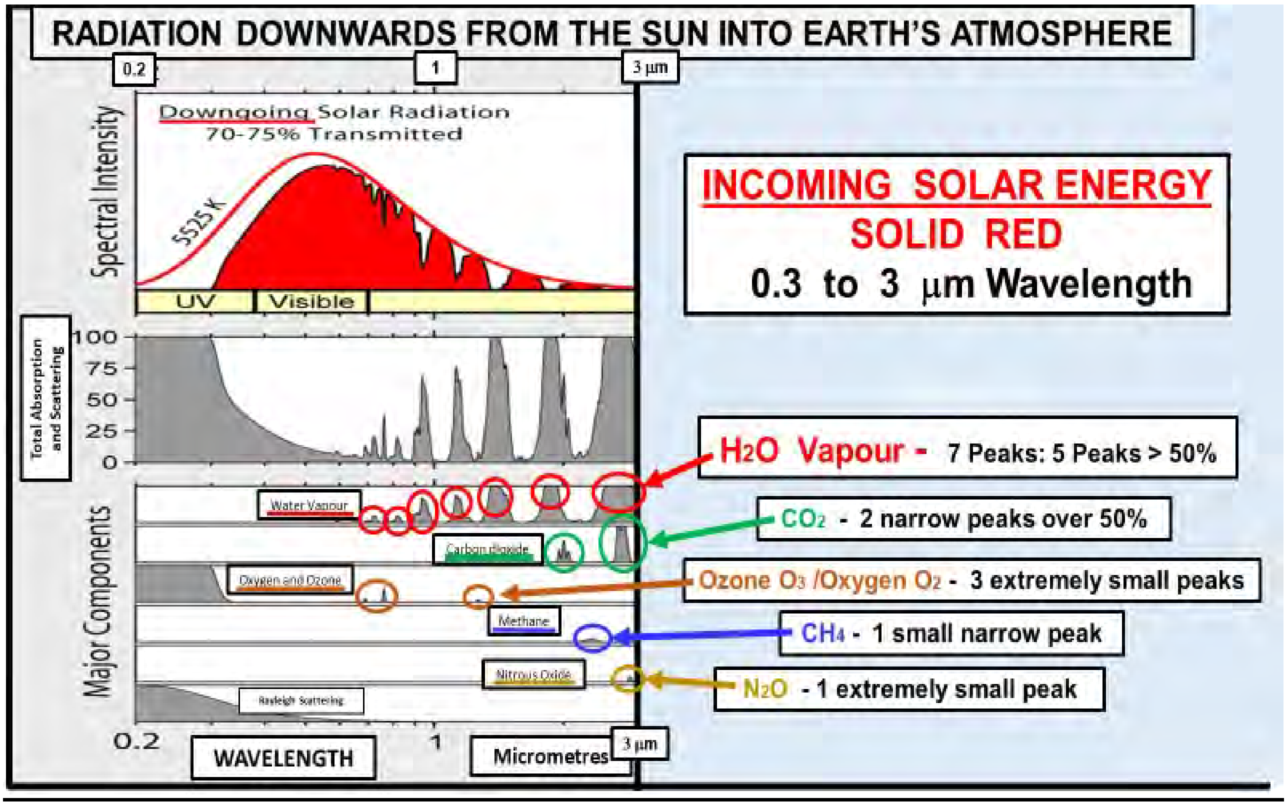

Figure 2 Incoming solar Radiation in the 0.3 to 3 micrometre wavelength range (5)

Figure 2 shows that the absorption peaks for methane, nitrous oxide, and ozone are all extremely small (far less than 50% absorption) and all very narrow, and thus unreactive to almost all incoming solar radiation. Carbon dioxide only has 2 absorption peaks and only one potentially can absorb 100% across a narrow wavelength band which happens to coincide with the wide water vapour peak anyway. In contrast, water vapour has 7 absorption peaks, 3 operating at 100% and wider than all others, as well as 2 above the 50% level.

It can be concluded that the dominant GHG absorbing solar radiation is water vapour. The absorption potential of solar radiation by the other GHG is minuscule or virtually non-existent. From an agricultural emissions point of view, the 'culprits' like methane and nitrous oxide can clearly be discounted as having any appreciable effect on *incoming* solar radiation.

Outgoing (longwave) radiation back from earth

Less than 60% of solar radiation actually reaches the planet's surface. When it does, the solar radiation 'impacts' the earth's surface by 'exciting' all surface molecules (land and sea) to a varying extent. These molecules vibrate, rotate, twist, or oscillate more and emit longer-wavelength radiation. The energised molecules themselves can now also move faster and collide more with all other molecules.

Greenhouse gases within the first few hundred metres elevation absorb some of this radiant energy in various ways depending on the structure of the molecule. None absorb over the total span of wavelengths (3 to 70 micrometres). Each gas is sensitive to a specific band of wavelengths as shown in Figure 3. The height of each peak indicates the amount of energy absorbed at each band of wavelengths. The peak width indicates the sensitivity of that greenhouse gas and thus the potential proportion of all the emitted long-wave energy re-radiated from the planet's surface.

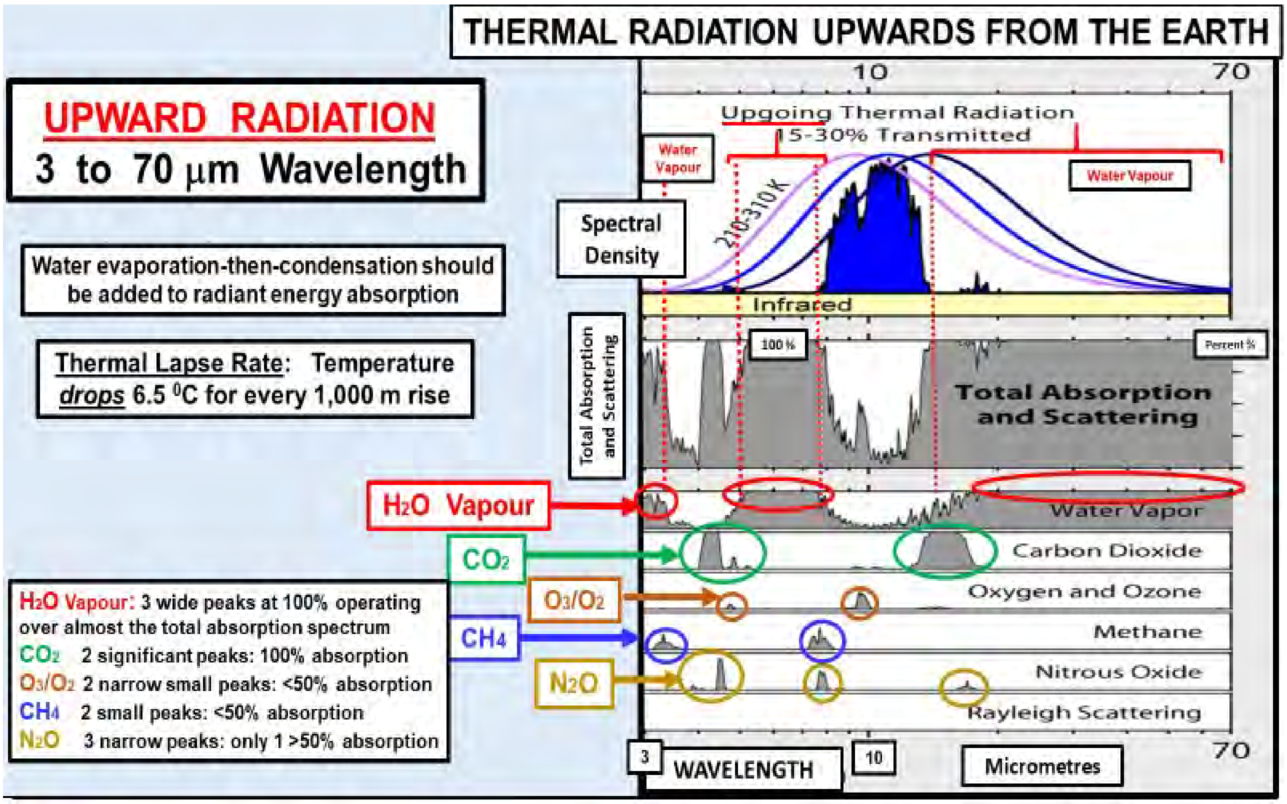

Figure 3 Total (longwave) re-radiation from earth in the 3 to 70 micrometre wavelength range (5)

Clearly both methane and ozone are very limited, each with 2 narrow bands and each absorbing less than 50% of radiant energy over those small absorption bandwidths. Nitrous oxide has 3 very narrow bands; only one band reaches almost 100% absorption at a single point. As all three (methane, ozone, nitrous oxide) are very, very low in concentration and cannot possibly absorb much long-wavelength radiation anyway, their contributions overall are minuscule.

Carbon dioxide only has 2 bands. They are slightly wider than methane and nitrous oxide, but operate over a very small proportion of the total re-radiation span from earth (<8% of the total wavelength range). In stark contrast water vapour, which is at a far higher concentration, is fully active over 80% of the total span *(note Logarithmic Scale).*

From Figure 3, water vapour is active over more than 80% of the entire re-radiation region. If radiation is the key concern (but noting there is more happening), then the focus must be on water vapour. Carbon dioxide makes a very small contribution, and methane, nitrous oxide and ozone are inconsequential.

3. OTHER ENERGY TRANSFER MECHANISMS THAT MUST BE EXAMINED SIMULTANEOUSLY

Energy transfer on the planet and in the atmosphere is more than radiation alone (2). Weather changes are complex. Large-scale convective mixing, evaporation, condensation and conduction are all in play all the time, in addition to thermal radiation. Massive ocean conveyer systems and ocean upwellings, El Nino and La Nina changes, storms, sub-surface saline currents, monsoons, tornados, jet streams and trade winds are all highly significant, and must be included (2). The magnitude of these effects vary as the earth rotates (overnight, or diurnal cycles) or revolves around the sun (seasonal changes) and depends strongly on location (latitude) and position (continent, island, proximity to the sea, etc.).

The mechanism that is often discounted or overlooked is phase change. With 70.9% of the world surface covered by oceans and lakes, the amount of evaporation of water followed by condensation into clouds is enormous. No other greenhouse gas can do that. Clouds act as umbrellas on hot sunny days. They can also form, amalgamate or dissipate over a very short period, so they rapidly compensate for thermal energy transfer in the atmosphere.

All gases are distributed fairly evenly by diffusion and mixing. Air density drops quickly with increasing altitude with simultaneous temperature lowering (a thermal lapse rate of 6.5 °C drop per km rise in elevation). Water vapour is different. It is non-uniform in the atmosphere, because as it cools it can condense to make clouds, mists or fogs. Certain clouds with the right conditions precipitate liquid water (rain) or snow and even ice (hail). These cool the lower atmosphere and the planet's surface, while scrubbing dust and some carbon dioxide from the atmosphere. Hence water offers some degree of self-regulation and self-compensation not possible with other greenhouse gases. If the planet heats up for any reason, the large oceans will heat up also. Hence more water will evaporate, the atmosphere will increase in humidity, more clouds will form, bringing more umbrella shielding, precipitation and atmospheric and planet cooling.

CONCLUSION

The GHG concentration of the actual atmosphere is 1.028% of the total atmosphere, based on water vapour being 1% (20°C, 75% Relative Humidity). The main gases from possible agricultural sources (methane and nitrous oxide) total only 0.02% of all the GHG, or 0.00021% of the total atmosphere. Also less than half of those two are possibly man-made (0.0001%). Methane and nitrous oxide have been shown to have only a few narrow radiant energy absorption bands, with none absorbing 100% at their active wavelengths. Hence, it can be concluded from the available evidence that their potential contribution to any change in weather is minuscule.

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HOW TO PROVE FOR YOURSELF THAT CARBON DIOXIDE IS NOT THE MAIN CAUSE of WEATHER CHANGES and CLIMATE PATTERNS

GEOFFREY G DUFFY DEng, PhD, BSc, ASTC Dip., FRSNZ, FIChemE, CEng

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Anyone with access the web can easily prove for themselves that carbon dioxide is actually a minor player in weather changes and the resultant climate patterns. Only two data sources are required:

- radiation energy from the Sun with the subsequent re-radiation energy back from the earth, and,
- water vapour content in the atmosphere (termed humidity).

The first shows that carbon dioxide gas is a poor greenhouse gas (absorber of radiation) and it is completely swamped by water vapour and clouds. The second shows that the concentration of carbon dioxide is so low that it is again dominated by water vapour.

The sources are:

Radiation (1): https://commons.wikimedia.org/wiki/File:Atmospheric_Transmission.png

Humidity (2): http://www.lenntech.com/calculators/humidity/relative-humidity.htm

1. **Radiation:** Let us examine the total radiation first. The graphical data from the web page show the electromagnetic radiant energy coming from the Sun (mainly visible light, infrared energy and some UV) and the reradiation back form the earth (see the yellow bar). The red curve shows the solar radiation (the Sun's surface is over 5,000 ^{0}C), and the blue curves show radiation back from cooler earth (-63^{0}C to 37^{0}C range).

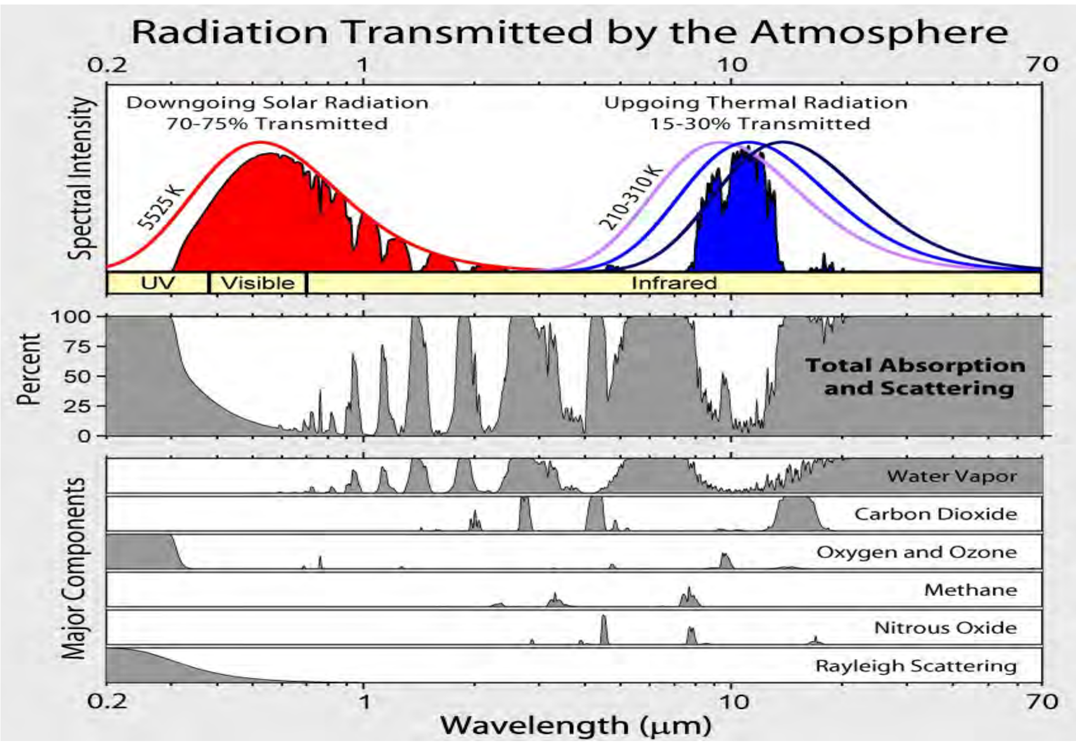


Figure 1 Radiation transmitted by the atmosphere. Radiation energy from the Sun is 0.3 to 3□m (UV, visible and short-wavelength infrared energy). Radiation energy from earth 3 to 70□m is longer-wavelength infrared radiation (1)

Let us examine the Solar radiation component first and take the left-hand part of the graph (Figure 1) where the incoming electromagnetic energy is 0.3 to 3□m (yellow bar).

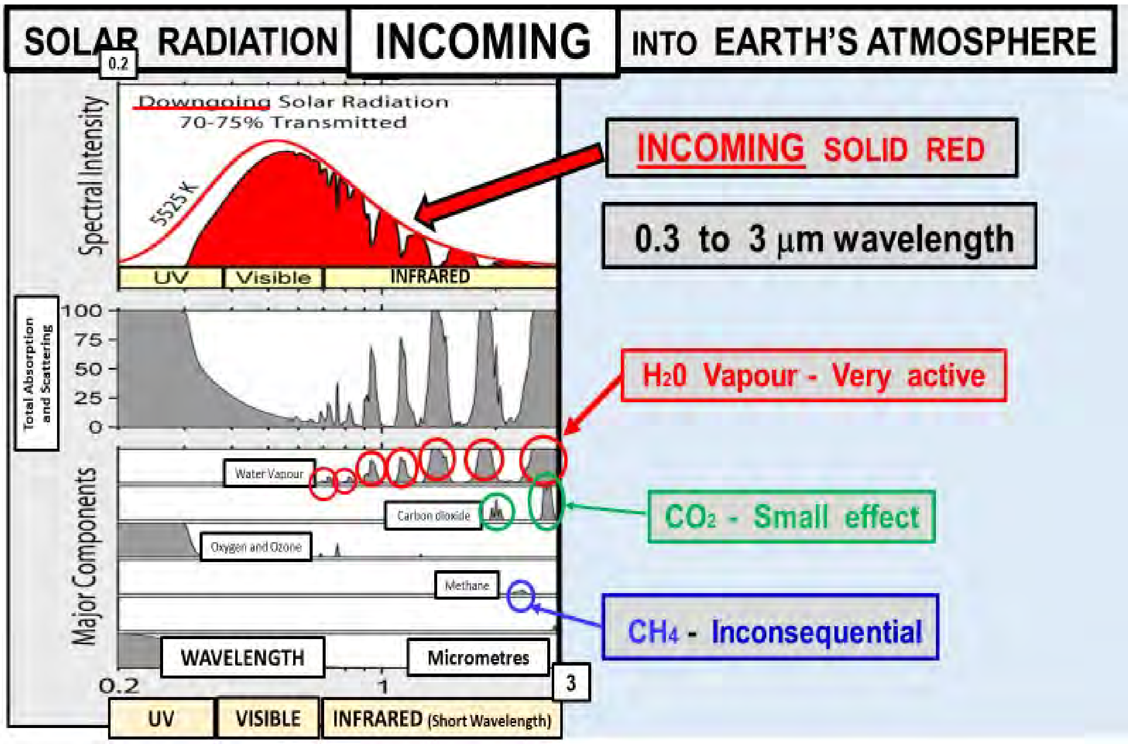


Figure 2 Solar radiation spectrum showing graphically that water vapour is more effective in absorbing large amounts of incoming radiant energy from the Sun (1).

We note immediately that carbon dioxide CO_2 has only 2 radiation absorption bands while water vapour has 7 absorption peaks (5 peaks over the 50% absorption level). Carbon dioxide can actually absorb only over about 8% of the total span, whereas water vapour is active over 44% of the entire 0.3 to 3□m span. This shows that water vapour is the most effective or more dominant solar energy greenhouse gas absorber (by a factor of about 5; or 50 times greater than the effect of man-made CO_2).

We can also observe from this graph, that methane CH_4 with a peak absorption level less than 10% has only a minute absorption band at about 2.2□m and is inconsequential [only 1.7 ppm (parts per million), or less than 0.0002% of the atmosphere anyway].

It is worth noting that less than 60% of the total incoming solar energy actually reaches planet earth. Some is reflected back into outer space by clouds, snow, ice, and by the vast ocean surface (almost 71% of the planet's surface area). This incoming radiant electromagnetic energy 'excites' molecules of all solid and fluid matter in our lower atmosphere and at the planet's surface. Molecules vibrate, rotate, or oscillate, and then emit or re-radiate electromagnetic energy upwards, this time at longer wavelengths. The visible energy portion of solar energy is mostly reflected and very little is absorbed by matter. However, is vital in both photosynthesis and phytoplankton activity where carbon dioxide is chemically transferred to oxygen and myriads of organic molecules used to make tress, scrubs, plants, and all crops.

If we now examine upwards re-radiation from our lower temperature earth we observe that we have infrared radiation at longer wavelengths (3 to 70□m – yellow bar in Figure 3).

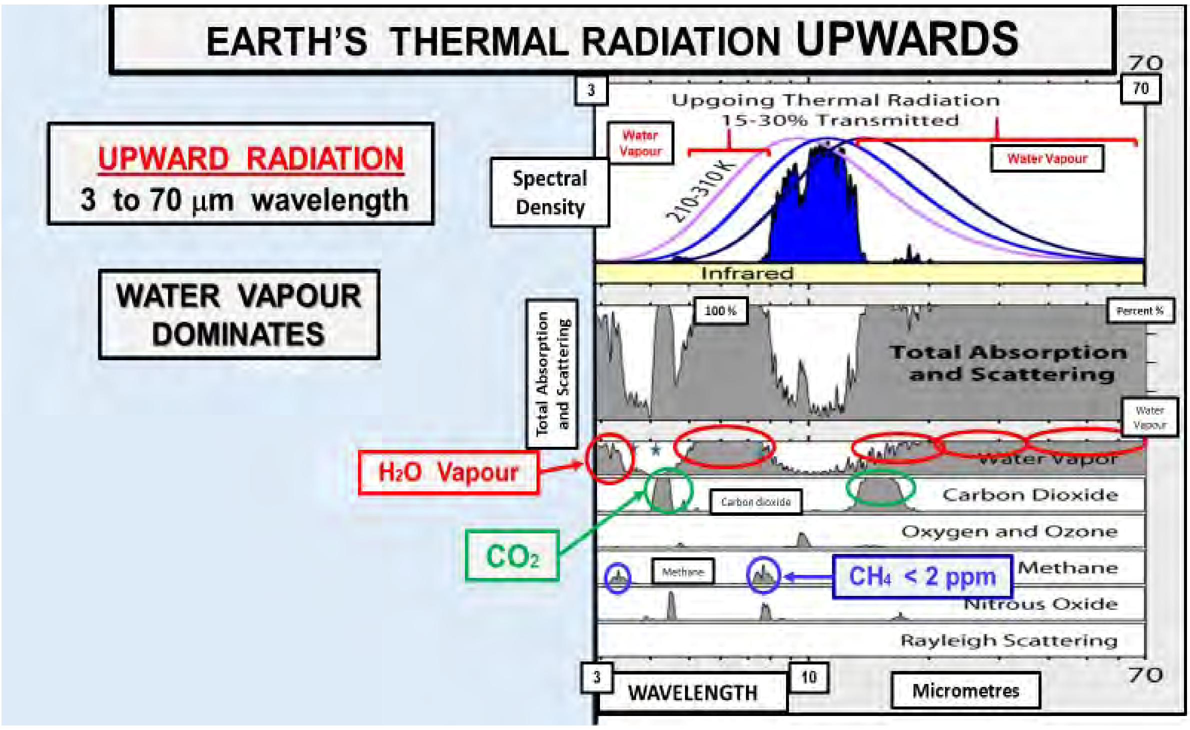


Figure 3 Re-radiation spectrum for radiation from Earth showing that the strongest greenhouse gas water vapour is far superior to both carbon dioxide and methane (1)

Again atmospheric carbon dioxide only has 2 additional absorption bands. One band is matched by water vapour and would have to compete. The other band is more effective, but again over a very narrow range. Over the entire 3 to 70m span, water vapour is able to absorb across 86% of the radiant energy spectrum at levels greater than 50%. Carbon dioxide by contrast is only active over less than 7.5% of the total 3 to 70m span. Clearly water vapour is a far more effective absorber of radiant energy coming from earth (actually by a factor of about 12; or more than 120 over man-made CO_2), and is again the dominant greenhouse gas.

We can note also that CH_4 has 2 very small and narrow absorption bands and has to compete directly with water vapour at the same bandwidths, once more at very low absorption levels (<60%). The atmospheric concentration of methane is extremely low concentration (<2ppm), and therefore it is not possible to affect re-radiation to any significant extent.

Back to Figure 1: The Total Radiant Energy Transmitted in the atmosphere. If we examine the total 0.3 to 70m radiation energy span, we see that carbon dioxide is only active over 8% of the full span whereas atmospheric water vapour is active over a total of 87.4% of the entire range. We can only conclude that atmospheric water vapour is far superior as a radiation greenhouse gas overall. Of course, water and water vapour do far more as they can form protective clouds as well and produce precipitation to cool and scrub the atmosphere. CO_2 is a radiation-only, noncondensable greenhouse gas.

2. **Atmospheric concentration:** It is well known that carbon dioxide is a low concentration atmospheric greenhouse gas; 400ppm$_v$ or 0.04%. It has increased only at about 1ppm$_v$ per year (about 1% change/year) over the last century. Surprisingly, far less than 1/10 of that is purported

to be man-made (less than 0.1ppm_v/year), meaning that less than 12ppm_v (<0.004%) was contributed by mankind in just over 100 years.

To find the amount of water vapour in the atmosphere we can use Humidity Charts or Tables, or obtain data from a typical web source. As mentioned above, the Lenntech site (2) is easily accessed and used, although its units are on a mass basis. Relative Humidity RH % provides good indicator. At 100% RH the atmosphere is saturated with water vapour at a specified temperature. A RH percentage value of zero means bone-dry air.

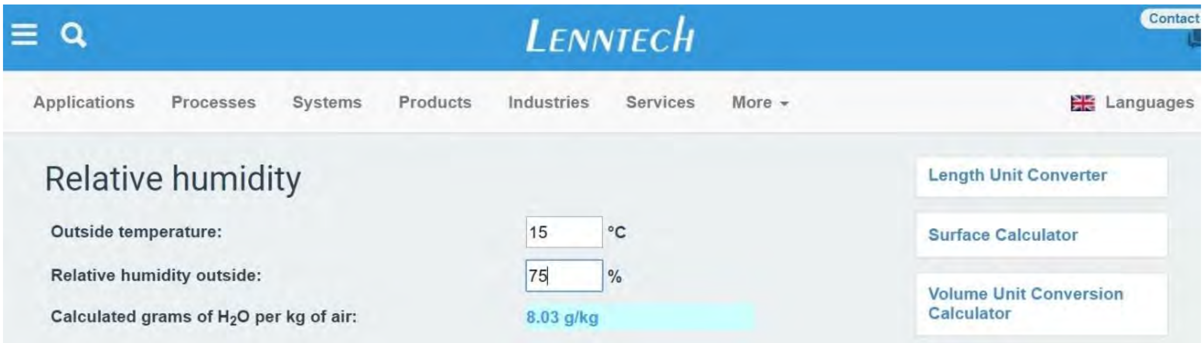
At 0^0C and say 75% relative humidity, there is 3.15 grams of water per kilogram of air which 3,150 ppm_m or 0.31%. This is much higher than atmospheric CO_2 at 0.04% and man-made CO_2 at <0.004%.

At 20^0C and 75% RH there is 10.96 grams of water per kilogram of air which 10,960 ppm_m or 1.1%: again very much higher (270 times higher) than MAN-MADE CO_2 at <0.004%.

For a typical summer tropical temperature of say 35^0C and 75% relative humidity, there is 27.93 grams of water per kilogram of air which 27,930 ppm_m or 2.79% (about 70 times greater than CO_2, OR about 700 times greater than MAN-MADE CO_2).
In the tropics at 40^0C and 80%, the water vapour concentration is over 100 times greater than CO_2 at almost 4.1% (40,690 ppm_m).

At all temperatures above about -35^{0}C (at polar regions, or equivalent to about 7- 8 km in elevation), the concentration of water vapour is larger than the concentration of carbon dioxide. CO_2 probably exceeds water vapour in concentration above about 6 - 7 km elevation, but more than 50% of the total mass of the atmosphere is below about 6 km anyway, where water vapour is far stronger in radiation absorption over a wider range of wavelengths. Even at -60^{0}C the water vapour content is still 100 ppm$_m$. CO_2 with only two narrow active absorption bands can only possibly absorb about 8% of the incoming solar radiant energy anyway at these at high altitudes.

Probably the most surprising fact is that the atmospheric water vapour concentration can increase even with NO change in temperature at all. This is shown in the following two plots where an extremely small 5% change in relative humidity from 70% to 75% at 15^{0}C (approximately the average world temperature now) increases the atmospheric water vapour concentration by 540ppm$_m$ (from 7,490ppm$_m$ to 8,030ppm$_m$). This is more than the total current atmospheric CO_2 concentration of 400ppm$_v$, and is achieved with only a 5% relative humidity change which can occur rapidly, even at constant temperature.



Hence water vapour is not only a superior radiation greenhouse gas, it is also far higher in atmospheric concentration. The reader can easily determine water vapour concentration for other temperatures using the Lenntech site (2). *[Some further data are presented in a Table at the end of this article].*

3. **The power of water vapour that carbon dioxide does not share**: Carbon dioxide is a radiationonly greenhouse gas and affects radiation only to a small extent. Radiation-superior water vapour contributes three additional and dominant effects that no other non-condensable greenhouse gas can. These are: (a) cloud formation; (b) precipitation mainly as rain, and, (c) humidity compensation in the atmosphere.

(a) Clouds: As warm moist air rises the atmospheric temperature decreases. If saturation occurs (100% humidity), then the vapour-to-liquid phase change can produce clouds, mists, or fogs. Large changes can occur over small distances and time scales (seconds to hours), as clearly demonstrated by clear skies going to cloudy skies very quickly, even while watching. These energy transfers are augmented by bulk mixing (winds, thermals etc) as well as any local precipitation. During daylight hours, clouds act as shielding 'parousel shade-umbrellas' as they can intercept some portion of incoming radiation and reflect or reradiate it back to outer space. Clouds therefore can contribute to cooling on earth during the day. Certain clouds can also reflect or re-radiate some long-wave radiation coming from earth back to earth to make the planet's surface and lower atmosphere slightly warmer. Clouds either grow, amalgamate, disperse, or disappear back into water vapour. The speed of cloud formation, distribution, and dispersion is indeed fast, showing the innate ability of water and water vapour in the atmosphere to adapt, self-buffer, self-compensate, and self-correct with any thermal changes. Data show that there over 300 million square kilometres of the planet's land and oceans are covered by water-formed clouds (about 2/3or 66% planet area) (3). It is postulated that cloud cover over land is about 10-15% less than that over the vast oceans (3).

(b) Precipitation: Rain (snow and hail too) cools the atmosphere and then the planet surface and scrubs some dust from the air as well. Some CO_2 is absorbed or scrubbed also to form weak carbonic acid which is neutralised when and if it eventually contacts the ocean due to the presence of carbonaceous materials like sea shells. Consequently, the oceans will always remain alkaline (pH>7) while ever there are shells and molluscs present. Evaporationcondensation-precipitation is unique to water/water vapour which happens to be the best radiative absorber and emitter as well.

(c) Humidification: Humidity is a strong function of both temperature and differences in moisture concentration. The amount in the air is an indicator of energy demand as well. Some water vapour may condense as dew or a fog, while in slightly different and special circumstances, some more may quickly be generated. All other greenhouses gases cannot do that. If for any reason whatsoever the mean global temperature or the regional temperature increases, then because of the massive ocean area, more water would evaporate with the potential formation of compensatory clouds and rain.

4. **More than radiation?** As shown there are other active heat-energy transfer mechanisms operating worldwide that drive weather variations and thus climate change apart from radiation. All heat energy transfer depends on temperature differences (for radiation; the fourth power of temperature differentials). Thermal energy can also be transferred by bulk mixing (natural and forced convection) where neighbouring molecules collide and are transported in larger volumes by pressure and temperature differences. These swirling eddies collide with solid or liquid surfaces to exchange energy, and then energy is transferred into these bodies by conduction. Breezes, winds, storms, cyclones and tornadoes are examples of atmospheric convective mixing. But mixing is a major transfer mechanism within the oceans as well. Ocean currents, ocean conveyors, tidal flows and upwellings are examples of convective liquid bulk mixing. Both sea and air currents transfer thermal energy at the interface, and this is augmented by waves (surface mixing and increased air-water surface area). Energy can also be conducted to and from the oceans or solidus materials on land. Hot air rises, expands and cools (thermals). The Thermal Lapse Rate (4) shows that temperature drops 6.5 ^{0}C per kilometre rise above the planet (-0.65 ^{0}C /100m rise). This helps us understand how clouds form so easily.

5. **Increase in carbon dioxide over the last century**: It is interesting to focus, not just on the current *total* 400+ppm$_v$ CO_2 atmospheric concentration, but also on the 120ppm$_v$ *increase* in CO_2 over 100+ years (280 to 400ppm$_v$). It has been shown that either a small temperature change or a very small relative humidity change with NO temperature change, can both accomplish more than the effect of the total equivalent 120ppm CO_2 increase over a century very quickly. These small and often rapid changes over minutes or hours clearly far exceed the total effect of the carbon dioxide increase over the last 100+ years.

Conclusion: It is therefore hard to conclude that carbon dioxide is THE major contributor in weather change and the ultimate climate (weather patterns). A simple analysis of easily accessible web information (radiation absorption spectra and humidity data) has shown that water vapour is a far more effective and a stronger atmospheric greenhouse gas than carbon dioxide. Water is also able to phase-change rapidly to evaporate, humidify, and condense and produce clouds as well. As shown, carbon dioxide and methane are strictly limited to radiation-only and are not highly successful at that anyway.

References:

1. Radiation transmitted by the atmosphere; graphical spectra: https://www.google.co.nz/search?q=Solar+radiation+energy+spectra&espv=2&biw=1680&bih=944&tbm=isch&tbo=u&source=univ&sa=X&ved=0ahUKEwiCsKyG1bPSAhUDHpQKHUoBAX0QsAQIMg&dpr=1#imgrc=oJSWW8Hq-bIPIM
2. Humidity Calculator: http://www.lenntech.com/calculators/humidity/relative-humidity.htm 3. USGS science for a changing world - cloud cover: https://water.usgs.gov/edu/watercycleatmosphere.html
4. Thermal Lapse Rate: https://en.wikipedia.org/wiki/Lapse_rate

EXAMPLES of HUMIDITY CHANGES with TEMPERATURE and also when there are NO TEMPERATURE CHANGE*

TEMPERATURE ^{0}C	RELATIVE HUMIDITY %	PARTS per MILLION ppm$_m$	COMMENT Mass percent
-35	100	470	0.047%
-10	100	2,250	0.23%
0	100	4,100	0.41%
10	75	5,880	0.59%
14*	60 *[14 ^{0}C]*	6,030	0.6%
14*	70 *[14 ^{0}C]*	7,040 *[16.7% increase]*	0.7%
20	75	10,960	1.06%
25*	75 *[25 ^{0}C]*	14,970	1.5%
25*	85 *[25 ^{0}C]*	16,970 *[13.3% increase]*	1.7%
30*	75 *[30 ^{0}C]*	20,450	2.05%
30*	100 *[30 ^{0}C]*	27,270 *[33.3% increase]*	2.73%
35	80	29,790	2.98%
40	90	45,780	4.58%

Typical atmospheric water vapour concentration data at selected temperatures and humidities expressed in parts per million by mass and by mass percentage. Note: the temperature of -35^{0}C is equivalent to the temperature at about 7-8 km elevation (4).

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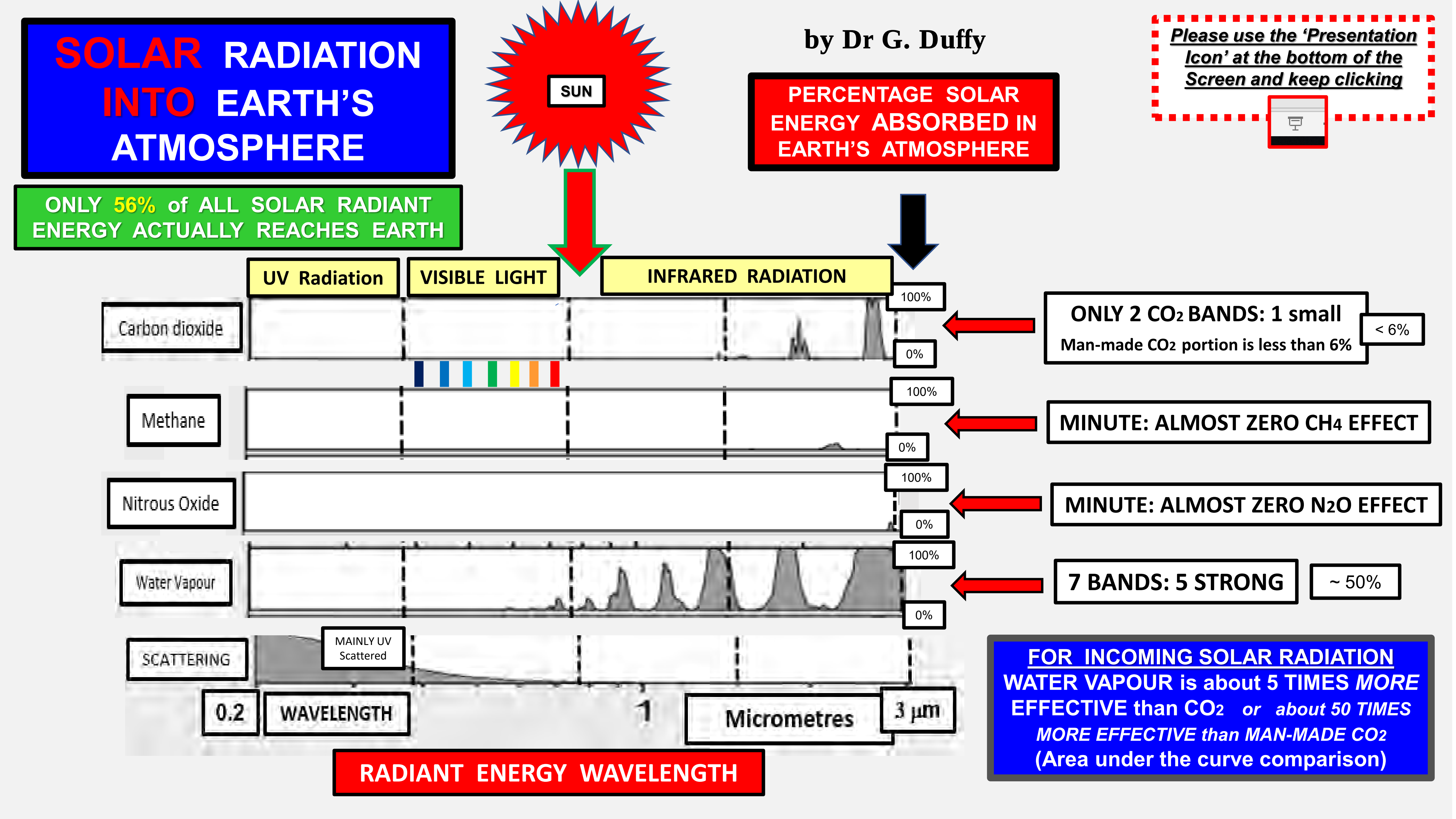
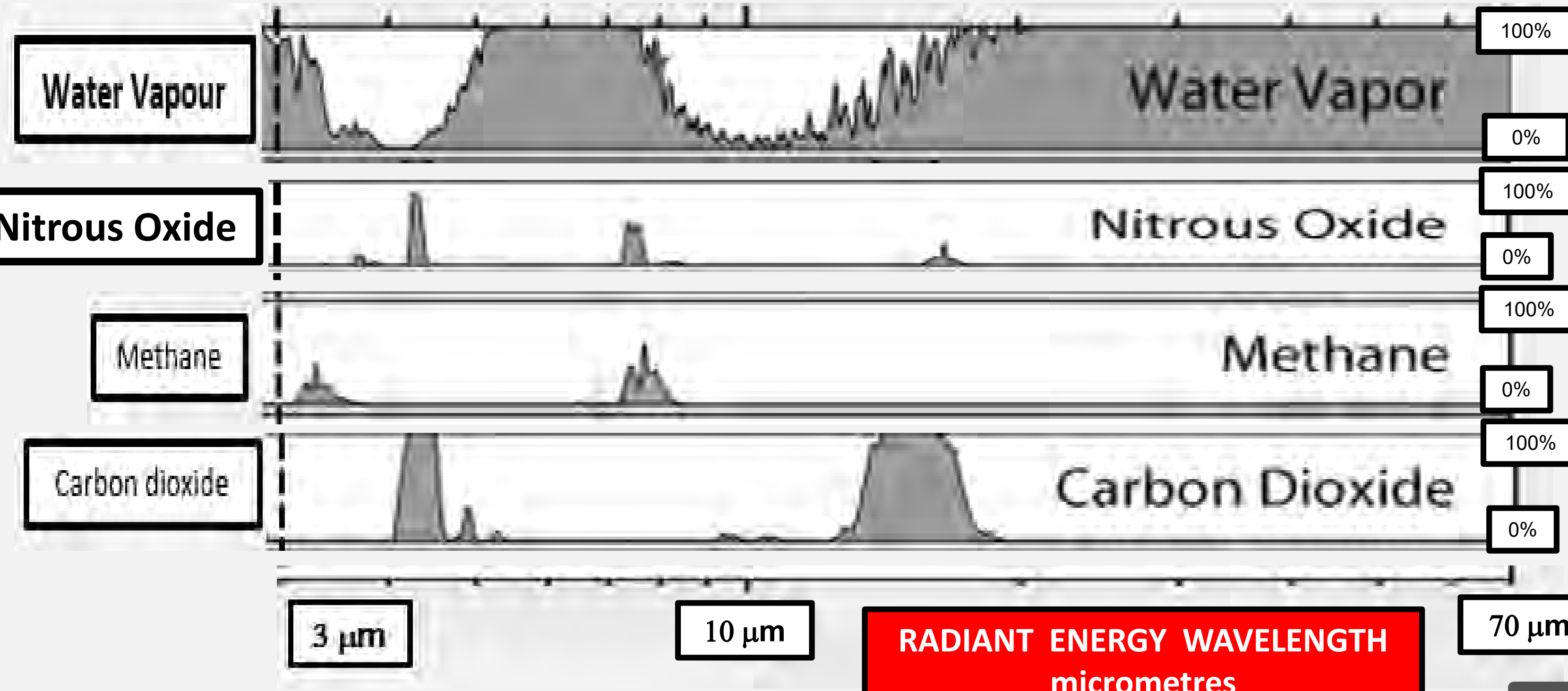

SOLAR RADIATION INTO EARTH'S ATMOSPHERE
SUN
by Dr G. Duffy
Please use the 'Presentation Icon' at the bottom of the Screen and keep clicking
PERCENTAGE SOLAR ENERGY ABSORBED IN EARTH'S ATMOSPHERE
ONLY 56% of ALL SOLAR RADIANT ENERGY ACTUALLY REACHES EARTH
UV Radiation
VISIBLE LIGHT
INFRARED RADIATION
Carbon dioxide
100%
0%
ONLY 2 CO_2 BANDS: 1 small
Man-made CO_2 portion is less than 6%
< 6%
Methane
100%
0%
MINUTE: ALMOST ZERO CH_4 EFFECT
Nitrous Oxide
100%
0%
MINUTE: ALMOST ZERO N_2O EFFECT
Water Vapour
100%
0%
7 BANDS: 5 STRONG
~ 50%
SCATTERING
MAINLY UV Scattered
0.2
WAVELENGTH
1
Micrometres
3 µm
RADIANT ENERGY WAVELENGTH
FOR INCOMING SOLAR RADIATION
WATER VAPOUR is about 5 TIMES MORE EFFECTIVE than CO_2 or about 50 TIMES MORE EFFECTIVE than MAN-MADE CO_2
(Area under the curve comparison)

RE-RADIATION BACK FROM EARTH TO SPACE

PERCENTAGE RADIANT ENERGY ABSORBED

by Dr G. Duffy



DOMINANT COVERS >80% ENTIRE SPAN

5 to 100 times the concentration of CO_2

ONLY 2 N_2O BANDS – Minute concentration: 7/10,000 of CO_2

ONLY 2 SMALL CH_4 BANDS
Minute concentration 4/1,000 of CO_2

ONLY 2 MORE CO_2 BANDS
Man-Made CO_2 is less than 6% CO_2

RADIANT ENERGY WAVELENGTH micrometres

FOR RADIATION BACK FROM EARTH
WATER VAPOUR is >12 TIMES *MORE* EFFECTIVE than CO_2 *or >120 TIMES MORE EFFECTIVE than MAN-MADE CO_2*
(Area under the curve comparison)

FROM EARTH

EARTH
- 60C to +40C

RADIANT ENERGY
ALL Long-wave Infrared Energy

by Dr G. Duffy

CLIMATE CHANGE - THE BIGGER PICTURE

WHAT CAUSES WEATHER CHANGES and LONG-TERM CLIMATE PATTERNS

The high-temperature surface of the Sun (~5,500 ^{0}C) emits most of its solar energy at *short* wavelengths (0.1 - 3μm). Incoming solar energy (mainly visible, near-infrared radiation, with some UV) is *not* all absorbed initially to any extent when it first strikes planet earth's atmosphere. Fortunately much of the UV is absorbed in the Stratosphere by oxygen-ozone. Some of the incoming sun's energy is reflected back into outer space by clouds, ice, and snow on the mountains and at the poles. Some radiation is either scattered or absorbed by the atmosphere, and the rest hurtles to the planet's surface of which 70% is water. This solar *radiant* energy 'excites' molecules making up the ocean surface and land. In turn these molecules re-emit *radiation* of much *longer* wavelengths (3 - 70μm) than the incoming energy from the Sun (0.1 - 3μm), and some of the radiant energy in this band is absorbed/reradiated by the so-called greenhouse gases.

It is the re-emitted energy from the planet's surface (mainly as infrared energy) that is absorbed in the atmosphere just *near* the earth's surface mainly by water vapour in the air as well as carbon dioxide and some other greenhouse gases. Most of this radiant energy absorption is virtually completed within a few hundred metres above the earth's surface which is now cooler. The warmer near-surface air does not form a 'stationary' blanket, but rises, expands, and cools (thermals) *[air temperature decreases about 6.5 ^{0}C per kilometer-rise above earth (a decrease of 0.65^{0}C per 100 metres (called the Thermal Lapse Rate) which also highlights the need for reported worldwide temperature data to be normalised to sea level (elevation correction)].*

It is not just radiation alone! Temperature *differences* set up density and pressure differences, and thus cause thermals, breezes and winds. These bulk convective air movements also augment the transfer of energy from the earth's surface over and above the contribution of radiation. These air movements affect the transfer of energy across and away from the planet's surface, so in reality, no stationary thermal blanket could persist for long anyway (hence no green-*house as such*). Energy is virtually dissipated into the Troposphere *[Troposphere: lower 17 to 20km of the atmosphere above the planet containing 80% of the atmospheric-air mass and 99% of the total water vapour in the air],* warming the upper Tropospheric layer slightly, which then radiates its energy back into the colder Stratosphere above it and then into outer space. Very clearly then, radiation *from* the planet's surface occurs in concert with air mixing movements by natural convection (thermals) and forced convection (winds).

But that is not all!! Water transfers vast amounts of energy by *evaporation* and *condensation*. Surface liquid water in the vast oceans, lakes and rivers can evaporate and produce billionsof tonnes of water vapour worldwide in the Troposphere. Some of this condenses to produce clouds (mists, fogs) and then rain and/or snow. No other atmospheric gases do that! The energy transfer is huge. Unfortunately, these powerful energy transfer mechanisms of evaporation/condensation as well as mass convective air movements as winds are often totally ignored in favour of radiation being myopically selected as the only player. The greenhouse gas radiation absorption/emission contribution is only significant near the planet's surface anyway, and water vapour (about 0.5 to 4+% of the atmosphere) is about 10 to over 100 times greater in concentration and is more effective than traces of carbon dioxide CO_2 which is only 0.04% (man-made CO_2 even less: <0.004%). Adding extra CO_2 simply increases by a few metres the height above the earth over which the radiant energy emitted from the earth or sea can possibly be absorbed by CO_2. CO_2 still has to compete with water vapour at the same time because water vapour absorbs over the very same wavelength bands and far, far more. The fact that water vapour is a far more effective greenhouse gas simply cannot be ignored!

<u>What happens at night?</u> The Sun plays no 'radiation-part' at night with half the planet facing away from the Sun (about 50% of each day on average). The earth and water surfaces are initially warmer than the local Troposphere, so some energy can still be radiated upwards at night. But winds and turbulent air and sea mixing motions do not change greatly from daylight to night time, so thermal energy is still transported by bulk motion (winds, thermals, and water evaporation/condensation). Evaporation and condensation occur night *and* day too; 24-7. Thus the *major* solar *radiation* effects with CO_2 and H_2O involved can only be 12-7 on the sunny side. Of course, normal radiation occurs all the time even at much lower temperature differences. Nevertheless, the overall magnitude of the effectiveness of CO_2 is basically half-time and is strictly limited as a radiation mechanism contribution!

In summary: It is important to see that most of the 'absorption' of the Sun's energy occurs near sea level and earth level, and that the sea and earth heat up the adjacent atmosphere by direct air-impingement contact (thermal convection and conduction) as well as by radiation. These result in a warmer lower Troposphere, which then radiates energy back out into outer space. In nature, all these actions continue to drive energy and matter toward a quasi-equilibrium which in fact is never actually reached.

<u>Why evaporation is a key player:</u> Evaporation of water from oceans, lakes, and rivers requires energy to 'convert' water from the *liquid* state to the *vapour* or *gaseous* state. This evaporative energy comes from both the Sun's incident energy and the liquid water itself. Evaporation causes a slight ocean-surface cooling (evaporative cooling), but the moist air rises, cools, and under certain conditions forms clouds, mists, and fogs. Large amounts of water vapour condense giving up huge amounts of energy. This energy from condensation as clouds form, heats the upper atmosphere which in turn is radiated back to outer space (some radiation back to earth too from certain types of clouds). Clouds can act as umbrella-type shades also on sunny days, thereby reducing some radiation ever reaching the planet in daylight hours. We strongly experience that shading effect on a very hot day when clouds suddenly come over, to prove that clouds alone have an immense effect on local and short-term temperatures and thus weather changes. About 66% of the planet is covered by clouds at any one time.

<u>Let's get real about carbon dioxide:</u> Most of the CO_2 is *not* in the atmosphere. 93% of *all* CO_2 is in the oceans (38,000 billion tonnes), with about 5% on land in the plants and soils (2,000 billion tonnes). <u>Only</u> 2% of the total CO_2, or 850 billion tonnes of CO_2 is in the atmosphere, and well less than 10% of that 2% is man-made (<85 billion tonnes)! Over 90% of atmospheric CO_2 is produced naturally from decaying vegetation, fires, volcanoes, and warming oceans (CO_2 is less soluble in warmer water). Surprisingly over 80% of the world's *active* volcanoes are under the sea bubbling out both liquid and gaseous methane CH_4 and CO_2 *(and the sea is still alkaline)*. Indeed combustion reactions (fossil-fueled power stations, fires, cars etc) produce CO_2 and water, but it is the fine pollutant particles like unburned carbon and chemicals *(like oxides of sulphur and nitrogen)* resulting from *incomplete* combustion that are the major problems affecting local temperatures, weather, smog, as well as human health. It has been said that ruminating animals produce more greenhouse gases than all the buses, trucks and cars in the world combined! Water by far the major greenhouse gas, cannot be controlled or taxed, so CO_2 is measured, blamed, and potentially made taxable, even though most of the *atmospheric* CO_2 (>90%) is naturally occurring. But by contrast, in the sea, phytoplankton and algae growth from the extra atmospheric CO_2 has increased *tenfold* over 50 years, and these are the main suppliers of the oxygen that we breathe. Higher crop yields and greater vegetation growth rates have been reported worldwide due to the increased CO_2 over the last 3 or so decades. Water vapour is greater in concentration than CO_2, absorbs radiation over a greater range of energy bandwidths, transfers more energy by evaporation-condensation and forms clouds to act as umbrellas, and then kindly 'dumps' rain/snow to scrub the atmosphere from dust and some CO_2. CO_2 is really a minor player! [Incidentally, methane CH_4 at less than 1.8 ppm is totally insignificant as it absorbs only at two wavelength bands (3.2 and 7.8μm micro-metres) at less than 50% levels, when simultaneously water vapour already absorbs most at the 100% level at the same wavelengths and over much wider bands of energy levels as well].

<u>The misunderstood principle of equilibria</u>: When *any* system is not in equilibrium, the *<u>differences</u>*, in say temperature, pressure, or mass-quantity like water vapour, are all active driving forces attempting to restore equilibrium (zero differences). The powerful driving-force *differentials* keep working to minimise the *differences* and ideally to restore equilibrium (where the differences would be truly 0). For example, if the planet did heat up markedly for *any* reason whatsoever, more water would evaporate, more clouds would form to shield or shade the planet from the Sun's energy, and so equilibrium would be partially restored. More clouds mean more rain and snow, more cooling, and air scrubbing of dust and some CO_2! The very observable dynamic cloud formation-and-depletion alone is a significant indicator of the planet's natural compensatory and self-buffering ability, but the very fact that we have local small-scale and local humidity variations as well, also points to the planet's natural inbuilt adaptability and self-regulatory capacity.

<u>Radiation and CO_2 are simply not the only issues:</u> Weather changes are complex. Thermal radiation, convection, evaporation-condensation, and conduction are all in-play ALL the time, but there are many more underrated energy transfer mechanisms that make enormous contributions. Massive ocean conveyer systems and ocean up-wellings, El Nino and La Nina patterns, storms, sub-surface saline currents, monsoons, tornados, Jet Streams and Trade Winds, all must be highly significant. The magnitude of these effects vary as the earth rotates (overnight or diurnal cycles), as the earth revolves around the sun (seasonal changes), and depend strongly on location (latitude), and position (continent, island, and closeness to the sea etc). Over many years weather patterns (like temperature variations, rainfall etc) reoccur, so that an 'annual weather trend' is established and the general average recurrent pattern is termed the 'Climate' at that location. Actually it is the natural, prolific and often repeatable weather changes that are always occurring that set up some general approximate average weather patterns over longer periods, called 'Climate'. So climate is 'formed'; but climate itself cannot cause anything as it is simply a 'pattern' or an overall average trend in weather change; an outcome!

<u>Driven mainly by the sun</u>! The Sun triggers all the above energy transfer mechanisms on planet earth. Molten magma affects the earth's crust and induces sub-ocean volcanic gas emissions and tectonic plate energy transfers. Warming we have experienced over the last century, and even before that, coming from the Little-Ice-Age, is a natural phenomenon. Solar activity has been particularly high over the warming period last century, but the more recent changes in sun spot activity have resulted in a zero-mean global temperature rise for well over 17 years. However, CO_2 went up over 8% in that same period of stable worldwide average temperature, so we cannot attribute, link, or blame CO_2 for that! No; we must not isolate radiation and CO_2 as the only cause. We must examine all the other macro-energy transfer actions operating unceasingly on our planet.

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