

Water Vapor's Roles in Global Warming

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Abstract

Water vapor has been hitherto neglected in greenhouse gases budget. According to physical law, warmer atmosphere can hold more water vapor before precipitation, which could make the Earth even warmer. A mathematical model is presented in this paper to predict the effect of water vapor in global warming, in addition to the well known effects of carbon dioxide. It was found by surprise that water vapor, both emitted from fossil-fueled power plants and evaporated from earth's surface is the major contributor to global warming (about 90%), though the root cause that trigger the warming is still the rise of carbon dioxide concentration, which contributes only 10%. The sensitivity of the production of water vapor in relation to the production of carbon dioxide is estimated and its possible catastrophic nonlinear effect is pointed out.

Keywords: Water vapor as greenhouse gas, Effects of water vapor, Greenhouse effect, Global warming

1. Introduction

Scientific evidences, personal as well as societal experiences have confirmed that our world has been getting warmer over the years, slowly at the start of the Industrial Revolution and appears to be much faster over the past three decades. Numerous adverse effects caused by the warming are forecast; the most dreadful of them all is, perhaps, the melting of the polar ice caps which will result into wide spread floods in low altitude areas of the world. Extraneous carbon dioxide gas in the atmosphere spewed from smoke stacks of fossil-fueled power plants has been identified as the main culprit for the cause of this phenomenon, with other trace gases such as methane and nitrous oxide playing minor supporting roles.

Water vapor, though acknowledged by many scientists as an important greenhouse gas, is generally regarded as an indigenous, constant background-gas that does not contribute to additional increase in global temperature. It is well known that water vapor could absorb solar radiation at about the same extent and at the same spectral frequency as CO_2 [1].

Moreover, WV also can absorb additional radiation at shorter wavelengths. Thus the present of equal amount of extraneous WV potentially could be more harmful than the present of CO_2 .

Water vapor can be present in the atmosphere from two sources: emission from fossil-fueled power plants and evaporation/transpiration from earth's surface. Effects of emitted WV on global warming has been negated in whole or in parts by the fact that it would eventually precipitate as snow, rain and dew, in an integrated manner with those WV that naturally evaporates from earth's surface. For the moment we will assume that this argument holds (but will come to discuss this issue further later.)

2. Mathematical models

The mathematical model for global warming without the effect of water vapor will be presented first. The records of CO_2 concentration rise [2] and temperature rise [3] of the world's atmosphere covering the period of 1970-2000 are as shown in Figs. 1 and 2.

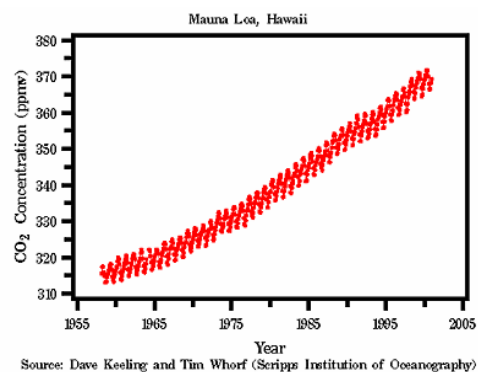


Figure. 1 Record of CO_2 concentration in atmosphere [2]

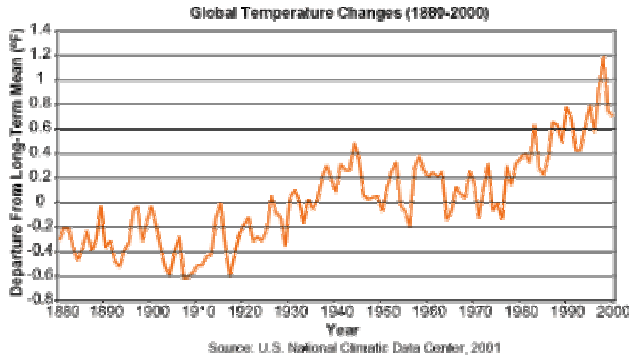


Figure 2. Record of atmosphere's temperature change [3]

The general trends during 1970-2000 are the increases of both CO_2 and temperature in approximately linear manners. Over this 30 years period the temperature rises by about $1^\circ F$ ($0.55^\circ C$) while CO_2 concentration rises by about 43 ppm. The linear increases suggest a simple linear mathematical model,

$$\Delta T = d \Delta C \quad (1)$$

where Δ represents incremental change, T, C are temperature and CO_2 concentration, respectively. The constant coefficient, d , can be estimated from the linear variations in both graphs as

$$d = \frac{0.55}{43} = 0.0128 \text{ } ^\circ C / ppm. \quad (2)$$

The rationale and the mathematical model for the contribution of water vapor will now be discussed. It is an established scientific knowledge that when the air warms up, its capability to admit water vapor before condensation is higher. Thus, a warmer globe is at the same time also a wetter globe; and this is being proved for example by the greener desert in Africa due to a more humid atmosphere [4]. These extraneous WV absorbs more solar radiation from the Sun and from the Earth, causing the globe to be warmer still, which renders it to admit even more WV, ad infinitum. This seems to be a positive feedback loop without a restraining mechanism for equilibrium; If this is true, it is very alarming. A mathematical model of global temperature to account for both CO_2 and WV concentrations is written as,

$$\Delta T = d \Delta C + e \Delta W \quad (3)$$

where w is the water vapor concentration in the atmosphere and d and e are coefficients that presumably could be determined by experiments, or by deciphering global meteorological data

over the past years. Note that d here is not the same d as appeared in eqs. 1 and 2. It should be noted also that W is the average background water vapor concentration in the atmosphere which cannot be reduced by precipitation. As reasoned earlier, the amount of WV that could be present in the atmosphere also increases with its temperature; this could be modeled most simply as,

$$\Delta W = f \Delta T \quad (4)$$

where f is another empirical coefficient which is related to vapor pressure of the atmosphere; it is perhaps a function of T itself but it will be assumed for the time being, for simplicity, as a constant. Putting (4) into (3) and rearrange, there is obtained:

$$\Delta T = \left[\frac{d}{1 - ef} \right] \Delta C \quad (5)$$

Now, by using the same data in figures 1 and 2 above and by comparing with eq. 2, it must be concluded that

$$\frac{d}{1 - ef} = 0.0128 \text{ } ^\circ C / ppm \quad (6)$$

If the value of e and f are known then the real contribution of CO_2 (hence WV) in global warming could be estimated through the value of d 's in conjunction with the interpretations of equations (1) and (3). As reasoned earlier, by observing the absorption bands of CO_2 and WV, e is evidently larger than d . For a conservative estimate it will be assumed here that e is equal to d . The value of f can be estimated from a psychrometric chart such as in [5]. The rationale for the estimation is that the background relative humidity of the atmosphere is constant regardless of its increased temperature. This should be a plausible hypothesis since it should be a natural adjustment for a warmer (thus dryer) atmosphere to absorb more WV to restore its natural equilibrium level. For demonstration purpose the background relative humidity is assumed to be constant at 40%; and the starting dry-bulb temperature is assumed to be at $20^\circ C$; this fixes a point in the psychrometric chart. The slope of the constant relative humidity curve in the psychrometric chart at this point can then be used to estimate the value of f . A rough estimation is done here by taking the secant's slope obtained by incrementing the temperature by 5

$^{\circ}\text{C}$ along this curve. The increase in humidity ratio ($2.2 \text{ g H}_2\text{O/kg dry air}$) over this temperature range is now used to estimate the value of f to be $704 \text{ ppm/}^{\circ}\text{C}$. (All ppm's used are based on volume basis.) Putting estimated $e (=d)$ and f into eq. (6), the value of d is computed as,

$$d = 0.00128 \text{ }^{\circ}\text{C/ppm} \quad (7)$$

3. Discussion

It is seen that the value of d in eq. 7 is about 10 folds smaller than that computed in eq. 2 for the case of ignoring WV contribution. By comparing eq. 1 and 3, this suggests that extraneous CO_2 contributes only about 10% in increasing the earth's temperature while the much larger 90% is contributed by extraneous WV. Though reduced to a minor contributor, it still requires an initial rise of a small CO_2 concentration to trigger the major effort by WV.

The sensitivity of WV produced by the production of CO_2 can be computed by dividing the amount of WV produced by the amount of CO_2 produced. This gives the number as,

$$\frac{\Delta W}{\Delta C} = \frac{387.2 \text{ ppm}}{43 \text{ ppm}} = 9.005 \quad (8)$$

Assuming that CO_2 and WV are equally potent greenhouse gases, this ratio implies simply, and consistently with the previous calculation, that the direct effect of CO_2 in global warming is only about 10% ($1/(1+9.005)$) while the indirect effect due to increased background water vapor is 90 %.

Insofar as its effect is a linear one (i.e., linear f), the effect of extraneous WV in global warming, though huge in comparison to that of CO_2 , should not appreciably change the level of future global temperature predicted by the various existing forecasting models that depend solely on CO_2 mechanism. By combining eq. 4 and 5, it is obtained that,

$$\frac{\Delta W}{\Delta C} = \frac{df}{1-ef} = 9.005 \quad (9)$$

This is also the sensitivity as defined in eq. 8. It is expected to be an increasing function of T simply because f appears to be an increasing function of T , as by observing the psychrometric chart. In other words, WV, hence T , should be increasing at an exponential-liked rate in time even if CO_2 increases at a constant rate. Moreover, the value of e is likely to be greater

than that of d . These two factors should contribute to increase the sensitivity in a non-linear manner which could result into a much warmer globe than predicted by a linear model. It is thus suggested that experimental measurements should be carried out in a timely manner to determined the magnitudes and the functional relationships of d, e, f so that the seriousness of the role of increased background WV in global warming can be accurately assessed.

A small consolation is found by differentiating eqs. 3 and 4 with time, which gives,

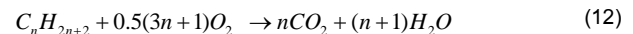
$$\frac{\partial T}{\partial t} = \left[\frac{d}{1-ef} \right] \frac{\partial C}{\partial t} \quad (10)$$

$$\frac{\partial W}{\partial t} = \left[\frac{df}{1-ef} \right] \frac{\partial C}{\partial t} \quad (11)$$

These indicate that as CO_2 stabilizes ($\partial C/\partial t = 0$) the temperature and water vapor increases will also stop. The positive feedback effect of continued temperature and water vapor rises does not appear here. Unless, as earlier speculated, if f is an increasing function of T then it is seen that T and W will be increasing at an ever higher rate.

Additional caution is in order here that the coefficient in eq. 11 is about 9.0, meaning that water vapor is being added into the atmosphere at the rate of 9 times faster than that of CO_2 . This could greatly effect the biosphere, such as the growth rates of some living organisms that are humidity sensitive (e.g., mushrooms), the transpiration rate of plants, etc.

Coming back to the previous argument about the effect of emitted WV from fossil-fuel power plants: does it totally precipitate back to the earth's surface in a totally synchronized manner with the evaporative WV so that we do not have to worry about its contribution to global warming? Assuming a paraffin structure of the fossil fuel, the complete-combustion equation can be written as,



It is seen that H_2O is produced even more than CO_2 in molecular number. It is argued here that during precipitation periods of the year (i.e., Winter in the temperate zone and rainy season in the tropical zone), WV emission in the local areas perhaps mostly precipitates; but some of it might escape into dryer areas of the globe which do not precipitate (also to upper atmosphere); this will contribute to local wet up and local warm

up around those affected dryer areas which eventually contribute to the global climate. The scenario becomes worsen in non-precipitating seasons (Summer in the temperate zone and non-rainy seasons in the Tropic) where most emitted WV contributes to increase local background humidity which cause local warm up for many months in a year until it precipitates in the next precipitating season, while some of it, again, escape into dryer locales of the globe where precipitation hardly occur. The effects of emitted WV is thus localized and annually varied. It should, to some extent, modify the large scale and long time behavior of global warming due to accumulative contributions of CO_2 and evaporative WV. The author's opinion is that we still do have to be concerned about emitted WV because its effectiveness for being a greenhouse gas is presumably even greater than CO_2 itself. And if we are worried about other trace gases' effects such as methane, why are we not worried about emitted WV that are being produced at even higher amount and at the same rate as the major gas itself?

4. Conclusion

The mathematical model proposed in this paper and the numerical estimations of the models' coefficients from meteorological data and from a psychrometric chart predicted that global warming is caused about 90% by extraneous water vapor that can be additionally admitted by the warmer atmosphere, and only 10% by carbon dioxide which is still the root cause of global warming. A nonlinear effect is speculated which could possibly yield a much higher earth's temperature than the predictions of most atmospheric models that do not take into account of this non-linear effect.

5. Reference

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