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OBSERVATIONAL CLIMATE DATA AND COMPARISON WITH MODELS

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ABSTRACT

We consider two examples of observations of Earth's temperature that strongly disagree with the general climate models (GCMs). The first example shows that the temperature trend of the lower troposphere is less than at the surface, which is opposite to that given from the GCMs. The second example is the Pinatubo volcano event. Here analysis of the event yields a short response time and a small climate sensitivity which implies negative feedback; neither result is explained by the GCMs. We also consider in this paper the validity of the generally accepted hypothesis that the CO_2 concentration in the atmosphere is causally related to CO_2 emissions.

I. INTRODUCTION.

The topic of this seminar series, "global warming", is timely because of the possibility of anthropogenic influence on the climate since the beginning of the industrial era. The series title suggests that this means average temperature of the earth. The natural variation in the global mean temperature of the earth is generally agreed to be about 0.6°C during the last 100 years. Various natural climate variations include solar, volcanoes, El Niño, clouds, and shifts in ocean normal modes. These effects are comparable in magnitude to that expected from anthropogenic carbon dioxide (CO_2). climate forcing. We consider two examples below where the observations strongly disagree with the GCM models. We also challenge the hypothesis that present day atmospheric CO_2 concentrations are causally related to anthropogenic emissions. We begin with a review of the temperature history of Earth.

<u>Temperature History of the Earth</u>

It is useful as a reference to review the temperature history of the earth.

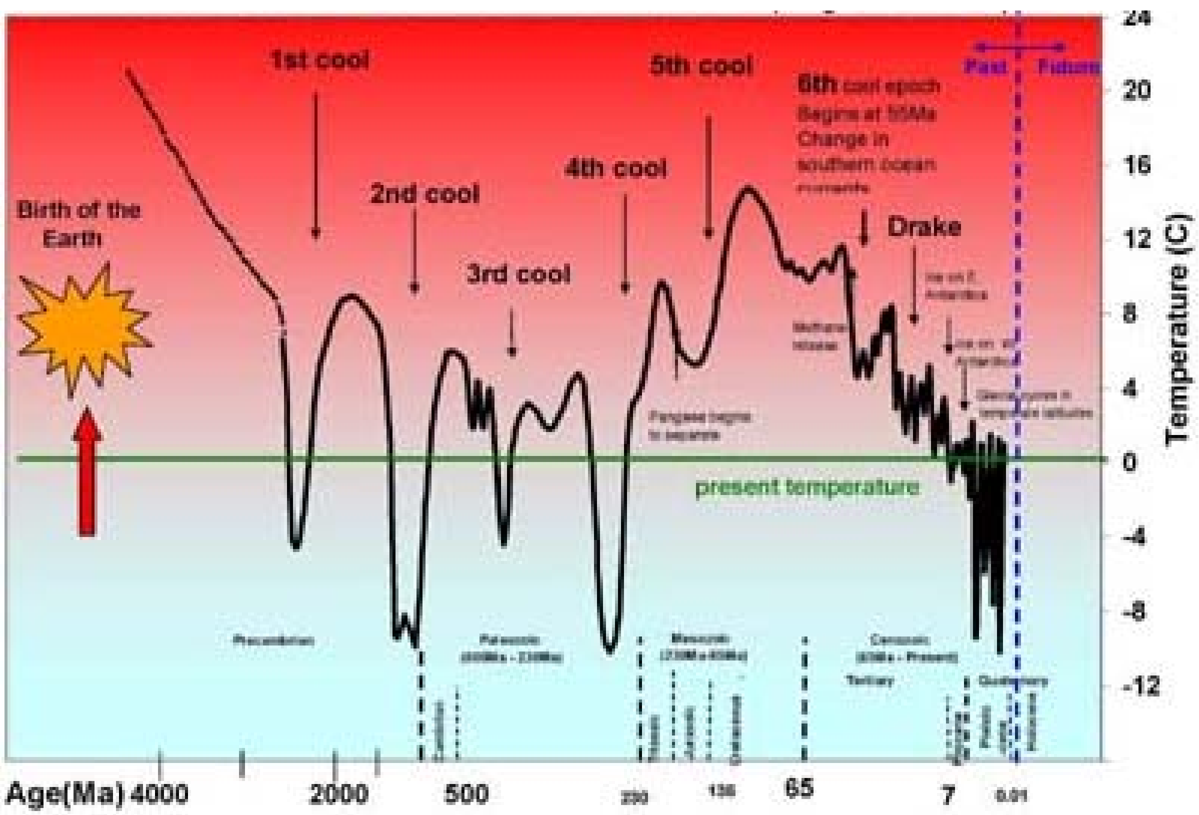

Figure 1 Temperature History of Earth. 5000Ma. (Douglass and Vacco[1])

Figure 1 shows a plot of the temperature history of the Earth for the last 5000 Ma [Douglass and Vacco[1]]. One notes that the total range in temperature is surprisingly small -- about 30°C. The oceans have neither evaporated nor frozen. The major cold periods tend to occur when because of continental drift there is a land mass at the South Pole where ice can accumulate. Secondly, there is a general cooling that has been going on for the last 50Ma which appears to be related to Antarctica geophysical events – changes in southern ocean currents, opening of the Drake Passage, slow accumulation of ice on the land, *etc*. Thus, it is empirically observed that over the history of Earth the excursions of the temperature from the mean are rather small, suggesting that there are negative feedback processes that bring the climate system back to the mean.

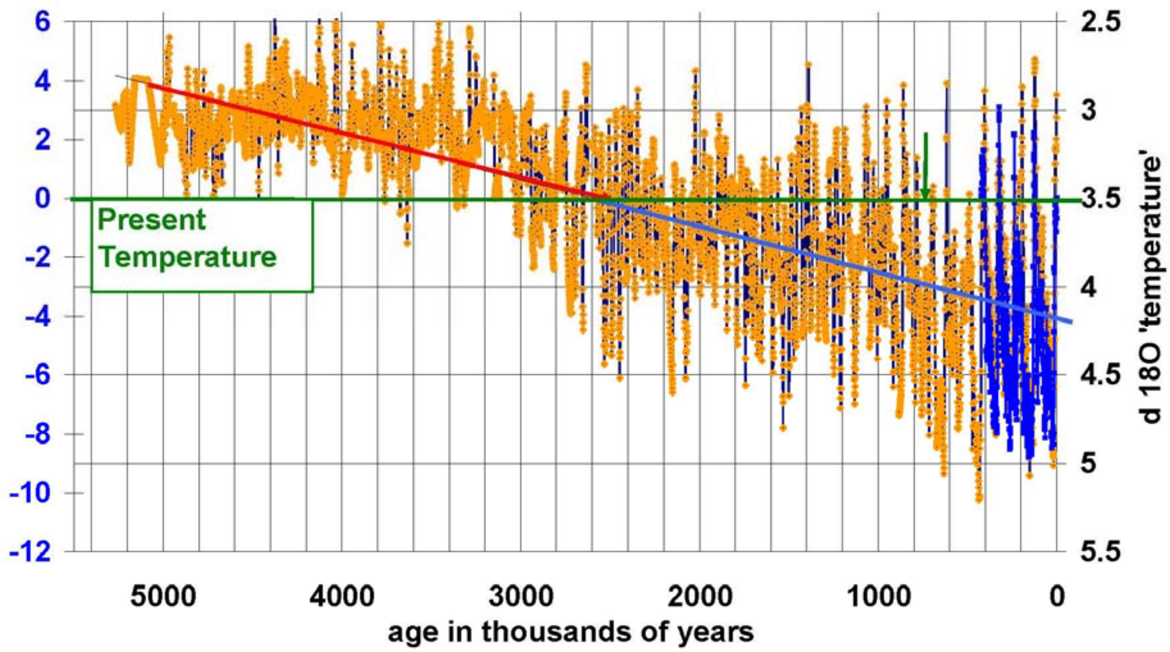

Fig 2. 5Ma to present (Douglass and Vacco[1]). Temperature (˚C) vs. age. There are two data sets, Tiedemann data from 5Ma to the near present and the Vostok ice core data from 0.5Ma to near present. Correlation over the period of overlap is greater than 0.7.

Fig 2 shows the last 5Ma. Here one sees a negative linear trend of about −2°C/Ma. Superposed are about 100 cycles of Milankovitch temperature oscillations of period 41,000 years whose amplitude is increasing as one gets closer to the present.

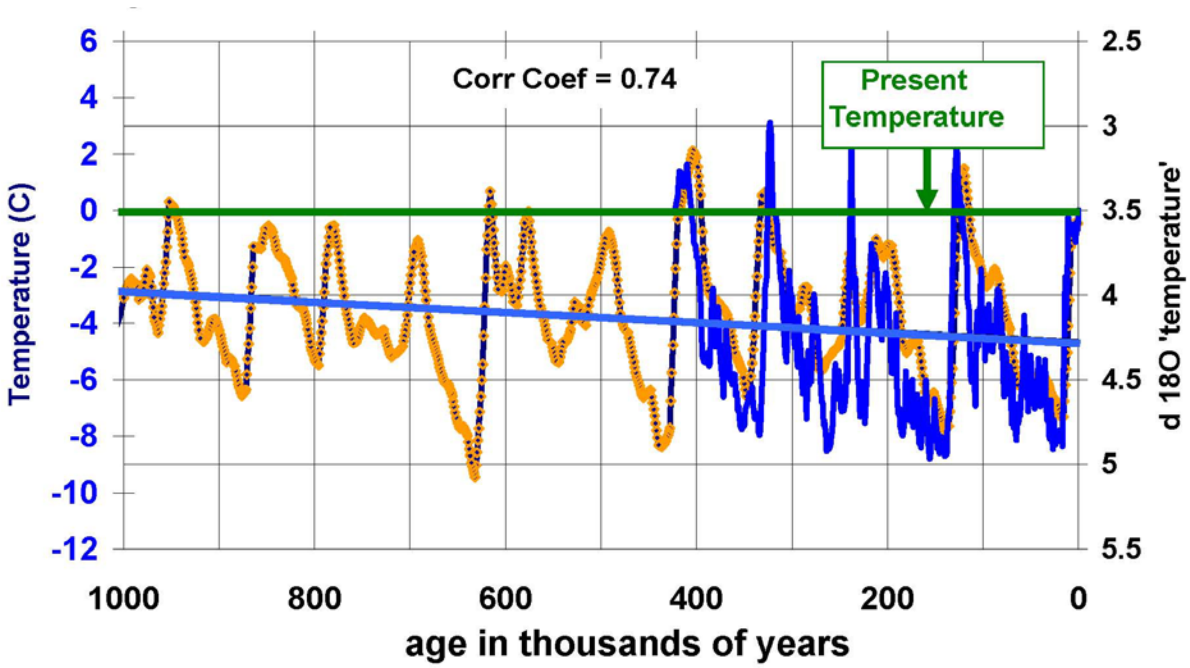

Fig 3 The last million years (Douglass and Vacco[1]). Same data as in Fig 2).

Fig 3 shows the last 1 Ma. The negative trend of − 2°C/Ma is indicated. Note that Earth's present temperature is about 5˚C above this trend line. The heavy curve for the last 400 ka is the Vostok ice core data[3] showing 4 ice-age cycles. The cycle period is commonly given as 100ka. The actual values are 80, 80, 120, and 120 which are near multiples of 41ka. There are a number of points to be made. 1. The amplitude of the temperature oscillations is about 8˚C. 2. The duration of the warm part of the cycle has an average of about 8 ka. The present warm period, the Holocene, has been going on for 12 ka. We are living on "borrowed time". The earth will probably go into a new ice-age in the next 2-5ka. The scientists of 40 years ago were right [NAS/NRC report[4]]. Global "cooling" is the climate threat that we should prepare for – however, we have a lot of time.

II. THE CLIMATE SYSTEM

Climate formalism

Climate formalism[5] considers that a climate forcing ΔF_i (such as solar, volcano, CO_2) can cause a change in the mean temperature ΔT_i of the earth. In equilibrium the relation is given by

$$\Delta T_i = \lambda_i \Delta F_i\,, \qquad (1)$$

where λ_i is the corresponding climate sensitivity. If there are feedback processes then

$$\lambda_i = g_i \lambda_0 \qquad (2)$$

where λ_0 is an intrinsic (no-feedback) sensitivity and the gain g and feedback f are related by

$$g_i = \frac{1}{1 - \sum_j f_{ij}}\;. \qquad (3)$$

[See Hansen *et al*.[6] and Lindzen[7]]. Here the summation over feedbacks f_j is representative of all feedbacks, which can be more complex. There is at least one more parameter – the response time τ.

Again Hansen[6] and Lindzen[7] have shown that

$$\tau = g\tau_0 \qquad (4)$$

where g is the gain from above and τ_0 in an intrinsic response time. If there is more than one forcing and assuming independence

$$\Delta T = \sum_i \lambda_i \Delta F_i\,. \qquad (5)$$

Note that since the λ_i are in general different that one can not express eq.5 as a sum over ΔF_i times a constant λ.

Physical Energy Balance models (EBMs)

One can estimate the parameters for a particular forcing of the climate system by comparing ΔF_i and ΔT_i using EBMs[8]. One of the simpler non-trivial EMBs can be used to connect ΔF_i and ΔT_i.

$$\tau_i \frac{d\Delta T_i}{dt} + \Delta T_i = \lambda_i \Delta F_i \qquad (6)$$

where τ_i and λ_i are coefficients to be determined.

The General Climate Models GCMs

Much of the development of the GCMs does not follow the description outlined above. Many papers describing GCMs start by enumerating the various ΔF_i. These forcings are the inputs to the GCM and a ΔT is calculated. A common "test" of the GCMs is to compare the ΔT of the model to a particular ΔT data set. These models are then characterized by a single number, T_{2x}, the equilibrium temperature of the GCM when the forcing is doubled CO_2. This is called the "climate sensitivity" of the GCM. To describe a GCM by this single metric is simplistic and misleading. At the most, T_{2x} gives some information about CO_2 forcing while saying nothing about the others. Agreement with a particular temperature data set by adjusting the free parameters in the various climate forcings can not be accepted as a validation of the GCM.

III. ANALYSIS OF CLIMATE DATA

There are many examples of observations that strongly disagree with the GCMs. We discuss only two.

A. Temperature trend vs. altitude

A leading climate problem continues to be the disparity between the temperature trends reported for Earth's surface and the much smaller trends observed in the lower troposphere --- just the opposite to what the GCM models predict. This problem has been highlighted in a National Research Council report[9]. More recently, Douglass, Pearson and Singer[10] confirmed the NRC conclusion and extended the analysis. In addition to showing the existence of a general disparity in trends between surface and atmosphere, they demonstrated its detailed dependence on altitude. It is found to be opposite in sign to what would be expected from three leading GCM models (Fig.4).

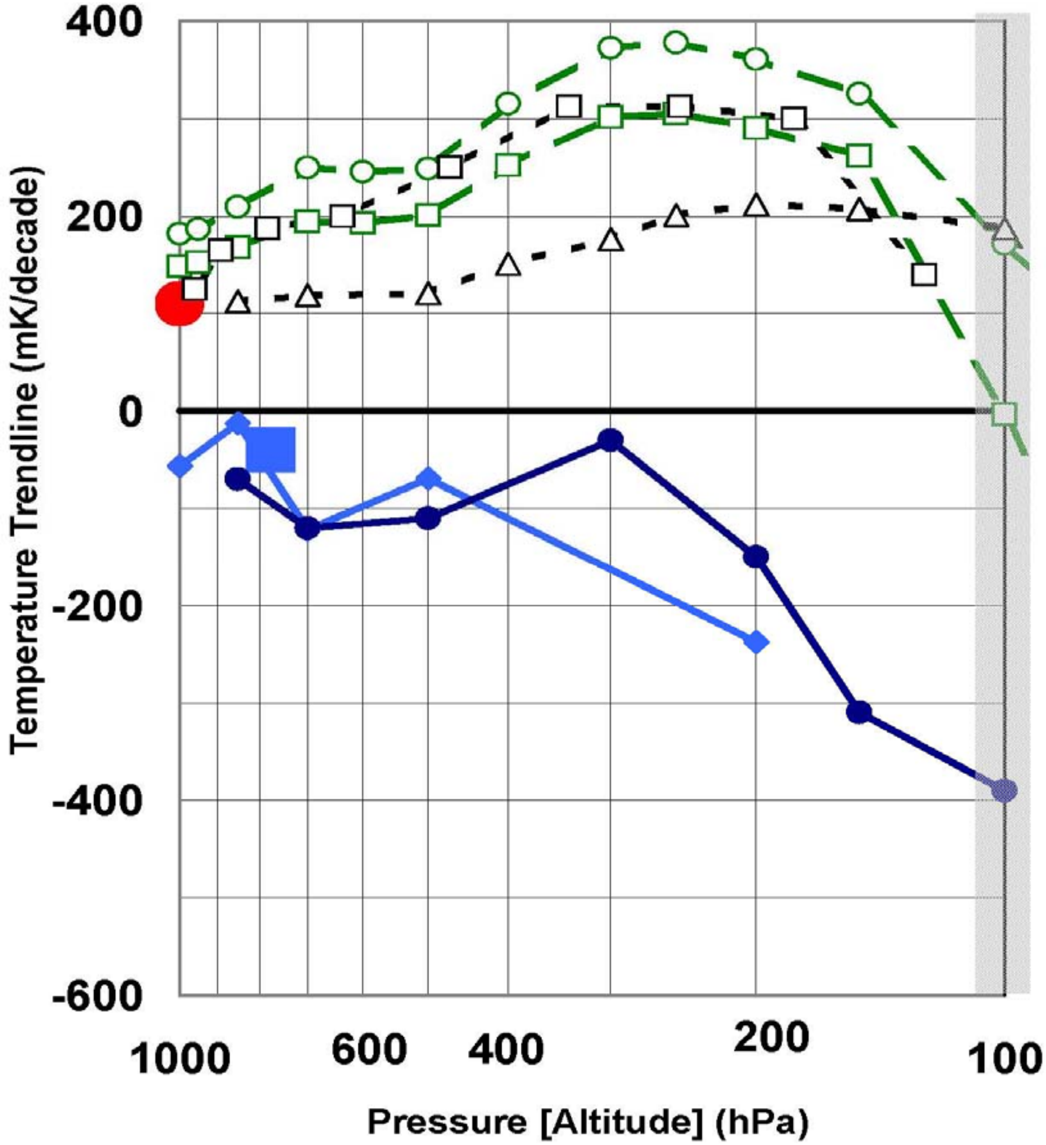

Figure 4. From Douglass/Pearson/Singer[10]. Leading climate models (dashed lines) show positive temperature trends (tuned to surface temperatures – CIRCLES) and increasing with altitude. Balloon radiosondes (two independent data sets – solid lines) show the opposite and agree with satellite result (MSU-UAH – shown by SQUARE)

B. Pinatubo Volcanic Eruption

The Pinatubo eruption was one of the largest climate events in the last 100 years. Douglass and Knox[11,12] have studied this climate event in some detail. From their paper:

> *We determine the volcano climate sensitivity λ and response time τ for the Mount Pinatubo eruption. This is achieved using observational measurements of the temperature anomalies of the lower troposphere and the aerosol optical density (AOD) in combination with a radiative forcing proxy for AOD. Using standard linear response theory we find $\lambda = 0.18 \pm 0.04$ K/(W/m^2), which implies a negative feedback of -1.0 ± 0.4. The intrinsic response time is $\tau = 5.8 \pm 1.0$ months*

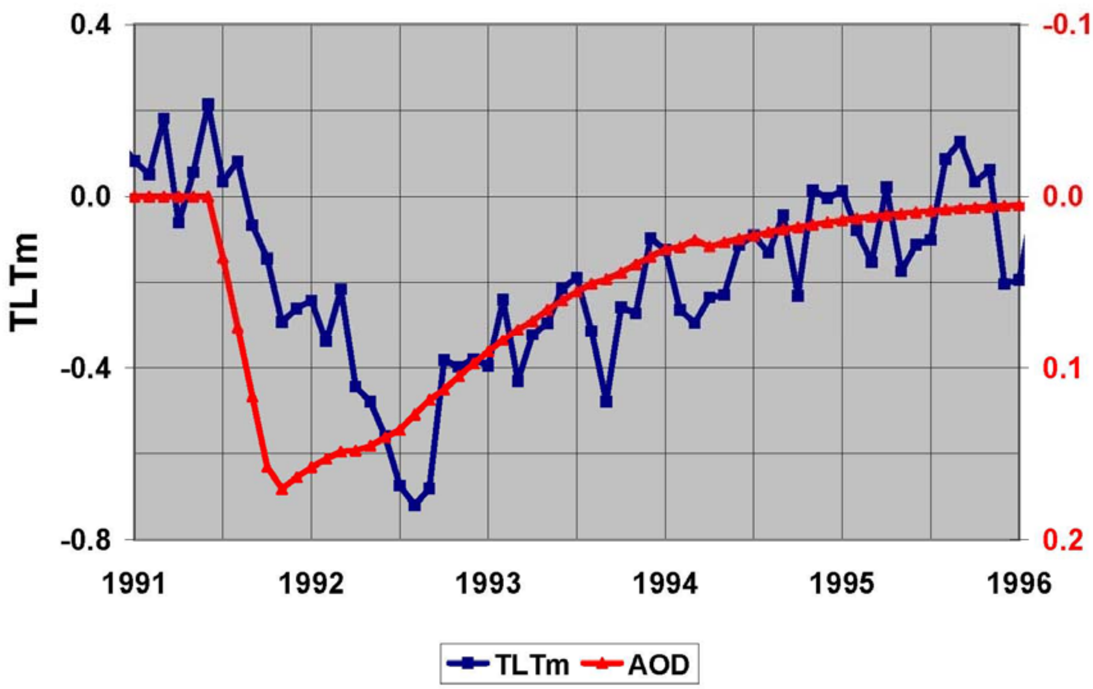

Figure 5. Temperature anomaly and aerosol optical density (AOD) during the Pinatubo event.

IV DISCUSSION

We show in two cases where the GCMs fail to agree with the observations. In the case of the disparity of the temperature trend with altitude the disagreement is even in the sign of the effect. For the case of the Pinatubo climate event, short response times and low climate sensitivities disagree with the GCMs.

Lindzen[13] states that “[T]he argument is no longer over whether the models are correct [they are not] but rather whether their results are at all possible.”. As shown above the models are, in fact, in strong disagreement with some observations. However, this may be because the underlying physical processes are incorrect or incomplete. This is not necessarily fatal to the models. The models have the potential to be enormously useful. However, at present, the modelers appear to be more focused on changing the input parameters to obtain a fit to a particular temperature time series than on examining the underlying physical processes in the model.

APPENDIX. WHAT IS THE CAUSAL RELATION BETWEEN CO_2 EMISSIONS AND CONCENTRATION OF CO_2 IN THE ATMOSPHERE?

This topic is indirectly related to the main text. It bears on the question of anthropogenic influence on Earth's climate system.. Recent measurements raise questions about the fundamental hypothesis, so we have added this discussion to this paper.

The CO_2 global warming hypothesis is illustrated in Fig A1. Much effort is presently being focused on processes B and C, the relationship between the change in the temperature of Earth and that of the concentration of CO_2 in the atmosphere. .

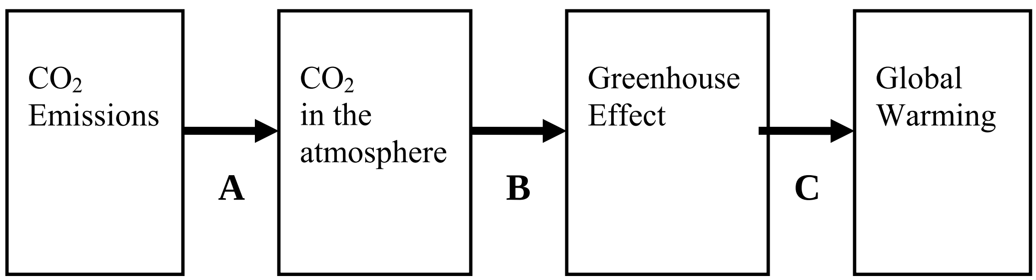

Fig A1 The global warming hypothesis

We wish to discuss process A in the context of more recent observations. Fig A2 shows the cumulative concentration of CO_2 in the atmosphere. The CO_2 measurements from 1958 to the present is from the Mauna Loa Observatory[14] and the CO_2 data from ice core[15] ranges from 1830 to 1980. The two data sets join smoothly. It is seen that CO_2 in the atmosphere has been increasing since 1830 although there was a decrease at about 1940-1942.

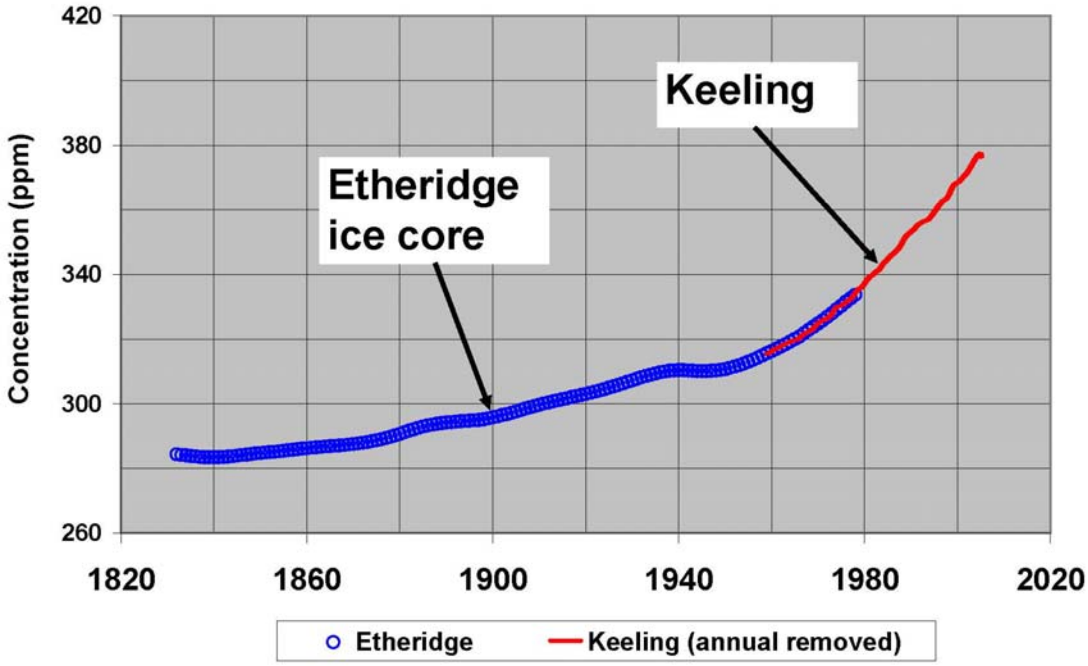

Fig A2 Atmospheric CO_2 vs. time. Ice core data from 1830 to 1978. Measurements at Mauna Loa since 1959.

Figure A3 shows the annual change in atmospheric CO_2. The annual rate R_A for the atmospheric is defined

$$R_A = \frac{100}{340}\left(\frac{\Delta C}{\Delta t}\right)_{year}.$$

Also shown is the annual estimated CO_2 emissions given by CDIAC[16]. The CO_2 emission rate R_E is defined in s similar same way. It is important to note that the CDIAC data includes only the estimated annual values from fossil fuel consumption, gas flaring and cement manufacturing -- “anthropogenic” activities. It does not include CO_2 from biomass burning or coal fires[17]. Thus we will refer to the CDIAC values as anthropogenic CO_2 emissions.

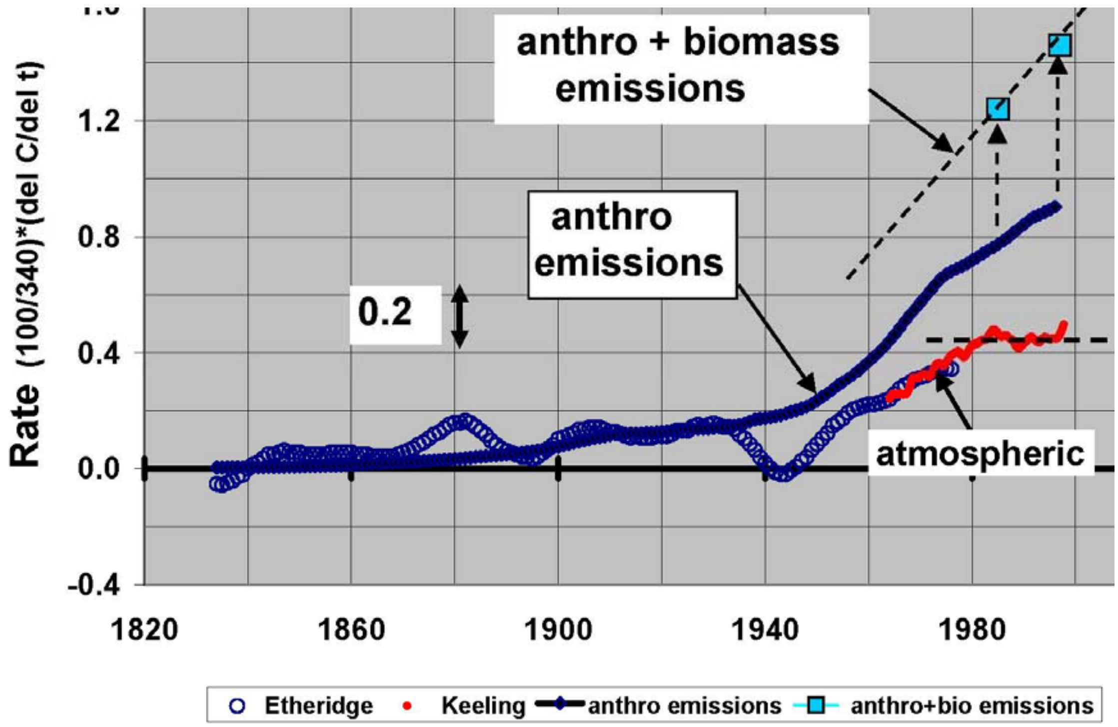

Fig A3. Annual CO_2 Rates. The derivative of the atmospheric CO_2 curve in fig A2 minus volcano and El Niño effects yields the atmospheric rate. Anthropogenic emission rate from CDIAC. See text for biomass emission rate.

It is commonly stated and generally accepted that “CO_2 emissions cause atmospheric values of CO_2 to increase”. Is there a causal relationship between the variables in these two plots? One, of course, knows that a correlation between two quantities does not prove a causal relationship. There is a general trend for both to increase, but this is not true for 1880-95 and 1935-44. For the period 1959-1978, Keeling[14] noted that the CO_2 in the atmosphere was 0.56 times the [anthropogenic] CDIAC values. This factor has been widely quoted with the difference of 1-0.56 = 0.44 being referred to as the “missing carbon” problem. After 1985 it is seen that the Keeling 0.56 relation is not valid.

Atmospheric rate R_A is constant.

It has been recognized that both volcano[18] and El Nino[19,20] events cause Earth's temperature to change and that the underlying geophysical processes cause CO_2 to be emitted/absorbed into the atmosphere although for different reasons. In both cases an increase/decrease in temperature causes an increase/decrease in atmospheric CO_2 -- an effect opposite to the global warming hypothesis.. The 1997-98 El Niño was the largest such event in the last century and caused correspondingly large increases in CO_2.

In order to remove the effects of volcanoes and El Niño from the Keeling data we performed a regression analysis on the CO_2 rate R_A using these as regression variables. We found $\Delta T = 5.0 * \Delta R_A(CO_2)$ [shown on Fig A3] and we subtracted these effects. It is R_A corrected for these two effects that is plotted in Fig A3. We see that for the last 25 years that the rate for atmospheric CO_2 is nearly a constant with the value $R_A= 0.44$. That R_A is now constant has been previously pointed out by Michaels[21].

The rate R_E of CO2 emissions continues to increase.

It is seen from Fig. A3 that the [anthropogenic] CDIAC CO_2 rate R_E continues to increase. In addition, there are other sources of CO_2 emissions not tallied by CDIAC. One of these sources is the massive coal fires in northern China.[Cassels et al.[22]; Stracher and Taylor[23]]. Some of these fires have been burning for centuries. It is estimated that these fires account for 2-3% of the annual world CO_2 fossil fuel emissions. Stated another way " [T]his is equivalent to the CO_2 emitted per annum from all vehicles in the United States."[23]. This is only a small part of the non-tallied CO_2 emissions. Biomass burnings (forest fires, *etc*,) has been estimated by Ito *et al*.[24] to be 4054 Tg CO_2/year for 2000. This works out to a rate of $R_E = 0.56$. .Likewise, Cruetzen and Andreae[25] estimate 1600-4100 Tg for 1990. Biomass burning is estimated to be 40-50% of that reported by the CDIAC. These estimates for 1990 and 2000 have been added to the [anthropogenic] CDIAC rates and are shown in Fig A3. The dotted line represents an estimate of the total annual CO_2 emissions. One can see that the ratio of R_A/R_E is now about 0.3 -- far below the 0.56 value of Keeling.

Implications

The data show that for the last 25 years R_A is not increasing even though R_E evidently is. There appears to be a set of mechanisms regulating the CO_2 flux to/from the atmosphere to keep R_A constant. If so, then there is no simple causal relation between CO_2 emissions and the CO_2 content of the atmosphere. Under this scenario one can increase *or decrease* CO_2 emissions without changing R_A. What then is the rationale for regulating CO_2 emissions?

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