Environmental Effects of Increased Atmospheric Carbon Dioxide

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ABSTRACT  A review of the research literature concerning the environmental consequences of increased levels of atmospheric carbon dioxide leads to the conclusion that increases during the 20th Century have produced no deleterious effects upon global weather, climate, or temperature. Increased carbon dioxide has, however, markedly increased plant growth rates. Predictions of harmful climatic effects due to future increases in minor greenhouse gases like CO₂ are in error and do not conform to current experimental knowledge.

SUMMARY

World leaders gathered in Kyoto, Japan, in December 1997 to consider a world treaty restricting emissions of “greenhouse gases,” chiefly carbon dioxide (CO₂), that are thought to cause “global warming” – severe increases in Earth’s atmospheric and surface temperatures, with disastrous environmental consequences.

Predictions of global warming are based on computer climate modeling, a branch of science still in its infancy. The empirical evidence – actual measurements of Earth’s temperature – shows no man-made warming trend. Indeed, over the past two decades, when CO₂ levels have been at their highest, global average temperatures have actually cooled slightly.

To be sure, CO₂ levels have increased substantially since the Industrial Revolution, and are expected to continue doing so. It is reasonable to believe that humans have been responsible for much of this increase. But the effect on the environment is likely to be benign. Greenhouse gases cause plant life, and the animal life that depends upon it, to thrive. What mankind is doing is liberating carbon from beneath the Earth’s surface and putting it into the atmosphere, where it is available for conversion into living organisms.

RISE IN ATMOSPHERIC CARBON DIOXIDE

The concentration of CO₂ in Earth’s atmosphere has increased during the past century, as shown in figure 1 (1). The annual cycles in figure 1 are the result of seasonal variations in plant use of carbon dioxide. Solid horizontal lines show the levels that prevailed in 1900 and 1940 (2). The magnitude of this atmospheric increase during the 1980s was about 3 gigatons of carbon (Gt C) per year (3). Total human CO₂ emissions – primarily from use of coal, oil, and natural gas and the production of cement – are currently about 5.5 Gt C per year.

To put these figures in perspective, it is estimated that the atmosphere contains 750 Gt C; the surface ocean contains 1,000 Gt C; vegetation, soils, and detritus contain 2,200 Gt C; and the intermediate and deep oceans contain 38,000 Gt C (3). Each year, the surface ocean and atmosphere exchange an estimated 90 Gt C; vegetation and the atmosphere, 60 Gt C; marine biota and the surface ocean, 50 Gt C; and the surface ocean and the intermediate and deep oceans, 100 Gt C (3).

![Fig. 1. Atmospheric CO₂ concentrations in parts per million by volume, ppm, at Mauna Loa, Hawai. These measurements agree well with those at other locations (1). Periodic cycle is caused by seasonal variations in CO₂ absorption by plants. Approximate global level of atmospheric CO₂ in 1900 and 1940 is also displayed (2).](image)

![Fig. 2. Surface temperatures in the Sargasso Sea (with time resolution of about 50 years) ending in 1753 as determined by isotope ratios of marine organisms remaining in sediment at the bottom of the sea (7). The horizontal line is the average temperature for this 3,000 year period. The Little Ice Age and Medieval Climate Optimum were naturally occurring, extended intervals of climate departures from the mean.](image)

So great are the magnitudes of these reservoirs, the rates of exchange between them, and the uncertainties with which these numbers are estimated that the source of the recent rise in atmospheric carbon dioxide has not been determined with certainty (4). Atmospheric concentrations of CO₂ are reported to have varied widely over geological time, with peaks, according to some estimates, some 20-fold higher than at present and lows at approximately 18th-Century levels (5).

The current increase in carbon dioxide follows a 300-year warming trend: Surface and atmospheric temperatures have been recovering from an unusually cold period known as the Little Ice Age. The observed increases are of a magnitude that can, for example, be explained by oceans giving off gases naturally as temperatures rise. Indeed, recent carbon dioxide rises have shown a tendency to follow rather than lead global temperature increases (6).

There is, however, a widely believed hypothesis that the 3 Gt C per year rise in atmospheric carbon dioxide is the result of the 5.5 Gt C per year release of carbon dioxide from human activities. This hypothesis is reasonable, since the magnitudes of human release and atmospheric rise are comparable, and the atmospheric rise has occurred contemporaneously with the increase in production of CO₂ from human activities since the Industrial Revolution.
ATMOSPHERIC AND SURFACE TEMPERATURES

In any case, what effect is the rise in CO₂ having upon the global environment? The temperature of the Earth varies naturally over a wide range. Figure 2 summarizes, for example, surface temperatures in the Sargasso Sea (a region of the Atlantic Ocean) during the past 3,000 years (7). Sea surface temperatures at this location have varied over a range of about 3.6 degrees Celsius (ºC) during the past 3,000 years. Trends in these data correspond to similar features that are known from the historical record.

For example, about 300 years ago, the Earth was experiencing the “Little Ice Age.” It had descended into this relatively cool period from a warm interval about 1,000 years ago known as the “Medieval Climate Optimum.” During the Medieval Climate Optimum, temperatures were warm enough to allow the colonization of Greenland. These colonies were abandoned after the onset of colder temperatures. For the past 300 years, global temperatures have been gradually recovering (11). As shown in figure 2, they are still a little below the average for the past 3,000 years. The human historical record does not report “global warming” catastrophes, even though temperatures have been far higher during much of the last three millennia.

What causes such variations in Earth’s temperature? The answer may be fluctuations in solar activity. Figure 3 shows the period of warming from the Little Ice Age in greater detail by means of an 11-year moving average of surface temperatures in the Northern Hemisphere (10). Also shown are solar magnetic cycle lengths for the same period. It is clear that even relatively short, half-century-long fluctuations in temperature correlate well with variations in solar activity. When the cycles are short, the sun is more active, hence brighter; and the Earth is warmer. These variations in the activity of the sun are typical of stars close in mass and age to the sun (13).

Figure 4 shows the annual average temperatures of the United States as compiled by the National Climate Data Center (12). The most recent upward temperature fluctuation from the Little Ice Age (between 1900 and 1940), as shown in the Northern Hemisphere record of figure 3, is also evident in this record of U.S. temperatures. These temperatures are now near average for the past 103 years, with 1996 and 1997 having been the 42nd and 60th coolest years.

Especially important in considering the effect of changes in atmospheric composition upon Earth temperatures are temperatures in the lower troposphere – at an altitude of roughly 4 km. In the troposphere, greenhouse-gas-induced temperature changes are expected to be at least as large as at the surface (14). Figure 5 shows global tropospheric temperatures measured by weather balloons between 1958 and 1996. They are currently near their 40-year mean (15), and have been trending slightly downward since 1979.

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The computer models on which forecasts of global warming are based predict that tropospheric temperatures will rise at least as much as surface temperatures (14). Because of this, and because these temperatures can be accurately measured without confusion by complicated effects in the surface record, these are the temperatures of greatest interest. The global trend shown in figures 5, 6 and 7 provides a definitive means of testing the validity of the global warming hypothesis.

**THE GLOBAL WARMING HYPOTHESIS**

There is such a thing as the greenhouse effect. Greenhouse gases such as H₂O and CO₂ in the Earth’s atmosphere decrease the escape of terrestrial thermal infrared radiation. Increasing CO₂, therefore, effectively increases radiative energy input to the Earth. But what happens to this radiative input is complex: It is redistributed, both vertically and horizontally, by various physical processes, including advection, convection, and diffusion in the atmosphere and ocean.

When an increase in CO₂ increases the radiative input to the atmosphere, how and in which direction does the atmosphere respond? Hypotheses about this response differ and are schematically shown in figure 9. Without the greenhouse effect, the Earth would be about 14 °C cooler (25). The radiative contribution of doubling atmospheric CO₂ is minor, but this radiative greenhouse effect is treated quite differently by different climate hypotheses. The hypotheses that the IPCC has chosen to adopt predict that the effect of CO₂ is amplified by the atmosphere (especially water vapor) to produce a large temperature increase (14). Other hypotheses, shown as hypothesis 2, predict the opposite — that the atmospheric response will counteract the CO₂ increase and result in insignificant changes in global temperature (25-27). The empirical evidence of figures 5-7 favors hypothesis 2. While CO₂ has increased substantially, the large temperature increase predicted by the IPCC models has not occurred (see figure 11).

The hypothesis of a large atmospheric temperature increase from greenhouse gases (GHGs), and further hypotheses that temperature increases will lead to flooding, increases in storm activity, and catastrophic world-wide climatological changes have come to be known
The computer climate models upon which "global warming" is based have substantial uncertainties. This is not surprising, since the climate is a coupled, non-linear dynamical system—in layman's terms, a very complex one. Figure 10 summarizes some of the difficulties by comparing the radiative CO$_2$ greenhouse effect with correction factors and uncertainties in some of the parameters in the computer climate calculations. Other factors, too, such as the effects of volcanoes, cannot now be reliably computer modeled.

Figure 11 compares the trend in atmospheric temperatures predicted by computer models adopted by the IPCC with that actually observed during the past 19 years—those years in which the highest atmospheric concentrations of CO$_2$ and other GHGs have occurred.

In effect, an experiment has been performed on the Earth during the past half-century—an experiment that includes all of the complex factors and feedback effects that determine the Earth's temperature and climate. Since 1940, atmospheric GHGs have risen substantially. Yet atmospheric temperatures have not risen. In fact, during the 19 years with the highest atmospheric levels of CO$_2$ and other GHGs, temperatures have fallen.

Not only has the global warming hypothesis failed the experimental test; it is theoretically flawed as well. It can reasonably be argued that cooling from negative physical and biological feedbacks to GHGs will nullify the initial temperature rise (26, 30).

The reasons for this failure of the computer climate models are subjects of scientific debate. For example, water vapor is the largest contributor to the overall greenhouse effect (31). It has been suggested that the computer climate models treat feedbacks related to water vapor incorrectly (27, 32).

The global warming hypothesis is not based upon the radiative properties of the GHGs themselves. It is based entirely upon a small initial increase in temperature caused by GHGs and a large theoretical amplification of that temperature change. Any comparable temperature increase from another cause would produce the same outcome from the calculations.

At present, science does not have comprehensive quantitative knowledge about the Earth's atmosphere. Very few of the relevant parameters are known with enough rigor to permit reliable theoretical calculations. Each hypothesis must be judged by empirical results. The global warming hypothesis has been thoroughly evaluated. It does not agree with the data and is, therefore, not validated.

**GLOBAL WARMING EVIDENCE**

Aside from computer calculations, two sorts of evidence have been advanced in support of the "global warming" hypothesis: temperature compilations and statements about global flooding and weather disruptions. Figure 12 shows the global temperature graph that has been compiled by National Aeronautic and Space Administration's Goddard Institute of Space Studies (NASA GISS) (23, 33, and 34). This compilation, which is shown widely in the press, does not agree with the atmospheric record because surface records have substantial uncertainties (36). Figure 13 illustrates part of the reason.

The urban heat island effect is only one of several surface effects that can confound compiled records of surface temperature. Figure 13 shows the size of this effect in, for example, the surface stations of California and the problems associated with objective sampling. The
East Park station, considered the best situated rural station in the state (37), has a trend since 1940 of minus 0.055 °C per decade. The overall rise of about plus 0.5 °C during the 20th century is often cited in support of "global warming" (38). Since, however, 82% of the CO$_2$ rise during the 20th century occurred after the rise in temperature (see figures 1 and 12), the CO$_2$ increase cannot have caused the temperature increase. The 19th century rise was only 13 ppm (2).

In addition, incomplete regional temperature records have been used to support "global warming." Figure 14 shows an example of this, in which a partial record was used in an attempt to confirm computer climate model predictions of temperature increases from greenhouse gases (41). A more complete record refuted this attempt (42).

Not one of the temperature graphs shown in figures 4 to 7, which include the most accurate and reliable surface and atmospheric temperature measurements available, both global and regional, shows any warming whatever that can be attributed to increases in greenhouse gases. Moreover, these data show that present day temperatures are not at all unusual compared with natural variability, nor are they changing in any unusual way.

### SEA LEVELS AND STORMS

The computer climate models do not make any reliable predictions whatever concerning global flooding, storm variability, and other catastrophes that have come to be a part of the popular definition of "global warming." (See Chapter 6, section 6-5 of reference 14.) Yet several scenarios of impending global catastrophe have arisen separately. One of these hypothesizes that rising sea levels will flood large areas of coastal land. Figure 15 shows satellite measurements of global sea level between 1993 and 1997 (43). The reported current global rate of rise amounts to only about plus 2 mm per year, or plus 8 inches per century, and even this estimate is probably high (43). The trends in rise and fall of sea level in various regions have a wide range of about 100 mm per year with most of the globe showing downward trends (43). Historical records show no acceleration in sea level rise in the 20th century (44). Moreover, claims that global warming will cause the Antarctic ice cap to melt and sharply increase this rate are not consistent with experiment or with theory (45).

Similarly, claims that hurricane frequencies and intensities have been increasing are also inconsistent with the data. Figure 16 shows the number of severe Atlantic hurricanes per year and also the maximum wind intensities of those hurricanes. Both of these values have been decreasing with time.

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**Fig. 13.** Surface temperature trends for the period of 1940 to 1996 from 107 measuring stations in 49 California counties (39, 40). After averaging the means of the trends in each county, counties of similar population were combined and plotted as closed circles along with the standard errors of their means. The six measuring stations in Los Angeles County were used to calculate the standard error of that county, which is plotted alone at the county population of 8.9 million. The "urban heat island effect" on surface measurements is evident. The straight line is a least-squares fit to the closed circles. The points marked "X" are the six unadjusted station records selected by NASA GISS (23, 33, and 34) for use in their estimate of global temperatures as shown in figure 12.

**Fig. 14.** The solid circles in the oval are tropospheric temperatures for the Southern Hemisphere between latitudes 30 S and 60 S, published in 1996 (41) in support of computer-model-projected warming. Later in 1996, the study was refuted by a longer set of data, as shown by the open circles (42).

**Fig. 15.** Global sea level measurements from the Topex/Poseidon satellite altimeter for 1993 to 1997 (43). The instrument record gives a rate of change of minus 0.2 mm per year (43). However, it has been reported that 50-year tide gauge measurements give plus 1.8 mm per year. A correction of plus 2.3 mm per year was added to the satellite data based on comparison to selected tide gauges to get a value of plus 2.1 mm per year or 8 inches per century (43).

**Fig. 16.** Annual numbers of violent hurricanes and maximum attained wind speeds during those hurricanes in the Atlantic Ocean (46). Slopes of the trend lines are minus 0.25 hurricanes per decade and minus 0.33 meters per second maximum attained wind speed per decade.
As temperatures recover from the Little Ice Age, the more extreme weather patterns that characterized that period may be trending slowly toward the milder conditions that prevailed during the Middle Ages, which enjoyed average temperatures about 1 °C higher than those of today. Concomitant changes are also taking place, such as the receding of glaciers in Montana’s Glacier National Park.

**FERTILIZATION OF PLANTS**

How high will the carbon dioxide concentration of the atmosphere ultimately rise if mankind continues to use coal, oil, and natural gas? Since total current estimates of hydrocarbon reserves are approximately 2,000 times annual use (47), doubled human release could, over a thousand years, ultimately be 10,000 GT C or 25% of the amount now sequestered in the oceans. If 90% of this 10,000 GT C were absorbed by oceans and other reservoirs, atmospheric levels would approximately double, rising to about 600 parts per million. (This assumes that new technologies will not supplant the use of hydrocarbons during the next 1,000 years, a pessimistic estimate of technological advance.)

One reservoir that would moderate the increase is especially important. Plant life provides a large sink for CO₂. Using current knowledge about the increased growth rates of plants and assuming a doubling of CO₂ release as compared to current emissions, it has been estimated that atmospheric CO₂ levels will rise by only about 300 ppm before leveling off (2). At that level, CO₂ absorption by increased Earth biomass is able to absorb about 10 GT C per year.

As atmospheric CO₂ increases, plant growth rates increase. Also, leaves lose less water as CO₂ increases, so that plants are able to grow under drier conditions. Animal life, which depends upon plant life for food, increases proportionally.

Figures 17 to 22 show examples of experimentally measured increases in the growth of plants. These examples are representative of a very large research literature on this subject (49-55). Since plant response to CO₂ fertilization is nearly linear with respect to CO₂ concentration over a range of a few hundred ppm, as seen for example in figures 18 and 22, it is easy to normalize experimental measurements at different levels of CO₂ enrichment. This has been done in figure 23 in order to illustrate some CO₂ growth enhancements calculated for the atmospheric increase of about 80 ppm that has already taken place, and that expected from a projected total increase of 320 ppm.

As figure 17 shows, long-lived (1,000- to 2000-year-old) pine trees have shown a sharp increase in growth rate during the past half-century. Figure 18 summarizes the increased growth rates of young pine seedlings at four CO₂ levels. Again, the response is remarkable, with an increase of 300 ppm more than tripling the rate of growth.

Figure 19 shows the 30% increase in the forests of the United States that has taken place since 1950. Much of this increase is likely due to the increase in atmospheric CO₂ that has already occurred. In addition, it has been reported that Amazonian rain forests are increasing their vegetation by about 34,000 moles (900 pounds) of carbon per acre per year (57), or about two tons of biomass per acre per year.

Figure 20 shows the effect of CO₂ fertilization on sour orange trees. During the years of growth, the bark, limbs, and fine roots of sour orange trees growing in an atmosphere with 700 ppm of CO₂ exhibited rates of growth more than 170% greater than those at 400 ppm. As the trees matured, this slowed to about 100%. Meanwhile, orange production was 127% higher for the 700 ppm trees.

Trees respond to CO₂ fertilization more strongly than do most other plants, but all plants respond to some extent. Figure 21 shows the response of wheat grown under wet conditions and when the wheat was stressed by lack of water. These were open-field experiments. Wheat was grown in the usual way, but the atmospheric CO₂ concentrations of circular sections of the fields were increased by means of arrays of computer-controlled equipment that released CO₂ into the air to hold the levels as specified.

While the results illustrated in figures 17-21 are remarkable, they are typical of those reported in a very large number of studies of the effect of CO₂ concentration upon the growth rates of plants (49-55).

Figure 22 summarizes 279 similar experiments in which plants of

![Fig. 17. Standard normal deviates of tree ring widths for (a) bristlecone pine, limber pine, and fox tail pine in the Great Basin of California, Nevada, and Arizona and (b) bristlecone pine in Colorado (48). The tree ring widths have been normalized so that their means are zero and deviations from the means are displayed in units of standard deviation.](image)

![Fig. 18. Young Eldarica pine trees were grown for 23 months under four CO₂ concentrations and then cut down and weighed. Each point represents an individual tree (56). Weights of tree parts are as indicated.](image)

![Fig. 19. Inventories of standing hardwood and softwood timber in the United States compiled from Forest Statistics of the United States (58).](image)
DISCUSSION

There are no experimental data to support the hypothesis that increases in carbon dioxide and other greenhouse gases are causing or can be expected to cause catastrophic changes in global temperatures or weather. To the contrary, during the 20 years with the highest carbon dioxide levels, atmospheric temperatures have decreased.

We also need not worry about environmental calamities, even if the current long-term natural warming trend continues. The Earth has been much warmer during the past 3,000 years without catastrophic effects. Warmer weather extends growing seasons and generally improves the habitability of colder regions. "Global warming," an invalidated hypothesis, provides no reason to limit human production of CO\textsubscript{2}, CH\textsubscript{4}, N\textsubscript{2}O, HFCs, PFCs, and SF\textsubscript{6} as has been proposed (29).
Fig. 23. Calculated growth rate enhancement of wheat, young orange trees, and very young pine trees already taking place as a result of atmospheric enrichment by CO₂ during the past two centuries (a) and expected to take place as a result of atmospheric enrichment by CO₂ to a level of 600 ppm (b). In this case, these values apply to pine trees during their first two years of growth and orange trees during their 4th through 10th years of growth. As is shown in figure 20, the effect of increased CO₂ gradually diminishes with tree age, so these values should not be interpreted as applicable over the entire tree lifespan. There are no longer-running controlled CO₂ tree experiments, yet, even 2,000 year old trees still respond significantly as is shown in figure 17.

REFERENCES

23. The Climate Research Unit, East Anglia University, United Kingdom; [http://www.cru.uea.ac.uk/advance10k/climdata.htm/].
40. Landsea, C. W. et. al. (1996) Geophys. Res. Let. 23, 1697-1700; [landsea@aoml.noaa.gov].