Increasing Carbon Dioxide and Global Climate Change

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Abstract

No evidence can be found for catastrophic global warming from the recent rise in the air's carbon dioxide content as a result of human activities. The elevated carbon dioxide concentration in the air has, however, had a positive impact on plant growth.

Introduction

The earth is warmer than it would be in the absence of the greenhouse gases in the atmosphere. Most of the greenhouse effect is natural and caused predominantly by water vapor and water droplets in clouds, then followed by, in diminishing order of importance, carbon dioxide, methane and other minor gases in the air. Since the Industrial Revolution, carbon dioxide concentration has been increasing in the air owing to human actions like coal combustion and deforestation,[1] with a rapid rise in the last several decades. The increase in the air's carbon dioxide would suggest a rising global temperature, all other things being equal. However, it is difficult to calculate the *response* of the climate system to the small amount of energy added by the presence of extra carbon dioxide in the air. The reason is that climate is a complex, dynamical and non-linear system, with positive and negative feedbacks, and knowledge of the causes and responses of climate change is presently insufficient to give an accurate response.

Methods

Will the recent or expected future rise in the air's concentration of carbon dioxide produce significant and catastrophic global warming? This question is often studied by way of computer simulations of the climate (e.g., General Circulation Models; GCMs). The simulations yield specific outcomes that are testable by comparing the results to measurements of the climate. We will discuss simulation outcomes and measurements of global temperatures, Arctic temperatures and the Antarctic paleoclimate extending back 420,000 years inferred from ice cores.

According to computer simulations, increases in greenhouse gases over the last 100 years should have caused a rise of roughly 1 C in the global average temperature and 2 C in the Arctic temperature.[2] These forecasts are important tests of the computer scenarios.

Temperature records at the surface – Thermometer records collected in the last 150 years near the surface over land and sea from different parts of the world show an average temperature rising roughly 0.5 C starting about 100 years ago (Figure 1)[3]. At first glance it seems that the observed warming occurred owing to increased carbon dioxide concentration in the air in the last 100 years and is thus good evidence for global warming from human activities.

But there are three problems with that conclusion. First, it ignores the most important feature of the temperature record: the 20th-century warming was not steady. A significant warming took place before 1940, while most (~80%) of the carbon dioxide from human activities entered the air after 1940. That means that *much of the temperature rise of the last 100 years occurred before the greenhouse gases from human activities existed in the atmosphere*. The warming of the early 20th-century must be mostly natural. Of the 0.5 C rise observed, at most only a few tenths of a degree can be attributed to the increases in greenhouse gases. The few tenths degree C rise in surface temperature since 1940 is far below the warming predicted by the computer scenarios with increased carbon dioxide concentration in the air.

The second problem is uncertainty in the surface records. There is the urban-heat-island effect: thermometers in growing cities record extra warmth owing to the machinery and pavement of modern cities. Although a correction has been attempted for this effect in Figure 1, the correction process is uncertain and introduces systematic error to the record.[4]

Another uncertainty in the surface record is its uneven and scanty surface coverage. Good records with near-continual coverage for the last 100 years cover only 18% of the surface of the earth, leaving vast areas of the southern and tropical oceans inadequately sampled.[5]

A third problem with the surface record arises because 100 years is insufficient for gauging the size of natural fluctuations in the climate. The natural warming of the 20th century should be placed in the perspective of a longer view of climate change. There are no worldwide instrumental records going back further, but temperature records or reconstructions do extend back in several regions. For example, the natural variability of temperature in the mid-latitude Atlantic Ocean (32°N) over the last 3000 years has been reconstructed from ocean-bottom sediments (Figure 2).[6] The longer view, hidden by the bias of the shortness of the instrumental records, shows substantially more variability in temperature. Evident are periods like the Little Ice Age, a period including the 17th and 18th centuries, a global cooling roughly equivalent to 1 C compared to the present, and the Medieval Climate Optimum of the 10th - 11th centuries, a warming of slightly above the present temperature in some regions. This record does not stretch as far back as the Holocene Optimum, 6500 years ago – the warmest interval of the last 10,000 years after the end of the last major ice age of the Pleistocene. The record of natural variability shows the 20th century warming is not unusual, either in its amplitude or rate.

Temperature measurements from satellites -- In the last 20 years precise readings of the temperature of the lower troposphere over nearly the entire earth have become available from satellites (Figure 3).[7]One deficiency of the satellite record, like the surface record, is its short period of coverage. However, according to the computer scenarios, atmospheric carbon dioxide has increased enough that the global temperature in this low layer of air should have increased by approximately 0.5 C. The satellite record shows no such increased warming trend, in contradiction to the computer scenarios.

The satellite records are often dismissed on two grounds. First, they are claimed to be imprecise. This is incorrect because they have been verified by measurements made *in situ* by balloon-borne instruments. The second claim is that the satellite records are immaterial because people do not live at an altitude of a few kilometers, the layer of air sensed by the satellites. This criticism is irrelevant because computer scenarios claim that the lower troposphere warms at least as much as the surface.[8]

Arctic temperature records – According to the computer forecasts, climate over polar latitudes is very sensitive to global warming. The forecasts say that the polar regions should have warmed by roughly 2 C in the last 50 years, enough to begin melting polar ice. Melting the polar ice produces a positive feedback that amplifies any warming. The reason is that ice reflects much of the sunlight and helps keep the polar regions cold. But as the temperature rises and the ice melts, the bare ground or sea underneath absorbs more of the Sun's energy and magnifies the warming. One long-term view of the lower Arctic (Figure 4) comes from proxy records like tree-ring growth.[9] There is a rapid warming in the record, but it began in the mid-19th century, and must be natural because it predates most of the rise in the air's carbon dioxide concentration. This record suggests that the Arctic has cooled since 1950. Instrumental measurements (Figure 5) also contradict the intense warming trend projected by the computer scenarios. On the average over the last 40 years, the temperature does not show the large, increasing warming trends projected by the computer simulations.[10] That observed lack of warming may seem contradictory to recent newspaper reports of a thinning or diminishing extent of Arctic sea-ice.[11] However, sea ice will change in response to several factors, including not also temperature, but also ocean currents and salinity, wind, terrain, etc. The recent observed sea-ice changes cannot have been caused by human-made global warming because Arctic temperatures are not showing the expected increasing warming trend. No increasing warming trend of the kind expected from human-made global warming has occurred in recent decades, when most of the increase in the air's carbon dioxide concentration took place. In the test of the Arctic temperature record, the computer scenarios exaggerate the observed warming by more than ten-fold.

Paleoclimate and ice core measurements – For the past several million years the earth has been in a continual state of major ice ages. The warm, equable inter-glacial periods like the current Holocene of the last ca. 10, 000 - 12,000 years are rare. The ice ages last around 100,000 years, and the inter-glacial periods around 10,000 years. One important trigger for the shift between glacial and inter-glacial states is changing insolation as a result of changes in the geometric properties of the earth's orbit, e.g., obliquity, precession and eccentricity. Following the trigger must be an amplification of climate change through feedbacks like sea-ice or vegetation changes, or both. Records of the local temperature (from measurements of the deuterium content of the melted, individual ice core layers) and the air's carbon dioxide content through the past cycle of four major glaciations and de-glaciations have been constructed from measurements in the ever-accumulating layers of snow and ice in ice cores drilled in Antarctica (Figure 6)[12].

Such a correlation is often cited as the best empirical evidence that atmospheric carbon dioxide changes drive temperature changes.

The ice core record itself undermines the hypothesis. The changes in temperature in the ice core record precede the changes in carbon dioxide by several hundred to one thousand years. According to the ice core results, shifts in carbon dioxide do not provoke the temperature changes; the changes in atmospheric carbon dioxide concentration occur in response to changes in temperature.

The temperature information yields three conclusions: (1) the computer scenarios exaggerate the warming that should have already occurred; (2) most of the warming this century must have been natural because the warming predates the large increase in minor greenhouse gases; and (3) the ice core records of the paleoclimate do not support the idea that carbon dioxide changes caused the major temperature shifts into and out of the ice ages.

Natural factors of climate change: The Sun – one reason for the exaggerated forecasts of the computer scenarios may rest in incomplete knowledge of natural climate variations. One such natural factor may be changes in the brightness of the Sun over decades to centuries. The magnetism on the Sun's surface is marked by the coverage of sunspots – cool areas of intense magnetic fields. The number of sunspots varies with an 11-years period (Figure 7). This magnetic cycle is linked to a brightening and fading in the Sun's total energy output.[13] Solar brightness changes of a few tenths percent sustained over decades could drive global temperatures to change.

The climate record indicates a solar influence of this kind. An example (Figure 8) is the record of the Sun's magnetism (a proxy for solar brightness change, whose direct measurements extend back only to 1979) and reconstructed land temperatures of the Northern Hemisphere over 240 years. The two curves are highly correlated over several centuries.[14] Those changes in the Sun's magnetism indicate changes in the Sun's brightness.

Assuming that the Sun's magnetic change is a proxy for the Sun's changing brightness,[15]computer simulations[16]of the climate suggest that a change of 0.4% in the Sun's brightness[17] would produce observed global average temperature changes of about 0.5 C over the last 100 years.

Additional evidence points to the Sun's signature in the climate record over many millennia. Every few centuries the Sun's magnetism weakens to low levels sustained for several decades. An example is the magnetic low from ca. 1640 - 1720, when sunspots were rare. That period was coincident with the climate cooling of the Little Ice Age. Quantitative records of the Sun's magnetism over millennia come from measurements of the isotopes radiocarbon (^{14}C, from tree rings) and ^{10}Be (from ice cores).[18] These cosmogenic isotopes are products of atmospheric neutrons created when the upper air is bombarded by highly energetic galactic cosmic rays.

The isotope records indicate that the Sun's magnetism of the 17th century was low then and for every few centuries before that, with occasional, sustained magnetic maxima (ca. 11th century). During the periods of weak magnetism, the Sun should dim compared to the average or magnetically high intervals, when the sun should brighten. Tree ring records from Scandinavia covering 10,000 years show that 17 out of 19 coolings line up with lows in the Sun's magnetism.[19]

The idea that the total energy output of the Sun changes is one of the simplest mechanism for the Sun's possible effect on climate change. However, the Sun's output comes in many wavelengths; it also emits energetic particles, and both are variable in time, space and frequency. The various components of the earth's atmosphere and surface respond to different aspects of the Sun's diverse energy outflows, in ways that are yet unknown. Understanding of the possible effects of the changing Sun on climate change is still evolving.[20]

Results and Discussion

What's wrong with the computer forecasts? At the heart of the climate scenarios is the calculation of the response of the climate system to energy input from increases in minor greenhouse gases. The most sophisticated computer program would have to track 5 million climate parameters and their interactions, a feat ideally requiring 10^{19} degrees of freedom.[21] The computer to carry out such a calculation does not yet exist. More importantly, the physics of many climate interactions and measured values of many parameters are poor. Furthermore, it is certain that not all the causes of natural climate change, e.g., El Niño-Southern Oscillation, or changes of the sun, are understood.

The poor simulation outcomes, as judged by the comparison with climate observations, highlight the fact that major physical processes are incorrectly modeled or completely neglected. The simulations calculate the effects of a 2% perturbation in the energy budget of the climate system (+4 Watts per square meter for a doubling of the carbon dioxide concentration in the atmosphere), in the face of uncertainties of 10% in the energy budget (compared to a total energy of ~242 Watts per square meter of incident sunlight at the top of the troposphere).[22] It does not seem possible to compute accurately the response of the climate to an added warming expected from doubling carbon dioxide when the unknowns in the climate physics are more than an order of magnitude larger. Moreover, the simulations have positive feedbacks that are perhaps unjustified (e.g., upper tropospheric water vapor) and so yield an artificial warming.[23]

The warming 100 years from now in the absence of any other effects except that of doubling the carbon dioxide content in the air can be estimated by scaling the observed temperature response to the presence of increased atmospheric carbon dioxide concentration in the last several decades. The warming from doubling the air's carbon dioxide content should be less than 0.5 C, an amount within the bounds of observed, natural climate change. A small, gradual warming should be not only tolerable but also beneficial, if the record of human history, climate change and the environment is any guide. [24]

It has become common to see impact studies giving catastrophic consequences of global warming based on the flawed computer scenarios. For example, it is incorrectly believed that diseases like malaria will spread to the populated countries of the high Northern latitudes as a result of warmer temperatures there. But malaria is endemic to those regions, and was common, especially during the colder temperatures of the Little Ice Age.[25] More importantly, the spread of diseases like malaria in economically advanced nations is increasingly controlled by modern medicine and technology.

Is carbon dioxide a pollutant? No, it is essential to life on earth. Based on extensive evidence from agricultural research on enhanced carbon dioxide environments both in the field and in labs, carbon dioxide increases should cause many plants to grow more vigorously and quickly.[26] The reason is that most plants evolved under and so are better adapted to higher-than-present atmospheric carbon dioxide concentrations. In experiments doubling the air's carbon dioxide content, the productivity of most herbaceous plants rises 30-50%, while the growth of woody plants rises more so. The impacts of enhanced plant growth and related soil changes may even provide a strong quenching effect of warming from carbon dioxide. The vegetation feedbacks as a result of carbon dioxide fertilization have yet to be correctly incorporated in the climate simulations.[27]

Partly as a result of elevated carbon dioxide in the air and more efficient agricultural practices, the U.S. has experienced in recent decades enhanced growth in vegetation. The acceleration of plant growth is of a magnitude that the U.S., despite its energy use and resultant prosperity, may not be a net emitter of carbon.[28]

There is no doubt about the improvement of the human condition through the unfettered access to energy. Energy use may also produce local unwanted pollutants as a byproduct. Those sources of true environmental pollution may be tolerated or mitigated, based on rational considerations of the risks of pollutants and benefits of energy use. But in the case of recent fears of anthropogenic carbon dioxide, science indicates at most a little warming and certainly better plant growth owing to the projected future increase of carbon dioxide content in the air. An optimal warming and enhanced plant growth should be of great benefit to mankind and the environment.

Figures

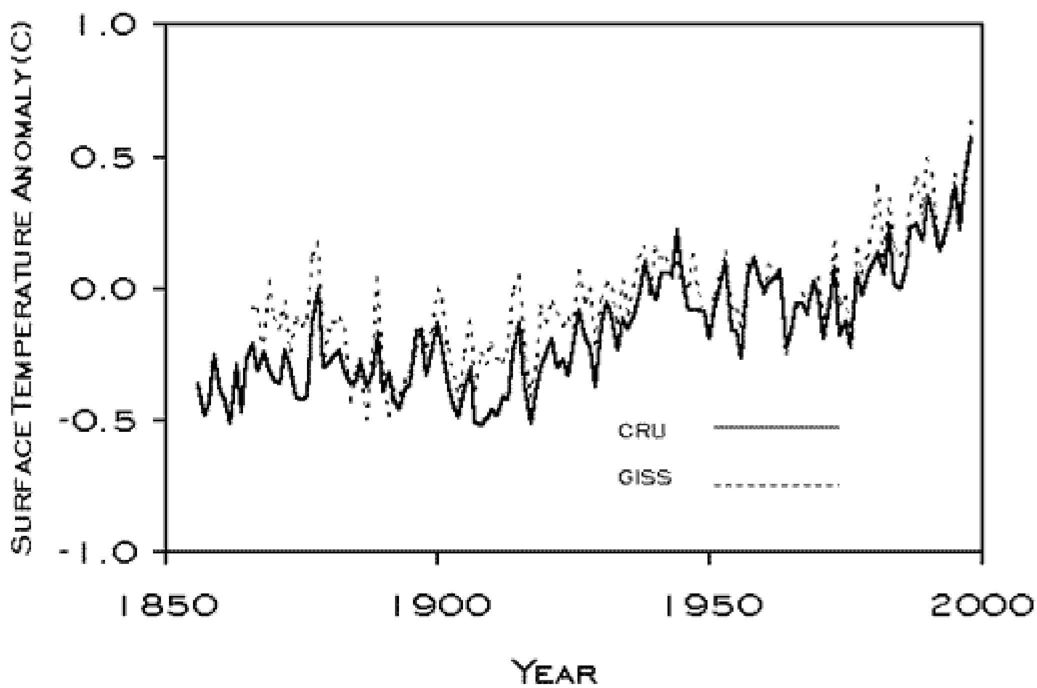

Figure 1 – Changes in annually-averaged surface temperatures sampled worldwide, compiled and analyzed over land and sea (University of East Anglia Climate Research Unit), and land only (NASA-Gadded Institute for Space Studies). The reason for the good agreement between the land plus sea and land alone records remains unknown

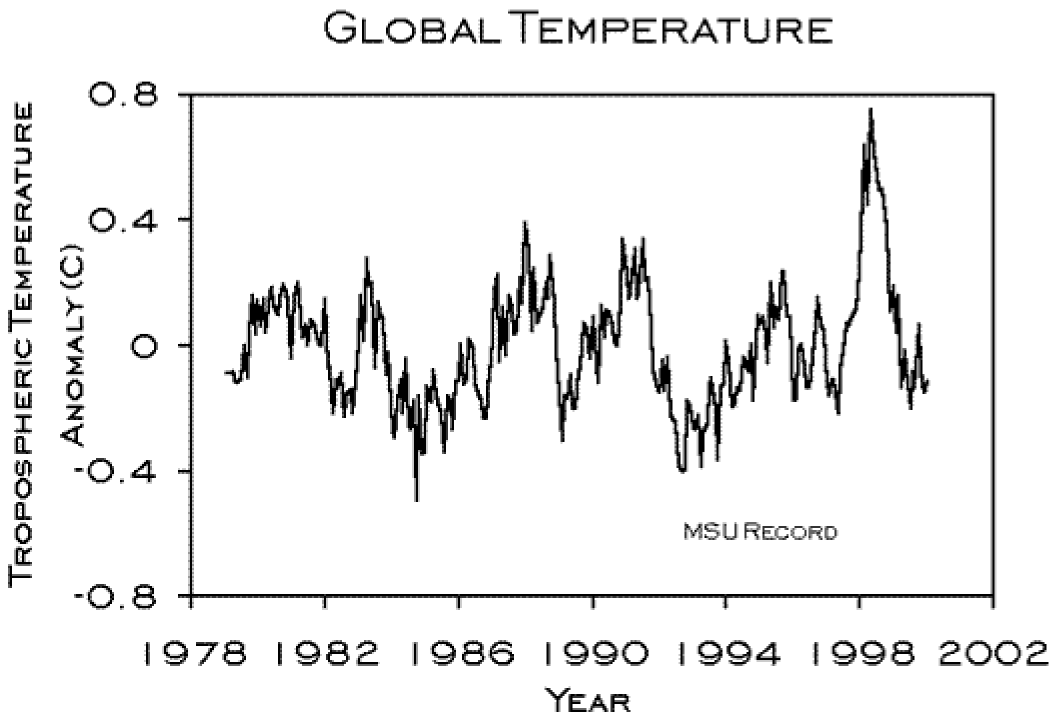

Figure 2 – Changes in monthly-averaged temperatures of the lower troposphere measured by satellites and between latitudes 82ºN and 82ºS.

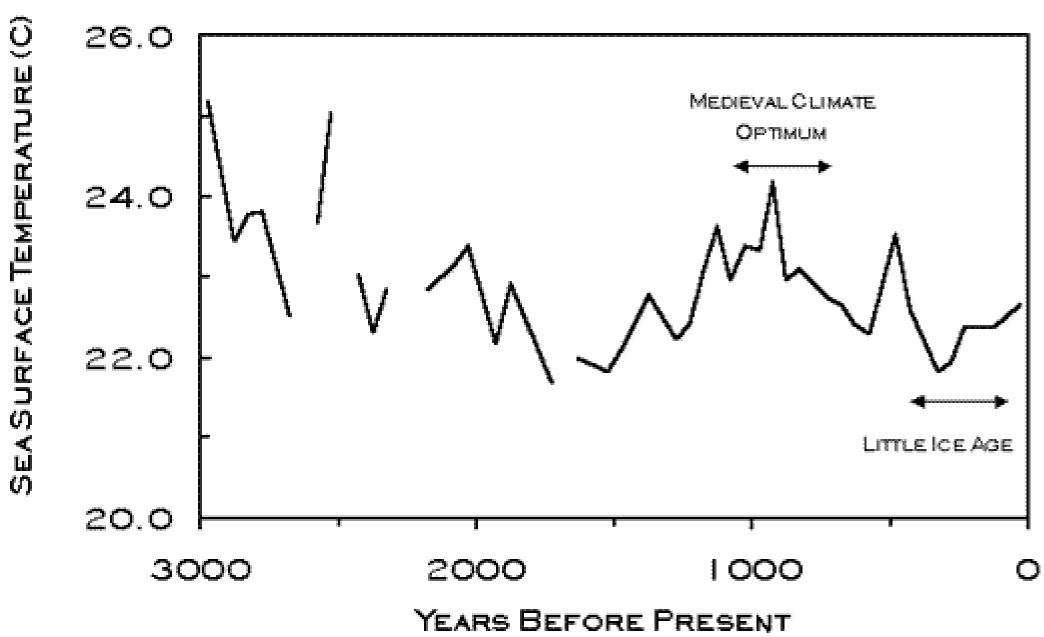

Figure 3 – Reconstructed temperatures of the Sargasso Sea (Keigwin 1996).

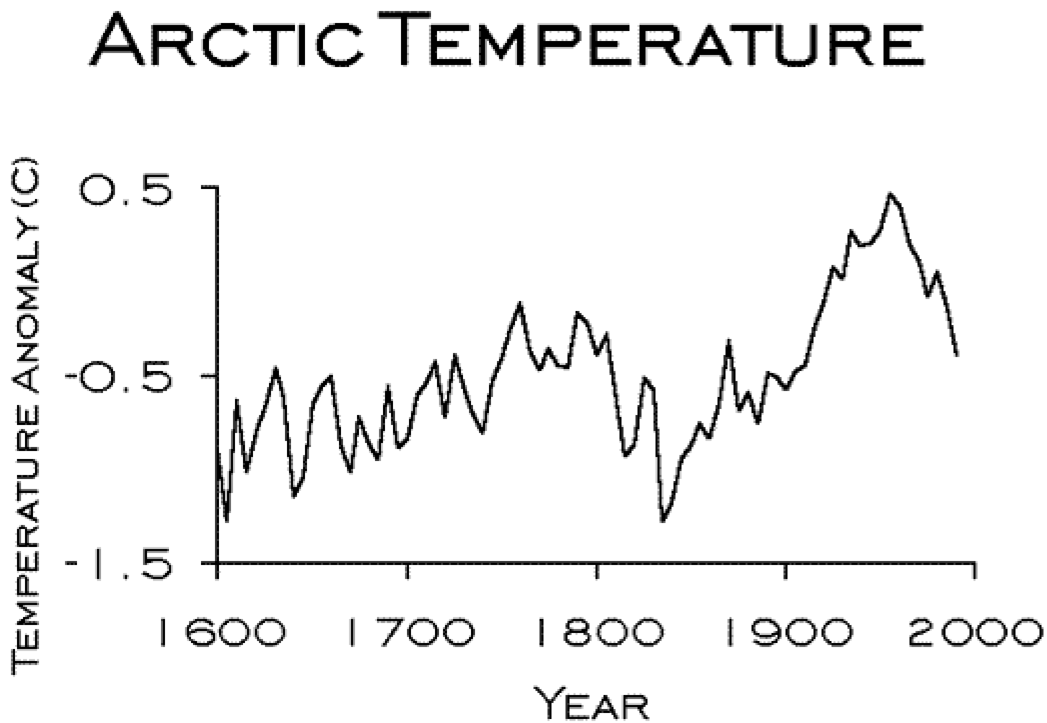

Figure 4 – Reconstructed temperature (highly weighted by summer temperature because the record is predominantly based on tree ring growth) of the near Arctic region (Overpeck et al. 1997) for the last 400 years.

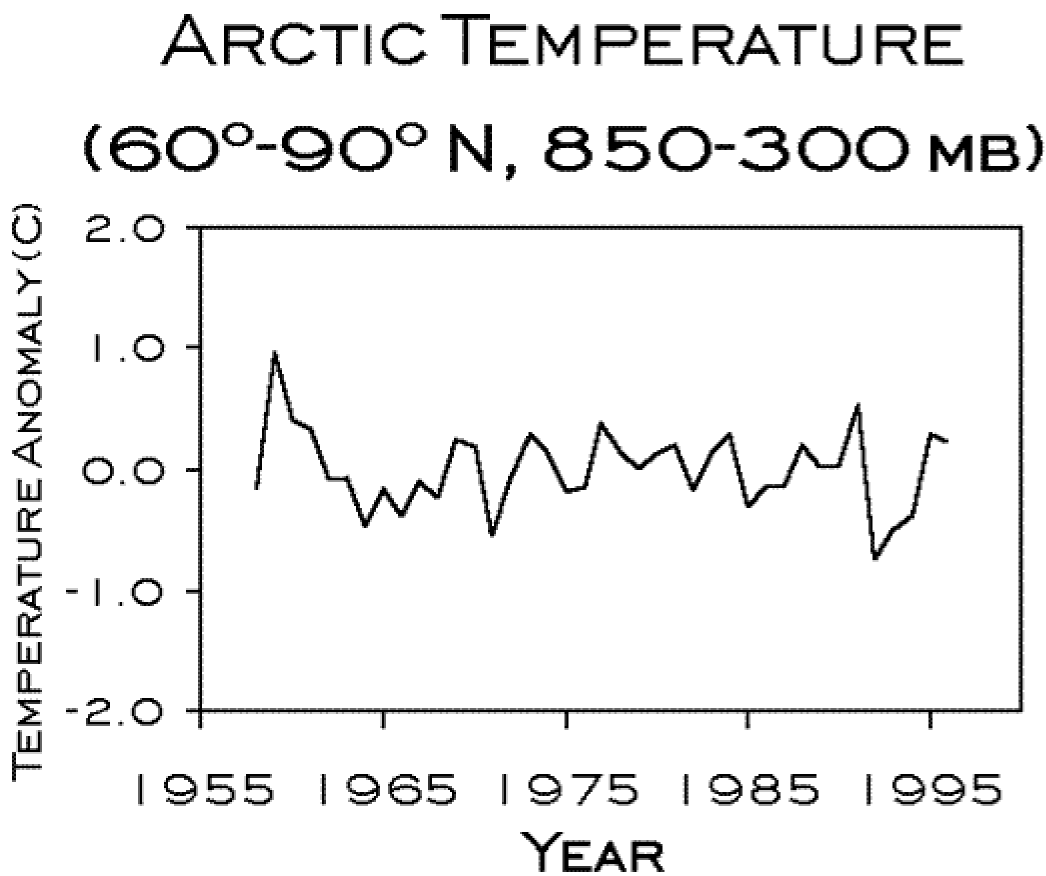

Figure 5 – Radiosonde record of lower-tropospheric temperatures in the Arctic (Angell 1999).

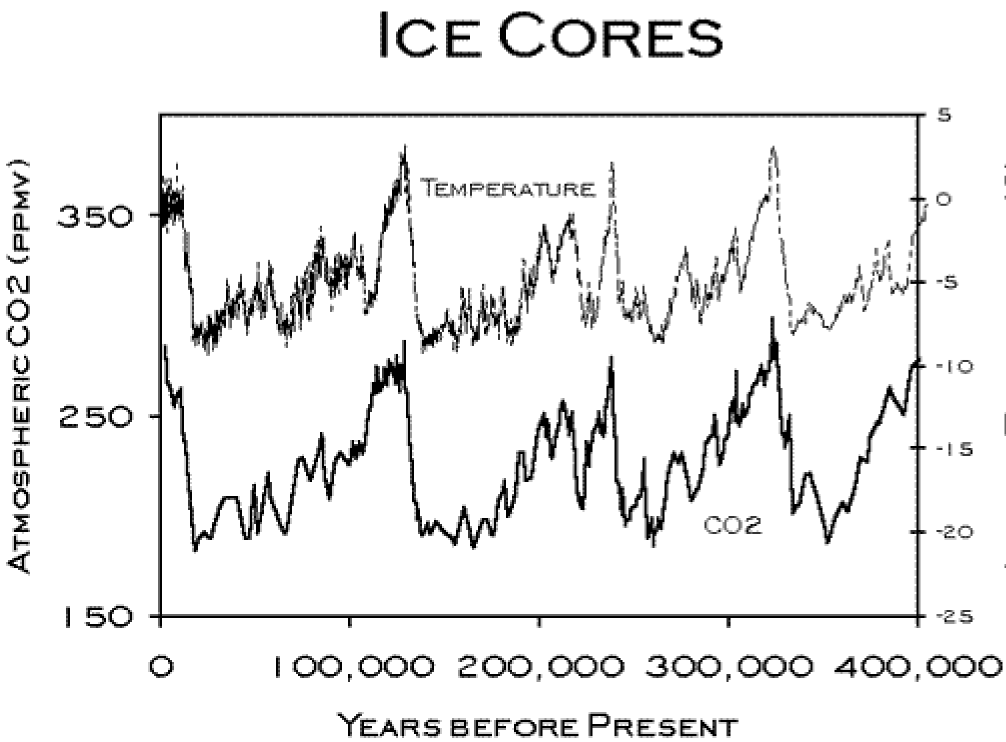

Figure 6 – Reconstructions of air temperature and carbon dioxide concentration from ice cores drilled in Antarctica (Petit et al. 1999; data kindly provided by J. R. Petit and colleagues).

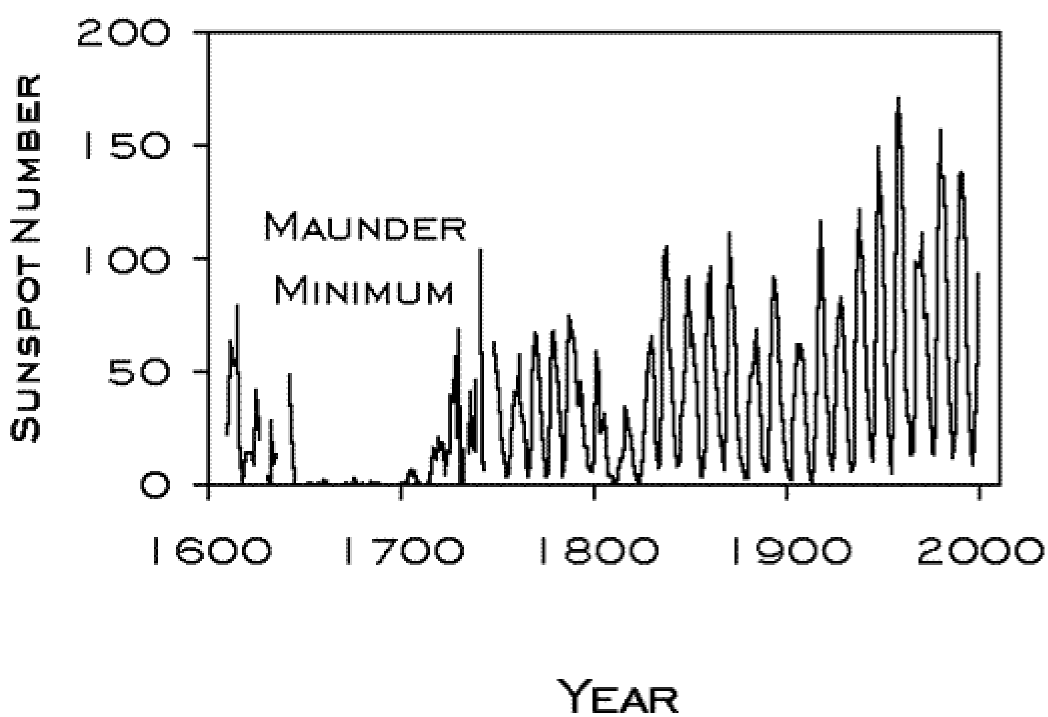

Figure 7 – Annually-averaged Sunspot Number. Note the approximate 11-year cycle in the sun's surface magnetism as well as the magnetically-low period ca. 1640 - 1720 ("Maunder Minimum").

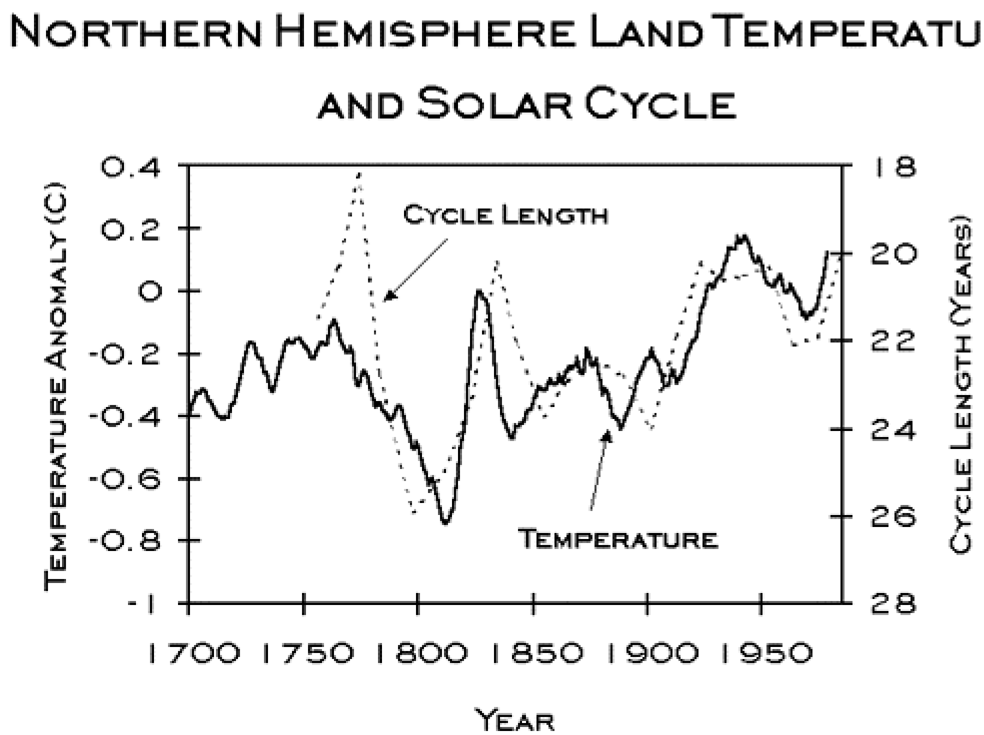

Figure 8 – Changes in the Sun's magnetism (the length of the 22-year, or polarity cycle, *dotted line*) and changes in Northern Hemisphere land temperatures (*solid line*). Shorter magnetic cycles are more intense, which suggests a brighter Sun (Baliunas and Soon 1995).

Literature Citations

[1] The carbon dioxide increase from human activities provides approximately half the added radiative energy to the climate system from greenhouse gases; the other half is from the sum of other greenhouse gases from human activities like methane and chlorofluorocarbons. All the greenhouse gas increases may be summed and considered equivalently as an increase in carbon dioxide alone. In terms of the equivalent increase in carbon dioxide alone, the rise in greenhouse gases to date is roughly equal to a 50% rise in carbon dioxide alone. A discussion of atmospheric greenhouse gas increases can be found in *Climate Change 1995: The Science of Climate Change*, 1996, eds. J. T. Houghton et al. (Cambridge: Cambridge University Press), 572pp.

[2] J. T. Houghton et al., 1996, *Climate Change 1995: The Science of Climate Change*.

[3] D. E. Parker, 1994, *Journal of Geophysical Research*, 99, 14373, D. E. Parker et al., 1995, *Climatic Change*, 31, 559, and P. D. Jones, 1994, *Journal of Climate*, 7, 1794, and updates from the East Anglia Climate Research Unit website; J. Hansen and S. Lebedeff, 1987, *Journal of Geophysical Research*, 92, 13345 and updates from the NASA-Goddard Institute for Space Studies website.

[4] See R. C. Balling, Jr., 1992, *The Heated Debate*, (San Francisco: Pacific Research Institute) 195pp.

[5] P. J. Michaels et al., 1998, *Climate Research*, 10, 15.

[6] L. D. Keigwin, 1996, *Science*, 274, 1504. (See also large temperature variability ca. 60,000 to 30,000 years ago in J. P. Sachs and S. J. Lehman, 1999, *Science*, 286, 756).

[7] J. R. Christy, 1995, *Climatic Change*, 31, 455; J. R. Christy, R. W. Spencer and E. S. Lobl, 1998, *Journal of Climate*, 11, 2016; J. R. Christy, R. Spencer and W. D. Braswell, 2000*, Journal of Atmospheric and Oceanic Technology*, in press. Data are from ftp://wind.atmos.uah.edu/ms/t2lt.

[8] See *Reconciling Observations of Global Climate Change*, 2000, National Research Council (Washington, DC: National Academy Press), 104pp. The report highlights the failure of the computer simulations to explain the observed lack of warming in the lower troposphere and leaves unresolved the important disagreement between the recent trends observed in the satellite and surface data.

[9] J. Overpeck et al., 1997, *Science*, 278, 1251.

[10] J. K. Angell, 1999, *Geophysical Research Letters*, 26, 2761; Arctic data kindly provided privately.

[11] Based on climate scenarios, K. Y. Vinnikov et al. (1999, *Science,* 286, 1934) state, “This strongly suggests that the observed decrease in northern hemisphere sea ice is related to [human-caused] global warming.” But, for analysis and interpretation of actual measurements, see C. H. Davis, C. A. Kluever and B. J. Haines, 1998, *Science*, 279, 2086 and W. Krabill et al., 1999, *Science*, 283, 1522; D. A. Rothrock, Y. Yu and G. A. Maykut 1999, *Geophysical Research Letters,* 26, 3469. For example, Krabill et al. note that Greenland’s coastal ice is thinning while its inland ice is thickening. Rothrock et al. conclude that the observed Arctic changes in sea ice could be explained by an increase in ocean heat flux, or equator-to-pole atmospheric heat transport or incoming short-wavelength radiation, none necessarily caused by global warming.

[12] J. R. Petit et al. 1999, *Nature,* 399, 429; H. Fisher et al. 1999, *Science*, 283, 1712; A. Indermühle et al., 1999, *Nature*, 398, 121.

[13] Over the cycle, the full range of brightness change is at most 0.14%. Such changes seem insufficient in amplitude and time scale to cause a temperature response of the climate system that is larger than 0.1 C over the period of observations.

[14] Northern Hemisphere land temperatures (from B. S. Groveman and H. E. Landsberg 1979, *Geophysical Research Letters*, 6, 767; P. D. Jones et al. 1986, *Journal of Climate and Applied Meteorology*, 25, 161) are shown because the global surface records do not reach back so far (S. Baliunas and W. H. Soon, 1995, *Astrophysical Journal*, 450, 896); first reported in a shorter temperature record by E. Friis-Christensen and K. Lassen 1991, *Science*, 254, 698; K. Lassen and E. Friis-Christensen, 1995, *Journal of Atmospheric and Terrestrial Physics*, 57, 835).

[15] It assumes that one knows the mechanism of solar change (i.e., total brightness), and the response of the climate to such change. Neither is known! Some wavelengths of sunlight may be more important than others in affecting the climate. For example, the solar ultraviolet irradiance may make changes in the chemistry in the stratosphere and troposphere (J. D. Haigh, 1996, *Science*, 272, 981); visible-wavelength irradiance changes may affect the lower atmosphere and sea surface (W. B. White, J. Lean, D. R. Cayan and M. D. Dettinger, 1997, *Journal of Geophysical Research*, 102, 3255). Both portions of the solar irradiance spectrum may combine to influence the dynamics of planetary-scale waves and Hadley circulation. In addition, brightness changes have been considered here independent of wavelength. Then, too, the Sun’s surface magnetism and wind modulate the galactic cosmic rays impinging on the geomagnetic field, and so the electrical (B. A. Tinsley, 1997, *Eos*, 78, No. 33, 341) and chemical (J. W.

Chamberlain, 1977, *Journal of Atmospheric Science*, 34, 737) properties of the upper atmosphere. In turn, cloud microphysics and cloud coverage may change (H. Svensmark & E. Friis-Christensen 1997, *Journal of Atmospheric & Terrestrial Physics*, 59, 1225). See also W. Soon et al., 2000, *New Astronomy*, in press.

[16] Further details can be found in E. Posmentier (1994, *Nonlinear Processes in Geophysics*, 1, 26) and W. H. Soon et al. (1996, *Astrophysical Journal*, 472, 891); the latter contains a diagnostic comparison of the model results to the observations.

[17] How believable is an irradiance change of 0.5% over 100 years? A recent analysis (R. Willson, 1997, *Science*, 277, 1963) finds a baseline change in irradiance between the solar minima in 1986 and 1996. Over a century, that base change would be about 0.4%. Additional, results from observations of surface magnetism and brightness changes in sunlike stars yield consistent results: changes of the Sun's brightness over decades may be as large as several tenths per cent (S. L. Baliunas and W. H. Soon, 1995, *Astrophysical Journal*, 450, 896).

[18] Why do the isotope records contain information on magnetic changes of the Sun? Cosmic rays, energetic particles from deep space, form ^{14}C and ^{10}Be at the top of the earth's atmosphere. The amount of cosmic rays hitting the earth's atmosphere, hence the amount of ^{14}C and ^{10}Be formed, is modulated by changes in the Sun's magnetism. ^{14}C may be subsequently bound in a carbon dioxide molecule and incorporated in a tree ring through photosynthesis; ^{10}Be precipitates into an ice layer accumulating in the ice sheets at high latitudes.

[19] W. Karlén and J. Kuylenstierna, 1996, *Holocene*, 6, 359; W. Karlén 1998, *Ambio*, 27, 270.

[20] W. Soon et al. 2000, *New Astronomy*, in press.

[21] J. L. Lions et al., 1997, *Journal of The Atmospheric Science*, 43, 1137.

[22] An effective doubling of the atmospheric concentration of carbon dioxide corresponds to the effect of adding 4 Watts per square meter of energy to the climate energy budget. But the *uncertainty* in calculating, e.g., the effect of humidity is about 20 Watts per square meter. An additional uncertainty of roughly 25 Watts per square meter stems from estimating the heat flow from the equator to the polar regions Such errors give rise to area-by-area "flux adjustments" of up 100 Watts per square meter in some regions of the coupled ocean-atmosphere simulations. ("...[W]ithout knowing the dynamical heat fluxes, it is clear...that one cannot even calculate the mean temperature of the earth." R. S. Lindzen 1997, *Proceedings of the National Academy of Science, USA*, 94, 8335). The uncertainty in cloud calculations is estimated to be about 25 Watts per square meter (e.g., K. Ya. Kondratyev 1997, *Bulletin of the American Meteorological Society* 78, 689).

[23] R. Fu, R. E. Dickinson and B. Newkirk, 1997, *Geophysical Research Letters*, 24, 2371; Y. Zhu, R. E. Newell and W. G. Read, 2000, *Journal of Climate*, 13, 836.

[24] H. H. Lamb, 1985, *Climate, History and the Modern World*, (London: Methuen), 387pp.

[25] P. Reiter, 2000, *Emerging Infectious Diseases*, 6, 1.

[26] K. E. Idso and S. B. Idso, 1994, Agriculture For Meteorology, 69, 153; S. B. Idso, 1989, Carbon Dioxide and Global Change: Earth in Transition (Tempe, AZ: IBR Press), 292 pp; S. B. Idso, 1991, *Bulletin of the American Meteorological Society*, 72, 962.

[27] W. Soon et al., 1999, *Climate Research*, 13, 149.

[28] S. Fan et al. 1998, *Science*, 282, 442; for South and Central America, see O. L. Phillips et al., 1998, *Science*, 282, 439.

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