CLIMATE STABILITY AND POLICY

by

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Starting in the 1980s and culminating in the Kyoto accords of 1997, followed by the awarding of the 2007 Nobel Peace Prize to Al Gore and the United Nation's International Panel on Climate Change (IPCC), international attention has been focused on the dangers of global warming owing to anthropogenic carbon dioxide emissions. In this essay, however, I will argue that humanity faces a much greater danger from the glaciation associated with the coming of the next Ice Age, and that the carbon dioxide increases that we have seen during the past two hundred years are not sufficient to avert such glaciation and its associated disruptions to the biosphere and civilization as we know it. Such conflicting considerations have obvious implications for the formulation of public policy regarding human attempts to manage climate change.

During most of the Phanerozoic eon, which began about a half-billion years ago, there were few glacial intervals until the late Pliocene 2.75 million years ago. Beginning at that time, the Earth's climate entered a period of instability with the onset of cyclical ice ages. At first these had a 41,000 year cycle, but about 1 million years ago the period lengthened to 100,000 years, which has continued to the present [1]. Over this period of instability the climate has been extraordinarily sensitive to small forcings,* whether due to Milankovitch cycles, solar variations, aerosols, or albedo variations driven by cosmic rays. The current interglacial has lasted for some ten thousand years—about the duration of past interglacials—and serious policy considerations arise as it nears its likely end. It is extremely unlikely that the current rise in carbon dioxide concentration—some 30% since 1750, and projected further increase over the next few decades—will significantly postpone the next glaciation. Figure 1 shows the representation from Wikipedia [2] of temperature over the Phanerozoic derived from the available proxy data.

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* Radiative forcing is defined as the change in net downward radiative flux at the tropopause resulting from any process that acts as an external agent to the climate system. It is usually measured in w/m^2.

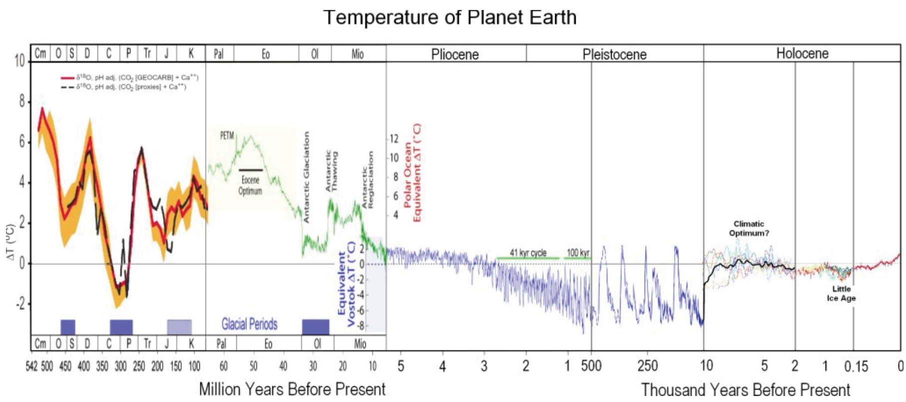

Figure 1. Temperature of the Earth over the Phanerozoic eon. Figure from Wikipedia [2].

As can be seen from the figure for the period of 500 kyr to 10 kyr before the present (BP), climate has had dramatic oscillations between glacial and interglacial periods. Interglacial intervals are considerably shorter than the glacial ones. Over the last 340 kyr, interglacials were also between 6 °C and 10 °C warmer than present day values [3] even though carbon dioxide concentrations were not higher than the current interglacial [4]. On the whole, the Earth for the last 5 million years has been colder than at any time in the last 550 million years, except for a glacial period 300 million years ago. This is despite the increasing luminosity of the Sun over the whole of the Phanerozoic [5].

It is known that the carbon dioxide geochemical cycle coupled with the evolution of both the Sun and biota over the Phanerozoic has led to the exceptionally low value of atmospheric carbon dioxide concentration that characterizes modern times [5]. These low levels have in turn resulted in the Earth entering a period of instability characterized by the cyclical ice ages of the past 2.75 million years. Beginning some 20 million years ago, carbon dioxide concentrations have remained generally below 500 ppmv. Although proxy data does show concentrations of this gas occasionally falling below this level previous to 20 million years ago, the average was above [6]. The glacial period centered around 300 Myr in the past was perhaps an exception.

The current interglacial period has lasted for some ten thousand years, comparable to the length of past interglacials. While policy considerations over the last couple of decades have concentrated on potential effects of rising temperatures—due, it is believed by many, to the increase in carbon dioxide concentrations from anthropogenic sources—these concentrations are quite low relative to those during times of climate stability that include most of the Phanerozoic. Even if all the temperature increase over the last century is attributable to human activities, a doubtful proposition at best, the rise has been a relatively modest 0.7 °C, a value within natural variations over the last few millennia. During the Holocene Maximum extending from some 7,000 years BP until 4,000 Yr BP, the temperature was about 1.3

^{o}C warmer than the 20th century; during the Medieval Maximum, that lasted from 1000 AD to 1400 AD, the temperature was 0.6-0.7 ^{o}C warmer than the 20th century. Thus, while an enduring temperature rise of similar magnitude over the next century would cause humanity to face some changes, these would undoubtedly be within our spectrum of adaptability (we have done so in the past).

Entering a new ice age would be catastrophic for the preservation of modern civilization. One has only to look at maps showing the extent of the glaciation during the last ice age to understand what a return to ice age conditions would mean. Even if the transition took centuries, the historical records of the Little Ice Age of the late 17th century make it clear that life would become increasingly difficult even in the early stages [7].

Over the near term, NASA maintains that Solar Cycle 25, peaking around 2022, could be one of the weakest in the last three centuries [8]. The sunspot minima around this time will be comparable to the Dalton Minima around 1805, and could cause a very significant cooling.

Given that the real danger facing humanity is a return to a new ice age, it makes sense to ask what concentration of carbon dioxide would be adequate to stabilize climate so as to extend the current interglacial indefinitely. Some idea of the range of concentrations needed can be had from the work of Royer [6] who found that over the Phanerozoic consistent levels of carbon dioxide below 500 ppmv are associated with the two glaciations of greatest duration—those that occurred during the Permo-Carboniferous some 300 Myr ago and the Cenozoic, within which we are now living. Cool climates were found to be associated with carbon dioxide concentrations below 1000 ppmv, while no cool periods were associated with concentrations above 1000 ppmv.

Some support for the idea that moderately increased carbon dioxide concentrations could extend the current interglacial period comes from the work of Berger and Lautre [9]. Working with projections of June insolation at 65 ^{o}N as affected by Milankovitch variations over the coming 130 kyr, they used a 2-dimensional climate model to show that moderately increased carbon dioxide concentrations, coupled with the small amplitude of future variations in insolation, could extend the current interglacial by some 50 kyr. The insolation variations expected over the next 50 kyr are exceptionally small and occur only infrequently, the last time being some 400 kyr in the past. They also found that a carbon dioxide concentration of 750 ppmv would *not* extend the interglacial beyond the next 50 kyr. In addition, concentrations of less than 220 ppmv would terminate the current interglacial.

One should not, however, take these carbon dioxide concentrations as the last word. The sensitivity of the climate to a doubling of carbon dioxide concentration could be in error. The change in forcing due to a change in carbon dioxide concentration is logarithmic and given by

$$\Delta F = \alpha \ln(C/C_0) \; w/m^2,$$

where C_0 and C are the initial and final carbon dioxide concentrations. Since 1990, the estimate by the IPCC of the coefficient α changed by 15% ($\Delta\alpha/\alpha = 0.15$) and "implicitly include[s] the radiative effects of global mean cloud cover" [10], and estimates of the radiative effect of clouds vary widely. If the actual sensitivity is significantly lower than current estimates—and there is good reason to believe that this is the case [11]—the concentration of carbon dioxide needed to extend the current interglacial would be increased.

IPCC projections for carbon dioxide concentrations by the year 2100 depend on projections of social and industrial development in countries with large populations that currently consume small amounts of energy per capita. The highest concentrations projected are about 1100 ppmv. This projection could be exceeded, however, if development in China and India accelerates and if other underdeveloped nations are able to overcome current social and economic impediments to modernization.

Even if development continues along its current trajectory, carbon dioxide concentrations are almost certain to fall in the range of 500-1000 ppmv over the next century. This is because there are good reasons to be very pessimistic about current international approaches to limiting carbon dioxide emissions—simply put, they are not realistic and instead are the result of political rather than scientific considerations. This is an observation, not a criticism since the current approach may be the best that is possible given existing international relationships and law, along with other aspects of political reality. Besides, many nations are aware of the predictions of the International Energy Agency that show that all alternative sources of energy will contribute no more than 2% to the world's energy supply by 2030 to 2040.

Two examples regarding fossil fuels may suffice to illustrate realistic constraints on curtailment of their use. First consider oil. Its use in industry is widespread for a variety of purposes in addition to energy production, but it will be irreplaceable in the transportation sector for decades. Apart from niche applications for other fuels, there are simply no good alternatives that are economically and politically viable. Some may be tempted to believe that the use of oil will be self-limiting, forcing the use of alternative fuels. This point of view is based on the claims of "peak oil" theorists. Such claims, however, show a misunderstanding of the meaning of "oil reserves". These reserves depend on price and are not a direct measure of the amount of oil physically available in the ground. The US alone has as much oil as Saudi Arabia locked in the shale deposits of four northern states, not to speak of the vast quantities of domestic natural gas that are now becoming available by the use of new drilling techniques. There is plenty of oil, perhaps as much as the 7200 billion barrels estimated by ExxonMobil, but these reserves cannot be brought to market as cheaply as oil from the Persian Gulf, and the economics of oil dictates that cheaper oil will be used first. Moreover, these sources cannot begin production immediately; there is a ramp up period of years. If the phasing-in of such reserves does not match the decline of current oilfields, rising prices and conflict over resources are inevitable. In the end the oil will become available and will be used unless a cheaper and realistic alternative can be found.

The argument that biofuels could replace oil is worth discussing. While the substitution of biofuels in the transportation sector appears at first blush promising, it has the severe handicap of competing with food production. In 2009, for example, some 25% of US grain crops were used to create ethanol. The competition for available farmland between biofuel and food production has raised prices around the world, causing increased malnutrition and in some places food riots. Without careful planning, more extensive development is likely to further raise the cost of food and other agricultural products much more than it already has with a likely increase in social unrest. Nor is it clear how planning could be done without interfering with the market mechanisms needed for efficient production—existing subsidies have already had this effect.

There are other problems: One attractive choice for biodiesel fuel is rapeseed oil, but to produce enough biodiesel from this source to fuel the country would require some 1.4 *billion* acres. For comparison, the U.S. now has only 400 *million* acres under cultivation. In addition, there is the fresh water, already in short supply, and the fertilizer needed for this increased cultivation. Even if cellulose can be used as a feedstock, biofuels based on agriculture are unlikely to replace oil any time soon.

The other example is electricity. In the United States, about 40% of carbon dioxide emissions are from the burning of fossil fuels to generate electricity. Projections by the International Energy Agency and the Energy Information Administration indicate that alternative sources of electricity such as solar and wind have no possibility of being able to displace this use of fossil fuels any time soon, if ever. The choice is between coal and nuclear, and the latter—while undergoing a limited renaissance until the 2011 accident in Japan due to a severe earthquake and tsunami—is beset by political obstacles, perhaps the most important of which is the prevalent concern about waste disposal. This concern, however, is political not technical [12]. By burning the waste as fuel, the radioactivity of the *real* waste falls below that of the original ore in less than 500 years and its disposal is straightforward.

There is only one practical way known today to stabilizing carbon dioxide concentrations over the next few centuries: nuclear power coupled with the long-term development of a hydrogen economy based on nuclear energy. Keep in mind that hydrogen is not an energy source, but an energy carrier—hydrogen is not found naturally and must be produced. A hydrogen economy does not necessarily mean that nuclear-generated hydrogen must be burned directly; the hydrogen may be used in the production of liquid fuels, probably the most efficient and economical form for storage and distribution. But this approach is not even on the international agenda.

Unless the international approach to stabilizing carbon dioxide concentrations changes dramatically, the world will continue to depend on fossil fuels for generations to come, and the burning of such vast quantities of fossil fuels is bound to have a serious environmental impact. The developed world cannot legislate how the developing world will use these fuels, and history has shown that commercialization will likely be at the lowest cost to the producer with the concomitant release of vast quantities of pollutants as well as carbon dioxide. China is a perfect contemporary example. Yet if the grinding poverty that most people in the developing world must live under today is to end through development along the Western model—and no alternative model has been shown to be viable—the required energy has to come from somewhere.

Resolving these issues is far beyond the purview of the IPCC. But that United Nations organization could have an important role in the future. The IPCC and the climatology community in general should devote far more effort to determining the optimal range of carbon dioxide concentrations that will stabilize the climate and extend the current interglacial period indefinitely.

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